SCHOOL OF MINES
COLORADO

QUARTERLY

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Science

Science

The Campus

QUARTERLY

OF THE

COLORADO SCHOOL OF MINES

Vol. XIII No. 1

Catalogue Edition

GOLDEN, COLORADO
1918

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CALENDAR

1917

November 29, Thursday	Thanksgiving Recess
November 30, Friday	
December 1, Saturday	
December 20, Thursday	Christmas Recess begins

1918

January 2, Wednesday	Christmas Recess ends
January 26, Saturday	First Semester ends
January 28, Monday	Second Semester begins
February 4, Monday	Course for Prospectors begins
February 12, Tuesday	Lincoln's Birthday (A Holiday)
February 22, Friday	Washington's Birthday (A Holiday)
March 2, Saturday	Course for Prospectors ends
May 31, Friday	Second Semester ends Commencement Exercises
June 3, Monday	Summer Field Work begins
July 13, Saturday	Summer Field Work ends
July 15, Monday	Summer School begins
August 24, Saturday	Summer School ends
August 28, Wednesday	Examination for Entrance to the Class of 1922 and Re-examination of Matriculated Students
August 29, Thursday	
August 30, Monday	
September 2, Monday	Registration
September 3, Tuesday	
September 4, Wednesday	Opening of the First Semester of the Academic Year 1918-19
November 28, Thursday	Thanksgiving Recess
November 29, Friday	
December 30, Saturday	
December 23, Monday	Christmas Recess begins

BOARD OF TRUSTEES

The regular meetings of the Board of Trustees are held in Golden at the School of Mines on the second Thursday of each month.

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The Development of Modern Mill Systems
Recent Advances in Coarse Crushing

WALTER G. SWART, Duluth, Minn.
Mining Engineer
Recent Developments in Dry Milling
Modern Practice in Zinc Metallurgy
Electrostatic Ore Separation

THOMAS B. CROWE, Victor, Colo.
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The Metallurgy of Cripple Creek Ores

JOHN A. TRAYLOR, New York, N. Y.
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L. S. PIERCE, Denver, Colo.
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W. H. TRASK, Jr., Denver, Colo.
Central Colorado Power Co.
Hoisting

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Metallurgical Engineer
The Future of Chemical Engineering

JAMES M. McCLAVE, Denver, Colo.
Metallurgist
Ore Concentration

PHILIP ARGALL, Denver, Colo.
Consulting Metallurgist
The Flotation Process

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The Colorado Workmen's Compensation Act

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Safety and Conservation in Life Insurance

NEWCOMB CLEVELAND, Denver, Colo.
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The Insurance Angle of Our Workmen's Compensation Act

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Interpretation and Use of Financial Reports

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Gold Mining Camps in Colorado

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Mining Engineer
Mining Conditions in Mexico

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Alaska Gold Placers
Siberian Gold Placers

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State Commissioner of Mines
Oil Flotation of Ores

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American Red Cross Society
First Aid to the Injured

JOHN W. AMESSE, M. D., Denver, Colo.
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United States Bureau of Mines
Miner's Consumption

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Rocky Mountain Fuel Co.
Coal Deposits and Coal Mining in Colorado

CAPTAIN GODFREY L. CARDEN, U. S. A.
Service in the U. S. Coast Guard

REV. CHAS. L. MEAD, New York
The Y. M. C. A. War Fund

LOCATION AND DESCRIPTION, HISTORY, ORGANIZATION, AND FINANCIAL SUPPORT

LOCATION AND DESCRIPTION

The Colorado School of Mines is in the south central part of the City of Golden, Jefferson County, Colorado. It occupies a plat of approximately twenty-three acres, picturesquely situated about 200 feet above the bed of Clear Creek, at the base of the scenic front range which lies about fifty miles to the east of the main range of the Rocky Mountains. Farther east, about thirteen miles, lies the city of Denver which can be reached by three railway lines: the Denver and Intermountain Railroad, Arapahoe Street Station; the Denver and Northwestern Railway, Arapahoe Street Station or Union Depot; or the Colorado & Southern Railway, Union Depot.

Golden has about three thousand inhabitants and is one of the oldest cities in Colorado. The altitude is five thousand seven hundred feet above sea level, or about four hundred fifty feet above Denver. The climate is invigorating and bracing, with open winters and a large proportion of clear days.

The Colorado School of Mines is particularly fortunate in its natural surroundings and proximity to a rich, practical laboratory. The state of Colorado is famous for its basic industries, the mining of gold, silver, and the baser metals, all of which, together with their allied branches of industry, are highly developed within a relatively small area, of which every part is easily accessible from Golden. In addition, the vast vanadium, tungsten, uranium, and radium fields are better represented here than in any other part of the world. In view of its great number and variety of mining and metallurgical enterprises the state offers unexcelled opportunities for practical study.

The school is fortunately situated for the geologist. The surrounding formations not only present the strikingly clear features so characteristic of the west, but also occur in great profusion and variety. In addition, certain features peculiar to this locality afford sufficiently complicated problems to be of great value to the student of geology. It is possible, therefore, without going more than a mile or two from the school to illustrate effectively most geological problems so that field geology can be carried on at the same time with class instruction.

In the immediate vicinity of Golden are numerous clay mines which produce pottery clay and fire clay; also lime and stone quarries. Within a few miles are extensive coal mines well equipped with hoisting and power machinery; pyritic smelting works; and the sites of dredging and placer operations.

In Clear Creek Canon, a short distance west of Golden, are the historic mining Camps of Central City, Black Hawk, Idaho Springs, and Georgetown, where placer drift mining is carried on in the old river beds, and a great variety of lode mines and milling plants are in operation. The ores of this district vary from free-milling gold quartz to complex silver-lead-zinc ores.

Farther west is the camp of Breckenridge, where placer mining is carried on, and the mining camps of Montezuma, Kokomo, and Robinson. To the southwest is the famous Leadville district, well known for its rich lead and zinc ores. West of Leadville is the once renowned silver mining camp of Aspen, and to the north of Leadville are the lead-zinc camps of Redcliff and Gilman.

At the Globe plant of the American Smelting and Refining Company in Denver the treatment of lead ores and dry ores of gold and silver is illustrated. Here also the many mining and metallurgical machinery plants afford an excellent opportunity for the study of recent improvements in metallurgical design.

West of Colorado Springs are located the Portland, the Standard, and the Golden Cycle Mills, which treat ore from the Cripple Creek district. Farther west are the prominent camps of Victor and Cripple Creek, in which are located some of the famous gold mines of the world. Near Victor are the well known Independence, the Portland, and the Ajax Mills, where low-grade Cripple Creek ores are successfully treated.

The plant of the Colorado Fuel and Iron Company, at Pueblo, possesses all the recently invented and approved devices for the production of iron and steel and for the working of these products into marketable forms. At Pueblo are located the Pueblo lead smeltery and the zinc smeltery of the Colorado Zinc Company. At Florence the Union Mill is located. At Canon City is the plant of the Empire Zinc Company. The Ohio and Colorado smeltery is located at Salida, and the Arkansas Valley smeltery at Leadville.

In the southwestern part of Colorado is the famous San Juan mining district, which includes the well known camps of Ouray, Telluride, Silverton, and Lake City, where many great mines are located and some of the most efficient milling plants in the world are to be found.

Coal mining is well represented in Colorado by the bituminous mines of the northern coal fields, the anthracite fields of Glenwood Springs, the coal fields of Trinidad, and numerous smaller fields. Oil fields are being developed and operated at Florence and at Boulder.

Many prominent mining camps in neighboring states are easily reached from Golden. Among these are the great copper districts of Montana, Utah, and Arizona, where the latest mining, milling, and smelting operations are in progress; the iron mines of Wyoming; and the gold mining camps of South Dakota.

No other mining school in the world has within easy access such a wide variety of mining properties, or such excellent opportunities for observing the latest and best milling and smelting operations.

HISTORY

The Colorado School of Mines was established by an act of the Territorial Legislature, approved February 9, 1874. Since that time the School has enjoyed a strong and steady growth in buildings, in equipment, in students, in faculty, and in the strength and rigor of its courses. Additions were made to the original buildings of 1880, by the building of 1882, and by the building of 1890, all of which are now united and called the Hall of Chemistry. The Hall of Physics was erected in 1894, the Assay Laboratory in 1900, and Stratton Hall in 1904. The Heating, Lighting, and Power Plant was completed in 1906. The Administration Building, named Simon Guggenheim Hall for the donor, was also erected in 1906. The Gymnasium was completed in 1908. The Experimental Ore Dressing and Metallurgical Building was completed in 1912.

ORGANIZATION

The general management of the School is vested by statute in a Board of Trustees, which consists of five members appointed by the Governor of the state, with the advice and consent of the Senate. The members of the Board of Trustees are appointed in alternating sets of two and three, and hold their office for a period of four years and until their successors are appointed and qualified. The Constitution of Colorado recognizes the School of Mines as an Institution of the State.

FINANCIAL SUPPORT

The Colorado School of Mines is supported by the income derived from an annual mill tax of the state. This is known as the "School of Mines Tax."

BUILDINGS

SIMON GUGGENHEIM HALL—Administration Building

This building, the gift of Senator Simon Guggenheim, was erected and furnished at a cost of $80,000. The corner-stone was laid by the A. F. and A. M. of Colorado, October 3, 1905. It is one hundred sixty-four feet long by fifty-seven feet wide and is surmounted by an ornate tower. The first floor is devoted entirely to the department of geology and mineralogy, and includes lecture room, laboratory, offices, two work rooms and a public museum; the second floor contains the library, the offices of the President and Registrar, the Faculty and Trustees' room; the third floor contains the Assembly Hall, two lecture rooms for mathematics, an office, and the Tau Beta Pi room. The building was dedicated October 17, 1906.

HALL OF CHEMISTRY

This is a continuous group of brick buildings which comprise the buildings of 1880, 1882, and 1890. The combined buildings of 1880 and 1882 contain the main chemical laboratories. In the building of 1890 are the office and laboratory of the professor of chemistry, the chemical lecture room, the physics laboratory, three recitation rooms, the laboratories for gas and water analysis, and the freshman and sophomore drawing room, the safety efficiency laboratories.

ASSAY BUILDING

This building, forty-six by ninety-two feet, was built in 1900 with funds contributed by the late W. S. Stratton, and enlarged in 1905. The design and equipment of this building make it one of the best of its kind in the country.

GYMNASIUM

This building, costing $65,000, was completed in September, 1908. The first floor contains a large swimming pool, shower bath, and locker room, finished in white marble and tiling. There is also a room for boxing and wrestling. The second floor contains the offices of the athletic director, athletic board, and secretary of the Y. M. C. A.; the Theta Tau room and the Integral Club room. The entire third floor is occupied by the gymnasium room proper. This contains fifty-two hundred square feet of clear floor space and a balcony which provides accommodation for two hundred spectators.

HEATING, LIGHTING, AND POWER HOUSE

The power plant, erected at a cost of $40,000, is designed to furnish light, heat, and power to the entire school. It is a simple but artistic brick building, eighty-three by one hundred twenty-two feet, with concrete floors and cement roof. The building is divided lengthwise into an engine room thirty-four feet wide, and a boiler room forty-five feet wide. A brick-lined steel stack one hundred twenty-five feet high carries all smoke to the upper air and away from the buildings.

STRATTON HALL

The corner-stone of this building was laid by the A. F. and A. M. of Colorado on November 20, 1902, and the building was completed in January, 1904. The first floor contains two large lecture rooms, each with apparatus room and private office. One-half of the second floor accommodates the surveying and mechanics in one large lecture room, with apparatus room and private office, and the other half contains a class room. The third floor is devoted entirely to a large drafting room for the junior and senior classes. The structure was named in honor of the late W. S. Stratton, who contributed $25,000 toward its cost.

THE EXPERIMENTAL ORE DRESSING AND METALLURGICAL BUILDING

This building, 100 by 150 feet, erected in 1912, was made possible by an appropriation of $100,000 by the legislature of Colorado. It is situated a short distance from the campus, on the bank of Clear Creek. It is intended to be not only a laboratory for the use of the students in ore dressing and metallurgy, but also a testing plant for the benefit of the mining industry. It is the largest and most complete plant of its kind in the United States.

RESIDENCE OF THE PRESIDENT

This is a brick building of two and one-half stories. It was built in 1888.

CARPENTER SHOP

This is well equipped for the special demands which are continually arising in a technical school. The work varies from ordinary repair work to the careful construction of special apparatus needed in the various laboratories.

MACHINE SHOP

This contains the necessary machinery for the maintenance and repair of equipment and also for the construction of such apparatus as is required for carrying on any new or original work.

LABORATORIES AND EQUIPMENT

THE EXPERIMENTAL ORE DRESSING AND METALLURGICAL PLANT

The Building

The experimental plant is situated on the bank of Clear Creek, a few blocks from the campus of the School. The building is 98 by 141 feet 8 inches on the ground floor. The framework is of structural steel resting on concrete foundations which have been carried down to a substantial bed of gravel. The walls consist of two and one-half inches of cement mortar, reinforced by "hy-rib," and are of natural cement color. The roof is of elaterite resting on a two-inch sheathing of matched Oregon fir. The ground floor is concrete and is divided into three benches. Above the ground floor, but covering only a part of the area, are two suspended floors of reinforced concrete, supported by steel framework. The building is well lighted and is properly ventilated.

Power

All machinery and apparatus requiring power are operated by alternating current motors supplied with current from the power house. For the generation of the current required, a producer-gas-power generator unit of 100 kv-a capacity has been installed in the power house. This unit is of Westinghouse design and consists of a bituminous suction gas producer, a vertical three-cylinder gas engine, and a direct-connected alternating current generator.

The producer has a number of noteworthy features. The principal one, and the one which contributes so largely to its success, consists of the two distinct fire zones. This feature makes it possible to operate successfully on very low-grade fuel, and eliminates the difficulties usually arising from the tar and hydrocarbons given off and deposited during the process of gas making. Ordinary Colorado lignite coal is used. From this is produced a cool, clean gas with a heat value of from 115 to 130 B. t. u. a cubic foot. To eliminate the loss of power on account of a reduced intake pressure, a motor-driven, positive-pressure type of exhauster is used. This draws the gas from the producer and delivers it to the engine at a pressure corresponding to about four inches of water.

The engine is of the standard Westinghouse vertical three-cylinder type, single acting, and using a four-stroke cycle. The cylinders are 15 in. diam. by 14-inch stroke. At a speed of 257 revolutions per minute, the engine operating on the producer gas, delivers 118 b. h. p. Compressed air is used for starting, and both engine and producer can be started readily, even though they have stood idle for several days.

Direct-connected to the engine through a spring coupling is a 100 kv-a, 2,300-volt three-phase, 60-cycle generator. The current is transmitted at this voltage to the experimental plant where it is stepped down to the working voltage of 440. The installation is such that the 100 kv-a machine can be operated in parallel with a steam turbine in the power house. In case of an emergency all power can be supplied from the turbine alone.

Sections

The plant contains four sections or units—sampling, concentration, cyanidation, and a fourth devoted to roasting and special features such as magnetic and electrostatic separation and flotation. For general equipment the plant contains a Curtis air compressor, bucket elevator, two motor operated platform elevators which give control over all the floors, a Ruggles-Cole dryer, ore bins, track scales, turn tables, and ore cars.

Sampling. This section contains the following equipment: One Vezin sampler, one Brunton sampler, one portable feed hopper, one set of 8 by 20 inch Traylor rolls, one dust collector, accessories for finishing the sample, such as laboratory crushers and pulverizers, bucking board, and sample riffles, one complete crude oil assay furnace outfit equipment for chemical analysis.

Concentration. This section contains: One 7 by 10 inch Blake crusher, one 2 D Gates gyratory crusher, one set of 14 by 30 inch P. and M. M. rolls, one set 12 by 24 inch P. and M. M. rolls, one 3½ foot Huntington mill, one 3½ foot Akron Chilean mill for regrinding, one Richards pulsator jig, one Harz jig of one compartment, one Harz jig of four compartments, one No. 6 Wilfley table, one Deister sand table, one Deister slime table, one Richards pulsator classifier, one Johnston vanner, one three compartment classifier, two Callow cones, five 850 lb. gravity stamps equipped with amalgamating plates, one 2 foot amalgamating pan made by the Denver Engineering Works Co., Pierce amalgamator, and clean up pans, also grizzlies, impact and revolving screens, sand pumps, elevators and concentrate driers.

For preliminary concentration: One Callow minature ore testing plant, which includes one 24 inch Wilfley table, one two compartment jig, one set hydraulic classifiers, one 6 in by 4 ft. amalgamating plate, one-quarter size Wilfley table, one-quarter size Card table.

Cyanidation. This section contains: one 3½ by 10 foot Pachuca tank, one Paterson agitator, one Dorr classifier, one Dorr thickener, one Butters filter, one 2 by 3 foot Oliver filter, one Gould wet vacuum pump, one 2 by 2 foot Abbe pebble mill, one 4 by 10 foot Denver Engineering Works tube mill, one thickening cone, one six compartment zinc box, one lead lined acid tank, one filter press for zinc slime, solution storage tanks, also small scale apparatus in the shape of agitators and precipitating devices.

Special Section. This section contains one Wetherill electromagnetic separator, one Dings electromagnetic separator, one Huff electrostatic separator, two laboratory size Callow pneumatic flotation cells, three laboratory size flotation machines, mineral separation type, one 6 cell Minerals Separation flotation machine, one Ruth 6-cell flotation machine.

Provision is made in this section for the installation of special machinery whereby its efficiency may be tested and comparison made with standard apparatus; for testing by roasting and magnetic or electrostatic separation, by dry tabling, and by such new processes and apparatus as may, from time to time, come before the metallurgical and mining public.

Research Features

Besides supplying the students of the school with a splendid laboratory and thereby increasing the efficiency of their studies, the plant can be used as a research laboratory by the faculty and the alumni of the school.

COLLECTION OF COMMERCIAL ORES

Most collections of ores are classified according to their mineral contents, but the department of mining is pursuing the policy of gathering average ore samples from every mining district. These are arranged geographically so that the typical ores of each mining district are placed together. Such an arrangement is found to be of great educational value to the classes in mining. The collection now numbers about 1,250 specimens.

MINERALOGICAL AND GEOLOGICAL LABORATORY AND CABINET

Under the name cabinet is embraced not only the display collections, which may perhaps be called the cabinet proper, but also the other collections that have been prepared mainly for the purpose of class instruction. These collections are necessarily changing from year to year, as new material is constantly being added. This new material is obtained partly by purchase, but mainly by direct collecting, by gifts, and by means of exchange with other institutions. The display collections are not thoroughly classified, but are arranged in different cases with a view to displaying certain groups of minerals, or minerals from certain localities. The various collections, which together contain sixty-six thousand specimens, consist of display, type, and working or study collections of minerals, fossils, rocks, and ores. The rock collections include a general collection from different countries, one devoted to Colorado localities, and still others that cover particular countries or localities.

MINERALOGICAL LABORATORY

Aside from the special advantages due to location, the department of geology is admirably equipped for practical teaching. The entire first floor of Guggenheim Hall is occupied by this department. The south end of the building is occupied by a commodious lecture room, with a seating capacity of more than a hundred, and by a separate mineralogical laboratory with table space for between fifty and sixty students, also by two small recitation rooms. On the extreme north end of the building is the public museum, devoted to a display of fine minerals. Additional space is provided for working rooms, office, packing, and storage rooms.

METALLURGICAL COLLECTIONS

The School has a fine collection of models from the works of Theodore Gersdorf, Freiberg, Saxony, which illustrate types of furnaces in this and other countries. Each model is made to scale and is complete in every detail. In addition to these models are the following to illustrate the best modern practice: Working model of a twenty-stamp mill, on a scale of one and one-half inches to the foot; working model of crushing rolls; working model of a Dodge crusher; model of modern blast furnace for lead-silver ores, with water jackets, smaller models, such as the complete set used in the famous Keyes and Arents lead-well suit. There is also a large collection of ores, ore dressing and metallurgical samples and products.

METALLURGICAL LABORATORY

This laboratory is equipped with apparatus for the study of the quantitative relations of the various agencies taking part in metallurgical changes. The Junker, the Mahler Bomb, and the Parr calorimeters, the Wanner optical, the Le Chatelier, and

Bristol electrical pyrometers, together with several electrical furnaces and a Hoskin gasoline furnace, are used for obtaining the desired temperature for experimentation. Desks and apparatus are provided for small-scale work in concentration, amalgamation, chlorination, and cyanidation. Ten separate flotation cells of the Minerals Separation Company's type and a Callow pneumatic cell, all power driven, are provided for the experimental work in the flotation process. The necessary chemical equipment for analyses is also provided. For the physical examination of ores and metallurgical products, five small dissecting, two Leitz, and one Bausch and Lomb compound metallographic microscopes are provided. The necessary standard screens are available. Provision for large scale work is made in the experimental ore dressing and metallurgical plant.

ASSAY LABORATORY

This laboratory is divided into parting, balance, furnace, storeroom, and office. It is equipped with thirty-two coal-fired muffle furnaces, seven Case distillate furnaces, one gasoline furnace, two Braun cupel machines, two Iler cupel machines, and two bullion rolls, one of which is of the Braun type. In order to avoid dust, change of temperature, and direct sunlight, the balance room has no outside walls, and is lighted by means of skylight. The equipment includes seven special pulp balances, five silver balances, three gold balances, one Thompson multiple rider balance, and one Mine & Smelter Supply Company button balance, Wilfred Heusser type, No. 1000, sensitive to 1-500 milligram. This variety is selected in order to acquaint the student with the various mechanisms and adjustments in assay balances. Each student has his own muffle, with his own coal bin, pulp balance, and desk, conveniently arranged with regard to his furnace; he has also access in the balance room to the best type of assay and pulp balances.

SURVEYING EQUIPMENT

The equipment of the department of surveying is well adapted to the practical course given. For transit work there are twenty-four light mountain transits, of which eleven are equipped for underground surveys. There are also three heavy transits, one of which is of English and one of German make. In addition to the transits there are three plane tables for taking topography. For leveling, seven wye levels and five dumpy levels of standard manufacture are used. The department is well supplied with leveling rods of various makes and types, stadia rods, tapes, hand levels, pocket transits, range poles, and other accessories. The instruments are manufactured by such well known firms as C. L. Berger & Sons, Buff & Buff, Heller & Brightly, Eugene Dietzgen & Co., Peter Herr & Co., W. and L. E. Gurley, Keuffel & Esser, William Ainsworth & Sons, Weiss & Heitzler, Young & Sons, Negretti & Zambra (English), and Max Hildebrand (German).

CHEMICAL LABORATORIES

The freshman, sophomore, and junior laboratories accommodate two hundred and fifty students, and are equipped with especially designed tile-topped oak desks, provided with low reagent shelves, gas, water, filter pumps, and large porcelain sinks. The balance rooms are equipped with Sartorius, Becker, and Spoerhase balances. Gas is supplied to the building from a 300-light Detroit gas machine, which is connected with buried supply tanks outside the buildings. Good ventilation is obtained by means of two Sturtevant fans.

HYDRAULIC LABORATORY

The hydraulic laboratory contains weirs and orifice tanks for the determination of coefficients of discharge, calibrated tanks for water measurements, a steel pressure tank for artificial heads, pumps for water supply, and gages for pressure. A hydraulic ram is used to illustrate this class of apparatus and for testing. A long sheet-iron trough with a car over it is used for calibrating current meters. Water wheels and centrifugal pumps are tested for efficiency under various conditions of head and load. A swinging tank is used to measure jet reactions. Friction losses in pipes and elbows are measured. Hook gages are used for the accurate determination of low heads. Streams and ditches in the vicinity of Golden are gaged by means of the current meter, by rod floats, by slope, and by a Pitot tube. A two-inch Venturi meter and manometer set is used in measuring pipe flow.

PHYSICAL LABORATORIES

The physical laboratory is in the basement of the Chemistry Building. Adjoining the main laboratory is a balance and instrument room, and a dark room containing a complete Lummer-Brodhun photometer and an optical bench. The equipment is particularly adapted to the instruction of students of engineering, and is designed to teach the principles of elasticity and efficiency of machines, composition and resolution of forces, various forms of motion, density, velocity and pitch of sound, focal length of lenses, magnifying power, and the principles of the construction of telescopes. The heat equipment is particularly well adapted for calorimetry, heat expansion determinations, and for the determining of the mechanical equivalent of heat. A complete line of galvanometers, standard resistances, condensers, ammeters, voltmeters, dynamometers, permeameters, Potentiometers, standard cells, and a Kelvin balance compose the electrical apparatus; in magnetism all the principles which underlie the construction of magnets for lifting purposes and for the separation of ores are demonstrated in the laboratory.

TESTING LABORATORY

The laboratory is provided with a motor-driven 100,000-pound Riehle testing machine arranged for experiments in tension, compression, shearing, and flexure of materials. Extensometers for measuring elongations and compressions are employed. Numerous steel sections provide useful problems in determining centers of gravity and moments of inertia.

The equipment for cement testing includes a 2,000-pound Riehle testing machine, and a 2,000-pound Olsen automatic shot cement-testing machine for testing briquettes in tension. The specific gravity of cement is determined by means of the Le Chatelier apparatus. A nest of fineness sieves and a set of very sensitive scales equip the student for the fineness test. Setting is determined by means of the complete Vicat apparatus. Trowels, spatulas, large slate mixing boards, beakers, moulds, damp box, and immersing vats, provide apparatus for the making and setting of briquettes and for the soundness tests. Moulds are used for making cubes and cylinders of concrete for compression tests. The use of reinforced concrete is illustrated by complete models of forms for the manufacture of reinforced concrete columns and beams, and by numerous samples of various kinds of reinforcing bars.

ELECTRICAL LABORATORY

This laboratory is equipped with standard makes of voltmeters, ammeters, and wattmeters, inductive and non-inductive resistances for artificial loads, a Thomson apparatus for induction experiments, a slip indicator for induction motors, an automatic speed recorder which can be used for finding the acceleration curves of motors, an Alden absorption dynamometer for motor testing, a contact apparatus for alternating current and voltage wave form, and a split phase rotary field apparatus. The generators available for laboratory work include a 100 kv-a, 2,300 volt, 60 cycle, 3 phase Westinghouse alternator, driven by a Westinghouse producer gas engine, a 75 kw. 230 volt, 3 wire, d. c. Westinghouse generator, driven by a 112 h. p. 2,300 volt, 3 phase, synchronous motor, a 75 kw. Bullock twin unit continuous current generator set, driven by a 110 h. p. De

Laval turbine, a 30 kw. 1,100 volt, 125 cycle, single phase General Electric alternator, a 15 kw. 130 volt compound, continuous current generator designed and built at the school, an 8 kw. Crocker-Wheeler generator, a 6 kw. 130 volt Westinghouse generator, a 7½ kw. 125 volt compound machine, a 3 kw. 5 and 10 volt electrolytic generator, a small single phase rotary converter, a 2 kw. 120 volt compound Brush machine, a series arc light machine, and a small Edison shunt generator. The Bullock generators can be connected at the switchboard to supply the 120-240 volt 3 wire lighting and power circuits, or they can be put in parallel and thus supply more than 600 amperes for electrothermic work. The motors include a 10 h. p. 220 volt, 60 cycle, 3 phase constant speed induction motor of General Electric make, two 5 h. p. series motors with controllers, a 5 h. p. 3 phase, two-speed induction motor, used for electric drilling, a 4 h. p. single-phase Wagner motor, a 400-2,000 rev. per min. adjustable speed experimental motor designed and built at the school, a 20 h. p. series motor, and a large number of 3 phase motors and shunt machines of standard makes in daily use about the shops and buildings. The storage batteries of 54 cells each are in daily use and are available for study. In addition to these generators and motors, a modern 5 panel d. c. switchboard and 7 panel a. c. and d. c. switchboard with the usual instruments, switches, and auxiliaries, afford excellent opportunities for the study of electric plant equipment. The engine room is utilized as a part of the dynamo laboratory, but the laboratory in stratton Hall, equipped with numerous circuit outlets and portable instruments, is used chiefly for the study of motors and their auxiliaries. At present there are 78 generators and motors available for study. Transformers up to 80,000 volts are in use.

MINING LABORATORY

The laboratory work in mining is carried on principally at the tunnel belonging to the school. The equipment here consists of numerous drills which are taken apart, reassembled, and used by the student; forges, anvils and tools for blacksmithing; the air receiver, valves, gages, fuses and switches connected with the compressed air and electric power transmission from the power plant; two mining cars; materials for track laying, and all other supplies usually found at a tunnel house. Among the makes of rock drills used by the students are Rand, Ingersoll, Sergeant, Leyner, McKiernan, Wood, Hardsocg, Shaw, Ingersoll-Leyner, Dreadnaught, Waugh, and Temple-Ingersoll. All of the mountings, such as bars, tripods, and arms, and a supply of drill steel, are also provided. For the measurement of air consumption in drilling operations, the Clark, Drillometer, and displacement meters are installed. Batteries, galvanometers, and rheostats are provided in connection with electric shot firing. In the laboratory at the school are two working size models of the Bleichert system of aerial trams; numerous models of mines; an explosive tester; a collection of rock cores taken by diamond drills; models of timbering methods; many mine maps; instruments for measuring ventilation; lantern slides illustrating mining operations; samples of wire ropes and drill steels; lamps of the open and safety patterns; a dry placering machine; and many photographs of mines and operations.

MECHANICAL ENGINEERING LABORATORY

The heating, lighting, and power plant is well equipped for mechanical engineering laboratory practice. The boiler room contains the following principal equipment: One 200 h. p. and one 100 h. p. Babcock & Wilcox water tube boilers, each equipped with a chain grate; one 80 h. p. tubular boiler equipped with plain grate; Green Engineering Company fuel economizers; Babcock & Wilcox independently fired super-heater; Webster feed-water heater, boiler feed and vacuum pumps and injectors; one Wilcox water weigher; a 125 by 5-foot self-supporting steel stack supplemented by a steam-driven 42-inch Sirocco fan for induced draft; eight 25-ton steel bunkers for coal storage; and a 125 h. p. Westinghouse double-flow gas producer equipped with wet and dry scrubbers, mixing and gas storage tank, and motor-driven exhauster.

The engine room contains the following principal apparatus: 10 by 12-inch high speed Russell engine; 6 by 9-inch throttling Sturtevant engine; 75 kw. De Laval steam turbine geared to twin generators; 7 by 6-inch two-cylinder vertical Westinghouse Jr. engine; 15 by 14-inch three-cylinder vertical Westinghouse gas engine direct connected to alternator; 6¾ by 14-inch single Fairbanks, Morse & Company gas engine; 8¾ by 14-inch Priestman oil engine; a Studebaker four-cylinder automobile motor; a J. George Leyner Engineering Works two-stage air compressor, capacity 275 cubic feet of free air per minute; and a small Westinghouse air-brake.

The laboratory is well equipped with auxiliary apparatus such as indicators, prony brakes, Orsat apparatus, calorimeters and manometers, for conducting experimental work.

SAFETY AND EFFICIENCY ENGINEERING LABORATORY

The equipment consists of six sets Draeger breathing apparatus, two-hour type; one set Draeger breathing apparatus, one-half-hour type; five sets Fleuss breathing apparatus, two-hour type; three sets Westfalia breathing apparatus, two-hour type;

one set Westfalia breathing apparatus, one-half-hour type; all equipped with extra oxygen cylinders, various accessories, and supplies; four large oxygen cylinders for storage; one refilling pump; one pulmotor; one lungmotor; Edison, Manlite, and Wico electric lamps, with charging station; electric flash lights; various types of safety lamps; stretchers, splints, bandages, compresses, and all other necessary first aid material; fuse, squibs, electric detonators, and shot-firing batteries; mine telephones, mine signs, and other safety and efficiency appliances.

DRAWING ROOMS

Freshman and Sophomore. This occupies the upper floor of the Hall of Chemistry. The floor area is about four thousand square feet. It is lighted by windows on the north, east, and west, and by eight large skylights in the roof. A suitable office for the instructors is in a central position, in which all drawings are filed and all records are kept. Each student is provided with a drawing table, a drawer, a drawing board, and a stool. The present equipment accommodates about one hundred fifty students. There are many models to aid the students in their work.

Junior and Senior. The entire third floor of Stratton Hall is used for the junior and senior drawings. The room is 90 by 60 feet, lighted by windows and a large skylight. Each student is provided with a drawing table, a drawer, a drawing board, and a stool. Most of the drawing tables are independent and adjustable. The room has recently been equipped with especially constructed tables for the advanced work of the seniors. The present equipment accommodates about one hundred sixty students. There is a blue-print room fully equipped with an adjustable printing frame and all other necessary appliances. In one corner of the room is the office of the instructors, where all drawings and records are filed. There are for the use of the students a complete set of trade catalogues and a large number of blue prints from industrial corporations. These are kept up to date.

REQUIREMENTS FOR ENTRANCE

FRESHMAN CLASS

Unit Course. A unit course of study is defined as a course covering a school year of not less than thirty-six weeks, with five weekly periods of at least forty-five minutes each.

Fifteen units are required for entrance, of which twelve are specified and three may be chosen from a list of electives.

Specified Units

Essentials of Algebra	1	unit
Advanced Algebra	½	unit
Plane Geometry	1	unit
Solid Geometry	½	unit
Languages, other than English	2	units
English	3	units
History	2	units
Physics	1	unit
Chemistry	1	unit

Specified Units	12
Elective Units	3
Total Units for Entrance	15

Elective Units

The three elective units may be selected from the following list: Drawing, Shop Work, Mathematics, Latin, Greek, French, German, Spanish, History, English, Science, Psychology, Political Economy. In allowing credit for drawing and shop work two forty-five minute periods will be regarded as equivalent to one forty-five minute period of classroom work. Half units are accepted in all studies except in physics and chemistry, provided that not less than one full unit shall be accepted in language.

Entrance

(a) By Certificate

A graduate of an accredited high school in the State of Colorado will be admitted without examination upon the presentation of proper credentials from the principal of his high school, provided that the studies he has successfully completed cover the requirements for entrance. Blanks for this purpose will be sent, on application to the registrar.

Graduates of accredited high schools in other states will be accepted in the same manner as graduates of accredited high schools in Colorado.

(b) By Examination.

All other candidates for admission will be required to pass entrance examination. These examinations are held in Golden.

For the benefit of any student who cannot take the examination in Golden, conveniently, on account of the distance, arrangements will be made so that he may take the examination under the direction of some responsible person at his own home, or near it.

Entrance examinations for the class of 1922 will be held in Golden on Wednesday, Thursday and Friday, August 28, 29, and 30, 1918.

It is the opinion of the Faculty of the Colorado School of Mines that every candidate for the freshman class should have taken a thorough course of at least four years in a good high school, or its equivalent, and during the last year of his preparation should have had a thorough review of mathematics. Special attention should be given to the preparation in chemistry and physics.

If a first year student is found to be deficient in any of the subjects required for entrance, the faculty reserves the right to require such student to remove his deficiency before proceeding with his regular work.

REGISTRATION

The first Monday and Tuesday of September are the registration days for the first semester; and the first day of the second semester is the registration day for that semester.

DESCRIPTION OF THE UNITS REQUIRED FOR ENTRANCE

ENGLISH (3 Units)

(a) **Grammar** The student should have a sufficient knowledge of English grammar to enable him to point out the syntactical structure of any sentence which he meets in the prescribed reading. He should also be able to state intelligently the leading grammatical principles when he is called upon to do so.

(b) **Reading** The books prescribed by the Joint Committee on Uniform Entrance Requirements in English form the basis for this part of the work.

The list is divided into two parts: the first consists of books to be read with attention to their contents rather than to their form, the second consists of books to be studied thoroughly and minutely.

The lists thus divided are as follows:

I Books prescribed for reading

Group I (Two to be selected)

Shakespeare's *As You Like It*, *Henry V*, *Julius Caesar*, *The Merchant of Venice*, *Twelfth Night*

Group II (One to be selected)

Bacon's *Essays;* Irving's *Life of Washington; The Sir Roger de Coverly Papers* in *The Spectator; Franklin's Autobiography*

Group III (One to be selected)

Chaucer's *Prologue;* Spencer's *Faerie Queene* (selections); Pope's *The Rape of the Lock;* Goldsmith's *The Deserted Village;* Palgrave's *Golden Treasury* (*First Series*), *Books II and III*, with especial attention to Dryden, Collins, Gray, Cowper and Burns

Group IV (Two to be selected)

Goldsmith's *The Vicar of Wakefield;* Scott's *Ivanhoe;* Scott's *Quentin Durward;* Hawthorne's *The House of the Seven Gables;* Thackeray's *Vanity Fair;* Mrs. Gaskell's *Cranford;* Dickens' *A Tale of Two Cities;* George Eliot's *Silas Marner;* Blackmore's *Lorna Doone*

Group V (Two to be selected)

Irving's *Sketch Book;* Lamb's *Essays of Elia;* De Quincey's *Joan of Arc* and *The English Mail Coach;* Carlyle's *Heroes and Hero Worship;* Emerson's *Essays;* Ruskin's *Sesame and Lilies*

Group VI (Two to be selected)

Coleridge's *The Ancient Mariner;* Scott's *The Lady of the Lake;* Byron's *Mazeppa* and *The Prisoner of Chillon;* Palgrave's *Golden Treasury* (*First Series*), *Book IV*, with especial attention to Wordsworth, Keats and Shelley; Macaulay's *Lays of Ancient Rome;* Poe's *Poems;* Lowell's *The Vision of Sir Launfal;* Arnold's *Sohrab and Rustum;* Longfellow's *Evangeline;* Tennyson's *Gareth and Lynette*, *Lancelot and Elaine*, and *The Passing of Arthur;* Browning's *Cavalier Tunes*, *The Lost Leader*, *How They Brought the Good News from Ghent to Aix*, *Evelyn Hope*, *Home Thoughts from Abroad*, *Home Thoughts from the Sea*, *Incident of the French Camp*, *The Boy and the Angel*, *One Word More*, *Herve Riel*, *Pheidippides*

II Books prescribed for study and practice

Shakespeare's *Macbeth*, Milton's *Lycidas*, *Comus*, *L'Allegro*, and *Il Penseroso;* Burke's *Speech on Conciliation with America* or Washington's *Farewell Address* and Webster's *First Bunker*

Hill Oration; Macaulay's *Life of Johnson*, or Carlyle's *Essay on Burns.*

(c) **Composition** Regular and persistent training in both written and oral composition should be given throughout the entire school course. The topics should be so chosen as to give practice in the four leading types of prose discourse, namely, description, narration, exposition, and argument.

(d) **Rhetoric** The instruction in this subject should include the following particulars: Choice of words, structure of sentences and paragraphs, the principles of narration, description, exposition and argument.

The teacher should distinguish between those parts of rhetorical theory which are retained in text books merely through the influence of tradition and those which have a direct bearing upon the composition work. The former may be safely omitted.

HISTORY (2 Units)

Any two of the following periods may be offered:

I Ancient History, with special reference to Greek and Roman History, with a short introductory study of the more ancient nations and the chief events of the early middle ages, down to the death of Charlemagne

II Mediaeval and Modern European History, from the death of Charlemagne to the present time

III English History

IV American History, or American History and Civil Government

MATHEMATICS (3 Units)

The courses offered by the school are so exacting that a thorough training in the following subjects is essential:

I **Essentials of Algebra** (1 Unit) The four fundamental operations for rational algebraic expressions; factoring; complex fractions; the solution of equations of the first degree containing one or more unknown quantities; radicals; theory of indices; quadratic equations and equations containing one or more unknown quantities that can be solved by the methods of quadratic equations; problems dependent on such equations.

II **Advanced Algebra** (½ Unit) This course should begin with a thorough review of the essentials. Later work should cover an introduction to the graphical representation of linear and simple quadratic expressions; ratio and proportion; variation; binomial theorem; the progressions; and logarithms.

III **Plane Geometry** (1 Unit) Completed, with the solution of original exercises and numerical problems.

IV **Solid Geometry** (½ unit) Properties of straight lines and planes; of dihedral and polyhedral angles; of projection: of polyhedrons, including prisms; of pyramids and the regular solids; of cylinders, cones and spheres; of spherical triangles, and the mensuration of surfaces and solids.

CHEMISTRY (1 Unit)

The equivalent of Brownlee's **Elementary Chemistry**, Bradbury's **Elementary Chemistry** or Remsen's **Briefer Course of Inorganic Chemistry**, with experiments.

PHYSICS (1 Unit)

The equivalent of Carhart and Chute's **High School Physics**, or Gage's **Principles of Physics**, together with systematic laboratory practice such as is outlined in Crew and Tatnall's **Laboratory Manual in Physics**.

The two units required in languages other than English may be offered in Greek, Latin, French, German, or Spanish.

ADMISSION TO ADVANCED STANDING

Applicants who are graduates of technical or scientific schools or colleges of good standing will be admitted without examination upon the presentation of proper credentials. They will be permitted to take any subject taught in connection with the regular courses, provided, in the opinion of the instructor, their previous experience and training will enable them to pursue the subject with profit. Each case will be judged on its own merits, but applicants will be advised to become candidates for a degree and to complete one of the regular courses of the school.

Applicants who have partly completed the course in technical or scientific schools or colleges of good standing will be admitted without examination upon the presentation of proper credentials. Due credit will be allowed for the successful completion of work which is equivalent to that given in the Colorado School of Mines. Plates of drawings, laboratory note books, and catalogues of the institution attended, should be submitted with applications for advanced standing. All credits given to advanced standing students are given provisionally, with the understanding that such credits may be withdrawn at any time in case a student fails to maintain a creditable standing. Application blanks will be furnished, on request to the Registrar.

DEGREES

The degree of E. M. (Engineer of Mines) will be conferred upon a candidate who fulfils the following conditions:

(a) He must complete the prescribed work of the freshman and sophomore years.

(b) He must complete the required work in one of the groups and enough additional elective work to make a total of one hundred credit hours. The presentation of a thesis is optional, but if presented six credit hours are allowed for it.

No diploma will be delivered until the full requirements of the course of study are satisfied, and all accounts with the school are settled.

The degree of M. S. (Master of Science) may be conferred upon a candidate who already holds a degree from this school or an equivalent degree from a similar institution of good standing, and whose application for such degree shall have been approved by the faculty; provided, that the candidate completes work equivalent to fifty credit hours, chosen with the approval of the faculty, and presents an acceptable thesis. Before being accepted as a candidate the applicant must file a record of his previous attainments.

DEPARTMENTS OF INSTRUCTION

COURSES OF INSTRUCTION

TABULAR VIEW

FRESHMAN YEAR

FIRST SEMESTER	Page	Lect. Hrs.	Lab. Hrs.	SECOND SEMESTER	Page	Lect. Hrs.	Lab. Hrs.
Required				**Required**			
Mathematics I.........	71	3		Mathematics III.......	72	3	
Mathematics II........	72	2		Mathematics IV.......	73	2	
Chemistry I...........	48	5		Chemistry II..........	48	5	
Chemistry III..........	48	1		Chemistry IV..........	49	1	
Chemistry V...........	49		6	Chemistry VI..........	49		6
Mechanical Engineering I	76	2		Mechanical Engineering III	76	2	
Mechanical Engineering II	76		6	Mechanical Engineering IV	77		6
English I..............	63	2		English II.............	63	2	
Geology and Mineralogy I	65	3		Geology and Mineralogy II	65	3	
Physical Training......	135			Physical Training	135		
				Civil Engineering I....	82	1	
				Civil Engineering II... is given during six weeks of the summer following the close of the freshman year.	82		
Elective				**Elective**			
Spanish I..............	112	2		Spanish II.............	112	2	

TABULAR VIEW

SOPHOMORE YEAR

FIRST SEMESTER	Page	Lect. Hrs.	Lab. Hrs.	SECOND SEMESTER	Page	Lect. Hrs.	Lab. Hrs.
Required				**Required**			
Mathematics V........	73	3		Mathematics VI	74	3	
Physics I.............	104	5		Physics III............	105	5	
Physics II.............	104		6	Physics IV............	105		6
Chemistry VII.........	50	1		Chemistry VIII........	50	1	
Chemistry IX.........	50		6	Chemistry X...........	50		6
Mechanical Engineering V	77	2		Mechanical Engineering VII	77	2	
Mechanical Engineering VI	77		3	Mechanical Engineering VIII	78		3
English III.............	63	2		English IV.............	64	2	
Geology and Mineralogy III	66	2	6	Geology and Mineralogy IV	66	2	6
Metal Mining I	93	1		Metal Mining II.......	94	2	
Physical Training	135			Physical Training......	135		
				Metal Mining III...... is given during the four weeks of the summer following the close of the sophomore year.	94		
				Metal Mining XV...... is given for two weeks of the summer following the close of the sophomore year.	100		
Elective				**Elective**			
Spanish III............	112	2		Spanish IV............	113	2	
Mathematics VII.......	74	2		Mathematics VIII......	74	2	

TABULAR VIEW

GROUP I METAL MINING

JUNIOR YEAR

FIRST SEMESTER	Page	Lect. Hrs.	Lab. Hrs.	SECOND SEMESTER	Page	Lect. Hrs.	Lab. Hrs.
Required				**Required**			
Civil Engineering III..	83	3		Civil Engineering IV...	83	3	
Mechanical Engineering IX	78	1		Geology and Mineralogy VII	68	1	3
Mechanical Engineering X	78		6	Mechanical Engineering XI	79	1	
Metallurgy I...........	87	1	6	Mechanical Engineering XII	79		6
Metallurgy III.........	88	3		Metallurgy IV.........	89	3	
Metal Mining IV.......	95		3	Metal Mining VII......	96	2	
Metal Mining V........	95	1		Metal Mining X.......	97	3	
Metal Mining VI......	95	1					
Metal Mining VIII.....	96	2					
Metal Mining IX.......	96	1					
Elective				**Elective**			
Chemistry XV.........	52	2		Chemistry XIII........	51	1	
Coal Mining I..........	54	2		Chemistry XIV........	52		6
Geology and Mineralogy V	67	3		Chemistry XVI........	52	2	
Geology and Mineralogy VI	67	2		Civil Engineering V...	84		3
Electrical Engineering I	59	3		Coal Mining II.........	54	2	
Electrical Engineering II	59		3	Electrical Engineering III	60	3	
Metallurgy V	89	2		Electrical Engineering IV	60		3
Physics V.............	105	2		Metallurgy VI	89	2	
Safety Engineering I..	108	1		Physics VII..........	106		3
Safety Engineering II..	109		3	Safety Engineering III.	110	1	
Spanish V.............	113	1		Safety Engineering IV.	111		3
				Spanish VI...........	113	1	

TABULAR VIEW

GROUP I METAL MINING

SENIOR YEAR

FIRST SEMESTER	Page	Lect. Hrs.	Lab. Hrs.
Required			
Mechanical Engineering XIV	80	2	
Mechanical Engineering XV	80		6
Metallurgy VII	90	4	
Metallurgy VIII	90		3
Metal Mining XI	97	2	
Metal Mining XIII	99	2	
Elective			
Civil Engineering VIII	85		6
Coal Mining IV	56		3
Electrical Engineering V	61	2	
Electrical Engineering VI	61		3
Geology and Mineralogy X	69	2	
Mechanical Engineering XVI	80	2	
Metallurgy XII	91	1	
Mining Law I	102	1	
Thesis—Credit three hours.			

SECOND SEMESTER	Page	Lect. Hrs.	Lab. Hrs.
Required			
Civil Engineering VI	84	2	
Civil Engineering VII	85		3
Metal Mining XII	98	2	
Metal Mining XIV	99	1	
Metal Mining XVI	100	1	
Elective			
Chemistry XVII	52		3
Chemistry XVIII	53		6
Civil Engineering IX	86		6
Coal Mining VI	57	2	
Coal Mining VII	57	1	
Coal Mining VIII	58		3
Electrical Engineering VII	62	2	
Electrical Engineering VIII	62		3
Geology and Mineralogy XI	69	2	
Geology and Mineralogy XII	69	3	
Mechanical Engineering XVII	81	3	
Mechanical Engineering XVIII	81		3
Metallurgy X	91	3	
Metallurgy XI	91		3
Metallurgy XIII	92	2	
Metallurgy XIV	92		3
Mining Law II	102	1	
Thesis—Credit three hours.			

TABULAR VIEW

GROUP II COAL MINING

JUNIOR YEAR

FIRST SEMESTER	Page	Lect. Hrs.	Lab. Hrs.	SECOND SEMESTER	Page	Lect. Hrs.	Lab. Hrs.
Required				**Required**			
Civil Engineering III..	83	3		Civil Engineering IV...	83	3	
Coal Mining I.........	54	2		Coal Mining II........	54	2	
Metallurgy I...........	87	1	6	Mechanical Engineering XI	79	1	
Metallurgy III.........	88	3		Mechanical Engineering XII	79		6
Metal Mining IV......	95		3	Metallurgy IV.........	89	3	
Metal Mining V.......	95	1		Metal Mining VII......	96	2	
Metal Mining VI.......	95	1		Safety Engineering III.	110	1	
Safety Engineering I..	108	1		Safety Engineering IV.	111		3
Safety Engineering II.	109		3				
Elective				**Elective**			
Electrical Engineering I	59	3		Civil Engineering V...	84		3
Electrical Engineering II	59		3	Geology and Mineralogy VII	68	1	3
Geology and Mineralogy V	67	3		Electrical Engineering III	60	3	
Geology and Mineralogy VI	67	2		Electrical Engineering IV	60		3
Mechanical Engineering IX	78	1		Metal Mining X........	97	3	
Mechanical Engineering X	78		6	Metallurgy VI..........	89	2	
Metal Mining VIII.....	96	2		Physics VII...........	106		3
Metal Mining IX......	96	1		Spanish VI............	113	1	
Metallurgy V..........	89	2					
Spanish V.............	113	1					

TABULAR VIEW

GROUP II COAL MINING

SENIOR YEAR

FIRST SEMESTER	Page	Lect. Hrs.	Lab. Hrs.
Required			
Coal Mining III........	55	2	
Coal Mining IV........	56		3
Mechanical Engineering XIV	80	1	
Mechanical Engineering XV	80		6
Elective			
Electrical Engineering V	61	2	
Electrical Engineering VI	61		3
Geology and Mineralogy X	69	2	
Mechanical Engineering XVI	80	2	
Metallurgy VII........	90	4	
Metallurgy VIII.......	90		3
Metallurgy XII........	91	1	
Metal Mining XI.......	97	2	
Mining Law I.........	102	1	
Thesis—Credit three hours			

SECOND SEMESTER	Page	Lect. Hrs.	Lab. Hrs.
Required			
Chemistry XVII.......	52		3
Coal Mining V.........	56	2	
Coal Mining VI........	57	2	
Coal Mining VII.......	57	1	
Coal Mining VIII......	58		3
Elective			
Chemistry XVIII......	53		6
Civil Engineering VI...	84	2	
Civil Engineering VII..	85		3
Civil Engineering IX...	86		6
Electrical Engineering VII	62	2	
Electrical Engineering VIII	62		3
Geology and Mineralogy XI	69	2	
Geology and Mineralogy XII	69	3	
Mechanical Engineering XIII	79	2	
Mechanical Engineering XVII	81	3	
Mechanical Engineering XVIII	81		3
Metallurgy X.........	91	3	
Metallurgy XI.........	91		3
Metallurgy XIII.......	92	2	
Metal Mining XII......	98	2	
Metal Mining XIV.....	99	1	
Metal Mining XVI.....	100	1	
Mining Law I.........	102	1	
Thesis—Credit three hours			

TABULAR VIEW

GROUP III METALLURGY

JUNIOR YEAR

FIRST SEMESTER	Page	Lect. Hrs.	Lab. Hrs.	SECOND SEMESTER	Page	Lect. Hrs.	Lab. Hrs.
Required				**Required**			
Chemistry XI..........	51	1		Chemistry XIII........	51	1	
Chemistry XII.........	51		6	Chemistry XIV........	52		6
Civil Engineering III...	83	3		Civil Engineering IV...	83	3	
Metallurgy III.........	88	3		Metallurgy II..........	87	1	9
Metallurgy V..........	89	2		Metallurgy IV.........	89	3	
Metal Mining V........	95	1		Metallurgy VI.........	89	2	
Metal Mining VI.......	95	1		Metal Mining VII......	96	2	
Elective				**Elective**			
Chemistry XV.........	52	2		Chemistry XVI........	52	2	
Coal Mining I.........	54	2		Coal Mining II.........	54	2	
Electrical Engineering I	59	3		Electrical Engineering III	60	3	
Electrical Engineering II	59		3	Electrical Engineering IV	60		3
Geology and Mineralogy V	67	3		Geology and Mineralogy VII	68	1	3
Geology and Mineralogy VI	67	2		Metal Mining X.......	97	3	
Mechanical Engineering IX	78	1		Physics VII...........	106		3
Mechanical Engineering X	78		6	Safety Engineering III.	110	1	
Metal Mining VIII.....	96	2		Spanish VI............	113	1	
Metal Mining IX.......	96	1					
Physics V............	105	2					
Physics VI............	106		3				
Safety Engineering I..	108	1					
Spanish V............	113	1					

TABULAR VIEW

GROUP III METALLURGY

SENIOR YEAR

FIRST SEMESTER	Page	Lect. Hrs.	Lab. Hrs.	SECOND SEMESTER	Page	Lect. Hrs.	Lab. Hrs.
Required				**Required**			
Metallurgy VII........	90	4		Metallurgy X..........	91	3	
Metallurgy VIII........	90		3	Metallurgy XI.........	91		3
Metallurgy IX.........	90		3	Metallurgy XIII.......	92	2	
Metallurgy XII.........	91	1		Metallurgy XIV.......	92		3
Elective				**Elective**			
Civil Engineering VIII.	85		6	Chemistry XVII.......	52		3
Coal Mining III........	55	2		Civil Engineering VI...	84	2	
Coal Mining IV........	56		3	Civil Engineering VII..	85		3
Electrical Engineering V	61	2		Coal Mining V.........	56	2	
Electrical Engineering VI	61		3	Coal Mining VI........	57	2	
Geology and Mineralogy X	69	2		Coal Mining VII.......	57	1	
Mechanical Engineering XVI	80	2		Electrical Engineering VII	62	2	
Metal Mining XI......	97	2		Electrical Engineering VIII	62		3
Metal Mining XIII.....	99	2		Geology and Mineralogy XI	69	2	
Mining Law I.........	102	1		Geology and Mineralogy XII	69	3	
Thesis—Credit three hours				Metal Mining XII......	98	2	
				Metal Mining XIV.....	99	1	
				Metal Mining XVI.....	100	1	
				Mining Law II.........	102	1	
				Thesis—Credit three hours			

TABULAR VIEW

GROUP IV MINING GEOLOGY

JUNIOR YEAR

FIRST SEMESTER	Page	Lect. Hrs.	Lab. Hrs.	SECOND SEMESTER	Page	Lect. Hrs.	Lab. Hrs.
Required				**Required**			
Civil Engineering III..	83	3		Civil Engineering IV...	83	3	
Geology and Mineralogy V	67	3		Geology and Mineralogy VII	68	1	3
Geology and Mineralogy VI	67	2		Geology and Mineralogy XIII	70		
Metallurgy I	87	1	6	Credit three hours. This course is given for four weeks during the summer following the close of the junior year.			
Metallurgy III.........	88	3		Metallurgy IV.........	89	3	
Metal Mining IV.......	95		3	Metal Mining VII......	96	2	
Metal Mining V.......	95	1					
Metal Mining VI......	95	1					
Elective				**Elective**			
Chemistry XI..........	51	1		Chemistry XIII........	51	1	
Chemistry XII.........	51		6	Chemistry XIV........	52		6
Chemistry XV.........	52	2		Chemistry XVI........	52	2	
Coal Mining I.........	54	2		Civil Engineering V...	84		3
Metal Mining VIII.....	96	2		Coal Mining II........	54	2	
Metal Mining IX.......	96	1		Electrical Engineering III	60	3	
Metallurgy V..........	89	2		Electrical Engineering IV	60		3
Physics V.............	105	2		Mechanical Engineering XI	79	1	
Physics VI............	106		3	Mechanical Engineering XII	79		6
Safety Engineering I..	108	1		Metal Mining X.......	97	3	
Safety Engineering II..	109		3	Metallurgy VI.........	89	2	
Spanish V............	113	1		Physics VII...........	106		3
				Safety Engineering III.	110	1	
				Safety Engineering IV.	111		3
				Spanish VI...........	113	1	

TABULAR VIEW

GROUP IV MINING GEOLOGY

SENIOR YEAR

FIRST SEMESTER	Page	Lect. Hrs.	Lab. Hrs.
Required			
Geology and Mineralogy VIII or IX..........	68		6
Geology and Mineralogy X	69	2	
Elective			
Civil Engineering VIII.	85		6
Coal Mining III........	55	2	
Coal Mining IV........	56		3
Electrical Engineering V	61	2	
Electrical Engineering VI	61		3
Mechanical Engineering XVI	80	2	
Metallurgy VII........	90	4	
Metallurgy VIII........	90		3
Metallurgy XII........	91	1	
Metal Mining XI.......	97	2	
Metal Mining XIII.....	99	2	
Mining Law I.........	102	1	
Thesis—Credit three hours			

SECOND SEMESTER	Page	Lect. Hrs.	Lab. Hrs.
Required			
Geology and Mineralogy XI	69	2	
Geology and Mineralogy XII	69	3	
Elective			
Chemistry XVII.......	52		3
Chemistry XVIII.......	53		6
Coal Mining V.........	56	2	
Coal Mining VI........	57	2	
Coal Mining VII.......	57	1	
Coal Mining VIII......	58		3
Civil Engineering VI..	84	2	
Civil Engineering VII..	85		3
Electrical Engineering VII	62	2	
Electrical Engineering VIII	62		3
Mechanical Engineering XIII	79	2	
Mechanical Engineering XVII	81	3	
Mechanical Engineering XVIII	81		3
Metallurgy X..........	91	3	
Metallurgy XIII........	92	2	
Metallurgy XIV.......	92		3
Metal Mining XIV.....	99	1	
Metal Mining XVI.....	100	1	
Mining Law II........	102	1	
Thesis—Credit three hours			

CHEMISTRY

Melville Fuller Coolbaugh, Professor
Charles Darwin Test, Assistant Professor

The courses in Chemistry are arranged especially for the needs of the mining and metallurgical engineer. These branches of engineering demand a thorough understanding of the laws and theories of inorganic chemistry, and the ability to apply this knowledge to analytical and industrial problems.

I. GENERAL CHEMISTRY **Lectures**

The fundamental principles of Chemistry are taught in this course. Emphasis is laid upon the nature of chemical reactions and the forces which influence them. The work also includes a study of the non-metallic elements and compounds, with special reference to their production and industrial uses.

Prerequisites: Entrance requirements.

Text: Smith, **General Chemistry for Colleges**

Lectures and recitations five hours a week during the first semester of the freshman year.

Required of all students. (Coolbaugh, Test)

II. GENERAL CHEMISTRY **Lectures**

This course is a continuation of Course I and deals with the chemistry of the metallic elements and their compounds. The cement, glass, clay, and alkali industries are considered, and elementary metallurgy is introduced in connection with the more important metals.

Prerequisite: Course I

Text: Smith, **General Chemistry for Colleges**

Lectures and recitations five hours a week during the second semester of the freshman year.

Required of all students. (Coolbaugh, Test)

III. QUALITATIVE ANALYSIS **Lectures**

The principles of qualitative analysis are emphasized in this course, and consideration is given to the relative solubility of substances, oxidation and reduction reactions, and the reactions involved in the systematic analysis of the common inorganic substances. The aim of this course is to teach rapid, accurate qualitative analysis methods and to serve as an introduction to quantitative analysis.

Prerequisite: Entrance requirements

Texts: Prescott and Johnson, **Qualtitative Analysis**
Treadwell-Hall, **Analytical Chemistry, Vol. 1**

One hour a week during the first semester of the freshman year

Required of all students. (Coolbaugh)

IV. QUALITATIVE ANALYSIS **Lectures**

This is a continuation of Course III and deals with the problems involved in the solution of mixtures, minerals, and alloys; with special methods of analysis, and with the separation and detection of some of the rarer elements.

Prerequisites: Courses I and III

Texts: Prescott and Johnson, **Qualitative Analysis**
Treadwell-Hall, **Analytical Chemistry, Vol. 1**

One hour a week during the second semester of the freshman year.

Required of all students. (Coolbaugh)

V. QUALITATIVE ANALYSIS **Laboratory**

This covers the separation and detection of the cations and anions involved in the analysis of solutions and dry mixtures.

Prerequisite: Entrance requirements

Texts: Prescott and Johnson, **Qualtitative Analysis**
Treadwell-Hall, **Analytical Chemistry, Vol. 1**

Six hours a week during the first semester of the freshman year.

Required of all students. (Coolbaugh, Test)

VI. QUALITATIVE ANALYSIS **Laboratory**

This is more advanced qualitative analysis than that given in Course V and includes the separation and detections involved in the analysis of ores, slags, and alloys

Prerequisites: Courses I, III, and V

Texts: Prescott and Johnson, **Qualitative Analysis**
Treadwell-Hall, **Analytical Chemistry, Vol. 1**

Six hours a week during the second semester of the freshman year.

Required of all students. (Coolbaugh, Test)

VII. QUANTITATIVE ANALYSIS **Lectures**

The aim of this course is to study the general principles of gravimetric analysis as applied to simple precipitation methods, and the principles of volumetric analysis as applied to titration methods which involve the use of acids and alkalies, and also oxidizing and reducing reagents.

Prerequisites: Courses IV and VI

Texts: Treadwell-Hall, **Analytical Chemistry, Vol. II**
Quantitative Notes

One hour a week during the first semester of the sophomore year.

Required of all students. (Test)

VIII. QUANTITATIVE ANALYSIS **Lectures**

This course involves a study of the application of the principles given in Course VII to the analysis of fuels, ores, slags and alloys.

Prerequisite: Course VII

Texts: Treadwell-Hall, **Analytical Chemistry, Vol. II**
Quantitative Notes

One hour a week during the second semester of the sophomore year.

Required of all students. (Test)

IX. QUANTITATIVE ANALYSIS **Laboratory**

Simple salts are analyzed gravimetrically; standard solutions are prepared and unknown substances are determined by titration methods.

Prerequisites: Courses IV and VI.

Texts: Treadwell-Hall, **Analytical Chemistry, Vol. II**
Quantitative Notes

Six hours a week during the first semester of the sophomore year.

Required of all students. (Coolbaugh, Test)

X. QUANTITATIVE ANALYSIS **Laboratory**

The course deals with mineral analysis including both gravimetric and volumetric methods with their application to industrial and smelter practice. Coal, simple alloys, ores of the common metals, slags and mattes are analyzed.

Prerequisites: Courses VII and IX

Texts: Treadwell-Hall, **Analytical Chemistry, Vol. II**
Quantitative Notes

Six hours a week during the second semester of the sophomore year.

Required of all students. (Coolbaugh, Test)

XI. ADVANCED QUANTITATIVE ANALYSIS Lectures

Credit one hour.

This work is an extension of the quantitative analysis of the sophomore year and includes more advanced ore analysis; the calorific determination of solid, liquid, and gaseous fuels, the examination of oils, gas analysis, and the analysis of waters and boiler scale.

Prerequisites: Courses VIII and X

References: Low, Technical Methods of Ore Analysis
Gill, Gas and Fuel Analysis for Engineers
Lord and Demorest, Metallurgical Analysis

One hour a week during the first semester of the junior year.

Required of Group III. (Coolbaugh)

XII. ADVANCED QUANTITATIVE ANALYSIS Laboratory

Credit two hours.

Laboratory practice to cover subjects treated in Course XI.

Prerequisites: Courses VIII and X

References: Low, Technical Methods of Ore Analysis
Gill, Gas and Fuel Analysis for Engineers
Lord and Demorest, Metallurgical Analysis

Six hours a week during the first semester of the junior year.

Required of Group III. (Coolbaugh, Test)

XIII. METALLURGICAL CHEMISTRY Lectures

Credit one hour.

This course is to familiarize the student with the analytical methods used in conjunction with metallurgical processes. The subjects taught are the technical methods connected with the metallurgy of iron and steel, zinc, lead, copper, bismuth, mercury, cadmium, tin, nickel, cobalt, and the rarer elements of commercial importance.

Prerequisites: Courses VIII and X

References: Lord and Demorest, Metallurgical Analysis
Johnson, Chemical Analysis of Special Steels, Steel-Making Alloys and Graphites
Scott, Standard Methods of Chemical Analysis

One hour a week during the second semester of the junior year.

Required of Group III. (Coolbaugh)

XIV. METALLURGICAL CHEMISTRY **Laboratory**

Credit two hours.

Laboratory practice to cover subjects treated in Course XIII

Prerequisites: Courses VIII and X

References: Lord and Demorest, **Metallurgical Analysis**
Johnson, **Chemical Analysis of Special Steels, Steel-Making Alloys and Graphites**
Scott, **Standard Methods of Chemical Analysis**

Six hours a week during the second semester of the junior year.

Required of Group III. (Coolbaugh, Test)

XV. PHYSICAL CHEMISTRY **Lectures** (Elective)

Credit two hours.

A study of the laws underlying chemical phenomena from the standpoint of their application to the problems of the metallurgical and geological student. Some of the subjects considered are: Modern theories of solution, the phase rule, colloids, and the law of mass action.

Prerequisites: Courses VIII and X

References: Walker, **Physical Chemistry**
Nernst, **Theoretical Chemistry**
Washburn, **Principles of Physical Chemistry**

Two hours a week during the first semester of the junior year. (Test)

XVI. PHYSICAL CHEMISTRY **Lectures** (Elective)

Credit two hours.

This is a continuation of Course XV and considers the subjects of surface tension, thermo chemistry, electrolysis, and electrolytes.

Prerequisite: Course XV

References: Walker, **Physical Chemistry**
Nernst, **Theoretical Chemistry**
Washburn, **Principles of Physical Chemistry**

Two hours a week during the second semester of the junior year. (Test)

XVII. FUEL AND GAS ANALYSIS **Laboratory**

Credit one hour.

The student determines the heating value of solid, liquid and gaseous fuels by means of the bomb and gas calorimeters. He also analyzes flue gas, illuminating gas, and smelter gases.

Prerequisites: Courses VIII and X

Reference: Gill, Gas and Fuel Analysis for Engineers

Three hours a week during the second semester of the senior year.

Required in Group II. (Coolbaugh, Test)

XVIII. OIL AND ROCK ANALYSIS Laboratory (Elective)

Credit two hours.

A study of the refining methods for oils, the examination of oil shales, and of lubricating and other oils for viscosity, flash and fire tests, and the analysis of rocks.

Prerequisites: Courses VIII and X

References: Hillebrand, The Analysis of Silicate and Carbonate Rocks
Washington, Manual of the Chemical Analysis of Rocks

Six hours a week during the second semester of the senior year.

(Coolbaugh, Test)

COAL MINING

James Cole Roberts, Professor

I. PRINCIPLES OF COAL MINING Lectures

Credit two hours.

The subjects discussed in this course are: distribution and occurrence of coal; the world's production and available supply of coal and coke, with special reference to that of the different states; the losses each year as compared with production: the origin of coal; classification; general geological features of coal-bearing areas, together with the geological and structural features bearing on the economical mining of coal; the prospecting of coal-bearing areas by surface examinations, prospect machines drifts, and drill holes; the different types of drilling machines with the rate and cost of boring in different strata: examination and reporting on developed and undeveloped coal properties; preparation of coal by wet and dry processes; ultilization of fuels; manufacture, handling, and utilization of wood, charcoal, peat, lignite, bituminous and anthracite coals, coke, petroleum, natural and artificial gas. Students are required to visit and witness actual mining operations.

References: Hughes, Textbook of Coal Mining
Redmayne, Modern Practice in Mining
Mayer, Mining Methods in Europe
Beard, Mine Ventilation
Beard, Mine Gases and Explosion
Wilson, Mine Ventilation
Wabner, Ventilation of Mines
Somermeier, Coal, Its Composition, Analysis, Utilization and Valuation
Coal Miners' Pocketbook
United States Bureau of Mines, Publications

Two hours a week during the first semester of the junior year.

Required in Group II (Roberts)

II. METHODS OF COAL MINING Lectures

Credit two hours.

Methods of development and operation of coal mines are taken up in this course. Drifts, slopes, and shafts are discussed and compared; the dip and thickness of coal seams; character of roof and floor or walls of vertical seams; driving and sinking through rock and coal; surface stripping and mining by steam shovels; longwall, room and pillar, panel, and other systems; advancing and retreating systems; the driving of entries, rooms, and crosscuts; width of rooms and pillars in thick and thin seams of coal: drawing of pillars; the proportion of coal that can be safely and economically taken in advance work; methods of working thick and thin seams, lying flat, rolling, pitching, or vertical; methods of working overlying seams with special reference to the recovery of the largest possible yield of coal per acre; shooting off the solid; undercutting of coal by hand (pick mining) and by machines; the operation of the various types of coal cutters, punches, and shearers, with special reference to the economy of each type and the conditions under which each may be used to advantage; single, double, and multiple entry systems compared; surface subsidence; culm flushing as practiced in the anthracite regions of Pennsylvania.

References: Hughes, Textbook of Coal Mining
Redmayne, Modern Practice in Mining
Mayer, Mining Methods in Europe
Beard, Mine Ventilation
Beard, Mine Gases and Explosion
Wilson, Mine Ventilation
Wabner, Ventilation of Mines
Somermeier, Coal, Its Composition, Analysis Utilization and Valuation
Coal Miners' Pocketbook
United States Bureau of Mines, Publications

Two hours a week during the second semester of the junior year.

Required in Group II (Roberts)

III. PRACTICES OF COAL MINING Lectures

Credit two hours.

Timbering of shafts, slopes, drifts, entries, rooms and crosscuts, by the use of wood, steel and concrete, with the relative merits and costs of each; haulage systems; hand tramming; mules or horses; rope; compressed air; electric and gasoline locomotives, hoisting; operation of various types of hoisting engines, using steam, compressed air, or electricity; cages; headframes and tipples; drainage; sources of mine water, its control and ejectment.

References: Hughes, Textbook of Coal Mining
Kerr, Practical Coal Mining
Redmayne, Modern Practice of Mining
Duncan and Penman, Electrical Equipment of Collieries
Shearer, Electricity in Coal Mining
Pamely, Colliery Managers' Handbook
Coal Miners' Pocketbook
United States Bureau of Mines, Publications

Two hours a week during the first semester of the senior year.

Required in Group II. (Roberts)

IV. COAL MINING Laboratory

Credit one hour.

This course consists of field work in prospecting and examining coal bearing lands, following outcrops with actual practice in operating prospecting drills, and visits to points where drilling operations are carried on; sampling of outcrops and coal in the mine: sampling of carload lots of coal in the yards, and on the tipple of operating mines; cutting down and preparing samples for analysis and analyzing samples for proximate, ultimate, and B. t. u. Each student is required to undercut, shoot, and load out a coal face by hand (pick mining) and by each type of machine, to familiarize himself with the different types.

References: Hughes, Textbook of Coal Mining
Kerr, Practical Coal Mining
Redmayne, Modern Practice in Mining
Duncan and Penman, Electrical Equipment of Collieries
Shearer, Electricity in Coal Mining
Pamely, Colliery Managers' Handbook
Coal Miners' Pocketbook
United States Bureau of Mines, Publications
The Trade Catalogs

Three hours a week during the first semester of the senior year.

Required in Group II. (Roberts)

V. PRACTICES OF COAL MINING Lectures

Credit two hours.

This course is a continuation of Course III.

Two hours a week during the second semester of the senior year.

Required in Group II. (Roberts)

VI. COAL MINE EQUIPMENT Lectures

Credit two hours.

This course includes a study of typical mine constructions, such as headframes, tipples, breaker machinery, rolls, screens and various types of coal cutting machines, mechanical devices for loading coal into pit cars; types of pit cars, with special emphasis on tight end cars and rotary dumps; various types of mine fans and their housing; automatic weighing devices; box car loaders.

References: Hughes, **Textbook of Coal Mining**
Kerr, **Practical Coal Mining**
Redmayne, **Modern Practice in Mining**
Duncan and Penman, **Electrical Equipment of Collieries**
Shearer, **Electricity in Coal Mining**
Pamely, **Colliery Managers' Handbook**
Coal Miners' Pocketbook
United States Bureau of Mines, **Publications**
The Trade Catalogs

Two hours a week during the second semester of the senior year.

Required in Group II. (Roberts)

VII. ECONOMICS OF COAL MINING Lectures

Credit one hour.

The subjects taken up in this course are: The general conditions that should precede the opening of coal mines, such as topography, title, climatic conditions, transportation facilities, possible townsite and living quarters for workmen and their families, available water supply, administration and superintendence: contract system as opposed to day labor; costs of operation; maintenance, depreciation, and amortization; methods of acquiring coal lands from the government and individuals; leasing of coal lands; market and trade conditions; preparation of coal for different markets: selling price of coal as compared with cost at the mines; freight rates to various markets and cost of coal to the consumer; company charges for insurance, physicians and hospitals; disposal of unsalable products.

One hour a week during the second semester of the senior year.

Required in Group II. (Roberts)

VIII. COAL MINING Laboratory

Credit one hour.

This course is a continuation of Course IV and includes in addition a critical study of typical mine constructions, with preparation of working drawings of cages, cars, headframes, and tipples.

References: Trade Catalogues

Three hours a week during the second semester of the senior year.

Required in Group II. (Roberts)

ELECTRICAL ENGINEERING

William J. Hazard, Professor

It is the desire of the department to make the electrical courses as independent as possible, that the student may have considerable freedom in the choice of his work. Since there is a logical sequence of studies in principle, practice, and design, it is highly desirable that the student elect his courses in groups. Though not required, it is strongly recommended that those who select Groups I, II or IV should elect E.E. Courses I to VI, inclusive.

I. DIRECT CURRENT MACHINERY **Lectures** (Elective)

Credit three hours.

This course includes a study of the operating principles of direct current generators, motors, meters, switchboards, and auxiliaries, field and usefulness of each type, methods of connection and control, use and care of storage batteries, and the calculation of circuits.

Prerequisites: Physics III and IV
Text: Gray, **Principles and Practice of Electrical Engineering**
References: Morse, **Storage Batteries**
Crocker and Arendt, **Electric Motors**
Lyndon, **Storage Battery Engineering**
Jansky, **Electrical Meters**
Langsdorf, **Principles of Direct Current Machines**
Franklin and Esty, **Elements of Electrical Engineering, Direct Currents**

Three hours a week during the first semester of the junior year. (Hazard)

II. DIRECT CURRENT MACHINERY **Laboratory** (Elective)

Credit one hour.

In this work the common types of voltmeters, ammeters, and wattmeters are studied and calibrated; switchboards are drawn and used; and the common generators and motors, including the three wire and interpole machines, are studied. Series-parallel and standard mining locomotive controllers are wired up and used with two series motors.

Prerequisites: Registration in Course E.E. I or an equivalent preparation

References: Swenson and Frankenfield, Testing of Electromagnetic Machinery, Vol. 1
Karapetoff, Experimental Electrical Engineering, Vol. 1

Three hours a week during the first semester of the junior year. (Hazard)

III. ALTERNATING CURRENT MACHINERY Lectures (Elective)

Credit three hours.

The plan of this course is similar to that of Course I, but treats of alternating current principles and apparatus, generators, and motors with their auxiliaries and characteristics, transformers, rectifiers, and converters, and the calculation of single and three phase circuits.

Prerequisites: Physics III and IV

Text: Gray, Principles and Practice of Electrical Engineering

References: Miller, American Telephone Practice
Van Deventer, Telephonology
Lawrence, Principles of Alternating Current Machinery
Bailey, The Induction Motor
Franklin and Esty, Elements of Electrical Engineering, Alternating Currents

Three hours a week during the second semester of the junior year. (Hazard)

IV. ALTERNATING CURRENT MACHINERY Laboratory (Elective)

Credit one hour.

A study is first made of the alternating current instruments which are subsequently used in the experimental work. This is followed by a variety of experiments on inductive circuits. Transformers are connected and used in many ways. The starting and running characteristics of induction motors are studied under normal conditions and under some abnormal conditions that are frequent causes of trouble. Synchronizing is done in several ways.

Prerequisites: Registration in Course E.E. III or an equivalent preparation

References: Swenson and Frankenfield, Testing of Electromagnetic Machinery, Vol. 2
Karapetoff, Experimental Electrical Engineering, Vol. 2

Three hours a week during the second semester of the junior year. (Hazard)

V. ELECTRICITY APPLIED TO MINING Lectures (Elective)

Credit two hours.

The characteristics of electrical machines and auxiliaries which are adapted to the needs of the various operations of mining and milling are first discussed and then problems based upon these principles are given. The applications discussed, include surface plants, air compression, fans, drilling, coal cutting, shot firing, lighting, haulage, hoisting, pumping, dredging, and signaling. Foundations for electrical machines are designed and circuits discussed. In connection with electricity applied to metallurgical work, the discussion includes motor applications, control and protection, the production of current for electrolytic processes and furnaces, magnetic separation, electrostatic separation and precipitation. All of the above subjects are, of course, discussed in detail by the special departments concerned and only the electrical features are considered in this course.

Prerequisites: E.E. I and II or III and IV

References: Croft, American Electrician's Handbook
Davies, Foundations and Machinery Fixing
Standard Handbook for Electrical Engineers
Koester, Hydroelectric Developments and Engineering
Underhill, Solenoids, Electromagnets and Electromagnetic Windings
Coombs, Pole and Tower Lines
Rosenthal, Transmission Calculations
Lundquist, Transmission Line Construction
Shearer, Electricity in Coal Mining
Duncan and Penman, Electric Equipment of Collieries

Two hours a week during the first semester of the senior year. (Hazard)

VI. APPLIED ELECTRICITY Laboratory (Elective)

Credit one hour.

This is the laboratory course accompanying E.E. V. It includes a study of the standard hand operated compensators with "no voltage" and "overload" releases, resistance starters, automatic contactor starters, motor driven fans and various tests of generators and motors.

Prerequisites: E.E. I and II or III and IV

Three hours a week during the first semester of the senior year. (Hazard)

VII. ELECTRICAL INSTALLATIONS **Lectures** (Elective)

Credit two hours.

This is primarily a design course in small installations, though the work may be varied to suit the needs of the individual student. Course VIII should be taken in conjunction with it.

Prerequisite: E.E. V.

Text: Brown, **Electrical Equipment**

References: **Electrical Handbooks**
Trade Bulletins
Catalogues

Two hours a week during the second semester of the senior year. (Hazard)

VIII. ELECTRICAL INSTALLATIONS **Drawing** (Elective)

Credit one hour.

This is a drawing course to accompany E.E. VII.

Prerequisite: Registration in E.E. VII

References: **Electrical Handbook**
Trade Bulletins
Catalogues

Three hours a week during the second semester of the senior year. (Hazard)

ENGLISH

Victor Clifton Alderson, President

I. ENGLISH COMPOSITION Lectures

This course is designed to train the student in the essentials of English composition. Practical exercises will be given to develop orderly arrangement and clear expression of thought.

Prerequisites: Entrance requirements

References: Kittredge and Farley, Advanced English Grammar
Canby and Others, English Composition in Theory and Practice
Wooley, Handbook of Composition

Two hours a week during the first semester of the freshman year.

Required of all students. (Alderson)

II. BUSINESS CORRESPONDENCE Lectures

This course is a continuation of Course I. It aims to give a practical grasp of business correspondence and to familiarize the student with the type of English composition requisite as a basis for professional report writing.

References: Kittredge and Farley, Advanced English Grammar
Canby and Others, English Composition in Theory and Practice
Wooley, Handbook of Composition

Two hours a week during the second semester of the freshman year.

Required of all students. (Alderson)

III. REPORTS Lectures

This course is designed as a preparation for technical writing. The fundamentals of the subject will be studied and reports upon assigned topics will be required from the students.

References: Sypherd, Handbook of English for Engineers
Earle, Theory and Practice of Technical Writing
Rickard, A Guide to Technical Writing

Two hours a week during the first semester of the sophomore year.

Required of all students. (Alderson)

IV. TECHNICAL WRITING Lectures

This course is a continuation of Course III. The principal object of this course is to outline the best methods of presenting technical subjects for publication and for private reports.

References: Sypherd, Handbook of English for Engineers
Earle, Theory and Practice of Technical Writing
Rickard, A Guide to Technical Writing

Two hours a week during the second semester of the sophomore year.

Required of all students. (Alderson)

GEOLOGY AND MINERALOGY

Victor Ziegler, Professor
F. M. Van Tuyl, Assistant Professor

The college is very fortunately situated for the geologist. The surrounding formations present the strikingly clear features so characteristic of the West. In addition certain features peculiar to this particular location afford sufficiently complicated problems to be of great value to the student of geology. It is possible, therefore, without going more than a mile or two from the school, to illustrate very effectively most geological problems so that field geology can be carried on at the same time as class instruction.

I. GENERAL GEOLOGY Lectures

The aim of this course is to present the fundamentals of geology by means of lectures supplemented by the study of the textbook, and by assigned readings. It comprises a brief survey of the rocks and minerals of the earth's crust and a comprehensive study of the surface features of the earth with emphasis on the forces and agents which have produced these results and are still bringing about slow changes. Occasional field trips are required.

Prerequisites: Entrance requirements

Text: Pirsson and Schuchert, A Textbook of Geology, Part I

Lectures three hours a week during the first semester of the freshman year.

Required of all students. (Van Tuyl)

II. GENERAL GEOLOGY Lectures

This course is a continuation of Course I. It is a study of primary and secondary rock structures, with emphasis on the secondary features resulting from earth movements, such as faults and folds, and the value of their proper interpretation to the mining engineer.

Prerequisite: Course I

Text: Pirsson and Schuchert, A Textbook of Geology, Part I

References: Leith, Structural Geology
Lahee, Field Geology
Grabau, Principles of Stratigraphy

Lectures three hours a week during the second semester of the freshman year.

Required of all students. (Van Tuyl)

III. MINERALOGY **Lectures and Laboratory**

This course in mineralogy is essentially an introduction to Descriptive Mineralogy of the second semester. It comprises a discussion of the principles of crystallography and of blowpipe analysis. Only such portions of crystallography are emphasized as are of practical value in the determination and proper understanding of minerals. In the laboratory work a very thorough drill is given in the more practical portions of the subject. The work covers, in addition to work with the usual wooden crystal models, the determination by means of a pocket lens and contact goniometer of the forms on a large and representative series of natural crystals. The laboratory work in crystallography is followed by a thorough drill in the methods of blowpipe analysis, with practice in the determination of unknown minerals. The lecture time is devoted to a discussion of the fundamental principles of descriptive mineralogy.

Prerequisites: Chemistry I and II

Texts: Lewis, Determinative Mineralogy
Patton, Lecture Notes on Crystallography

Lectures two hours, laboratory six hours, a week during the first semester of the sophomore year.

Required of all students. (Ziegler, Van Tuyl)

IV. DESCRIPTIVE MINERALOGY **Lectures and Laboratory**

About three hundred of the more important mineral species are presented by lectures, in which special emphasis is placed on the recognition of minerals by means of their physical properties. Every attempt is made to make the course thoroughly practical so as to enable the student to recognize at sight such minerals as are met in mining operations. With this object in view, as thorough a drill as the time will allow is given to the actual handling and determining of minerals in the laboratory. In this work each student is expected to handle, to determine, and to be questioned and examined on approximately two thousand five hundred individual specimens.

Prerequisite: Course III

References: Fords, **Dana's Manual of Mineralogy**
Dana, **System of Mineralogy**
Lewis, **Determinative Mineralogy**

Lectures two hours, laboratory six hours, a week during the second semester of the sophomore year.

Required of all students. (Ziegler, Van Tuyl)

V. HISTORICAL GEOLOGY **Lectures**

Credit three hours.

A study of earth history with emphasis on the North American continent. The theories of the origin of the earth are discussed and the succession of events in its known history as revealed by the rocks are traced. Especial attention is given to the changes in relation of land and sea, the character and distribution of the deposits, the orogenic movements, volcanic activity, economic products and dominant life forms of each geological period.

Prerequisites: Courses I and II

References: Pirsson and Schuchert, **A Textbook of Geology, Part II**
Chamberlin and Salisbury, **Geology, Vol. II and III**
Rice, Adams and Others, **Problems of American Geology**

Lectures three hours a week during the first semester of the junior year.

Required in Group IV (Van Tuyl)

VI. STRUCTURAL GEOLOGY **Lectures**

Credit two hours.

This course covers practically Mining Geology. It includes a comprehensive study of rock structures with special emphasis on features important to the mining engineer. The graphic study of folds and faults and the interpretation of structure from maps receive special attention.

Prerequisites: Courses I to V, inclusive.

References: Leith, **Structural Geology**
Geikie, **Structural and Field Geology**
Hayes, **Handbook for Field Geologists**
Gunther, **The Examination of Prospects**
Tolman, **Graphical Solution of Fault Problems**

Lectures two hours a week during the first semester of the junior year.

Required in Group IV. (Ziegler.)

VII. LITHOLOGY **Lectures and Laboratory**

Credit two hours.

The object of this course is to present all the more commonly occurring rocks in such a way as to render their identification at sight reasonably accurate. The methods pursued are purely those applicable to the hand specimen without the aid of microscopic sections. The collection of the school is especially rich in those rocks that are usually encountered in mining operations in Colorado and adjacent states. Special emphasis, therefore, is laid upon such rocks and upon their various alteration forms.

Lectures one hour, laboratory three hours a week during the second semester of the junior year.

Required in Groups I and IV. (Ziegler, Van Tuyl)

VIII. MICROSCOPIC PETROGRAPHY

Credit two hours.

In this course the study of rocks and rock-forming minerals is carried on with the help of the petrographic microscope. It covers (a) the study of the optical properties of minerals with a view to their identification, and (b) systematic petrography or the identification of rock types by means of their structures and mineral components.

Laboratory six hours a week during the first semester of the senior year.

Required in Group IV.

Course IX may be substituted. (Ziegler)

IX. INDEX FOSSILS OF NORTH AMERICA **Lectures and Laboratory**

Credit two hours.

A course planned to meet the needs of students who desire to fit themselves for work in oil geology and all others to whom the ability to determine the age of sedimentary rocks by means of their fossils may be of value. Only the more important guide fossils of each system are studied. Special attention is given to the fossils characteristic of western formations of economic importance.

Prerequisite: Course V

References: Shimer, **An Introduction to the Study of Fossils**

Grabau and Shimer, **Index Fossils of North America**

Six hours laboratory a week during the first semester of the senior year.

Required in Group IV.

Course VIII may be substituted. (Van Tuyl)

X. ORE DEPOSITS **Lectures**

Credit two hours.

This course treats of the nature, origin, and occurrence of ore deposits. Among other subjects the criteria useful in the recognition of the various types of ore deposits, the changes in the character of ores with depth, and mineral associations and alterations, are discussed. Those features likely to be of use in the examination of mining prospects receive special attention.

Prerequisites: Courses I, II, III, IV, and VII

References: Beyshlag, Vogt and Krusch, **Deposits of Useful Minerals and Rocks**
Lindgren, **Mineral Deposits**

Lectures two hours a week during the first semester of the senior year.

Required in Group IV. (Ziegler)

XI. ECONOMIC GEOLOGY **Lectures**

Credit two hours.

This course includes a discussion of the more important mining districts of North America. In addition to ore deposits the more important non-metallic products and their distribution are included.

Prerequisite: Course X

References: Lindgren, **Mineral Deposits**
Beyshlag, Vogt and Krusch, **Deposits of Useful Minerals and Rocks**

Lectures two hours a week during the second semester of the senior year.

Required in Group IV. (Ziegler)

XII. OIL AND GAS **Lectures**

Three credit hours.

The chemistry and physics of the natural hydrocarbons, their origin, type of occurrence and geologic setting will be discussed in detail. Emphasis will be placed on the principles and laws of oil accumulation applicable to all fields. An effort will be made to train the student in the interpretation of the structural and geological phenomena characteristic of oil and gas fields.

Prerequisites: Course I to VII, inclusive

References: Johnson and Huntley, Oil and Gas Production
Hager, Practical Oil Geology
Engler and Hoefer, Das Erdol
Bacon and Hamor, the American Petroleum Industry

Three hours a week during the second semester of the senior year.

Required in Group IV. (Ziegler)

XIII. FIELD GEOLOGY

Credit three hours.

This course is intended to give field practice in geologic mapping and in the working out of structural details. The area selected is divided among individual squads and a complete map with structural sections is prepared through cöoperation of the different squads. The work covers four weeks at the close of the junior year. Camping equipment and instruments are furnished by the school. The student is expected to furnish bedding. The expense of the course will vary somewhat according to the location of the area worked. Ordinarily forty to forty-five dollars should cover all actual field expenses.

Prerequisites: Courses V, VI, and VII

Required in Group IV (Ziegler, Van Tuyl)

MATHEMATICS

Charles Roland Burger, Professor
George Eulas Foster Sherwood, Associate Professor

The courses in this department have been arranged to meet the extensive needs of students in the various branches of engineering. The subjects are treated so as to give the student both logical training and power of application. The principles which are of greatest value in engineering work are particularly emphasized. The courses offered serve as a sufficient prerequisite for the work in mathematical physics, physical chemistry, engineering and applied mechanics; and they mark the minimum of mathematical attainments that an engineer ought to possess. A special feature of the work is the early introduction of the calculus, the principles of which are introduced with those of analytic geometry and developed as needed, thus disregarding, to a certain extent, the traditional barrier that has existed between these subjects. By this means, the principles of the calculus are allowed to develop slowly, their sphere of usefulness is widened, the student gains a better grasp of mathematics as a whole, and is able, early in his course, to make direct application of his knowledge of mathematics to practical problems.

I. COLLEGE ALGEBRA

This course begins a rapid review of the fundamental operations as far as quadratics. Graphical work is early introduced in the belief that the illumination which it affords greatly enlivens the entire presentation of the subject and brings algebra into closer relationship with the other mathematical courses. Quadratics are given special emphasis. The progressions, inequalities, mathematical induction, proportion, variation, theory of limits, series, the binominal theorem, logarithms, exponentials, and determinants are all amply treated. Methods of approximating the roots of numerical equations are especially emphasized.

Much time is given to drill work in calculations involving formulas often met in engineering work. A special feature of the course is the persistent use of graphic methods in presenting facts—a practice which is becoming an indispensable requisite in engineering.

Prerequisites: Entrance requirements.

Text: Rietz and Crathorne, **College Algebra**

Three hours a week during the first semester of the freshman year.

Required of all students. (Burger, Sherwood)

II. TRIGONOMETRY

The general formulas of plane and spherical trigonometry are developed. Inverse functions, identities, and trigonometric equations are carefully considered. Much practice is given in the use of tables and the applications of trigonometry to mensuration in general. The astronomical triangle and such problems relating thereto as occur in surveying are dwelt upon particularly and graphical representation is given its needed emphasis.

Prerequisites: Entrance requirements

Texts: Crawley, **Short Course in Trigonometry**
Hodgman, **Surveyor's Tables**

Two hours a week during the first semester of the freshman year.

Required of all students. (Burger, Sherwood)

III. ANALYTIC GEOMETRY

This course being with the Cartesian coordinates of a point. Graphs of algebraic and transcendental functions follow. Loci in general, the straight line, conic sections, and cycloids are taken up in detail.

The methods and notation of the calculus are introduced early and are employed in the study of tangents and normals. The parametric equations of the conics and cycloids are developed and many applications to locus problems are introduced and discussed. The student is made familiar with the polar equations of the conics, spirals, ovals, and other plane curves. Emphasis is given to the graphical representation of the trigonometric, logarithmic, exponential, and other transcendental functions.

The analytic geometry of space is deferred until the second year when it is needed in the development of the calculus.

Prerequisites: Courses I and II

Text: Woods and Bailey, **Analytic Geometry and Calculus**

Three hours a week during the second semester of the freshman year.

Required of all students. (Burger, Sherwood)

IV. CALCULUS

This course introduces the student to the elements of the calculus. The language, the symbols, and the first processes of the infinitesimal analysis are explained and many illustrations in geometry, physics, engineering, and applied mechanics are introduced. The fundamental principles of continuity, limiting values, and the theory of infinitesimals are established. The differentiation of all the fundamental forms and the application of the differential calculus to problems involving maxima and minima, rates, and to the theorems of analytic geometry comprise a large part of the course. Integration is introduced as the inverse operation of differentiation and is applied to numerous problems involving areas, velocities, and geometry.

Prerequisites: Courses I and II

Text: Woods and Bailey, **Analytic Geometry and Calculus**

Two hours a week during the second semester of the freshman year.

Required of all students. (Burger, Sherwood)

V. CALCULUS

This course is a continuation of Course IV, in which students are made familiar with the elementary processes and applications of the differential calculus. A special feature of this course consists in carrying on the differential and integral calculus together. This method of instruction enables the student to grasp the more difficult notions of the subject in their inherent relations, and at the same time to apply this knowledge, early in the course, to the solution of engineering problems. The conception of the definite integral and its many applications are early introduced. The aim is to make clear the *rationale* of each process, and to arouse an early interest in the usefulness of the subject. The theory of single and multiple integration is applied to the principal methods of rectification and quadrature, and to the calculation of surfaces and volumes of solids of revolution.

Prerequisites: Courses I to IV, inclusive

Text: Woods and Bailey, **Analytic Geometry and Calculus**

Three hours a week during the first semester of the sophomore year.

Required of all students. (Burger, Sherwood)

VI. CALCULUS

This course is a continuation of Course V. The elements of solid analytic geometry are introduced to assist in the proper development of the calculus of functions of two or more variables. Simple differential equations are introduced in close connection with integration. Multiple integration in rectangular, polar, and cylindrical co-ordinates is taken up and many applications are made to problems in areas, volumes, moments of inertia, centers of gravity, and pressure. Solids of revolution, cylinders, space curves, ruled and quadric surfaces are all given their needed emphasis as applications of the calculus. The last part of this course is pre-eminently a problem course. The aim is to review, in a practical way, the mathematics of the last two years and thereby encourage the student to look upon his mathematics as an instrument of power and usefulness rather than one of mental development and culture.

Prerequisites: Courses I to V, inclusive

Text: Woods and Bailey, Analytic Geometry and Calculus

Three hours a week during the second semester of the sophomore year.

Required of all students. (Burger, Sherwood)

VII. HIGHER MATHEMATICS (Elective)

Credit two hours.

This course consists of a survey of the field of higher mathematics with special reference to the needs of engineering students mathematically inclined. The subjects will be treated in an elementary manner and will include: finite differences with application to interpolation and summation, vector analysis with problems in physics and mechanics, modern geometry pure and projective, advanced portions of the calculus not included in the regular courses, empirical formulas and calculations, and a brief history of mathematics.

Prerequisites: Courses I to IV, inclusive

Two hours a week during the first semester of the sophomore year. (Burger)

VIII. PRACTICAL ASTRONOMY AND LEAST SQUARES (Elective)

Credit two hours.

This course covers a study of the celestial sphere, including the sun, moon, earth, and planets; the constellations; the measurement of time; problems necessitating familiarity with, and use of, the Nautical Almanac; such problems of practical astronomy as may be solved by the surveyor, including: (1) latitude by the altitude of any heavenly body at culmination; (2) solar and stellar observations for meridian; (3) longitude by transit of the moon; (4) observations for determining the time; the development of the method of Least Squares; its application to problems in astronomy, surveying, physics, and chemistry.

Prerequisites: Courses I to IV, C.E. I and II

Text: Hosmer, Textbook on Practical Astronomy.

Two hours a week during the second semester of the sophomore year. (Sherwood)

MECHANICAL ENGINEERING

James Lyman Morse, Professor

I. DESCRIPTIVE GEOMETRY Lectures

This course includes problems relating to the point, line, plane, surfaces, intersection of solids and the development of their surfaces, and numerous practical applications to mine surveying and machine design.

Prerequisites: Entrance requirements
Text: Smith, Descriptive Geometry

Two hours a week during the first semester of the freshman year.

Required of all students. (Burger, Sherwood)

II. DESCRIPTIVE GEOMETRY Drawing

At the beginning of the course considerable time is given to the use of instruments, geometrical constructions, and lettering; then follows the direct application of the problems that are taken up in the lecture work.

Prerequisites: Entrance requirements
Text: Smith, Descriptive Geometry and Plates
Reinhardt, Lettering
French, Mechanical Drawing and Elementary Machine Design

Six hours a week during the first semester of the freshman year.

Required of all students. (Morse)

III. ELEMENTARY MACHINE DESIGN Lectures

This course includes a study of machine elements, the nature of materials entering into machine construction, and elementary calculations which involve the correct proportion, by empirical methods, of various machine parts.

Prerequisites: Courses I and II
Text: French, Mechanical Drawing and Elementary Machine Design

Two hours a week during the second semester of the freshman year.

Required of all students (Morse)

IV. ELEMENTARY MACHINE DESIGN **Drawing**

The object of this course is to give the student the principles of orthographic projection when applied to machine drawings executed according to modern drafting and shop practice. Considerable time is devoted to correct methods of lettering and dimensioning of drawings and free-hand sketching. Working drawings are submitted of the following: anchor-bolts, shaft-couplings, hangers, pipe-joints, valves, machine elements, and simple engine parts.

Prerequisites: Courses I and II

Text: French, **Mechanical Drawing and Elementary Machine Design**

Six hours a week during the second semester of the freshman year.

Required of all students. (Morse)

V. MACHINE DESIGN **Lectures**

This is a continuation of Course III. A brief outline of the various principles of mechanics, so necessary for the work, is here taken up. Special attention is given to problems which involve the transmission of power and the best solution of these from both the theoretical and practical point of view.

Prerequisites: Courses III and IV

Text: Marshall, **Machine Design**

Two hours a week during the first semester of the sophomore year.

Required of all students. (Morse)

VI. MACHINE DESIGN **Drawing**

This is a continuation of Course IV. The work is extended to include more complex problems. Complete working drawings of some of the following are submitted: shafting layouts; belt, fibrous, and wire rope drives; machine parts, conveyors, and conveyor systems.

Prerequisites: Courses III and IV

Text: Marshall, **Machine Design**

Three hours a week during the first semester of the sophomore year.

Required of all students. (Morse)

VII. KINEMATICS OF MACHINERY **Lectures**

This course begins with the theoretical analysis of mechanism and extends to the practical application of these principles to such problems as arise in practice. Special attention is given to the analysis of links, belting, cams, gears, and other contact mechanism.

Prerequisites: Courses V and VI

Text: Keown, **Elements of Mechanism**

Two hours a week during the second semester of the sophomore year.

Required of all students. (Morse)

VIII. KINEMATICS OF MACHINERY **Drawing**

This course supplements and is directly dependent upon the lecture work. This work is taken up from a practical point of view and applies such theory as is consistent with the most approved method of design. Designs and complete working drawings are made from machine parts, gears, cams and various systems and devices used for the transmission of power.

Prerequisites: Courses V and VI

Text: Keown, **Elements of Mechanism**

Three hours a week during the second semester of the sophomore year.

Required of all students. (Morse)

IX. HEAT POWER PLANT ENGINEERING **Lectures**

Credit one hour.

The greater portion of the semester is devoted to steam boiler subjects. After a brief historical treatment of the subject, the lectures cover the theory, principles of design, and construction of modern boilers. Numerous practical problems are assigned from time to time so that the student becomes thoroughly familiar with the design and operation of the leading types of boilers.

Prerequisites: Courses VII and VIII

Text: Allen and Bursley, **Heat Engines**

One hour a week during the first semester of the junior year.

Required in Group I. (Morse)

X. HEAT POWER PLANT ENGINEERING **Design**

Credit two hours.

The drafting room work is devoted principally to the design of power plant apparatus and to such other machinery as is usually to be found in a mine plant. Boilers, steam engines, hoists, conveying systems, and mill installations are designed and complete sets of detailed working drawings are required in all cases. The value of time is impressed upon the student and all work is done in accordance with the most approved manufacturing methods.

Prerequisites: Courses VII and VIII

Text: Fernald and Orrock, **Engineering of Power Plants**

Six hours a week during the first semester of the junior year.

Required in Group I. (Morse)

XI. HEAT POWER PLANT ENGINEERING **Lectures**

Credit one hour.

The lectures of this course embrace principally the subject of steam engines. The development of the steam engine is first carefully traced out, after which attention is given to thermodynamics and the fundamental principles which underlie the steam engine. Practical problems are assigned the student and great stress is laid upon all matters pertaining to the economical side of the subject.

Prerequisites: Courses VII and VIII

Text: Allen and Bursley, **Heat Engines**

One hour a week during the second semester of the junior year.

Required in Groups I and II. (Morse)

XII. HEAT POWER PLANT ENGINEERING **Design**

Credit two hours.

This course is a continuation of Course X, and enables the student to undertake and complete some of the more advanced problems in the design of power plant machinery.

Prerequisites: Courses VII and VIII

Text: Fernald and Orrock, **Engineering of Power Plants**

Six hours a week during the second semester of the junior year.

Required in Groups I and II. (Morse)

XIII. COMPRESSED AIR **Lectures** (Elective)

Credit two hours.

This course includes a study of the theory and practice of air compression. At the beginning considerable time is given to the study of such thermodynamics as is necessary to a successful pursuit of the course. After this the work comprises a study of the following principal items: single and multiple stage compression; absorption of heat during compression; transmission of power by compressed air; draining of moisture from pipe lines; reheating; the use of compressed air in motors and the various valve-gears used. A systematic study is made in the class room of the catalogues of one or more of the leading compressor builders.

Prerequisites: Courses VII and VIII
Text: Peele, **Compressed Air**
Trade Catalogues

Two hours a week during the second semester of the senior year. (Morse)

XIV. POWER PLANT DESIGN **Lectures**

Credit two hours.

This course includes a detailed study of the units and auxiliaries necessary to a power plant and their various connecting links. After this, problems affecting the type and location of power plants are taken up and then the work is extended to problems involving the best selection and number of units, location and arrangement, connection with auxiliaries, and the necessary housing for equipment. The items of first cost, operating cost, and depreciation are carefully considered.

Prerequisites: Courses XI and XII
Text: Gebhardt, **Power Plant Engineering**

Two hours a week during the first semester of the senior year.

Required in Groups I and II. (Morse)

XV. POWER PLANT DESIGN **Drawing**

Credit two hours.

The work in this course includes working drawings of some of the power plant equipment taken up and studied in detail in the lecture course. Such problems as the following are assigned: detail of piping systems, including live and exhaust steam, for a certain size plant; foundations for units and auxiliaries; flues and stacks; coal and ash handling machinery.

Prerequisites: Courses XI and XII

Six hours a week during the first semester of the senior year.

Required in Groups I and II. (Morse)

XVI. GAS ENGINES **Lectures** (Elective)

Credit three hours.

This course is intended to give the mining engineer a practical working knowledge of the gas engine. The theory and thermodynamics of the gas engine are carefully considered, together with the conditions affecting efficiency and operation. The best types of modern engines together with auxiliary apparatus are taken up and discussed with regard to special features and advantages. Each student is assigned a seminar paper upon some special subject of investigation. At the conclusion of the course these papers are presented before the class. A portion of the course is devoted to practice in operating and running the engines found in the laboratories.

Prerequisites: Courses VII and VIII

Text: Streeter, **The Gas Engine**

Two hours a week during the first semester of the senior year. (Morse)

XVII. PUMPING MACHINERY **Lectures** (Elective)

Credit three hours.

This course comprises a careful study of the principle, design, and operation of all kinds of pumping machinery. Special attention is given to the selection and installation of steam, electric, and compressed air pumps for mine service. Problems involving the calculations of capacity, slip, and duty of pumping engines are assigned to the students. Along with the study of pumping machinery considerable time is devoted to the study of air-lifts.

Prerequisites: Courses VII and VIII

Text: Greene, **Pumping Machinery**

Three hours a week during the second semester of the senior year. (Morse)

XVIII. MECHANICAL ENGINEERING **Laboratory** (Elective)

Credit one hour.

It is the purpose of this course to familiarize the student with the apparatus used in testing and engineering investigation. The practice work includes indicator practice: study of reduction motions; dynamometers; determination of the quality of steam; calibration of gages; valve setting; efficiency tests of boilers: flue gas analysis; test of air compressors; tests of steam turbines.

Prerequisites: Courses VII and VIII

Text: Moyer, **Power Plant Testing**

Reference: Smallwood, **Mechanical Laboratory Methods**

Three hours a week during the second semester of the senior year. (Morse)

MECHANICS AND CIVIL ENGINEERING

Harry Munson Showman, Professor

The aim of this department is to train the student in such subjects of civil engineering as may be required of a mining engineer. This includes a knowledge of plane surveying, analytical and applied mechanics, structural design, and hydraulics.

I. THEORY OF PLANE SURVEYING **Lectures**

The purpose of this course is to give preliminary instruction in the principles involved in surveying, and, by numerous problems, to enable the student to acquire speed and accuracy in calculations. Units and general methods of measurement are taken up first and are followed by chaining and transit problems; leveling, stadia surveying, plane-table mapping, and topographic surveying are studied in order. City, land, and railroad surveying are covered briefly. Methods of computation are thoroughly studied. These include closing and adjustment of traverses; omitted measurements; areas; parting off land; earthwork; and the reduction of solar observations for a true meridian.

Prerequisites: Math. I and II

Text: Breed and Hosmer, **Plane Surveying, Vol. I**
References: Johnson and Smith, **Theory and Practice of Plane Surveying**
Breed and Hosmer, **Higher Surveying, Vol. 2**
Wilson, **Topographic Surveying**
Tracy, **Plane Surveying**

One hour a week during the second semester of the freshman year.

Required of all students. (Showman)

II. PRACTICE OF PLANE SURVEYING **Lectures and Field Work**

The field work in plane surveying is conducted in the vicinity of Golden and comprises chaining, differential and profile leveling, triangulation, traversing, and numerous exercises with the transit. A topographical map of an extended territory is made by each squad with the transit and stadia. In addition, several days are spent with the plane table in rapid mapping.

At all times the combination of accuracy with economy of time is emphasized. Lectures are held as often as necessary to give detailed instruction in the adjustment and manipulation of instruments.

Prerequisite: Course I

References: Searles, Field Engineering
Pence and Ketchum, Surveying Manual
Johnson and Smith, Theory and Practice of Plane Surveying
Breed and Hosmer, Higher Surveying, Vol. 2
Wilson, Topographic Surveying

Six weeks in the summer following the close of the freshman year.

Required of all students. (Showman)

III. ANALYTICAL MECHANICS Lectures

Credit three hours.

This course consists of the study of the fundamental and derived laws of matter, force, and motion, with their application to engineering problems. The chief topics treated are composition and resolution of forces; solution of framed structures; attraction and gravitation; center of gravity; moment of inertia; kinetics of a particle; projectiles; work; power; energy; friction; kinetics of rigid bodies; and impact. The course is taught by text assignments, with lectures and recitations. Special emphasis is placed upon problem work.

Prerequisites: Math. V and VI; Physics I and II

Text: Poorman, Applied Mechanics

References: Minchin, Treatise on Statics
Routh, Dynamics
Ziwet, Theoretical Mechanics
Church, Mechanics of Engineering
Maurer, Technical Mechanics
Church, Notes and Examples in Mechanics

Three hours a week during the first semester of the junior year.

Required in Groups I, II, III, and IV. (Showman)

IV. APPLIED MECHANICS -Lectures

Credit three hours.

This is a continuation of Course III and consists of the study of elastic bodies; stresses and strains; tension; shear compression; torsion; flexure; combined stresses; elastic curves; safe loads; oblique forces; long columns; hooks; simple and continuous beams.

Prerequisite: Course III

Texts: Boyd, Strength of Materials
Cambria Steel

References: Merriman, Mechanics of Materials
Burr, Elasticity and Resistance of the Materials of Engineering
Lanza, Applied Mechanics

Three hours a week during the second semester of the junior year.

Required in Groups I, II, III, and IV. (Showman)

V. TESTING LABORATORY (Elective)

Credit one hour.

In this course tests are made to determine the strength and stiffness of building materials, such as cast iron, wrought iron, steel, plain and reinforced concrete, and wood in tension, compression, shearing, and flexure. Stone and brick are examined for strength, absorption, disintegration and other qualities which decide their economic values. Experiments to determine the strength of threaded bolts, riveted joints, welds, and nailed joints are included in the course. Tests of cement are made as specified by the American Society for Testing Materials.

Prerequisite: This course must be taken in conjunction with, or subsequent to, Course IV

References: Merriman, Mechanics of Materials
Burr, Elasticity and Resistance of the Materials of Engineering
Lanza, Applied Mechanics
Martens, Handbook of Testing Materials
Hatt and Schofield, Laboratory Manual of Testing Materials

Three hours a week during the second semester of the junior year. (Showman)

VI. HYDRAULICS Lectures

Credit two hours.

This course opens with a brief treatment of hydrostatics, takes up the theory and practical application of the properties of fluids in motion, and includes steady flow of liquids through pipes and orifices and over weirs; fluid friction and losses of head; time of emptying vessels; uniform flow of water in open channels; impulse and resistance of fluids; pumps and rams; the impulse water motor; overshot, breast, and undershot waterwheels; back water; theorem for flow in revolving pipe; turbine and reaction wheels.

Prerequisite: Course III
Text: Daugherty, Hydraulics
References: Merriman, Treatise on Hydraulics
Hughes and Safford, Hydraulics
Russell, Textbook on Hydraulics
Church, Hydraulics

Two hours a week during the second semester of the senior year.

Required in Group I. (Showman)

VII. HYDRAULICS Laboratory

Credit one hour.

Measurements are made of flow over weirs, through orifices, and through flumes and ditches. The determination of the approximate law of flow in pipes also forms part of the course. Water-wheels and centrifugal pumps are tested and the efficiency of the hydraulic ram under various conditions is determined.

Prerequisite: This course can be taken only in conjunction with Course VI
References: Church, Hydraulics
Merriman, Treatise on Hydraulics
Hughes and Safford, Hydraulics
Russell, Textbook on Hydraulics

Three hours a week during the second semester of the senior year.

Required in Group I. (Showman)

VIII. ENGINEERING CONSTRUCTION Lectures and Drawing (Elective)

Credit two hours.

In this course instruction is given in graphical analysis of the stresses of framed structures of the simpler forms. Comparison is made with the algebraic solutions of the same problems as far as possible. The design of roof and bridge trusses in steel is then taken up from the theoretical and practical points of view. Steel mill buildings are thoroughly discussed, an analysis of all stresses involved is made, and a complete design is required from each student. In connection therewith the forms, covering, lighting, ventilation, erection, and similar topics are carefully considered. The design and construction of steel head-frames and ore bins are taken up in detail.

Prerequisite: This course may be taken only with the consent of the instructor

Texts: Ketchum, **Steel Mill Buildings**
Cambria Steel
Lecture Notes

References: Ketchum, **Structural Engineer's Handbook**
Morris, **Designing and Detailing Simple Steel Structures**

Lectures and drawing six hours a week during the first semester of the senior year. (Showman)

IX. STRUCTURAL DETAILS **Lectures and Drawing** (Elective)

Credit two hours.

This course is a study of the methods of framing heavy timber. The student is first made familiar with the terms of framing, such as housing, notching, mortise and tenon, dovetailing, lag-screws, dowels and lugs, and from accepted unit stresses, he is led to design joints, splices, deepened beams, trussed beams, and head-frames from wood. A complete design of a combination wood and steel truss is required from each student. A brief study is made of the ordinary timbers used in construction, and the best modern methods of protecting them from the action of the elements and wood-destroying insects.

Prerequisite: This course may be taken only with the consent of the instructor

Texts: Jacoby, **Structural Details**
Cambria Steel
Lecture Notes

Reference: Kidder, **Architect's and Builder's Pocketbook**

Lectures and drawing six hours a week during the second semester of the senior year. (Showman)

METALLURGY

Irving Allston Palmer, Professor

I. ASSAYING Lectures and Laboratory

Credit three hours.

Special attention is directed toward making this course as practical as possible. The work includes the usual assays called for in the laboratory of mine, mill, or smeltery, and the methods, besides those in use so satisfactorily for many years, include also such "short cuts" as have been introduced by assayers who have many assays to make daily. The course covers the following: the fluxing of basic ores, silicious ores, and sulphide ores for practice; the assays of sulphide and oxide ores of lead; the assay of gold and silver ores of different types by various methods, with a comparison of results; the assay of zinciferous and cupriferous gold and silver ores; of arsenical and antimonial ores; and the crucible and scorification assay of mattes and concentrates.

Prerequisites: Physics III and IV
Geology and Mineralogy IV
Chemistry VIII and X
Text: Fulton's Manual of Fire Assaying
References: Lodge, Notes on Assaying
Brown, Manual of Assaying
Furman-Pardoe, Manual of Practical Assaying

Lectures one hour, laboratory six hours, a week during the first semester of the junior year.

Required in Groups I, II and IV. (Palmer)

II. ASSAYING Lectures and Laboratory

Credit four hours.

In addition to the work outlined in Course I all the products that the assayer may be called upon to handle are discussed. These include: blister, anode, and cathode copper; cyanide solutions, slime, and products; zinc retort residues; base, gold, and silver bullion. The latter is assayed by the fire and also by the Volhard and Gay-Lussac methods.

Prerequisites: Physics III and IV
Geology and Mineralogy IV
Chemistry VIII and X
Text: Fulton **Manual of Fire Assaying**
References: Lodge, **Notes on Assaying**
Brown, **Manual of Assaying**
Furman-Pardoe, **Manual of Practical Assaying**

Lectures one hour, laboratory nine hours, a week during the second semester of the junior year.

Required in Group III. (Palmer)

III. METALLURGY **Lectures**

Credit three hours.

The subjects included in this course comprise an extension of the work on fuels, involving the calculation of air required for combustion, weight of the products of combustion, heat carried away by flue gases, the heat value of various solid, liquid, and gaseous fuels; pyrometry and the modern methods of high temperature measurements; calorimetry and the various means of determining the calorific power of fuels; the fundamental metallurgical principles; and a study of the different types of metallurgical furnaces and their applications.

Iron and Steel. On account of the marked development in the metallurgy of iron, the general application of labor-saving devices, and the basal metallurgical principles involved in its production, this subject is considered first. Pig iron manufacture, with a study of the blast furnace and its accessories; the chemistry of the blast furnace; the utilization of furnace gases; the calculation of charges; the puddling process for wrought iron; the manufacture of steel by the Bessemer, open hearth, cementation, and crucible processes, with a consideration of the reactions involved; and the various furnaces and applications incident to a modern plant are taken up in logical order.

Prerequisites: Chemistry VIII and X
Physics III and IV
Geology and Mineralogy IV
Text: Hofman, **General Metallurgy**
References: Fulton, **Principles of Metallurgy**
Stoughton, **Metallurgy of Iron and Steel**
H. H. Campbell, **The Manufacture and Properties of Iron and Steel**

Three hours a week during the first semester of the junior year.

Required in Groups I, II, III, and IV. (Palmer)

IV. METALLURGY Lectures

Credit three hours.

Lead. The metallurgy of lead is considered in the following order: properties of lead and its compounds; ores of lead; sampling and purchasing of lead ores; fluxes and fuel; smelting in the ore hearth; roasting of ores, including the chemistry of the roasting process; blast furnace smelting, including construction, chemistry of the blast furnace, calculation of furnace charges, treatment of products; softening, desilverization, and refining of base bullion; Pattinson process; Parkes process; German and English cupellation.

Prerequisite: Course III
Text: H. F. Collins, **The Metallurgy of Lead**
Reference: Hofman, **The Metallurgy of Lead**

Three hours a week during the second semester of the junior year.

Required in Groups I, II, III, and IV (Palmer)

V. METALLURGY Lectures

Credit two hours.

This is an extension of Course III, and involves additional work in the study of the heat balance, blast furnace design, and a closer consideration of the details in the various methods of steel manufacture.

Prerequisites: Chemistry VIII and X; Physics III and IV; Geology and Mineralogy IV
Text: Stoughton, **Metallurgy of Iron and Steel**
Reference: H. H. Campbell, **The Manufacture and Properties of Iron and Steel**

Two hours a week during the first semester of the junior year.

Required in Group III. (Palmer)

VI. METALLURGY Lectures

Credit two hours.

Zinc. The following topics are considered: calcination; roasting and distillation by various methods, with a detailed study of furnace types, direct fired, and gas fired; manufacture of retorts; refining of spelter and general cost of production.

Prerequisite: Course V
Text: W. R. Ingalls, **The Metallurgy of Zinc and Cadmium**
References: L. S. Austen, **The Metallurgy of the Common Metals**
Hofman, **General Metallurgy**

Two hours a week during the second semester of the junior year.

Required in Group III. (Palmer)

VII. ORE DRESSING **Lectures**

Credit four hours.

The following represent the main divisions under which this subject is studied: jaw and gyratory breakers; rolls; stamps; special crushing and fine grinding apparatus; the various types of screens and classifiers; concentrating machines, including jigs, tables, vanners, and other slime devices; dry magnetic, electrostatic, and flotation concentration.

Text: **Richards, Textbook of Ore Dressing**
References: **Wiard, Theory and Practice of Ore Dressing**
Ralston and Rickard, Flotation
Hoover, The Flotation Process
Megraw, The Flotation Process
Del Mar, Tube Milling

Four hours a week during the first semester of the senior year.

Required in Groups I and III (Palmer)

VIII. ORE DRESSING **Laboratory**

Credit one hour.

The work consists of sizing tests of the products of various crushers and operations; slime settling; determinations of free settling ratios; concentrating by panning and by various mechanical devices; and comparative studies of the different forms of commercial sizing, classifying, and concentrating devices.

This course must be taken in conjunction with, or subsequent to, Course VII.

Three hours a week during the first semester of the senior year.

Required in Groups I and III. (Palmer)

IX. METALLURGY **Laboratory**

Credit one hour.

This course is intended to supplement the lecture work of the junior year and includes work with optical and electrical pyrometers; heat value of solid, liquid, and gaseous fuels by the Junker, Parr, and Bomb calorimeters; heat treatment of steel; the thermit process and the desilverization of base bullion.

Three hours a week during the first semester of the senior year.

Required in Group III. (Palmer)

X. METALLURGY **Lectures**

Credit three hours.

Gold and Silver. This course covers the following: metallurgy of gold and silver with special attention to stamp milling, amalgamation and cyanidation; the parting of gold and silver bullion by various commercial methods, with special attention to electrolysis and the sulphuric acid treatment. The various modifications of the cyanide process receive particular attention.

Copper. A critical study of the principles of copper metallurgy as covered by the best modern practice, together with the roasting of ores, blast and reverberatory smelting, pyritic smelting, converting of matte, refining of copper, treatment of oxidized ores, and hydrometallurgical methods.

Text: Hofman, **The Metallurgy of Copper**
References: Peters, **Principles of Copper Smelting**
Practice of Copper Smelting
Rose, **The Metallurgy of Gold**
Thompson, **Stamp Milling and Cyaniding**

Three hours a week during the second semester of the senior year.

Required in Group III. (Palmer)

XI. METALLURGY **Laboratory**

Credit one hour.

This work includes the testing of gold and silver ores by amalgamation and cyanidation; experimental work upon complex ores; the leaching of oxidized copper ores; and the laboratory study of such standard processes as lend themselves to small scale treatment.

References: Clennell, **The Cyanide Handbook**
Megraw, **Details of Cyanide Practice**

Three hours a week during the second semester of the senior year.

Required in Group III. (Palmer)

XII. METALLOGRAPHY **Lectures**

Credit one hour.

This course comprises a study of the general methods of investigating metals and alloys; the experimental determination and plotting of cooling curves; the physical mixture, including a consideration of aqueous solutions, fused salts and alloys; a discussion of freezing point curves and diagrams; the preparation of the sample and development of the structure by various etching media; the use of the microscope and methods of making microphotographs. Following a study of the constitution and microstructure of iron and steel and the industrial alloys as influenced by heat treatment, considerable time is spent in the investigation of mattes, speisses, bullions, and other metallurgical furnace products.

References: Howe, **The Metallography of Steel and Cast Iron**
Sauveur, **The Metallography and Heat Treatment of Iron and Steel**

One hour a week during the first semester of the senior year.

Required in Group III. (Palmer)

XIII. ELECTROMETALLURGY **Lectures**

Credit two hours.

This course is divided into two parts and covers the following subjects: (a) the electrolytic smelting and refining of metals and the parting of gold and silver bullion; (b) the electric furnace.

This is a course of lectures and recitations on modern practice in electric smelting and refining, in which the various types of furnaces and other equipment and their underlying principles are discussed and comparisons made with ordinary fire methods, followed by the direct application to the reduction and refining of metals.

References: W. Borchers, **Electric Smelting and Refining**
Stansfield, **The Electric Furnace**

Two hours a week during the second semester of the senior year.

Required in Group III. (Palmer)

XIV. ORE DRESSING **Laboratory** (Elective)

Credit one hour.

During the second semester of the senior year a practical course in ore dressing is given at the experimental plant. This plant contains standard-sized machinery and ores can be run in carload lots as in commercial work. The students are thus made familiar with actual milling operations. Ores are concentrated by various methods and the relative merits of different machines and processes are determined. It is aimed to keep in touch with the most recent progress in ore dressing and the newer ideas are tried out under actual working conditions.

Three hours per week during the second semester of the senior year. (Palmer)

METAL MINING

Harry John Wolf, Professor

The courses given in this department are intended to instruct the student in the theoretical as well as the practical subjects that are necessary to a thorough comprehension of the mining industry. The subjects range from the most elementary to those that teach the principles of mining, the various schemes or methods of developing and working mines, and the actual or practical operations involved in mining. Throughout these courses it is aimed to present the most approved ideas and to have the student feel that he is receiving instruction that is revised up to the time of presentation.

I. MINERAL LAND SURVEYING **Lectures**

This course covers instruction in the methods of acquiring title to mineral lands in the United States and in foreign countries. Special attention is given to practice in the western United States. Determination of meridian and latitude by solar and stellar observation is explained. Methods of sub-dividing the public lands and the regulation of land offices and Surveyors General are discussed and explained. Instruction is given in the preparation and filing of the documents used in acquiring title to lode and placer claims; mill and tunnel sites; timber, coal, and stone lands; water rights; dam and reservoir sites; and ditch, flume, and pipe lines. The duties of the United States Deputy Mineral Surveyors are explained and the student is familiarized with the field methods and office practice involved in obtaining United States patent to mineral lands. This course makes the student competent to pass the examination given by the Surveyor General to applicants for commissions as mineral surveyors.

Prerequisites: C.E. I and II
References: Underhill, **Mineral Land Surveying**
Hodgman, **Land Surveying**
General Land Office, **Manual of Instructions for the Survey of the Mineral Lands of the United States**

One hour a week during the first semester of the sophomore year.

Required of all students. (Wolf)

II. MINE SURVEYING **Lectures**

This course includes the theory involved in mine surveying. Among the subjects discussed are the following: the adjustment and uses of top and side telescopes and other transit accessories used in underground work; surface and underground surveys and traverses; carrying the meridian underground; underground connections; plumbing vertical shafts; determination of dip, strike, and thickness of mineral deposits from results of development, including drill-hole data; survey and measurement of stopes, rooms, and pits; methods of recording surveys in field books and office records; methods of mapping, including plans, elevations, and sections of underground workings, and the design and uses of mine models.

Prerequisites: C.E. I and II

References: Trumbull, **Manual of Underground Surveying**
Durham, **Mine Surveying**
Brough, **Mine Surveying**
Shurick, **Coal Mine Surveying**

One hour a week during the second semester of the sophomore year.

Required of all students. (Wolf)

III. MINE SURVEYING **Field Work**

This course embraces practice in laying out mining claims on the ground and in surveying underground workings. The students are organized in suitable squads for efficient work in the field. Each squad is required to survey a lode claim, placer claim, mill site, and tunnel site; locate and mark all corners, as required by law in the case of an actual survey; tie the surveys to proper section corners, or other monuments, and obtain all field data required for the calculation of intersections with conflicting claims. The practice in surface and underground work is given in one of the neighboring mining districts where typical mines are selected which provide a variety of problems common to mine surveying, such as shaft plumbing; adit and drift traversing; and making connections through shafts, tunnels, drifts, raises, winzes, and stopes. The student receives practice and acquires skill in the use of instruments, the taking of measurements, and the securing of important data under the numerous disadvantages and disagreeable conditions common to underground work. The location of water rights and the surveying of ditches, flumes, pipelines, and aerial tramways are included in this course.

Prerequisites: Courses I and II
References: Underhill, **Mineral Land Surveying**
General Land Office, **Manual of Instructions for the Survey of the Mineral Lands of the United States**
Field Notes
Plats and Mine Maps

Four weeks in the summer following the close of the sophomore year.

Required of all students. (Wolf)

IV. MINE MAPPING **Drawing**

Credit one hour.

This is a drafting room course wherein the student is required to perform all office work necessary in connection with the surveys made in Course III, Mine Surveying Field Work, including the preparation of plats, field notes and reports required by Land Office Directors and Surveyors General, and the drawing of accurate maps of all mine surveys and water rights.

Prerequisite: Course III
References: **Field Notes**
Mine Maps

Three hours a week during the first semester of the junior year.

Required in Groups I, II, and IV. (Wolf)

V. PROSPECTING AND EXPLORATION **Lectures**

Credit one hour.

This course is introductory to all the following metal mining courses. Following a presentation of the elementary and fundamental principles of mining, the great mining districts of the world, and famous individual mines and mineral discoveries, are described and discussed. The general principles of exploitation of mineral deposits are presented. Representative mining costs are reviewed and compared with reference to the conditions under which they obtain.

One hour a week during the first semester of the junior year.

Required in Groups I, II, III, and IV. (Wolf)

VI. MINING CLAIMS **Lectures**

Credit one hour.

This course involves a presentation of the regulations of the Land Office and Surveyors General, together with instruction in the approved methods of acquiring title to mineral lands with a view to avoiding legal entanglements and gaining maximum advantage to the locator. The course includes an elementary discussion of mining laws and regulations of the United States and foreign countries.

One hour a week during the first semester of the junior year.

Required in Groups I, II, III, and IV. (Wolf)

VII. PRINCIPLES OF MINING **Lectures**

Credit two hours.

This course is designed to give the student a general view and conception of the mining industry from a business man's viewpoint. Many of the prominent features of other mining courses are presented, with suitable discussion, but a study of technical details is avoided. The chief object of the course is to supply the needs of the student who requires a general knowledge of mining, but does not intend to specialize in metal mining.

Two hours a week during the second semester of the junior year.

Required in Groups I, II, III, and IV. (Wolf)

VIII. MINE ACCOUNTING **Lectures**

Credit two hours.

This course begins with the fundamental principles of bookkeeping. The student is taught how to use the various books, records, and blanks involved in standard systems of accounting. The course is designed to impart a clear knowledge of double entry bookkeeping. Special attention is given to systems employed in dealing with the accounts of mining corporations, classification of mine, mill, and smeltery accounts and the distribution of mining expenditures. The student is taught how to analyze costs, compile an operating statement, take off a trial balance, and prepare a financial report. Each student is required to enter in a set of blank forms the transactions covering a month's operations of a mining company.

References: Carlton, **American Mine Accounting**
Lawn, **Mine Accounts and Mine Bookkeeping**
Greendlinger, **Accounting Theory and Practice**
Wallace, **Simple Mine Accounting**
Wolf, **Notes on Mine Accounting**

Two hours a week during the first semester of the junior year.

Required in Group I. (Wolf)

IX. MINING CORPORATIONS **Lectures**

Credit one hour.

This course covers the essentials of corporation law involved in the organization and operation of industrial corporations, particularly those engaged in mining. The various steps in the life of a mining corporation are discussed and analyzed, and the ordinary vicissitudes and the usual methods of facing them are illustrated by typical examples. Methods of recording a corporation's activities in the general books of accounts are explained.

References: Lough, Corporation Finance
Bush, Uniform Business Law
Wolf, Notes on Mining Corporations
Corporation Laws

One hour a week during the first semester of the junior year.

Required in Group I. (Wolf)

X. PLACER MINING Lectures

Credit three hours.

This course covers the theory and practice involved in the recovery of precious metals from sand and gravel deposits. Among the subjects discussed are: panning, rocking, sluicing; methods of extracting gravel for sluicing; hydraulicing; drift mining; dry placering; dredges and their operation; thawing frozen ground. Typical operations are considered in detail, and special attention is paid to capacity of machinery and operating costs.

References: Longridge, Hydraulic Mining
Longridge, Gold and Tin Dredging
Wilson, Hydraulic and Placer Mining
Weatherbee, Dredging for Gold in California
Aubury, Gold Dredging in California

Three hours a week during the second semester of the junior year.

Required in Group I. (Wolf)

XI. METAL MINING Lectures

Credit two hours.

This course begins with a discussion of surface prospecting in various countries, the methods employed and the equipment required; and prospecting for ore, oil, and water by means of churn drilling and core drilling. Next, the methods of opening and developing the different types of mineral deposits are considered and compared. The various methods of excavating earth and rock are discussed and the different tools employed are described. Shaft sinking and tunnel driving are described, and the different systems of stoping are explained. The course includes the consideration of mine timbering; the kinds and properties of timber, and special methods of framing; methods of supporting vein walls with ore and waste filling; hand and machine drills and drilling methods; the different kinds of explosives and their use in blasting; underground haulage; hoisting; surface transportation; wire rope tramways; pumping; ventilation; lighting; and sanitation.

References: Hoover, Principles of Mining
Young, Elements of Mining
Storms, Timbering and Mining
Brinsmade, Mining Without Timber
Sanders, Mine Timbering
Brunswig, Explosives
Dana and Saunders, Rock Drilling
Brunton and Davis, Modern Tunneling
Lauchli, Tunneling
Crane, Ore Mining Methods
Gillette, Handbook of Rock Excavation
Ihlseng and Wilson, Manual of Mining
Peele, Mining Engineer's Pocketbook

Two hours a week during the first semester of the senior year.

Required in Group I. (Wolf)

XII. METAL MINING Lectures

Credit two hours.

This course includes the discussion and solution of a variety of practical mining problems which the student is likely to encounter in practice. Knowledge gained in previous mining courses is applied to problems in haulage, hoisting, surface tramming, and pumping. The selection and arrangement of surface and underground equipment is discussed. The various forms of power used in mining operations are discussed and their applications and relative advantages explained. Some of the lectures are illustrated by lantern slides of various mine structures and machinery installations; the subjects so illustrated are discussed and the engineering principles considered in their selection and involved in their operation are explained.

References: Hoover, Principles of Mining
Young, Elements of Mining
Walker, Electricity in Mining
Redmayne, Modern Practice in Mining
Tinney, Gold Mining Machinery
Ketchum, Design of Mine Structures
Peele, Mining Engineer's Pocketbook
Handbook of Mining Details
Details of Practical Mining

Two hours a week during the second semester of the senior year.

Required in Group I. (Wolf)

XIII. MINE VALUATION Lectures

Credit two hours.

This course includes a detailed discussion of the methods of mine sampling. The sampling of fissure veins, placer deposits, and coal seams is carefully explained. The measurement of ore bodies and the methods of estimating tonnage are described; the systems of classifying ore are discussed. The course includes an analytical study of the following subjects: factors influencing payability of ore; relation between vein width and stoping width; underground wastes and losses; mining costs; influence of mineralogical composition; losses and deductions involved in metallurgical treatment; milling, transportation, and smelting costs; valuation of ore bodies; valuation of surface and underground equipment; appraisement of water rights and other privileges; investigation of geological features and the probabilities and possibilities of extension of ore bodies; calculation of maintenance and depreciation of equipment; and amortization of capital. Methods of recording assays, tabulating calculations, and compiling data in comprehensive form, are described. Suggestions are given for the arrangement and presentation of the essential information required in mine reports.

References: Rickard, Sampling and Estimation of Ore in a Mine
Burnham, Modern Mine Valuation
Gunther, Examination of Prospects
Herzig, Mine Sampling and Valuing
Somermeier, Coal, Its Composition, Analysis, Utilization and Valuation
Spurr, Geology Applied to Mining
Eckel, Iron Ores
Hoover, Principles of Mining
Denny, Diamond Drilling for Gold and Other Minerals
Wolf, Notes on Mine Valuation

Two hours a week during the first semester of the senior year.

Required in Group I. (Wolf)

XIV. ECONOMICS OF MINING Lectures

Credit one hour.

This course begins with a brief review of the fundamental principles of political economy. Then follows an analytical discussion of the underlying factors which influence the operation of the various types of industrial enterprises, with special attention to mining corporations. The different classes of corporate securities are described and the factors which influence the value of mining securities are discussed. Mining costs are classified and analyzed. The application of business principles in mining is explained and emphasized.

References: Babson, Business Barometers
Rickard, Economics of Mining
Finlay, Cost of Mining
Skinner and Plate, Mining Costs of the World
Fish, Engineering Economics
Conway, Investment and Speculation
Walker, Political Economy
Seager, Economics
Meade, Economics
Bullock, Selected Readings in Economics

One hour a week during the second semester of the senior year.

Required in Group I. (Wolf)

XV. MINING LABORATORY

Credit two hours.

The work in this course is performed in a mine located on Mt. Zion, about three-quarters of a mile from the campus, where the school has built and equipped a mine shop and has driven a 7 by 8-foot adit. The shop is equipped with a forge and tools for blacksmithing, timbering, track-laying, piping and repair work; also drill steel, machine drills, mine cars, and other apparatus used in the underground work. The students work in squads of three or four and perform all of the usual duties involved in the driving of a tunnel, such as track-laying, timbering, drilling by hand and with machine drills, blasting, mucking, and tramming. Under the instruction of a practical miner the students learn to temper and sharpen their own steel to suit the varying conditions of ground and for the different makes of drills. Opportunity is afforded students to do extra work investigating the efficiency and power consumption of different makes of drills and the relative advantages of various brands of high explosives.

Two weeks in the summer following the close of the sophomore year.

Required in Group I. (Wolf)

XVI. MINE MANAGEMENT Lectures

Credit one hour.

This course includes a discussion of the following topics: personal qualities involved in efficient management: value of versatile technical knowledge and experience; general and department organization of working forces; application of the principles of efficiency engineering; value of business ability and diplomacy; influence of ideals, enthusiasm, loyalty and esprit de corps; systems of labor compensation; classification of labor and efficiency reward; contracts and specifications; leasing systems; marketing mine and mill products; analysis of smeltery contracts; analysis and distribution of mining cost; purchase of supplies; care and maintenance of surface and underground equipment; developing and operating policies; compilation of periodical operating reports.

References: Emerson, The Twelve Principles of Efficiency
Taylor, The Principles of Scientific Management
Parkhurst, Applied Methods of Scientific Management
Gilbreth, Motion Study
Galloway, Business Organization
Gestenberg and Hughes, Commercial Law
Brinton, Graphic Methods of Representing Facts
Wolf, Notes on Mine Management

One hour a week during the second semester of the senior year.

Required in Group I. (Wolf)

MINING LAW

Joseph S. Jaffa, Professor

I. MINING LAW (Elective)

Credit one hour.

a. Status of the law previous to the discovery of gold in 1848.

Organization of mining districts in California and other states; Federal legislation; subsequent state legislation.

b. Lode claims under the act of 1872.

Valuable mineral deposits; surveyed and unsurveyed land; vein or lode; in place; apex; mining claims and location.

c. Important requisites of a valid lode location.

Discovery and location; sinking of shaft; posting of notice and recording; size of location; apex within the location; end lines; side lines; side-end lines; overlapping.

One hour a week during the first semester of the senior year. (Jaffa)

II. MINING LAW (Elective)

Credit one hour.

d. Extralateral rights under the act of 1872.

Broad lodes; vein entering and leaving on same side line; vein crossing both parallel side lines; vein crossing end lines and side lines; miscellaneous cases.

e. Secondary veins.

f. Discussion and interpretation of Federal and State Courts of Sec. 2336 U. S. Rev. Statutes as to "the Space of Intersection".

g. Placer claims.

What is locatable as placer; acts of location; known lodes within placers.

h. Tunnel sites.

Location; location of blind veins in tunnel sites; rights of way through prior patented or unpatented claims.

i. Mill sites.

j. Annual labor or assessment work.

k. Abandonment, forfeiture, and relocation.

l. Patent.

One hour a week during the second semester of the senior year. (Jaffa)

PHYSICS

Claude Cornelius Van Nuys, Professor

The courses in Physics are intended to give the student a broad, general knowledge of the whole subject as well as the knowledge most essential to his work as a mining or metallurgical engineer. Special attention is given to the general laws underlying the science and the history of the discovery, and development of the important results is considered carefully. In the laboratory courses the purpose is to excite in the student an interest in experimentation and to develop the ability for careful observation and the testing and sifting of results.

I. MECHANICS OF SOLIDS AND FLUIDS, SOUND AND HEAT
Lectures

This course consists of lectures, illustrated by experiments and recitations with assigned problems. The subjects treated are mechanics, including the elements of kinematics, dynamics, and hydrostatics; the properties of matter; heat, including thermometry and expansion, calorimetry, change of state, conduction, radiation, kinetic theory of gases, and the elements of thermodynamics; sound, including wave motion in general, production and propagation of sound waves.

Only students who are registered in Math. V will be allowed to take this course.

Prerequisites: Mathematics I to IV, inclusive
Text: Duff, Textbook of Physics
References: Preston, Theory of Heat
Barton, Textbook of Sound

Three lectures and two recitations a week during the first semester of the sophomore year.

Required of all students. (Van Nuys)

II. PHYSICS Laboratory

This course is arranged to accompany Course I. Its aim is to teach the student the necessity of careful work as well as to acquire skill in physical measurements so that the important physical laws can be quantitatively verified.

Prerequisite: Registration in Course I

Six hours a week during the first semester of the sophomore year.

Required of all students. (Van Nuys)

III. GENERAL PHYSICS Lectures

This course is a continuation of Course I. The subjects treated are electricity and magnetism, including electrostatics, electrokinetics, thermo-electricity, magnetic induction, electromagnetism, electrolysis, the electro-magnetic theory, and electric oscillations; conduction of electricity through gases, and radioactivity; light, including propagation, reflection, refraction, dispersion, interference, emission, absorption, and polarization.

Prerequisites: Mathematics V; Courses I and II
Text: Duff, Textbook of Physics
References: Wood, Physical Optics
Starling, Electricity and Magnetism
Pidduck, Electricity and Magnetism

Three lectures and two recitations a week during the second semester of the sophomore year.

Required of all students. (Van Nuys)

IV. PHYSICS Laboratory

This course is a continuation of Course II.

Prerequisite: Course II

Course III must be taken in conjunction with this course.

Six hours a week throughout the second semester of the sophomore year.

Required of all students. (Van Nuys)

V. ELECTRON THEORY AND RADIOACTIVITY Lectures (Elective)

Credit two hours.

This course consists of lectures illustrated by experiments in the laboratory. The subjects considered are: conduction of electricity through gases; properties of Röntgen, Lenard, and Canal rays; study of X-ray spectrometry; methods used in the determination of the mass and charge of the electron; radioactive substances and their transformations, together with a study of the various laboratory methods of measuring the activity of radioactive minerals.

Prerequisite: Course III

Two hours a week during the first semester of the junior year. (Van Nuys)

VI. ELECTRICAL MEASUREMENTS Laboratory (Elective)

Credit one hour.

This course deals with the theory of the absolute and relative measurements of the various electrical and magnetic quantities and includes the actual measurement of these quantities in the laboratory.

Prerequisite: Course III

Three hours a week during the first semester of the junior year. (Van Nuys)

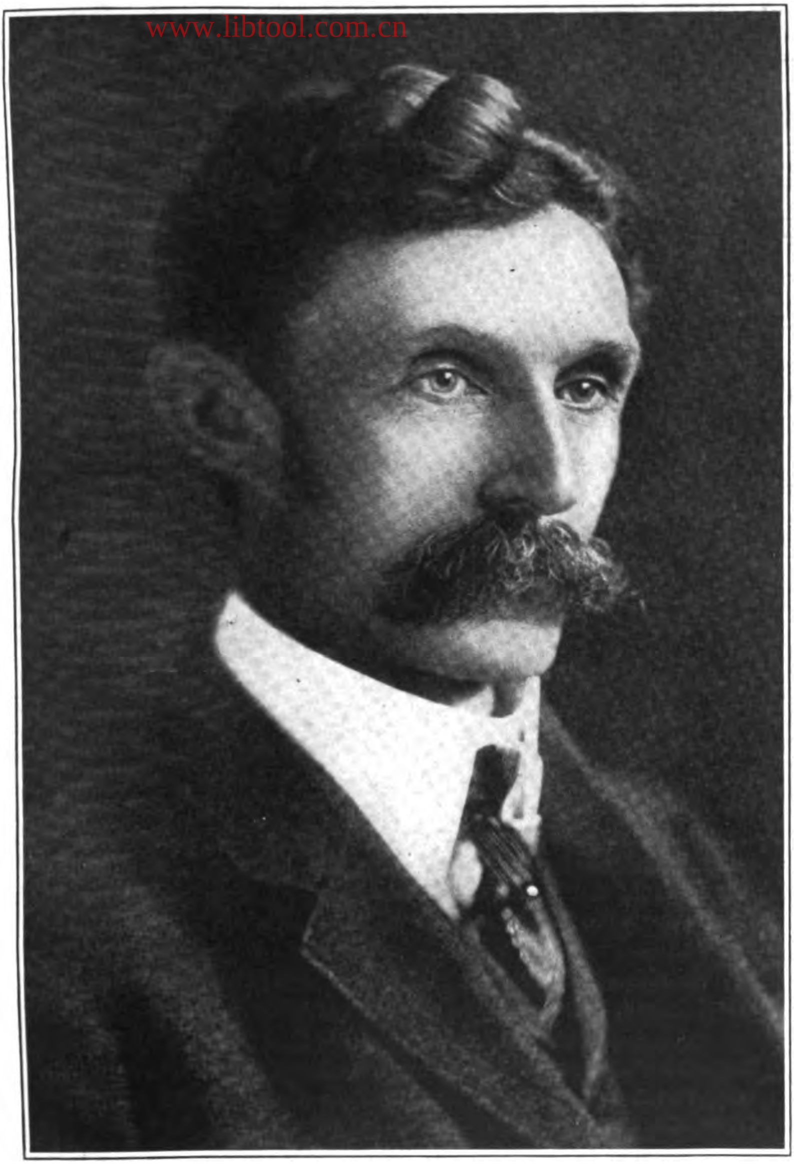
VII. ALTERNATING CURRENTS Laboratory (Elective)

Credit three hours.

The subjects considered are: E. m. f. and current curves; harmonic e. m. f.'s and current; circuits containing capacity; power in alternating circuits; graphical method of investigating harmonic e. m. f.'s and currents; parallel circuits; polyphase e. m. f.'s and currents; the two-phase system; the three-phase system; delta and star connections; the alternating current transformer; general equations; solution of equations under various conditions; transformer theory as applied to a. c. motors.

Prerequisite: Course III

Three hours a week during the second semester of the junior year. (Van Nuys)



DR. JOSEPH AUSTIN HOLMES
Late Director, United States Bureau of Mines

SAFETY AND EFFICIENCY ENGINEERING

James Cole Roberts, Professor

On August 12, 1915, the Board of Trustees passed the following resolution:

Whereas, the late Joseph A. Holmes, Director of the United States Bureau of Mines from the date of its creation, May 16, 1910, until his death in Denver, July 13, 1915, devoted his life to the advancement of safety and efficiency in the mining and metallurgical industries of the entire country; and

Whereas, it is meet and proper that a lasting memorial of him should be established and maintained; therefore

Be It Resolved by the Board of Trustees of the Colorado School of Mines that there be and hereby is created a full chair in this institution to be known as the Joseph A. Holmes Professorship of Safety and Efficiency Engineering.

I. SAFETY AND EFFICIENCY ENGINEERING **Lectures**

Credit one hour.

The subjects in this course are taken up with respect to their bearing on safety and efficiency as applied to mining, milling, and smelting operations.

Illumination: the importance of efficient lighting in mine, mill, and smelteries; use of oil, acetylene, gasoline, gas, arc, and incandescent lights; candles, carbide, safety, and portable electric lamps; the importance of efficient lighting around shafts and tipples.

Ventilation: deleterious and harmful gases found in coal and metal mines; approved methods of ventilation.

Explosives: the various types of explosives are discussed from the standpoint of safety and efficiency; safety measures involved in the storage, handling, and use of explosives; approved types of magazines and thaw houses; blasting and shot-firing by squibs, fuse, and electric detonators; tamping and tamping materials and the placing of holes.

Mine fires: history of some of the important mine fires; storage of oil, oiling and greasing cars underground; explosions; gas and dust explosions, and incendiarism.

Methods of fire prevention: fire patrols; systematic examination of all places where fires are likely to occur; doors; permanent stopings and bulkheads of non-combustible material; organization of fire fighting crews with fire drills.

Fire-fighting equipment: ample water supply; air line convertible into water line; sprinkling device in shaft; water plugs; fire extinguishers; telephones; fire signals; fire pumps; fire doors; ventilating fans; water barrels and fire buckets.

Methods of extinguishing fires: use of fire extinguishers; fighting fire directly with water; sealing off the fire zone, and introducing gases and steam; bulkheading and flooding; hydraulic flushing; use of rescue apparatus and gas analysis.

Gas and dust explosions: the excessive danger of gas and dust in coal mines; a brief history of some of the important explosions; means of preventing explosions; use of inert stone or adobe dust; Taffnell and Rice stone dust barriers.

References: Haldane, **Investigation of Mine Air**
Beard, **Mine Gases and Explosions**
Lamphrecht, **Recovery Work After Pit Fires**
Garforth, **Rules for Recovering Coal Mines After Explosions and Fires**
United States Bureau of Mines, **Publications**
United States Geological Survey, **Bulletins**
Cowee, **Practical Safety Methods and Devices**

One hour a week during the first semester of the junior year.

Required in Group II. (Roberts)

II. SAFETY AND EFFICIENCY ENGINEERING **Laboratory**

Credit one hour.

In this course thorough instruction and training is given in the care, testing, and handling of all lights used in the mines, such as candle, carbide, safety and electric lamps. The students are required to make inspection trips to operating mines, mills, and smelteries and inspect and report on them as to safe and efficient methods and practices. Instruction and training is also given in the various types of rescue apparatus—the lungmotor and pulmotor and other mechanical respiratory devices—and in the repair, upkeep, and maintenance of this equipment and accessory apparatus. The rescue training is conducted in the mine in irrespirable gases, and smoke, and under conditions which would exist in case of an actual mine fire or after an explosion. Students are required to build brattices and bulkheads, saw and set timbers and props, put out fires with hose and fire extinguishers, and carry injured men from mine workings filled with smoke and gases. Special attention is paid to mine rescue and recovery practices of the government, states, and mining companies. Each student is required to undergo a rigid physical and medical examination before he is permitted to take this training.

Reference: United States Bureau of Mines, Publications

Three hours a week during the first semester of the junior year.

Required in Group II. (Roberts)

III. SAFETY AND EFFICIENCY ENGINEERING Lectures

Credit one hour.

This course is a continuation of Course I and takes up the following subjects:

Laws of the various states relative to safety; policing and inspection of mines by federal and state officials and by company inspectors; industrial accident commissions and compensation laws of the different states; inspection and merit-rating systems as practiced by the Associated Insurance Companies; accidents, their causes, classification, and means of prevention; sanitation and health conditions; education and social welfare, night schools, mining institutes, moving pictures, and entertainments; trade agreements and relations between employers; unionism versus open shop; miners' organizations; discipline; reporting of unsafe or inefficient practices or conditions; safeguarding all machinery; careful investigation of all accidents immediately after their occurrence; public meetings of employers and employees in the interest of safety and efficiency; suggestion boxes and bulletin boards; bonus system; personal instruction to employees; statistics with methods of obtaining and recording them and their value from the standpoint of safety and efficiency; purchasing, storing, checking, and issuing materials and supplies; careful inspection of all tools and equipment; labor conditions; proper treatment of employees by employers; cooperation.

References: Haldane, Investigation of Mine Air
Beard, Mine Gases and Explosions
Lamphrecht, Recovery Work After Pit Fires
Garforth, Rules for Recovering Coal Mines After Explosions and Fires
United States Bureau of Mines, Publications
United States Geological Survey, Bulletins
Cowee, Practical Safety Methods and Devices

One hour a week during the second semester of the junior year.

Required in Group II. (Roberts)

IV. SAFETY AND EFFICIENCY ENGINEERING **Laboratory** Credit one hour.

This course involves a practical study of physiology, anatomy, and hygiene, and is followed by thorough instruction and training in the care and transportation of persons injured in and about mines, mills, and metallurgical plants. Students are required to become proficient in the use of compresses, tourniquets, bandages, splints, and stretchers.

References: Lauffer, **Electrical Injuries**
United States Bureau of Mines, **Publications**
American Red Cross, **Textbook on First Aid**
Johnson, **First Aid Manual**
Manson, **Tropical Diseases**
Kober and Hanson, **Diseases of Occupation and Vocational Hygiene**

Three hours a week during the second semester of the junior year.

Required in Group II. (Roberts)

SPANISH

I. SPANISH **Recitations and Conversation** (Elective)

Credit two hours.

This course is designed primarily for those students who expect to do professional work in Spanish-American countries. Facility in conversation and business correspondence will be the chief aim. The course will be conducted in Spanish, for the most part. Sufficient reading of simple exercises and grammar will be given to enable the student to acquire a practical use of the language.

Prerequisites: Entrance requirements
References: Rosenthal, **The Spanish Language**
Berlitz, **Método Berlitz**
Cortina, **Spanish in Twenty Lessons**
Graham and Oliver, **Spanish Commercial Practice**
Dolman, **Spanish Lessons**

Two hours a week during the first semester of the freshman year.

II. SPANISH **Recitations and Conversation** (Elective)

Credit two hours.

This course is a continuation of Course I, and consists of similar exercises in conversation and composition, but more advanced in character. This course will be conducted entirely in Spanish.

Prerequisite: Course I
References: Rosenthal, **The Spanish Language**
Berlitz, **Método Berlitz**
Cortina, **Spanish in Twenty Lessons**
Graham and Oliver, **Spanish Commercial Practice**
Dolman, **Spanish Lessons**

Two hours a week during the second semester of the freshman year.

III. SPANISH (Elective)

Credit two hours.

This is a continuation of Course II.

Prerequisite: Course II

Two hours a week during the first semester of the sophomore year.

IV. SPANISH (Elective)

Credit two hours.

This is a continuation of Course III.

Prerequisite: Course III

Two hours a week during the second semester of the sophomore year.

V. SPANISH (Elective)

Credit one hour.

This course is intended for irregular students who have only a brief time in which to get a start in the knowledge of the language.

One hour a week during the first semester of the junior year.

VI. SPANISH (Elective)

Credit one hour.

This is a continuation of Course V.

Prerequisite: Course V.

One hour a week during the second semester of the junior year.

INSPECTION TRIPS

The same importance is attached to the inspection trips as to class-room and laboratory work. Grades are given on reports submitted and satisfactory results are required for graduation.

METALLURGICAL TRIPS

The study of various metallurgical processes and plants may be prosecuted with great benefit in Colorado. Beginning with the junior year and continuing throughout the senior year, inspection trips are taken for the purpose of supplementing the laboratory work and for illustrating the lecture courses. Printed outlines of reports, carrying out all of the important features peculiar to the plant and to the practice, are given to the students. A written report on each trip is turned in for correction and criticism.

During the junior year the following plants are visited:

The Pueblo and Denver plants of the American Smelting and Refining Company, for a study of furnaces of various types and ore sampling.

The Minnequa plant of the Colorado Fuel and Iron Company at Pueblo, for a study of the manufacture of iron and steel and the working up of the product into commercial forms.

The Globe plant of the American Smelting and Refining Company, for a study of the metallurgy of lead.

The zinc plants of the American Smelting and Refining Company at Pueblo, and of the United States Smelting Company at Canon City, for a study of the metallurgy of zinc and the manufacture of pigment.

During the senior year the following plants are visited:

The Jackson, Newton, Hudson, and other mills in Idaho Springs, for the study of ore dressing.

The various stamp mills of Black Hawk and Central City, for the study of amalgamation.

The Colorado Zinc Company and the Blake-Morscher works in Denver, for magnetic and electro-static separation.

The cyanide mills of Colorado City and Cripple Creek for the cyanide process.

MINING TRIPS

During the junior and senior years, the students are taken to well known Colorado mining districts for the inspection of actual mining operations. These trips are arranged in such order as to introduce different interesting features and, at the same time, to emphasize definite portions of the classroom instruction. Attention is paid to surface plants, underground equipment, mining systems, and to all the regular operations, both above and below ground. Lectures precede these trips to explain their objects, the particular properties to be visited, and the operations to be witnessed. Printed outlines are furnished and each student is required to submit a report, illustrated by his own sketches.

ELECTRICAL AND MECHANICAL POWER PLANT TRIPS

In connection with the junior mining trip to Breckenridge, Colorado, a study is made of the application of electric power to dredging, milling, and mining. Near the end of the junior year the class visits the plants and sub-stations of the Denver City Tramway Company and of the Denver Gas and Electric Company. Here they see in operation nearly all the electrical machinery and apparatus studied during the year. The seniors make a combined steam and electric plant trip to the station of the Northern Colorado Power Company at Lafayette, Colorado.

AVAILABLE MINING, METALLURGY, ENGINEERING, AND GEOLOGICAL TRIPS

COLORADO

PORTLAND.

Metallurgy.

Colorado Portland Cement Company; crushing and fine grinding of raw material and clinker.

CANON CITY.

Metallurgy.

Empire Zinc Company: wet and magnetic separation of zinc ores and magnetic treatment of Wilfley table middlings; experimental plant with magnetizing roaster, magnetic separators, dry and electrostatic separators, and Elmore installation.

United States Smeltery: pigment smelting of complex zinc-lead ores, and the working of the product into a marketable form.

Geology.

A study of the mesozoic sedimentary formations that are upturned in fine hog-backs in a great semicircle around the Canon City basin.

LEADVILLE.

Metallurgy.

Arkansas Valley Plant of the A. S. and R. Company: lead smelting; Ropp, Brown-Horseshoe, Godfrey, and H. and H. roasting; briquetting, and blast furnace treatment of silver-lead ores.

Adams Mill: wet concentration of lead ores.

Yak Mill: magnetic concentration with International separators and Cleveland-Knowles separators, after a magnetizing roast.

Mining.

The students are taken into the Yak Tunnel, through the several mines connected therewith, and are finally hoisted to the surface of Breece Hill through the shaft of the Little Jonny mine. The Moyer, Tucson, and other mines are also visited. Excellent opportunity is afforded for studying the two distinctive kinds of ore bodies for which this district is noted, and to learn, by observation, how these dissimilar ore bodies are attacked and their contents successfully extracted. Interest attaches to the unusual complexity of the ores, which contain gold, silver, and most of the base metal sulphides, oxides, and carbonates.

Engineering.

Arkansas Valley Plant, A. S. and R. Company: steam power plant; capacity 1,500 h. p.; condensing Corliss engines belted to Connersville blowers; return tubular boilers equipped with underfeed stokers.

Colorado Power Company; steam power plant; Curtis turbines, direct connected to 3-phase, 6,600 volt, 60 cycle alternators; current stepped up to 100,000 volts for long distance transmission over steel tower line; small and moderate sized units; Alberger surface condensers with independent dry vacuum pump and centrifugal circulating pump; 400 h. p. B. and W. boilers, hand fired.

Yak Tunnel: Silver Cord property; two-drum electric hoist; motor driven compressors; compressed air and electric driven pumps; continuous current haulage.

Geology.

The Paleozoic series and fault systems are studied underground and the sharply defined moraines, and other glacial phenomena, on the surface.

SHOSHONE.

Engineering.

Central Colorado Power Company's Hydro-electric plant. Water from the Grand river is conducted through a tunnel cut inside of the mountain for approximately two and one-quarter miles, delivered through penstocks to central discharge turbines under a head of 165 feet; ultimate capacity of plant approximately 25,000 h. p.; ultimate transmission voltage 100,000.

SHOSHONE AND GLENWOOD.

Geology.

Archaean gneisses and schists, and uncomformable above these the paleozoic rocks exposed in the canyon of the Grand river; typical canon erosion and travertine deposits. At Glenwood the Mesozoic rocks.

UTAH.

BINGHAM.

Mining.

This district permits the study of three distinct systems of mining, namely, the overhead stoping, the caving, and the open pit. The extensive properties of the Utah Consolidated Mining Company and the Utah Copper Mining Company are open to the unrestricted inspection of the class. Further interest in this district comes from the opportunity to study aerial tram systems, difficult railroad engineering, and the operations of single companies under different systems.

Geology.

The carboniferous quartzite and limestone, with intruded igneous masses that have marmorized the limestone at contact; the relationship of the ore bodies to these contact phenomena.

BINGHAM JUNCTION.

Metallurgy.

United States Smelting Company: special roasting devices for lead ores, with neutralization and bag-housing of fumes.

GARFIELD.

Metallurgy.

Boston Consolidated Mining Company Mill: stamp milling of Bingham copper ores with Wilfley table and vanner concentration.

Utah Copper Company: roll crushing of Bingham ores wtih jigging, tabling, and vanning methods of concentration.

Engineering.

Utah Copper Company: steam power plant; capacity 10,000 boiler h. p.; 500 h. p. Heine boilers equipped with underfeed stokers; forced draft; concrete stacks; large cross compound Allis and Nordberg engines direct connected to A. C. generators; Wheeler surface condensers with independently driven Edwards air pumps.

American Smelting and Refining Company; steam power plant; large horizontal blowing engines; single stage air compressors driven by cross compound Corliss engines; Worthington surface condensers with Blake air and circulating pump; 500 h. p. Stirling boilers equipped with plain grates.

SALT LAKE CITY.

Metallurgy.

General Engineering Company; special devices for screening, classifying, and concentration of ores.

Geology.

Excursion into the Wasatch range, showing the great synclinal fold and the Wasatch fault; very recent faults and glacial features; Lake Bonneville terrace formations.

MONTANA.

BUTTE.

Metallurgy.

The Colusa-Parrot Smelting Company: crushing, wet concentration, roasting, and smelting of copper ores; Hancock and Woodbury jigs and special devices of local origin.

The Precipitation plants: recovery of dissolved copper from mine waters; leaching and recovery of soluble values from dumps.

Mining.

The mines of this district exhibit modern practices of lode mining in high grade copper ore. Among the noteworthy mining features studied are: deep mining with the involved difficulties of drainage, ventilation, and timbering; steel surface structures; automatic loading and dumping of ore; rapid hoisting; mechanical framing of timbers; handling of large volumes of acid water; square set stoping; the driving of working levels in country rock; the naturally high temperatures of the working places; and the systematic recording of every operation. Mine and geological underground surveying are exemplified in the practices of the Amalgamated Copper Company.

Geology.

Secondary enrichment of original sulphide ores; the relationship of these ore bodies to the remarkable fault systems of Butte; the study of granite, aplite, porphyry, and rhyolite rocks.

Engineering.

Anaconda Copper Company: mine plant at the New Leonard; 3,500 h. p. Nordberg hoist; 150 foot steel head frame; two stage Nordberg air compressors rope driven by induction motors; locomotive type of boilers.

Anaconda Copper Company: mine plants at the Diamond and Bell mines; very large air compressing plant; two stage compressors equipped for either steam or motor drive; 3,000 h. p. Allis hoisting engine; marine type of boilers; high steel head frame with automatic dumping attachments.

Missouri River Power Company: steam power plant; Westinghouse-Parsons turbines, connected to A. C. generators; surface condensers with independently driven air and circulating pumps; B. and W. boilers equipped with Roney stokers; high tension current station used as relay for the company's hydro-electric plants and operated in parallel with them.

ANACONDA.

Metallurgy.

New Reduction Works; track system for the delivery of ores and shipment of products; compressed air traction for yard haulage; concentrating mill of eight one-thousand ton units; bin systems; briquetting plant; largest furnaces in the world; reverberatory furnaces; converter plant; refining furnaces and casting department; arsenic plant, and flue systems. So much is to be seen here that considerably more time is spent in this plant than at any other point, and, owing to the courtesy of the management, much valuable instruction is possible.

The Anaconda Copper Mining Company: brick department; the manufacture of clay and silica brick of the highest degree of refractoriness and of all shapes.

Engineering.

New Reduction Works; general power plants; large triple expansion condensing Corliss engines belted to line shaft; two and four stage air compressors driven by cross compound Corliss engines; rotary blowers of the Connersville and Root types, direct connected to Corliss engines; rotary blowers, rope driven from induction motors; Stirling boilers equipped with plain grates; rotary converters and transformers for the high tension current brought in from the hydro-electric plants.

UNITED STATES BUREAU OF MINES EXPERIMENTAL STATION STAFF

Richard Bishop Moore, B.S., D.Sc.
Samuel C. Lind, A.B., B.S., Ph.D.
Herman Schlundt, B.S., M.S., Ph.D.
Julius E. Underwood, A.B., A.M.
John P. Bonardi, B.S.
Charles Wesley Davis, B.S.
Harry F. Yancey, A.B., A.M.
John Conley, B.S.

There are at the present time ten experimental stations belonging to the United States Bureau of Mines. These are situated at the present time at Pittsburgh, Pa.; Golden, Colo.; Salt Lake City, Utah; Tucson, Arizona; Berkeley, Calif.; Seattle, Wash.; Fairbanks, Alaska; Minneapolis, Minn.; Urbana, Ill., and Columbus, Ohio. In the majority of cases the stations are doing direct coöperative work with the state institutions, with the object of promoting efficiency in the mining industry. Each station has assigned to it a specific field of work, to which, however, it is not absolutely confined. The work of the Colorado station is mainly in connection with the rare metals, and the work of this station covers the whole country in its particular field. During the last three years a great deal of attention has been given to the radium ores of Colorado and Utah. Under a cooperative agreement with the National Radium Institute a plant was built in Denver for the experimental treatment of carnotite ore for the extraction of uranium, vanadium, and radium. During this period between eight and nine grams of radium element have been extracted and refined, valued at nearly a million dollars. Experimental work on the best methods of fractionation, and radium determinations, has been carried out and published.

Work at the present time is under way in connection with molybdenum, vanadium, uranium, and tungsten. The Bureau is interested in any problems in connection with these metals which promise increased production, a higher efficiency of treatment, or greater usefulness. It is also expected that the work of the Colorado station will be extended to the complex zinc and lead ores of the state. In order to do this it will be necessary to have a number of graduate fellowships, and these fellowships will give an opportunity to graduates of the School of Mines and others to get training in experimental work which it would be difficult for them to get elsewhere.

THE LABORATORIES

The laboratories and offices of the United States Bureau of Mines occupy the Engineering Building. These consist of two large general laboratories for analytical and research work on the second floor; a large laboratory for technologic experimental work in the basement; and in addition, a number of small private laboratories and rooms for special work. The equipment is adapted to investigations in connection with the rare metals, both on a small and semi-commercial scale. The technologic laboratory is equipped with leaching apparatus of various kinds, precipitating tanks, filter presses, steam-jacketed kettles, roasting and fusing furnaces.

"The equipment for work in radioactivity is excellent. Two rooms are especially reserved for this purpose. The Bureau possesses nearly two grams of radium which it has secured as its pro rata part of its cooperative work with the National Radium Institute. 500 milligrams of this radium is reserved at Golden for experimental work. In addition, during this year, the Bureau will undoubtedly, through its research work, accumulate supplies of mesothorium, ionium, and actinium."

COURSE FOR PROSPECTORS

The Course for Prospectors, which was inaugurated by the Colorado School of Mines in January, 1915, proved so popular and profitable to those who attended, that the course has been repeated each year since. As a result of the success which attended this innovation, it has become an established part of the work of the School of Mines and will be offered annually as long as there is any apparent need or demand. The fourth annual course will be given at Golden during the four weeks beginning February 4 and ending March 2, 1918. It is planned to condense the work so as to keep the prospectors occupied throughout each day. This will be an advantage from the point of view of instruction and will make the course less expensive to those who attend.

All of the courses will be of the most practical nature and will comprise instruction in mineralogy, common minerals, ores and rocks; elementary chemistry; principles of ore dressing, assaying, and the more common metallurgical processes; methods of valuing, buying, and selling ore; placer and lode mining; location of mining claims; first aid to the injured and safety engineering. They are given entirely by regular members of the faculty and consist of lectures, supplemented by practical laboratory demonstrations.

Prospectors and others who expect to take advantage of this work are asked to notify the school authorities as soon as possible, in order that ample preparation can be made for the work. Address all correspondence to The Registrar, Colorado School of Mines, Golden, Colorado.

FEE

A single fee of two dollars is charged for the entire course of four weeks and is payable on registration.

Outline of Subjects

COMMON ROCKS AND MINERALS

Professors Ziegler and Van Tuyl

Three hours lecture and six hours practical laboratory work a week.

This course is devoted to the study of common minerals, ores, and rocks. The instruction includes blowpipe reactions, with apparatus and appliances. A few of the rarer ores in which prospectors are just now greatly interested, such as those of tungsten and molybdenum, will also be considered.

GENERAL GEOLOGY; GAS AND OIL

Professors Ziegler and Van Tuyl

Three hours lecture work a week.

This course is devoted to such geological features as throw light on the origin and manner of occurrence of ore deposits and on the structural features frequently met with in mining. These latter include faults and folds, strikes and dips, and the mutual relationship of rock masses. Particular attention will be given to the kinds of rocks and geological conditions, which appear to affect ore deposition. An important part of prospecting is to know what may be sought for in the different formations. Gas and oil geology is a feature of this course.

CHEMISTRY

Professors Coolbaugh and Test

Two hours lecture and six hours practical laboratory work a week.

The object of the course is to make the prospector more familiar with the use of such apparatus and chemicals as may aid him in supplementing his field work, and to equip him with knowledge of the characteristic properties of the common metals. Some work on the commercially rare metals will also be given.

METALLURGY, ORE DRESSING AND ASSAYING

Professor Palmer

Three hours lecture and six hours practical laboratory work a week.

The following subjects will be treated:

Principles and methods of sampling as used in mines, mills, and smelteries; methods of assaying common ores; determination of the value of ores from assay or analysis; how ores are bought and sold; the value of an ore to the producer; simple tests for the prospector; nature of ores, crushing, sizing, and classification; course and fine concentration in water; methods of dry concentration; amalgamation; flotation; electrostatic and magnetic separation; determining percentage extraction; the cyanide process; leaching copper and zinc ores; smelting lead and copper ores; simple treatment plant for prospectors.

The laboratories and experimental plant afford exceptional opportunities for demonstration and the student is given every reasonable facility to study methods and mechanical appliances.

PLACER MINING

Professor Wolf

Two hours a week.

This course includes a discussion of the theory and practice involved in the recovery of precious metals from sand and gravel deposits. Among the subjects considered are: panning, rocking, sluicing, hydraulicing, dredging, and dry placering. Typical operations are described for the purpose of illustration.

MINING CLAIMS

Professor Wolf

Three hours a week.

This course includes instruction in the methods of acquiring title to mineral lands in the United States. Practical methods of locating and surveying mineral lands are described and instruction is given in the preparation and filing of documents used in acquiring title to lode and placer claims; mill and tunnel sites; timber, stone, and coal lands; water rights. Mining laws which are important to the prospector are discussed and explained.

LODE MINING

Professor Wolf

Two hours a week.

This course includes a discussion of surface prospecting, methods employed, and equipment required. The opening and development of prospects to the best advantage are discussed; also proper methods of sampling in the mine and on the dump.

MINE SAFETY ENGINEERING

Professor Roberts

Two hours lecture and three hours practical work a week.

The course in Mine Safety Engineering includes the following:

1. General safety in mines.

2. Explosives: Composition of explosives in general use in coal and metal mines and quarries; composition of resultant gases from explosives and the damage of going back too soon after shots are fired; the proper and improper methods of handling explosives.

3. Mines gases; gases encountered in coal and metal mines, prospect holes, and shafts; their composition, methods of de-

tecting, and removal; precautions to be taken to prevent accumulation; methods of recovering and removing men overcome.

4. Mine lighting.

5. Mine fires; their causes, methods of preventing and extinguishing.

6. Mine rescue methods and appliances, with demonstrations of various types of mine rescue apparatus in use, resuscitating devices, pulmotor and lungmotor.

7. First aid to the injured; a complete course in first aid will be given. This includes the following: the human body; wounds, with and without bleeding; bruises, sprains, and dislocations; fractures, simple and compound; bandages and splints; shock, fainting, poisoning.

SUMMER SCHOOL
1918

For the benefit of matriculated students who desire either to make up deficiencies or to do advanced work, and for the benefit of prospective students, a Summer School will be held during the summer of 1918 to begin July 15 and to end August 24.

Instruction will be given by regular members of the faculty. The following courses are offered:

Mathematics: Algebra, review; Solid Geometry; Chemistry, entrance requirements; Physics, entrance requirements; Mathematics; I. Algebra; II. Trigonometry; III. Analytic Geometry; IV. Calculus; V. Calculus; VI. Calculus. The fee for these courses is $2.00.

Mechanical Engineering; I. Descriptive Geometry, lectures; III. Elementary Machine Design, lectures; V. Kinematics of Machinery, lectures; VII. Machine Design, lectures. The fee for each of these courses is $2.00.

Chemistry: III. Qualitative Analysis, lectures; IV. Qualitative Analysis, lectures; VII. Quantitative Analysis, lectures; VIII. Quantitative Analysis, lectures. The fee for each of these courses is $2.00.

Mechanical Engineering: II. Descriptive Geometry, drawing; IV. Elementary Machine Design, drawing; VI. Kinematics of Machinery, drawing; VIII. Machine Design, drawing. The fee for each of these courses is $2.00.

Chemistry: V. Qualitative Analysis laboratory; VI. Qualitative Analysis, laboratory; IX. Quantitative Analysis, laboratory; X. Quantitative Analysis, laboratory. The fee for each of these courses is $7.00.

Metallurgy: I. Assaying, lectures, fee $2.00; II. Assaying, laboratory, fee $10.00.

A laboratory deposit, to cover the cost of material used, is required in each laboratory course. Any unused portion is returned at the end of the course.

SCHOLARSHIPS

One COLORADO SCHOLARSHIP is given each year to each of the high schools of the State of Colorado that are on the accredited list of the Colorado School of Mines. This scholarship has an approximate value of $175.00 and exempts the holder from the payment of all laboratory fees during the four years of the course. The scholarship is awarded on the recommendation of the principal and the faculty of the high school. A candidate for one of these scholarships must have successfully completed a four year high school course of study and present satisfactory credentials. The candidate must file his acceptance, in writing, with the Registrar on or before July first following his graduation. If a candidate fails to file his acceptance by July first, his scholarship will then become void and will be offered to a second candidate from the same high school who complies with the requirements. A scholarship will be honored only as long as the candidate maintains a regular and satisfactory record.

A UNITED STATES SCHOLARSHIP is awarded to each state of the Union. It exempts the holder from the payment of all laboratory and tuition fees during the course of four years, and has an approximate value of $800.00 for the course. This scholarship is awarded on the recommendation of the Superintendent of Public Instruction of each state.

The candidate shall have successfully completed a four-year course of study and be able to comply with the requirements for entrance. A scholarship will be granted only to a candidate who intends to enter the Colorado School of Mines at the beginning of the first school year following his graduation from high school. A candidate must file his acceptance with the Registrar in writing, on or before August first following his graduation. If a candidate fails to file his acceptance by that date, his scholarship becomes void and will be awarded to a second candidate nominated by the proper official making the award. A scholarship will be honored only as long as the candidate receiving it maintains a regular and satisfactory record.

A FOREIGN SCHOLARSHIP is awarded to each of the Latin-American Countries, to each of the Provinces of Canada and to the Philippine Islands.

List of foreign countries with the title of the official who makes the award:

CENTRAL AMERICA

Costa Rica, San José..............Minister of Public Instruction
Guatemala, Guatemala............Minister of Public Instruction
British Honduras, Belize. Inspector of Schools (A. Barrow Dillon)
Honduras (Republic), Tagucigalpa..Minister of Public Instruction
Nicaragua, Managua......................................
.......Minister of Foreign Relations and Public Instruction
Salvador, San Salvador..........Secretary of Public Instruction
Panama, Panama ....
........Secretary of Public Instruction (Guillermo Andreve)

SOUTH AMERICA

Argentina, Buenos Aires..........Minister of Public Instruction
Bolivia, Sucre........Minister of Justice and Public Instruction
Brazil, Rio de Janeiro....................................
.........Minister of Justice, Interior and Public Instruction
Chile, Santiago....Minister of Public Instruction (J. H. McLean)
Colombia, Bogota.................Minister of Public Instruction
Ecuador, Quito...................Minister of Public Instruction
Paraguay, Asuncion......................................
........Minister of Justice, Worship and Public Instruction
Peru, Lima...........Minister of Justice and Public Instruction
Uruguay, Montevideo.............Minister of Public Instruction
Venezuela, Caracas................Minister of Public Instruction
Mexico, D. F...
Director General de Educacion Publica (Señor Andres Osuna)
Philippine Islands, Manila..Superintendent of Public Instruction

CANADA

Alberta, Edmonton...........Chief Superintendent of Education
British Columbia, Victoria...Chief Superintendent of Education
Manitoba, Winnipeg......................Minister of Education
New Brunswick, Frederickton............................
.........................Chief Superintendent of Education
Nova Scotia, Halifax.........Chief Superintendent of Education
Ontario, Toronto.........................Minister of Education
Prince Edward Island, Charlottetown.....................
............Chief Superintendent of Education and Council
Quebec, Quebec...................Council of Public Instruction
Saskatchewan, Regina....................Minister of Education
Yukon Territory, Dawson...Superintendent of Public Instruction

This scholarship has an approximate value of $800.00 and exempts the holder from the payment of all laboratory and tuition fees during the entire course of four years.

GENERAL INFORMATION

TUITION

The Statutes of Colorado provide as follows:

"The said School of Mines shall be open and free for the instruction to all bona fide residents of this State, without regard to sex or color, and, with the consent of the Board, students from other states and territories may receive education thereat upon such terms and at such rates of tuition as the Board may prescribe."

The tuition for non-residents is one hundred fifty dollars a year, payable in two installments, seventy-five dollars at the beginning of each semester.

DEPOSITS

Deposits are required to cover the cost of supplies consumed. Any unused balance is returned.

For courses in Chemistry	$10.00
For Metallurgy I and II	10.00
For drawing (paid only once)	2.50
For locker (paid only once)	1.00

FEES

Fees are charged to cover not only the cost of materials and supplies furnished but also the wear on apparatus. No part of a fee is returnable. The athletic fee, although collected by the school, is turned over to the Treasurer of the Athletic Association and is expended only for athletic purposes.

Matriculation fee	$ 5.00
Athletic fee (paid each semester)	5.00
Graduation fee	5.00
Thesis fee	5.00

LABORATORY FEES

Chemistry V, VI, IX, X, XII, XIV, and XVIII (each)	$ 7.00
Chemistry XVII	5.00
Civil Engineering II	5.00
Civil Engineering V	2.00
Civil Engineering VII	1.00

Electrical Engineering II, IV, VI, and VIII (each)	$ 3.00
Geology and Mineralogy III, IV, VIII, and XIII (each)	5.00
Geology and Mineralogy VII and IX	3.00
Mechanical Engineering XVIII	5.00
Metallurgy I and II (each)	10.00
Metallurgy VIII and XVI (each)	5.00
Metallurgy IX and XI (each)	3.00
Mining III and XVI (each)	5.00
Physics II, IV, VI, and VII (each)	4.00

BOARD AND LODGING

The school has no dormitory. Board can be obtained in private families for six to seven dollars a week. Students' clubs furnish board for about twenty-four dollars a month. Rooms can be obtained for eight dollars to twelve dollars a month.

OTHER EXPENSES

There are other expenses incidental to the mining, metallurgical, engineering, chemical, and geological trips, which vary so widely that they can not be estimated.

Students leaving in mid-term, except on account of severe or protracted sickness, are not entitled to the return of fees or tuition. **All charges of the school are payable strictly in advance at the beginning of each semester.** No student is allowed to be graduated while indebted to the school. The Trustees reserve the right to make incidental changes in fees and deposits without printed notice, as new and unforeseen emergencies may arise.

Students who desire to earn money to defray their school expenses are advised to limit their work to the summer vacation. The course of study is too exacting to allow must time during the college year for outside work.

The total expenses of the college year, including room and board but exclusive of tuition, need not exceed five hundred dollars, and may be reduced considerably by strict economy.

THE QUARTERLY

Four times a year, in January, April, July, and October, the school issues the Quarterly. The various numbers include the Catalog, the Book of Views, Commencement addresses, and articles of a mining or of a metallurgical nature.

METHOD OF GRADING

The following system of grading is used:

A—Excellent

B—Good

C—Fair

D—Conditioned

E—Failed or Subject Dropped

A, B, and C are passing grades.

D (Conditioned) means that the student is not passed. The deficiency may be removed by passing a re-examination or by otherwise completing the work. Unless a condition is removed before the beginning of the next school year the D becomes an E.

E (Failed or Subject Dropped) means that the subject must be taken again, and that no subject depending upon this one may be taken until the E is removed. In removing an E the student must take the subject again either at a regular period or under conditions approved in writing and in advance by the head of the department.

Three hours of laboratory or of drawing are regarded as the equivalent of one lecture or recitation hour.

In case a student fails to complete his work in any subject the instructor may, at his discretion, report to the office not a D but an "Incomplete", which shall be designated by the letters "Inc." This is not regarded as a condition, but it becomes an E at the beginning of the next school year unless previously removed, or unless an extension of time is given in writing by the instructor in charge.

In case a student leaves school with one or more conditions and returns after an absence of a year or more, the term "next school year" will be interpreted to mean the next school year of his attendance; but in case he leaves at the close of the first semester he may return at a similar period a year or more later, subject to the conditions under which he left, as though there had been no break in his attendance, except in case of a changed curriculum.

THE LIBRARY

The school library occupies one-half of the second floor of Guggenheim Hall. The room is well lighted and ventilated and has a seating capacity for one hundred twenty readers. The library contains about fifteen thousand volumes and several hundred pamphlets, principally of a technical nature, and is being increased in subjects corresponding to instruction given in the school. Direct access to the shelves is permitted to all students in order that they may obtain the benefit of examining the books themselves. Books which are not needed for special reference work are loaned for home use for a period of two weeks. The card catalogue includes entries under author, title, and subject, arranged on the dictionary plan. The classification is an adaptation of the Dewey decimal system to the needs of a technical library.

The library subscribes to the publications of the leading scientific societies of the world and to the chief literary and scientific periodicals. It is especially rich in files of engineering journals, the material in which is available for ready reference through excellent periodical indexes received monthly. The library is a depository for the documents of the United States Geological Survey and has an unusually complete collection of the publications issued by state geological surveys and mining bureaus both in this country and abroad. A collection of mine reports has recently been indexed and made available for reference.

During the academic year the library is open from 8 a. m. to 12:30 p. m.; from 1:30 p. m. to 5 p. m., and from 7 p. m. to 10:00 p. m., except on Saturdays and holidays. On Saturdays the library is closed in the afternoon.

Y. M. C. A.

The Colorado School of Mines Young Men's Christian Association was one of 770 Student Associations in the colleges, universities, normal, professional, and preparatory schools of the United States and Canada, March 14, 1916. Five hundred and eighty-five of these institutions reported 204,182 young men enrolled as students on the above date, and of this number 75,091 were members of the College Young Men's Christian Associations.

The Y. M. C. A. of the Colorado School of Mines exists for the purpose of serving the men of the school in every possible way. When called upon to do so, the Association assists men in securing suitable boarding and rooming accommodations, and when possible, in securing employment to help them earn their expenses through school. Weekly Bible Study Classes and religious meetings are conducted during the greater part of the year. An Advisory Board, consisting of one alumnus, one local minister, one local business man, and two faculty members supervises the work of the Association.

SPEAKERS

DR. H. F. HALL..................................Denver, Colo.
"What Must I Do"

IRA E. LUTE.....................................Denver, Colo.
"Y. M. C. A. Work"

DEAN HART ....Denver, Colo.
"The Way of Salvation"

DR. C. L. MEAD..................................Denver, Colo.
"The Danger of the Fractional"

DR. LIVINGSTON FARRAND..................Boulder, Colo.
"The Other Man's Point of View"

BISHOP F. P. McCONNELL......................Denver, Colo.
"Keeping Oriented"

DR. W. B. PHILLIPS............................Austin, Texas
"Religious Life in the School of Mines"

JUDGE FREEMAN ....Denver, Colo.
"A Business Man's Religion"

HON. CLARENCE P. DODGE...........Colorado Springs, Colo.
"Christianity and the Present Crisis"

C. L. JOHNSON..................................Denver, Colo.
"China and the Future"

DAVID A. LATSHAW...........................New York City
"The Need of Christ"

PROF. W. J. HAZARD............................Golden, Colo.
"Early History of the Mines Y. M. C. A."

H. L. HEINZMAN...............................Kankakee, Ill.
"Sidelights on the European War"

DR. WINFIELD SCOTT HALL.........Northwestern University
"Sex Hygiene"

THE INTEGRAL CLUB

The Club Room is in the Gymnasium Building and is furnished in the ordinary style of a gentleman's club. The purpose of the Club is to foster good comradeship among the students. It is under the direct control and management of a student committee.

PRIZES

Each year, usually at commencement, prizes are awarded to certain students who have maintained an excellent scholastic record or who have submitted a meritorious thesis. These prizes may be in the form of cash, engineering instruments, or books. At the commencement exercises, May 26, 1916, the Brunton Transit, presented by David W. Brunton, of Denver, Colorado, was awarded to Walter H. Ralph and William M. Traver, Jr., for their thesis entitled, "Driving a Tunnel Through Mt. Zion."

At the commencement exercises, May 25, 1917, the Wolf Medal, presented by Harry J. Wolf, of the class of 1903, was awarded to Max T. Hofius, for high scholastic attainment.

SCIENTIFIC SOCIETY

The Scientific Society has for its object the presentation and discussion of technical and engineering subjects. From time to time, lectures are delivered before the Society by leading authorities on various topics of interest to its members and friends. The selection of these speakers is placed in the hands of an executive committee chosen from the senior and junior classes. All lectures are held in Simon Guggenheim Hall, on such nights as are most convenient for the majority of the students. The proceedings of the Society are printed in "The Colorado School of Mines Magazine." The alumni, faculty, senior, and junior classes of the institution constitute the active members of the organization; the sophomores and freshmen are associates.

LOAN FUNDS

The following loan funds have been established to assist worthy and deserving students through school.

The Natalie H. Hammond Loan Fund of $1,000.00 was donated to the school in July, 1909, by Mr. John Hays Hammond.

The Vinson Walsh Loan Fund of $1,000.00 was donated to the school in May, 1908, by Mr. Thomas F. Walsh, in memory of his son Vinson Walsh.

The Walter Lowrie Hoyt Loan Fund of $2,000.00 was donated to the school in May, 1912, by Mrs. Mattie B. Hoyt, in memory of her husband, Walter L. Hoyt.

Thirty-seven students have received financial assistance from these funds.

DEPARTMENT OF ATHLETICS AND PHYSICAL TRAINING

By virtue of the athletic fee required, all students entering the School of Mines become members of the Athletic Association. The Association is supported by the student fees, gate receipts, and by contributions from the alumni and other friends of the school. The affairs of the Association are managed by a Board of Control, which consist of: the Athletic Director, as Chairman; the captains of the football, baseball, basketball, and track teams; and the presidents of the junior and senior classes. The Athletic Association maintains an office in the gymnasium building, under the supervision of the athletic director. Training is required in regular gymnasium classes during the freshman and sophomore years.

ALUMNI ASSOCIATION

The aim of the Alumni Association is to promote acquaintance and friendship among the graduates, to encourage them to aid each other, and to make an organized effort to elevate and uphold the reputation and standard of their Alma Mater. To carry out these ideas, the Association, under the management of an Assistant Secretary and Treasurer, publishes monthly "The Colorado School of Mines Magazine" and conducts an employment bureau, or Capability Exchange, for the benefit of the members. This employment bureau also assists undergraduate students in securing employment during summer vacations and at other times, especially when such students are in need of funds to defray the cost of their education.

All graduates are earnestly requested to join the Association, and to keep the assistant secretary and treasurer advised of their addresses and occupations.

The officers of the Association are:

James H. Steele, '00..................President
John G. May, '01................Vice-President
Henry P. Nagel, '04..................Secretary
Arthur H. Buck, '97..................Treasurer

Executive Committee—Russell B. Paul, '02; Daniel Harrington, '00; Edwin H. Platt, '00.

Orville Harrington, '98..Asst. Sec'y. and Treas.
Editor and Manager of the Colorado School of Mines Magazine.
Manager of Capability Exchange.

The association holds its annual meeting and banquet on the day following the commencement exercises, unless otherwise provided for by the Executive Committee. All graduates are eligible to membership and are invited to the annual meeting and to the banquet.

MONTANA CHAPTER OF THE ALUMNI ASSOCIATION, BUTTE, MONTANA

James W. Dudgeon, '13...............President
Harold H. Goe, '08..............Vice-President
Lester J. Hartzell, '95......Secretary-Treasurer

UTAH CHAPTER OF THE ALUMNI ASSOCIATION, SALT LAKE CITY, UTAH

James S. Thompson '99..............President
Blair S. Sackett, '09.............Vice-President
A. C. Watts, '02...........Secretary-Treasurer

ENROLLMENT OF STUDENTS

SENIOR CLASS

Lindley M. Reith, President
Thos. H. Allan, Vice-President
Norman R. Copeland, Secretary
Robt. W. Gibson, Treasurer
Roger F. White, Editor

Albi, Charles.....Denver, Colo.
Allan, Thos. H.....Denver, Colo.
Chiang, L. C.....China
Copeland, Norman R.....Denver, Colo.
Gibson, Robert W.....Golden, Colo.
Jones, Wm. F.....Rock Springs, Wyo.
Reith, Lindley M.....Woodland, Calif.
Riddle, Donald D.....Golden, Colo.
Schneider, Henry G.....Denver, Colo.
Tsen, B. C.....China
White, Roger F.....Golden, Colo.

JUNIOR CLASS

Rene J. Mechin, President
Wm. A. Conley, Vice-President
Otto H. Metzger, Secretary
Chester M. Pittser, Treasurer
Claude Amidon, Editor

Amidon, Claude.....Pueblo, Colo.
Burwell, Blair, Jr.....Denver, Colo.
Chao, Yuan.....China
Charles, Wm. O.....Palisade, Colo.
Conley, Wm. A.....Dauglas, Ariz.
Coulter, Ronald S.....Colorado Springs, Colo.
Dickinson, Earl J.....Denver, Colo.
Mahoney, John F.....Rawlins, Wyo.
Maxson, Harold F.....Los Angeles, Calif.
Mechin, Rene J.....St. Louis, Mo.
Metzger, Otto H.....Meeker, Colo.
Miller, Guy E.....Canon City, Colo.
Mulford, Loren D.....Golden, Colo.
Parker, Russell L.....Denver, Colo.
Poulin, John A.....Naturita, Colo.
Prommel, Harold W. C.....Golden, Colo.
Putnam, Webster F.....Denver, Colo.
Romine, Thos. B.....Walla Walla, Wash.
Schneider, Chas. M.....Colorado Springs, Colo.

SOPHOMORE CLASS

John K. Houssels, President
Chas. P. Van Gilder, Vice-President
Fred L. F. Serviss, Secretary
Chas. L. Boeke, Treasurer
Donald L. Bailey, Editor

Abadilla, Quirico Abella..........................Tayabas, P. I.
Alvir, Antonio Delgado..........................Bulacan, P. I.
Bailey, Donald L..................................Denver, Colo.
Baldwin, Harry L..................................Denver, Colo.
Bell, Francis M................................Palisades, Colo.
Benbow, Jules C.........................Colorado Springs, Colo.
Berkovitz, Sam ....Pueblo, Colo.
Bilisoly, J. M....................................Golden, Colo.
Boeke, Chas. L......................................Lena, Ill.
Bilheimer, Earl L...................................Bath, Pa.
Bond, Frank C.................................Estes Park, Colo.
Brown, Prentice F.................................Denver, Colo.
Bunte, Ernest B...................................Denver, Colo.
Case, Wm. B.......................................Golden, Colo.
Christison, Wilburn E.........................Canon City, Colo.
Clifford, Thos. J..............................Edgewater, Colo.
Clough, Richard H.......................Colorado Springs, Colo.
Davis, Ninetta ....Denver, Colo.
Dunn, Geo. V......................................Golden, Colo.
Dutton, D. A.......................................Rifle, Colo.
Fessenden, John H., Jr.............................Tampa, Fla.
Flint, Howard ....Denver, Colo.
Gallucci, Nicholas ....Louisville, Colo.
Garnett, Samuel A.................................Pueblo, Colo.
Gifford, Donald W................................Norwood, Colo.
Graham, David J.................................Mishawaka, Ind.
Hardy, Earl B..................................Watertown, N. Y.
Hill, Thos B................................Cripple Creek, Colo.
Houssels, John K..............................Long Beach, Calif.
Huleatt, Wm. P....................................Chicago, Ill.
Hunter, Carl A.........................Hot Springs, So. Dakota
Irland, Burrall H.........................Webster Groves, Mo.
Johnson, R. P...................................Brighton, Colo.
Johnston, David C..............................Nashville, Tenn.
Keating, Paul H...................................Pueblo, Colo.
Kirkwood, David F.................Antofagasta, Chile, So. Am.
Klamann, Albert A.................................Denver, Colo.
Lee, E. H. Norton...............................Cheyenne, Wyo.
Levings, Wm. S.................................Leadville, Colo.
Lichtenheld, Fred A...............................Denver, Colo.
Linderholm, Carl T..............................Alamosa, Colo.
Linn, Herbert K...................................Denver, Colo.
Lynch, Victor J.........................Colorado Springs, Colo.

McKirahan, Samuel .... South Dakota
Miller, Harold H .... Youngstown, Ohio
Pittser, Chester M .... Gunnison, Colo.
Serrano, Juan Enrique .... Santiago, Chile, S. A.
Serviss, Fred L .... Golden, Colo.
Sisson, Myron L .... Golden, Colo.
Tanner, Horace A .... Golden, Colo.
Tost, Jacob F .... Ridge, Colo.
Van Gilder, Chas P .... Morristown, N. J.
Wichmann, Lothar E. C .... Telluride, Colo.

FRESHMAN CLASS

Ernest E. Bowers, President
Arthur K. Seeman, Vice-President
Robert M. Edwards, Secretary
Walter Hopkins, Treasurer
Joseph E. Edgeworth, Editor

Adamson, John N .... Bowen, Colo.
Allan, Rex J .... Grand Island, Neb.
Baldwin, James W .... Denver, Colo.
Bengzon, Ernesto .... Camiling, Tarlac, P. I.
Betton, Chas. W .... Colorado Springs, Colo.
Bevan, John G .... Colorado Springs, Colo.
Bianchi, Alfred P .... Chicago, Ill.
Boatright, Byron B .... Denver, Colo.
Bondoc, Hilario G .... San Pedro, P. I.
Bowers, Ernest E .... Colorado Springs, Colo.
Brinker, Fred A .... Denver, Colo.
Burger, C. Roland, Jr .... Golden, Colo.
Burleigh, Wm. P .... Chicago, Ill.
Coffey, Glen V .... La Fontaine, Ind.
Cole, Fred H., Jr .... Yuma, Colo.
Connors, Hugh M .... Denver, Colo.
DeBardeleben, Chas. F., Jr .... Birmingham, Ala.
DeFord, Ronald K .... National City, Calif.
Edgeworth, Joseph E .... Denver, Colo.
Edwards, Robert M .... Denver, Colo.
Eynon, Clarence .... Durango, Colo.
Farlow, Clarence A .... Pueblo, Colo.
Fidel, Henry P .... Grand Junction, Colo.
Finley, Hugh P .... Williamsburg, Ky.
Frenzell, E. Herbert .... Redlands, Calif.
Isidro de la Garza, Morales .... N. Leon, Mexico
Goodier, Benjamin D .... Denver, Colo.
Hamilton, Percy L .... Craig, Colo.
Harroun, Daniel S .... Malaga, N. Mexico
Hartung, Kirk G .... Cheyenne, Wyo.
Henderson, Jas. S .... Montrose, Colo.
Heydrick, Harold F .... Muskogee, Okla.
Hines, Fowler .... Arvada, Colo.
Hopkins, Walter .... Denver, Colo.
Ireland, Robert R .... Quincy, Ill.

Jenni, Alfred E.	Pueblo, Colo.
Johanson, Neil E.	Seattle, Wash.
Kay, Fred D.	Glens Falls, N. Y.
Kelly, Harry G.	East Las Vegas, N. Mexico
Kintz, George M.	Denver, Colo.
Lavery, Aloysius P.	Rexburg, Idaho
Litheredge, Robert W.	Loveland, Colo.
Littell, Horace V.	Denver, Colo.
Malinarich, C.	Santiago, Chile, S. A.
Marvin, Theo.	Sheldon, Iowa
Marx, Paul	Denver, Colo.
McKenna, W. J.	Colorado Springs, Colo.
Miller, Howard H.	Golden, Colo.
Moraes, José E. Albuquerque	Pernambuco, Brazil, S. A.
Moreno, Domingo	Santiago, Chile
Nelson, Fred M.	St. Joe, Mo.
Neumann, Gustave L.	Denver, Colo.
Prentiss, Louis W.	Washington, D. C.
Raiff, Ben L.	Columbus, Mont.
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Rogers, Bryant K.	Montclair, N. J.
Rooney, Lawrence P.	Denver, Colo.
Ruth, Joseph, Jr.	Idaho Springs, Colo.
Schneider, Geo. W.	Denver, Colo.
Seeman, Arthur K.	Brooklyn, N. Y.
Sims, Harold R.	Watkins, Colo.
Strock, Hale	Denver, Colo.
Stubbs, Paul	Saguache, Colo.
Surfluh, John S.	Los Angeles, Calif.
Thomson, Waldemar P.	Omaha, Neb.
Turner, Albert M.	Le Veta, Colo.
Valdez, D. Carl	Salida, Colo.
Vogel, Gustave Harold	Denver, Colo.
Wise, Leonard E.	Monocacy, Pa.
Wong, Yoong Yih	Eagle Pass, Texas
Zambrano, José	Monterrey, N. L., Mexico

CLASS OF PROSPECTORS
1917

Ashton, Charlotte V.	Denver, Colo.
Bartlett, Sidney E.	Cheyenne, Wyo.
Brooks, Edw. J.	Denver, Colo.
Coulter, Mrs. Mabel A.	Golden, Colo.
Cowan, Peter	Denver, Colo.
Fisher, Eldon J.	St. Louis, Mo.
Glasgow, R. Lee	Rico, Colo.
Gleason, M. J.	Harpers Ferry, Iowa
Graff, John	Denver, Colo.
Hare, Donald C.	Colorado Springs, Colo.
Harper, Theodore S.	Golden, Colo.
Hart, Harry P.	Denver, Colo.
Hinman, Florence T.	Golden, Colo.
Horlacher, Chas. W.	Denver, Colo.
Horsfall, Harold L.	Colorado Springs, Colo.

Jackson, Louis	Denver, Colo.
Mokler, T. R.	Boulder, Colo.
Nelson, James B.	Golden, Colo.
Nyquirt, Alex. A.	Denver, Colo.
Oilin, Alred	Denver, Colo.
Oliver, Jason D.	Breckenridge, Colo.
O'Neal, Claude G.	Andahisia, Ala.
Palmer, Harry W.	Denver, Colo.
Pedersen, Peter J.	Las Animas, Colo.
Rader, Geo. A.	Colorado Springs, Colo.
Rome, Robert C.	Colorado Springs, Colo.
Savage, S.	Shawmokin, Pa.
Seaholm, Geo. A.	Leadville, Colo.
Sears, Warren F.	Denver, Colo.
Sheehan, Henry P.	Denver, Colo.
Simon, Donald L.	Denver, Colo.
Thomson, Geo. B.	Kokomo, Colo.
White, Mrs. E. E.	Golden, Colo.

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Volume Thirteen Number Two

Quarterly

of the

Colorado School of Mines

April, 1918

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Golden, Colo.

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of the
Colorado School of Mines

Vol. Thirteen April, 1918 Number Two

The Oil Shale Industry

BY VICTOR C. ALDERSON,
President, Colorado School of Mines.

THE NATURE, ORIGIN, AND DISTRIBUTION OF OIL SHALE

NATURE OF OIL SHALE

Oil shale virtually contains no oil as such. It is a consolidated mud or clay deposit from which petroleum is obtained by distillation. In appearance the shale is black, or brownish-black, but on weathered surfaces it is white or gray. It is usually fine-grained, with some lime and occasionally sand. It is tough but, in thin sections, friable. When broken to a fresh surface it may give an odor like petroleum. Thin rich pieces may burn with a sooty flame.

ORIGIN OF OIL SHALE

Oil shale is one of a long list of natural deposits which result from the deposition of organic matter from plants or animals of a former geologic era—like anthracite, bituminous, and brown coal, peat, petroleum, and asphaltum. Beds of oil shale were laid down in lagoons, or wide expanses of quiet water. They contain a large amount of organic matter—low plant forms of life like algae; also pollen, fish scales, insects, and remains of animal and vegetable life sometimes changed beyond recognition.

WORLD-WIDE DISTRIBUTION OF OIL SHALE

Besides the extensive deposit in Colorado, oil shale is found in Utah, Wyoming, Nevada, Montana, California, Pennsylvania, West Virginia, Texas, Oklahoma, and Kansas. In Canada it is found in Quebec, New Brunswick, Nova Scotia, and Newfoundland. In Scotland, near Edinburgh and on the Isle of Skye. In France, at Autun and Buxiere les Mines. In South Africa, in the Transvaal, Mozambique, and Natal. Also in New South Wales, New Zealand, Tasmania, Brazil, Italy, Spain, Austria-Hungary, Serbia, and Turkey.

THE NEED OF MORE OIL

The total stock of crude oil on hand in the United States January 1, 1916, was 198,000,000 barrels. On November 1, 1917, this supply had been reduced to 158,000,000 barrels. The consumption of crude oil by Pacific refineries has been exceeding the production at the rate of a million barrels a month for the past year. There is no hope that the oil wells will last permanently. The world's supply is being rapidly exhausted. The production in the United States is not expected to last more than twenty-five years. As a matter of economic necessity the oil shales must be regarded as our great reserve of oil for the future.

Exposure of Shale, De Beque, Colo. (Courtesy of the D. & R. G. R. R.)

THE OIL SHALE INDUSTRY IN SCOTLAND

HISTORY OF THE INDUSTRY IN SCOTLAND

The first production of oil from bituminous material, on a commercial scale by slow distillation, was made by Young and Weldrum in 1848, who secured a patent for their process. In 1850 they erected a plant at Bathgate. In 1851 a second, the Crofthead oil works, was in operation. In 1857, when Young's patent expired, 38 new works were established. In 1860 there were 6; in 1870, 90; in 1880, 26; in 1890, 14; in 1900, 9. At the present time four companies are refining shale: Young's Paraffin Light & Mineral Co., Ltd.; the Oakbank Oil Co., Ltd.; the Broxburn Oil Co., Ltd., and the Pumpherston Oil Co., Ltd. There are three other companies which produce only oil and ammonium sulphate.

THE OIL SHALE OF SCOTLAND

The oil shale beds of Scotland occur within a small area, twenty miles in diameter, in the counties of West Lothian, Mid Lothian, and Lanarkshire. The center of the district is fourteen miles west of Edinburgh. The shale beds are simply very fine impalpable clay shale, brown to black in color, free from silica, easily cut with a sharp knife, and in form are plane or curly. The beds vary greatly in thickness; it is not uncommon to find a seam pinch out altogether, while another seam, above or below it, increases in thickness and richness as the first deteriorates. Faults, folds, and igneous intrusions are not uncommon. Mining is done entirely through shafts. "Kerogen" is the Scotch term given to the substance in the shale which produces petroleum. The richer shales yield from 30 to 40 gallons of oil to the ton of shale. The lower grade shale that yields only from 15 to 18 gallons of oil gives from 60 to 70 pounds of ammonium sulphate. That is, the shale that runs high in oil runs low in ammonium sulphate; the shale that is low in oil is high in ammonium sulphate.

PRESENT VALUE OF THE SCOTCH SHALES

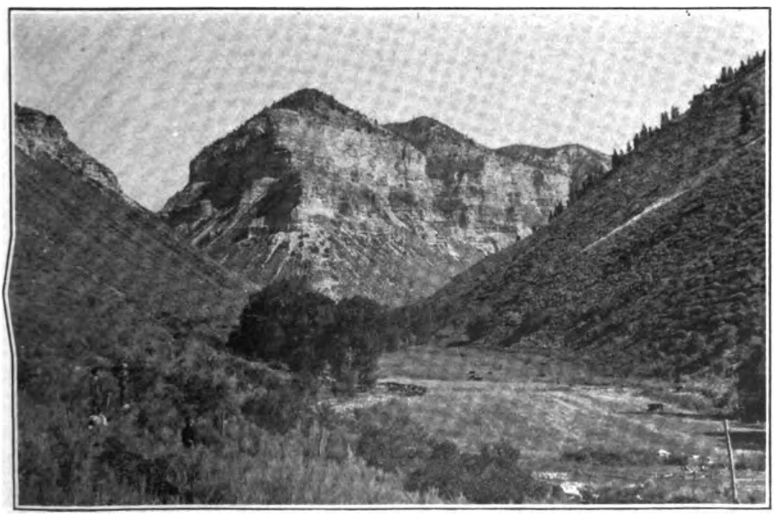
In the earlier days of the industry the shales that were worked produced more crude oil than the shales of today. Notably the Torbanehill material gave from 96 to 130 gallons of crude oil a ton. At the present time the production seldom exceeds 30 gallons a ton, and shale yielding only 15 gallons is successfully treated. The explanation for this lies in the fact that crude oil is not the only product of value that may be obtained. The ammonium sulphate is also valuable. If this is obtained in large quantity, as in the case of shales now being treated, the total result in crude oil, plus ammonium sulphate, may be economically profitable. The following series of products are secured from the Scotch shales:

1. Permanent gases used for fuel under retorts.
2. Naphtha, gasoline, and motor spirits.
3. Burning or lamp oil.
4. Intermediate oil used for gas-making.
5. Lubricating oil.
6. Solid paraffine.
7. Still grease.
8. Still coke, which contains some oil and is used for gas, smokeless fuel, and carbon for electrical purposes.
9. Liquid fuel used in the refineries.

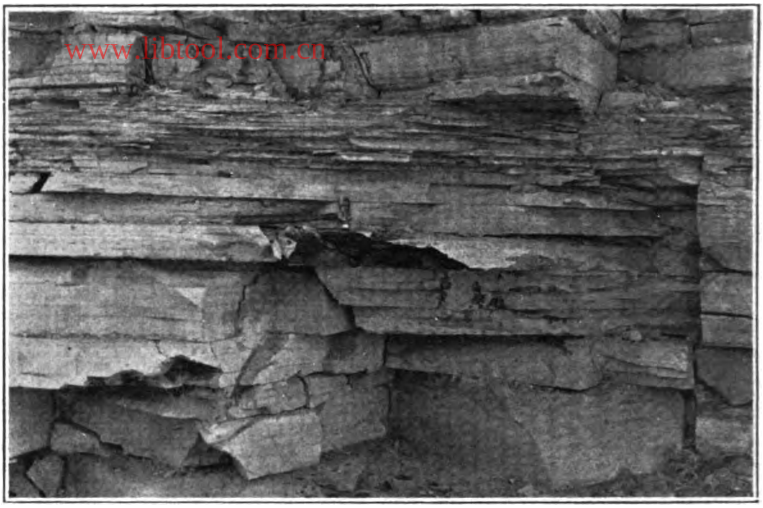
SCOTTISH OIL-SHALE SEAMS

The Scottish seams of oil shale that have been worked, at various times, have given approximately the following results:

Name	Thickness	Gal. of Crude Oil, Long Ton	Ammonium Sulphate Lb., Long Ton
Torbanehill		96-130	
Levenseat	11 in.	29	
Raeburn	3-6 ft.	40-55	14
Addiewell (Not much worked)	20 in.	28	13-18
Fells	3-5 ft.	26-40	20-35
(The principal shale of the West Calder District. Extensively worked)			
Oakbank Shale—			
Wee	1½ ft.	36	
Big	4 ft. 6 in.	22	
Wild	6 ft.	29½	34-41
Curly	6 ft.	22	35
Lower Wild	5 ft. 6 in.	19	



Pyramid Point, Parachute Creek, Grand Valley, Colorado (Courtesy of the D. & R. G. R. R.)



Close View of Oil-Shale Formation
(Courtesy of the D. & R. G. R. R.)

New	8 ft. 6 in.	21	
Dunnet	4-.12 ft.	24-33	14.34
(Extensively worked)			
Barracks	8 ft.	18-22	
Broxburn Shale—			
Broxburn gray	6 ft.	20-33	34-41
Broxburn curly	5 ft. 6 in.	19-33	11-38
Broxburn seam	5-6 ft	10-51	7-40
Pumpherston Seams—			
Jubilee	8 ft.	18	55
Maybrick	5 ft.	16	60
Curly	6 ft.	20	52-67
Plain	7 ft.	20	60
Wee	4 ft.	18	60
Mungle	2 ft.	35	30
(Not much worked)			

DESCRIPTION OF THE SCOTCH OIL WORKS

D. R. Steuart in Economic Geology, Vol. 3, 1908, p. 574, describes briefly the equipment as follows: "In a Scotch oil works there are the great benches of shale retorts sometimes more than 60 feet high, with the great stacks of numerous series of 3-inch pipes, 30 or 40 feet high, for air condensers. There is the three-story-high sulphate of ammonia house, with its high column-stills, the acid saturators for the ammonia, vacuum or other evaporator for the sulphate from the recovered sulphuric acid of the refinery, centrifugal driers, storing bins and grinding mills. In the refining departments the stills are small and, on account of the repeated distillations, very numerous; the washers for vitriol and soda are many; there are coolers, refrigerators, filter and hydraulic plate presses for the separation of the heavy oil and solid paraffin; great sweating houses for the paraffin refining; candle works; sulphuric acid making plants; acid recovery plant; engineer's, joiner's and plumber's shops—a very large and varied collection of apparatus covering much ground, so that for a comparatively small production there is a very large and expensive plant. A conspicuous feature of oil works is the great hills of spent shale."

THE ECONOMICS OF THE SCOTCH OIL-SHALE INDUSTRY

In 1906 the production of shale was as follows:

	Tons of Crude Shale
West Lothian	1,791,896
Mid Lothian	732,635
Lanarkshire	21,051
Total	2,545,582

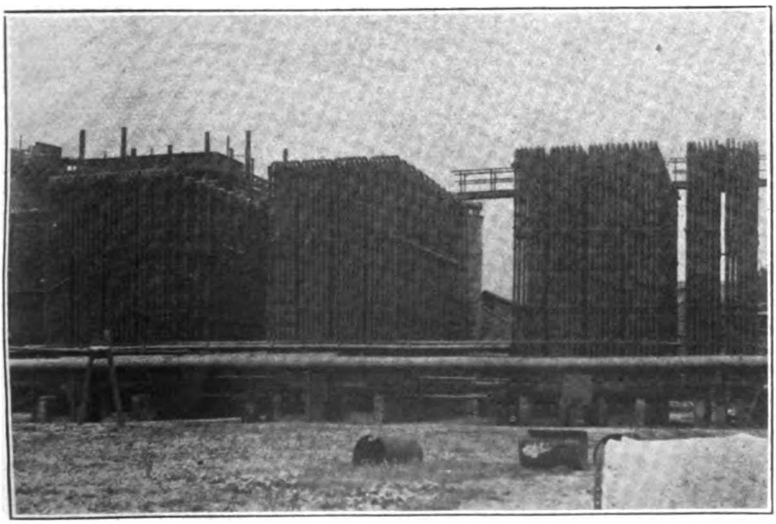
In the same year (1906) the refined products were as follows:

	(Approximately)
Naphtha	2,500,000 imp. gal.
Burning oils	17,000,000 imp. gal.
Intermediate oils	38,000 tons
Lubricating oils	40,000 tons
Solid paraffin wax	22,500 tons
Sulphate of ammonia	50,000 tons
Still coke	5,000 tons

In 1906 there were seven paraffin oil works in Scotland. Of these, three produced only crude oil and ammonia; the other four were larger and had fully equipped refineries. The paid up capital of these four was $7,500,000. The pay roll of the combined companies averaged $3,500,000.00 a year. There were employed 8,300 men, of whom 3,380 were miners.

The production of crude shale for various years was as follows:

	Tons of Shale
1873	524,095
1883	1,130,729
1893	1,947,842
1903	2,009,265
1907	2,690,028
1908	2,892,039
1909	2,967,057
1910	3,130,280



Condensers, Pumpherston Works, Scotland. (Courtesy of the Canadian Bureau of Mines

Mount Logan, De Beque, Colorado. (Courtesy of the D. & R. G. R. R.)

The present output of shale is approximately 3,500,000 tons annually, valued at $15,000,000.00. In the various parts of the industry 12,500 men are now employed.

The refineries are now producing from the oil shale approximately:

Burning oils	20,000,000 gallons
Naphtha	5,000,000 gallons
Lubricating oils	22,000,000 gallons
Paraffin wax	25,000 tons
Sulphate of ammonia	54,000 tons

DIVIDENDS AND COSTS

Dividends paid by the three large Scotch oil-shale companies for a period of years are as follows:

	Broxburn, Capital, $1,675,000. %	Oakbank Capital, $1,500,000. %	Pumpherston. Capital, $1,650,000. %
1895-1896	7½	5	
1896-1897	7½	0	
1897-1898	7½	0	
1898-1899	8½	5	
1899-1900	15	7½	20
1900-1901	20	12½	15
1901-1902	15	7½	7½
1902-1903	15	7½	20
1903-1904	15	12½	30
1904-1905	15	15	30
1905-1906	15	15	30
1906-1907	15	15	50
1912-1913	10	15	35
1913-1914	10	15	25
1914-1915			10
1915-1916	7½	10	25

In 1882 the net profit on each ton of shale treated in Scotland was, on the average, 89 cents. In 1897 the profit was 50 cents. In

1909 the cost of mining and manufacturing was $2.06 a ton and the net profit 83 cents a ton.

ISLE OF SKYE

In 1913 oil shale was discovered on the Isle of Skye. It is fine grained, brown in color, fossiliferous, tough, and resists disintegration by weathering. At the outcrops it is from seven to ten feet in thickness. Two samples from the outcrops gave:

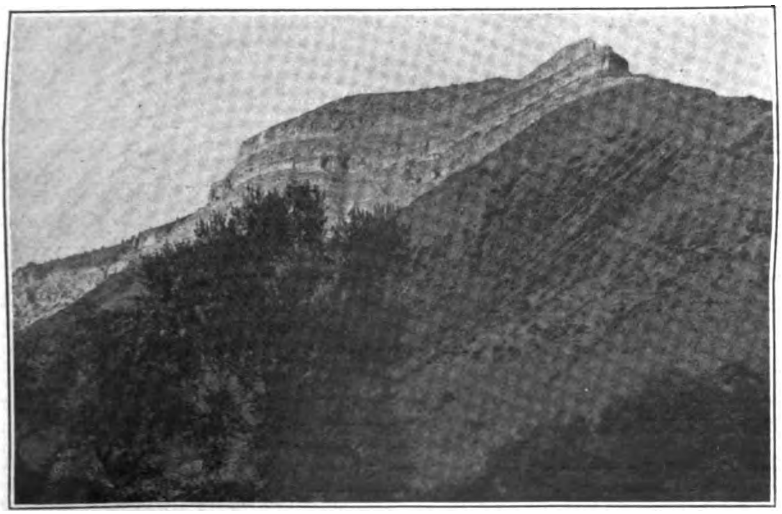
	Crude Oil, Gallons a Ton	Ammonium Sulphate, Pounds a Ton
1	12	6.2
2	12.8	7.4

THE OIL SHALES OF CANADA

As far as our present knowledge extends it is evident that Canada is not so well supplied with oil fields as the United States. For this reason the oil-shale industry may make rapid advancement there, since large beds of shale, rich in oil, are known to exist within the Dominion. The Geological Survey and the Bureau of Mines of the Dominion have already given considerable attention, in examinations and reports, to these deposits.

NEW BRUNSWICK SHALES

The oil shales of New Brunswick are located in three areas—the Taylorville, Albert mines, and Baltimore. Taylorville—In this locality are four beds of shale of good quality; one five feet, one three feet, and two, one foot ten inches thick. Albert Mines—In this locality are six beds of the following thickness (the most important in New Brunswick): 6½ feet; 3½ feet; 5 feet; 4½ feet; 6 feet; and one with thin beds of oil shale. Baltimore—In this locality are four beds, 4 feet, 5 feet, 7 feet and 6 feet thick, respectively.



A Mountain of Oil Shale, Conn Creek, De Beque, Colo.
(Courtesy of the D. & R. G. R. R.)

Five samples from the Albert mines, tested by the Canadian Bureau of Mines, gave the following results:

	Thickness	Crude Oil, Imp. Gallons, a Ton	Ammonium Sulphate, Pounds a Ton
Bed No. 1	6½ feet	48.5	82.8
Bed No. 2	3½ feet	38.8	60.3
Bed No. 3	5 feet	45.5	48.0
Bed No. 4	4½ feet	43.5	56.8
Bed No. 5	6 feet	27.0	49.0
Taylorville shales gave:			
Bed No. 1		43.0	93.0
Bed No. 2		48.0	98.0
Bed No. 3		37.0	110.0
Baltimore shales gave:			
Bed No. 1		54.0	110.0
Bed No. 2		49.0	67.0
Bed No. 3		40.0	77.0
Bed No. 4		56.8	30.5

Thirty-six tons of New Brunswick shale tested at the Pumpherston Oil Co., Scotland, gave an average of 40.09 gallons of crude oil and 76.94 pounds of ammonium sulphate a ton.

The New Brunswick Shale Co., Ltd., capitalized at $5,000,000.00, has been organized to develop the New Brunswick shales.

NOVA SCOTIA

Oil shales were first discovered in Pictou County in 1859. They are also found in Antigonish County. Analysis of Pictou County shale gave two satisfactory results.

	Crude Oil, Imperial Gal., a Ton	Ammonium Sulphate, Pounds a Ton
Bed No. 1	42.0	35
Bed No. 2	14.5	41
Analysis of Antigonish County shales gave:		
Bed No. 1	11.0	22.6
Bed No. 2	10.0	38.0
Bed No. 3	23.0	34.0

QUEBEC

The oil bearing shales of Quebec are found in the Gaspé Basin. The outcrops are from 12 to 15 inches in thickness. Samples tested by the Canadian Bureau of Mines resulted as follows:

	Crude Oil Imperial Gal., a Ton	Ammonium Sulphate, Pounds a Ton
Bed No. 1	30.0	42.20
Bed No. 2	31.5	40.00
Bed No. 3	36.0	59.50

On account of the thinness of these beds their economic value is doubtful.

NEWFOUNDLAND

The oil shales of Newfoundland cover an area of about 750 square miles. The largest deposit lies between the head of White Bay and Deer and Grand Lakes, and varies from 50 to 100 feet in thickness. The dip of the strata is slight and the outcroppings are bold. An analysis of typical shale gave 50 gallons of crude oil and 80 pounds of ammonium sulphate a ton. The Newfoundland shales have great prospective value.

OTHER FOREIGN DEPOSITS OF OIL SHALE

FRANCE Second only to the oil shale industry of Scotland ranks the French, which dates from 1830. After many years of successful operation it suffered from competition with oil wells until the French government in 1890 offered a premium for the production of oil from shale. This bonus, together with the adoption of efficient Scottish methods of treatment, revived the industry. The shales occur at depths from 150 to 300 feet. Five companies are now in operation on the shales of Autun and Buxiere les mines, where the shales produce 50 gallons of oil a ton.

AUSTRALIA Large outcrops of rich oil shales occur in the gorges of the Blue Mountains, New South Wales. The deposits are worked by the long-wall system. Fossils are found in the lower shale measures. These shales are reported to give 100 gallons of oil and 70 pounds of ammonium sulphate a ton. The government has established a system of bonuses, for the production of oil, which are expected to increase the present annual production from 3,000,000 to more than 20,000,000 gallons. There are two British-Australian companies in the field—the Commonwealth Oil Corporation, capital $6,000,000, operating at Newnes, and the British-Australian Oil Co., capital $1,460,000, operating at Temi in the Liverpool range. From 1865 to 1916, 1,751,367 tons of shale have been produced of a total value of $11,606,671.

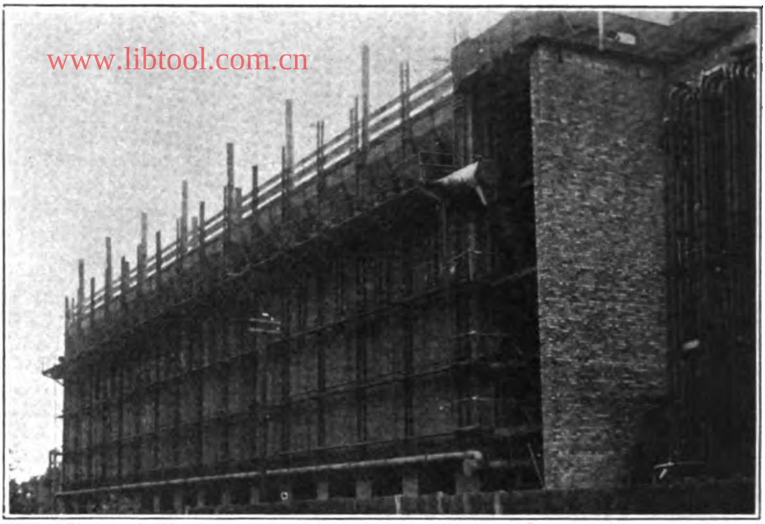
TRANSVAAL Oil shale is found in two districts—the Ermelo and the Wakkerstroom, fifty miles apart. Although these two deposits may prove to be one continuous bed, yet there is no evidence to that effect at the present time. In each case the shale is associated with a seam of coal. The Ermelo shales have produced from 30 to 34 gallons of crude oil a ton. The Wakkerstroom shale has yielded as much as 90 gallons a ton, but the shale is only 9 inches thick.

BRAZIL Oil shales are exposed at many places on the coast of Brazil. They have been examined by Professor John C. Branner of Leland Stanford Jr. University, and their composition determined by Sir Boverton Redwood of London. The richest yielded 44.73 gallons of crude oil and 19.58 gallons of ammoniacal water to the ton. The deposits have not been worked commercially.

THE OIL SHALES OF COLORADO

GEOLOGICAL POSITION The oil shales of Colorado belong in the Green River (Eocene) formation. Elsewhere they are found in the Cretaceous, Devonian, and Carboniferous. In recent geologic time this oil-shale region of Colorado was an extensive plateau through which the Grand River and its tributaries, Kimball, Conn, and Parachute creeks have cut valleys to a depth of 3,000 or more feet. On either side of the streams are now exposed great beds of shale—even mountains of it.

DEVELOPMENT WORK IN THE OIL SHALES At the present time (March, 1918) no deep development work has been done and no commercial extraction of the oil accomplished. As a result we have no exact knowledge of the change or the persistency of oil values with depth, nor the underground difficulties to be met in mining. However, to draw inferences from mining shale in Scotland, we are fairly safe in assuming that neither dust nor gas will be found. Up to the present time sampling has been done on weathered outcrops or from shale close to the surface. There is reason to expect that as unaltered shale is reached it will be found to be richer than shale near the surface. Dean E. Winchester reports that one sample taken after the weathered surface was removed gave 32 gallons of oil a ton. A foot and a half



Bench of Retorts, Pumpherston Company, Scotland.
(Courtesy of the Canadian Bureau of Mines)

was then removed by blasting. A sample then gave 55 gallons a ton. If this is typical we may reasonably expect that deep unchanged oil shale will prove to be much richer than shale near the outcrop, and as a result the total content of the oil-shale deposits may be much richer than at present estimated.

MINING OIL SHALE

The shale beds of Scotland are irregular and lie in synclinal troughs; they pinch out or expand; they have a dip of from 30 to 60 degrees; they are folded or faulted to a great extent and often altered by intrusive volcanic rocks. All mining is through shafts, some of which are very deep. In Colorado, however, the oil-shale beds are regular; they are virtually level; the greatest dip noticed is 10 degrees; faults and folds have not been found, and there is little likelihood, to judge from the outcrops and the formation, that they will be found; the level position of the oil shale enables it to be mined by the ordinary methods of coal mining, and, where the shale lies near the surface, the overburden may be removed and the shale merely quarried, as on Kimball Creek, thirty miles from De Beque. From the standpoint of cheap mining, if comparison is made with Scotland, the advantage is certainly with Colorado.

POSSIBILITIES OF THE SHALE INDUSTRY

Inasmuch as the oil-shale industry has been in operation in Scotland since 1850 — sixty-eight years — and has met and overcome technical, trade, and economic obstacles, it seems a mere matter of common sense for the pioneers of the industry in Colorado first to follow the well-known and successful methods of Scotland; to adapt these methods to Colorado conditions, and then to improve them as fast as possible by methods not now known. Besides the production of crude oil, gas, and ammonium sulphate, other possibilities may open, e. g., the nitrogen may be reclaimed in a form for use in the manufacture of munitions of war; aniline dyes and flotation oils may be obtained; possibly producer gas, a substitute for rubber, and other products may become valuable. The nitrogen content is especially valuable, as each per cent of nitrogen will yield theoretically 93 pounds of ammonium sulphate now worth 7.3

cents a pound. All in all, it should be realized that the oil-shale industry presents a long series of interesting technical-chemical problems to be solved by scientifically trained men. So true is this that the industry can be classed as a combined mining-chemical-manufacturing project.

In some quarters there exists two erroneous ideas, viz., that the distillation of oil from shale is a simple process and that a treatment once devised will apply to all oil shales. To be sure, in a laboratory retort a few pounds of shale can be heated and a small amount of oil produced. So can water be boiled in a tea kettle, but there is as much difference between this puny outfit and the great plants in Scotland as there is between the tea kettle and a great central power plant. Also shales vary to such an extent that each deposit should be tested in a careful, scientific manner; just as large bodies of low grade copper ore are tested and suitable treatment plants erected. As in handling low-grade ores, the large profits from oil shale will be made by handling a great tonnage at a low cost to the ton.

STRATIGRAPHICAL STATIONS

In Bulletin 581-A of the U. S. G. S., E. G. Woodruff and David T. Day have reported in detail on numerous exposures of the Green River formation in Colorado. The following extracts show the results of tests and the nature of the oil-shale seams:

RESULTS OF FIELD DISTILLATION

No. of Test	Locality	Thickness of Shale Sampled, Ft.	In.	Amt. of Shale Used, Pounds	Amt. of Oil Obtained, Gallons	Amt. of Oil to the Short Ton of Shale, Gallons
1	Conn Creek	1	4	100	3.1	62.2
2	Kimball Creek	6	0	150	2.4	31.6
3	Kimball Creek (second test)	6	0	156	2	26.2
4	Parachute Creek	5	10	150	1.5	20.0
5	4A Ranch	5	10	150	.78	10.4

EXPOSURE IN PARACHUTE CREEK

Total exposure 110 ft. 7 in.
Sec. 29, T. 5 S., R. 95 W.

Thickness of Seams.	Estimate.
31 feet	20 gal. a ton
4 ft. 10 in.	20 gal. a ton
5 ft. 10 in.	20 gal. by field test

SECTION ALONG MOUNT LOGAN TRAIL

Sec. 26, T. 7 S., R. 97 W.
Total exposure 1,086 ft. 10 in.

Thickness of Seams.	Estimate.
81 ft.	20 gal.
1 ft. 1 in.	20 gal.
8 in.	30 gal.
2 ft. 6 in.	25 gal.
9 in.	30 gal.
5 ft. 6 in.	20 gal.

EXPOSURE AT 4A RANCH.

Sec. 21, T. 6 S., R. 90 W.
Total exposure, 19 ft. 9 in.

Thickness of Seams.	Estimate.
5 ft. 3 in.	20 gal.
1 ft. 2 in.	25 gal.
4 in.	25 gal.

EXPOSURE ON THE NORTH SIDE OF KIMBALL CREEK

Sec. 5, T. 7 N., R. 100 W.
Total exposure, 86 ft.

Oil Shale, Grand Valley, Colorado. (Courtesy of the D. & R. G. R. R.)

Two samples, each from a seam six feet thick, gave 31.6 and 26.2 gallons of oil to the ton, respectively.

Dean E. Winchester, in Bulletin 641-F, of the U. S. G. S., gives a number of stratigraphical sections from which the following are taken to illustrate the thickness of the shales.

T. 1 N., R. 103 W. Total thickness, 929 ft. 1½ in.:

In this exposure are 14 seams of 7 in., 1 ft., 1 ft., 4 ft., 1 ft., 1 ft., 2 in., 1½ in., 2 in., 5 ft., 4 in., 2 ft., 10 in. and 3 ft. thickness, respectively, all of which are estimated to carry 15 gallons or more of oil to the ton.

T. 1 N., R. 104 W. Total exposure, 765 ft. 3 in.:

In this exposure are 25 seams of 6 in., 1 ft., 6 in., 8 ft., 5 ft., 1 ft., 6 in., 5 ft., 1 ft., 2 ft., 1ft., 2 ft., 1 ft., 1 ft., 6 in., 1 ft., 1 in., 1 ft., 2 in., 3 ft., 2 ft. 2 in., 1 ft., 1 in., 4 ft. and 1 ft. in thickness, respectively, all of which are estimated to carry 15 gallons or more of oil to the ton.

T. 1 N., R. 100 W. Total exposure, 399 ft. 4 in.:

In this exposure are 3 seams of 6 in., 1 ft. and 3 ft. thickness, respectively, which are estimated to carry 15 gallons or more of oil to the ton.

T. 1 N., Rs. 99 and 100 W. Total exposure, 874 ft. 9 in.:

In this exposure are 31 seams of 8 in., 1 ft., 7 ft., 1 in., 2 ft., 2 ft., 4 ft., 1 in., 6 in., 1 ft., 5 ft., 1 ft., 3 in., 6 in., 2 in., 1 ft., 2 in., 8 in., 8 in., 6 in., 1 ft., 1 ft., 6 in., 1 ft., 1 ft. 3 in., 2 ft., 6 in., 3 ft., 5 ft., 4 in., 3 ft., 3 ft. and 1 ft. in thickness, respectively, all of which are estimated to carry 15 gallons or more of oil to the ton.

T. 2 N., R. 98 W. Total exposure, 1,677 ft. 1¾ in.:

In this exposure are 9 seams of 5 ft., 5 ft., 4 ft., 11 in., 3 ft. 7 in., 5 ft., 6 in., 1 ft. and 1 ft in thickness, respectively, which are estimated to carry 15 gallons of more of oil to the ton.

T. 2 N., R. 97 W. Total exposure, 1,605 ft. 11½ in.:

In this exposure are 12 seams 3 ft., 3 ft., 5 ft., 2 ft., 2 ft., 2 ft., 5 ft., 2 ft., 10 ft., 3 ft., 8 in. and 3 ft. in thickness, respectively, that are estimated to carry 15 gallons or more of oil to the ton.

T. 1 N., R. 97 W. Total exposure, 2,496 ft. 6½ in.:

In this exposure are 27 seams, 1 ft., 3 in., 3 ft., 1 in., 5 ft. 11 in., 3 ft., 2 ft., 3 ft. 4 in., 6 in., 5 ft. 8½ in., 2 ft., 6 in., 2 ft., 3 ft., 5 ft., 5 ft., 5 ft., 3 ft., 1 ft., 1ft., 1ft., 3 in., 2 ft., 4 in., 3 ft. 4 in., 5 ft. 8 in. and 4 ft. 4 in. in thickness, respectively, all of which are estimated to carry 15 gallons or more of oil to the ton.

SUMMARY OF TESTS

In Bulletin 641-F of the U. S. G. S., Dean E. Winchester summarizes all the field tests in oil shales made by the survey as follows:

No. of Samples	Amount of Oil to the Ton
1913	
1	10.4 gal.
8	16-40 gal. (Average, 27.2 gal.)
1	45.2 gal.
1	61.2 gal.
1914	
17	Less than 10 gal.
22	10-20 gal.
11	20-30 gal.
3	30-40 gal.
2	40.6 gal.
1	65.3 gal.
1	86.8 gal.
1915	
6	Less than 10 gal.
7	10-20 gal.
7	20-30 gal.
9	30-40 gal.
5	More than 40 gal. (1-90 gal.)

In a few samples only was the yield of ammonium sulphate determined. This was found to range from 18.3 pounds by dry distillation, or 34 pounds by steam distillation, to 0.4 pound to the ton of shale. The yield of inflammable gas varied from 500 to 4,549 cubic feet to the ton.

DISTRIBUTION OF OIL SHALE DEPOSITS IN COLORADO

In northwestern Colorado and northeastern Utah the oil shale deposits underlie an area of approximately 5,500 square miles. In Colorado they occur chiefly in Garfield, Rio Blanco, Mesa, and Moffat counties, and cover 2,500 square miles. The towns of Grand Valley and De Beque, on the lines of the Denver & Rio Grande and Colorado Midland railroads, are the points of entrance.

THE DE BEQUE DISTRICT

The exposed shales of the De Beque district lie northeast, north, and northwest of the town, on both banks of Roan Creek, its largest tributaries, Conn, Kimball, and Dry Fork creeks, and on all of its smaller tributaries.

The Colorado Carbon Company has thirty-seven claims on Kimball Creek, twenty-seven miles from De Beque. Their main seam of heavy black shale is sixty feet thick and, according to the officials of the company, produces from 70 to 125 gallons of crude oil to the ton, with an average of 100 gallons. The company does not intend to treat the shale on the ground, but to ship it raw to Kansas City, where it will be retorted. The company has a half-mile tram installed at the plant and owns a ten-ton retort in Kansas City.

The Oil Shale Mining Company has 960 acres on Dry Creek, twenty miles northwest of De Beque. This company has erected the first distillation plant of the Henderson (Scottish) type in the United States. It has six retorts of six tons' daily capacity each. The first run for demonstration was made in July, 1917. The company has a 2,000-foot tram and full equipment on the ground. Active operations are expected to begin early in March. Their seam of oil shale is from

Broxburn Refinery, Scotland. (Courtesy of the Canadian Bureau of Mines

ten to twenty feet thick and, according to the claims of the company, gives an average of seventy-five gallons of oil to the ton.

The Mount Logan Oil Shale Mining and Refining Company has 1,180 acres on Mount Logan, four miles from De Beque. They have on the ground three twenty-ton retort units with full equipment, except an aerial tram, for which provision is now being made. Their seam is eleven feet thick and gives an average of 100 gallons of crude oil to the ton. Active work will begin as soon as the equipment can be installed.

The American Shale Refining Company has 12,000 acres on both sides of Conn Creek, twelve miles from De Beque. The company has erected a 150-ton retort in Denver which is now en route to the property. The cost of this retort was $40,000.00; succeeding retorts will probably cost $15,000.00 each. Each retort is 40 feet high and weighs 75 tons. They will be placed 200 feet above the creek level to give ample dumping ground. The process of distillation and refining has been worked out by the company's chemist and has engaged his time for the past two years. The material for a 3,000-foot tram is now on the ground. The capacity of the tram is 900 tons a day—sufficient to supply shale to six 150-ton retorts. The shale cliffs at the camp rise to a height of 2,500 feet. In these cliffs are the outcroppings of five well defined oil strata, but only the two richest will now be worked. From the camp the outcroppings of the rich shale can be seen at seven different exposures.

The first and richest is 200 feet below the summit of the cliff. This seam is sixty feet thick and is expected, from extensive tests made by the company, to yield a minimum of sixty gallons of crude oil to the ton. The second stratum is 200 feet below the first, is seventy-five feet thick and is expected to give an average of more than fifty gallons to the ton. Both strata are horizontal, lying in a great knob, or outlier, so that their extent can easily be determined.

The first stratum, as a whole, is estimated by the company to contain 9,000,000 barrels of crude oil and 9,000 tons of ammonium sulphate; the second 10,000,000 barrels of crude oil and 10,000 tons of ammonium sulphate. The company has expended to March 1, 1918, $83,101.00 in the development and equipment of its property.

THE GRAND VALLEY DISTRICT

In the Parachute region of the Grand Valley district is a well defined rich oil shale stratum—twelve to twenty feet thick—that is exposed on both banks of Parachute Creek and all its tributaries almost continuously for a total distance of sixty-nine miles. Many tests show that it will yield an average of at least fifty gallons of oil to the ton. Assuming that this stratum extends only a mile and a quarter back from the line of exposure—a conservative estimate—the area of this stratum is at least 55,000 acres. This estimate does not include the shale exposed on Battlement Mesa east and southeast of Grand Valley. Using the minimum thickness of twelve feet, allowing 25 per cent of the volume to be left as pillars, and counting only on forty-two gallons to the ton, this deposit would contain 1,012,500,000 barrels of crude oil.

A measure of the interest and activity in the oil-shale industry can be realized from the fact that since June, 1916, there have been more than 1,500 filings on oil-shale land in Garfield County, and $500,000 is expected to be spent on improvements in the district this summer. On December 16, 1916, the United States Government withdrew 45,440 acres of shale land in the Grand Valley district as a source of supply for the use of the United States Navy.

TESTS ON COLORADO OIL SHALE AT THE EXPERIMENTAL PLANT OF THE COLORADO SCHOOL OF MINES

Submitted by	Amount of Crude Oil a Ton
D. L. Killen, Denver, Colo	70 gallons
Benj. F. Koperlik, Pueblo, Colo	45.5 gallons
J. W. Hoke, Palisade, Colo.:	
No. 1	32 gallons
No. 2	24 gallons
F. A. Wadleigh, Denver, Colo.:	
No. 1.	
Oil	65.50 gal. a ton

DISTRIBUTION

Oil distilled at 150° C., 8.00 gal.
Oil distilled at 200° C., 3.50 gal.
Oil distilled at 250° C., 8.50 gal.
Oil distilled at 300° C., 9.00 gal.
Oil distilled above 300° C., 36.50 gal.
Total, 65.50 gal. a ton.

No. 2.

Oil .... 77.60 gal. a ton

DISTRIBUTION

Oil distilled at 150° C., 12.00 gal.
Oil distilled at 200° C., 7.00 gal.
Oil distilled at 250° C., 6.00 gal.
Oil distilled at 300° C., 10.00 gal.
Oil distilled above 300° C., 42.60 gal.
Total, 77.60 gal. a ton.

No. 3.

Oil ....30.00 gal. a ton

DISTRIBUTION

Oil distilled at 150° C., 5.6.
Oil distilled at 200° C., 3.2.
Oil distilled at 250° C., 7.2.
Total oil, 30.0 gal. a ton.

Ledge of Paper Oil Shale, Dry Fork, De Beque, Colo.

Joseph Bellis, Grand Valley, Colo.:

No. 1.

Oil ....75.0 gal. a ton

DISTRIBUTION

Distilled at 150° C., 14.40 gal.
Distilled at 200° C., 2.40 gal.
Distilled at 250° C., 12.00 gal.
Distilled at 300° C., 16.80 gal.
Distilled above 300° C., 29.40.
Total, 75.00 gal. a ton.

Joseph Bellis, Grand Valley, Colo.:

No. 2.

Oil ....60.0 gal. a ton

DISTRIBUTION

Distilled at 150° C., 14.00 gal.
Distilled at 200° C., 6.00 gal.
Distilled at 250° C., 3.40 gal.
Distilled at 300° C., 7.80 gal.
Distilled above 300° C., 28.80 gal.
Total, 60.00 gal. a ton.

Such analyses of Colorado oil shale are made at the Experimental Plant of the Colorado School of Mines, free of charge, as an aid to the upbuilding of the industry.

LOCATION OF OIL SHALE CLAIMS

The statute of 1897 says: "Any person authorized to enter lands under the mining laws of the United States may enter and obtain patent to lands containing petroleum or other mineral oils, and chiefly valuable therefor, under the provisions of the laws relating to placer mineral claims."

The location of oil lands as placers was general until 1896, when the Secretary of the Interior ruled adversely. Thereupon Congress, in 1897, passed a law re-establishing the former practice. The higher courts as yet have had no opportunity to pass upon the validity of title to oil-shale land located under the placer law.

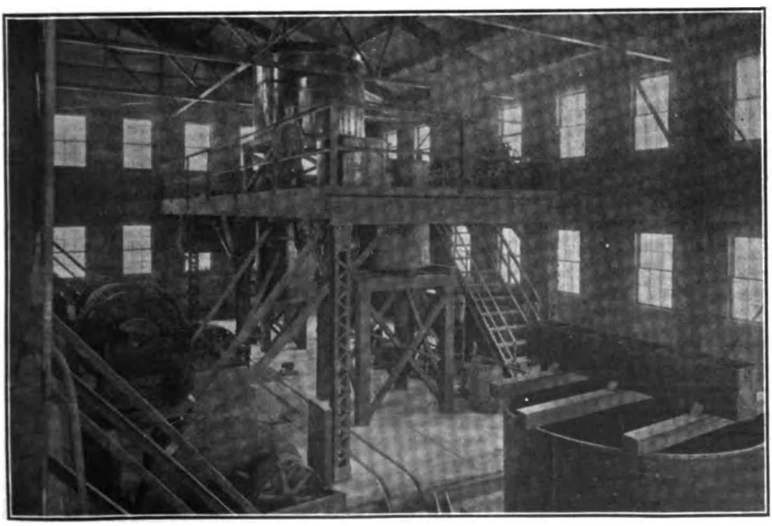
The well known case of Webb vs. the American Asphaltum Co. furnishes the nearest parallel case. In the Circuit Court of Appeals, Eighth District, it was held that asphaltum, when it is in solid form and is found as a vein or lode, should be located as a lode. At the present time no court decision has been rendered which involves specifically the point as to how oil shale lands shall be located; that is, whether as lode or as placer. It would seem, however, that from the peculiar formation of oil shale deposits they should be located as placers. As generally found in Colorado these deposits are virtually horizontal and cannot be said to have apexes within the sense that miners and the Mining Act of 1872 contemplate. Neither can horizontal oil shales, as found in Colorado, be said to be *in place* in the sense that we find deposits of other valuable minerals *in place* when found in lode, vein, or ledge formation. The shale deposits cannot even be said to have a clearly defined hanging wall, such as is contemplated by the statute, since they are not covered by a non-mineral bearing country rock such as the miner is accustomed to find as constituting his overhanging wall, but he finds merely an earthy deposit such as is generally found in the ordinary gold placer.

OPINIONS

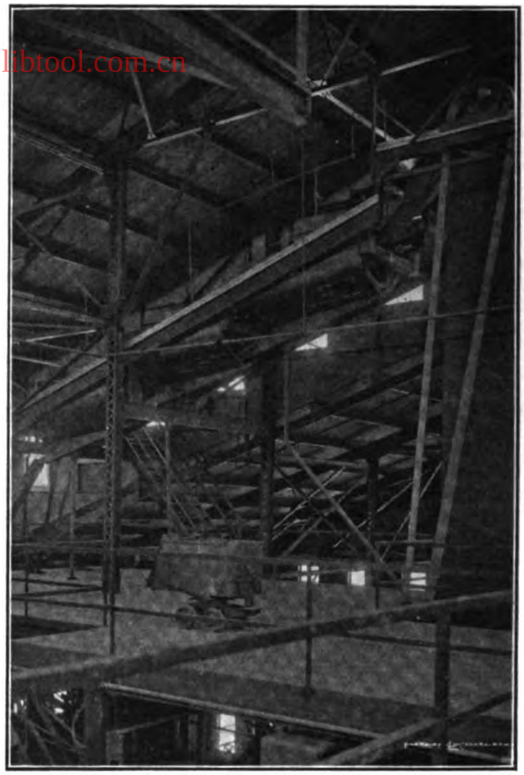
MR. DAVID T. DAY, U. S. BUREAU OF MINES, PETROLEUM AGE, OCTOBER, 1917

Referring to the first Government report on the oil shales of Colorado and Utah, Mr. Day said: "It was shown that considering only shales considerably richer than the Scotch, there is enough available oil in that region to furnish four times what we expect from all the oil fields in the United States. Years of investigation of this same field followed that report and extended the work into Utah and adjoining states, with the result that the estimate first made was amply verified. It was shown that the Uintah Basin in Colorado and Utah together can furnish eight times as much oil as all the oil fields in the United States put together."

"In fact, these shales make our fields of oil look like pygmies and give us a very satisfying sense of security for a bountiful supply of oil, even for the distant future.



Cyanide Section, Experimental Plant, Colorado School of Mines



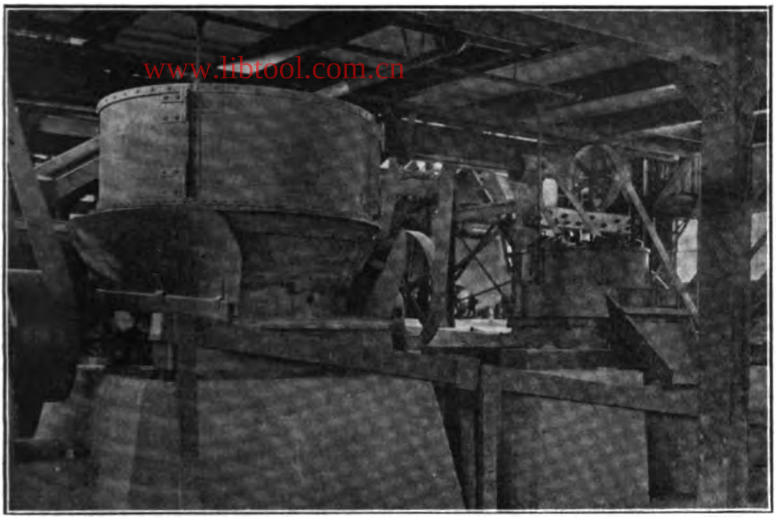
Trommels and Bucket Elevator, Experimental Plant, Colorado School of Mines

"The principal drawback to the development of oil from shales in the United States is the fact that a large investment is advisable (though perhaps not always necessary) in developing shale oil plants, and there is considerable inertia to embarking in a new line of industry with which no one is familiar.

"Now the time has come when the stimulus of increased prices does not bring sufficient additional crude oil. Mr. A. C. Bedford has shown that we need 330,000,000 barrels of oil in the United States, and we are getting 300,000,000. Even now 30,000,000 must come from somewhere else. Further, we all know that we must have more production, and if we must have it, we will have it, and we will have it from shales—and very soon."

PROFESSOR CHARLES BASKERVILLE, COLLEGE OF THE CITY OF NEW YORK, ENGINEERING AND MINING JOURNAL, JULY 24, 1909, P. 150

"The development of the Scotch shale-oil industry has been carried out with skill and energy, and it is to be regretted that the industry has not met with the entire commercial success it well deserves. Ever since 1850 it has only been by skilful management and the constant and intelligent application of science to the improvement of processes and to the utilization of waste products that the oil manufacturers of Scotland have been able to hold their own. The success of the companies now in operation, however,



Chilean and Huntington Mills, Experimental Plant, Colorado School of Mines

is shown by the following list of dividends paid annually: 1904-1907, Young's, 6 per cent; Oakbank, 15 per cent; Broxburn, 15 per cent; Pumpherston, 20, 30 and 50 per cent; Dalmeny, 10 and 25 per cent, and in 1906-1907, nil."

FRANKLIN K. LANE, SECRETARY OF THE INTERIOR

Mr. Lane said, in reply to a Senate resolution regarding gasoline, and referring to the shale beds of the country: "The development of this enormous reserve simply awaits the time when the price of gasoline or the demand for other distillation products warrants the utilization of this substitute source. This may happen in the future. At all events these shales are likely to be drawn upon long before the exhaustion of the petroleum fields."

VAN H. MANNING, DIRECTOR, UNITED STATES BUREAU OF MINES, BUREAU OF MINES YEAR-BOOK, 1917

"The question is being asked daily what this country is going to do when our petroleum resources are exhausted. We have as yet untouched our great reserves of shale that contain oil. These shales are found in many parts of the United States, and tremendous reserves are known in Colorado, Utah, and Wyoming. Some of our shales are much richer than the Scotch shales, and are conservatively estimated to contain many times the amount of oil that has been or will have been produced from all the porous formations in this country.

"To obtain the oil from oil shale it is necessary to heat the shale in great retorts. The oil is the result of destructive distillation and is driven off in the form of vapor and is later condensed by cooling. As stated above, this process has never been used in this country because of the lack of necessity, for our oil reserves are great, and it would not be commercially economical to invest money in retorts for distilling oil from shale that would have to compete with the crude oil obtained by other methods. But this condition will not last forever. In fact, it is thought that it will be only a very short time until the oil-shale industry will be one of magnitude."

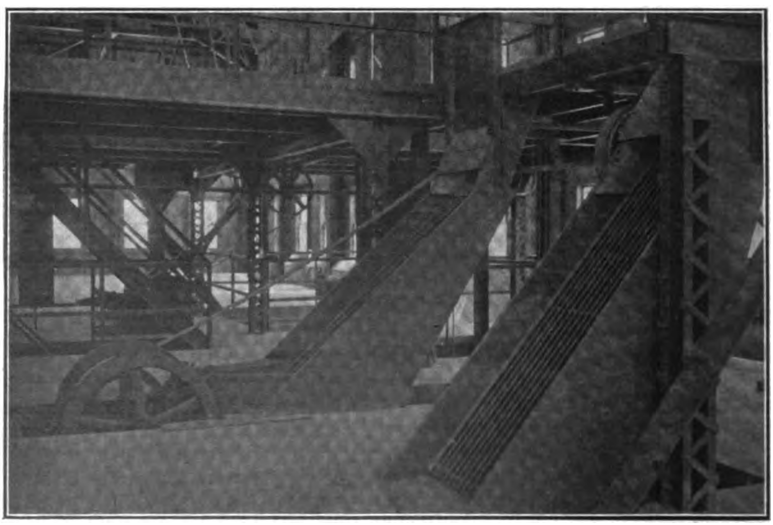
DEAN E. WINCHESTER, U. S. GEOLOGICAL SURVEY, BULLETIN 641-F, P. 141.

"In Colorado alone there is sufficient shale, in beds that are three feet or more thick and capable of yielding more oil than the average shale now mined in Scotland, to yield about 20,000,000,000 barrels of crude oil, from which 2,000,000,000 barrels of gasoline may be extracted by ordinary methods of refining, and in Utah there is probably an equal amount of shale just as rich. The same shale in Colorado, in addition to the oil, should produce, with but little added cost, about 300,000,000 tons of ammonium sulphate, a compound especially valuable as a fertilizer. The industry requires a large equipment of retorts, condensers, and oil refineries, as well as of mining machinery, so that it cannot be profitably handled on a small scale."

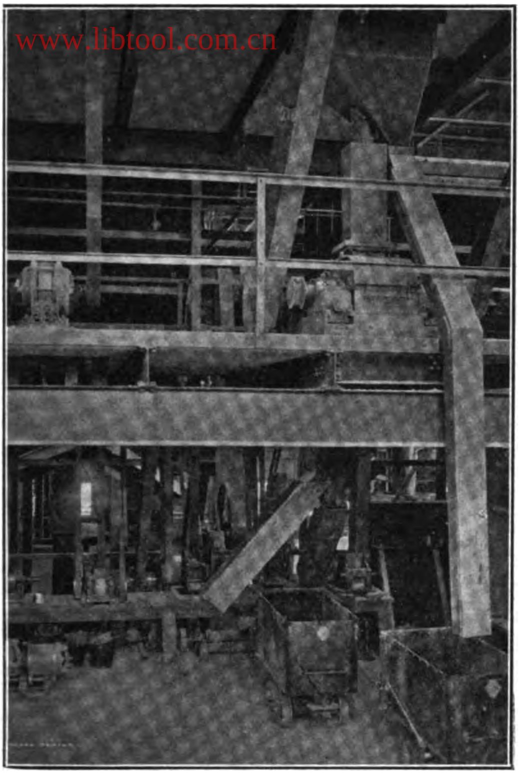
MR. DAVID T. DAY, ADDRESS BEFORE THE AMERICAN MINING CONGRESS, DENVER, JANUARY 23, 1918

"As to the handling of that shale after you get it out—the retorting of it—doesn't it seem sensible that as long as we have two well established industries, one in Scotland and one in France, that we should be content with the novelty of having richer shales and take their thoroughly reliable, well developed methods and transplant them over here, with the hearty good will and good wishes of our Scotch neighbors, and thus put the industry on a good basis with the known things, and then go into other processes. It seems to me that just now we are suffering in this country from a flood of chemists who find that the shale looks interesting and they hope they can develop something which they can make some money out of before it settles down and gets beyond them, so every chemist is making calculations and endeavoring to become an inventor.

"We propose to help you in any legitimate way we can to develop this shale industry, so that when the next year rolls around there will be from 200,000 to 1,000,000 barrels of oil out of the ground and safely in the trade as your contribution to the oil industries of the United States.



Grizzlies and Coarse Crushers. Experimental Plant Colorado School of Mines.



Sampling Section, Experimental Plant, Colorado School of Mines.

"There are a whole lot of troubles in the starting of this great new industry—an industry which commands as its raw material at least ten times as much oil in valuable shales as all the oil fields in the United States put together. You have a tremendous amount of raw material to draw upon. Therefore, you have the basis for a tremendous industry."

WALTER CLARK TEAGLE, PRESIDENT STANDARD OIL COMPANY OF NEW JERSEY

"The total number of wells completed in the United States in the first eleven months of this year (1917) was 21,302. Of the completed wells the total number that produced oil was 15,205. There was an increase in total production from all wells this year over last. The total production of petroleum in all parts of the country in the first ten months was about 272,000,000 barrels. The production for the eleven months is accordingly almost equal to the total yield for the twelve months of 1916, but that has not been sufficient to meet the demands of the refineries, for about 16,000,000 barrels have been taken from stock so far this year to supply the refiners. The stock of crude, accordingly, has decreased both in 1916 and in the present year. The total stock of crude on January 1, 1916, was 198,-000,000 barrels, including storage of crude held in private tank farms and leases. On November 1, 1917, it was approximately something over 158,000,000 barrels, or less than one-half a year's yield of crude.

OIL CONSUMPTION EXCEEDS PRODUCTION—PETROLEUM, JANUARY, 1918

"California crude stock is the lowest in years. Reduction of crude-oil stocks in California to slightly less than 34,000,000 barrels, the smallest in more than six and one-half years, emphasizes the strength of the oil situation on the Pacific Coast. Several million barrels are regarded as unavailable for use, so actual surplus is smaller than appears. Consumption of crude oil by Pacific Coast refineries has been exceeding production at rate of about 1,000,000 barrels a month the last year or so. In twenty-two months California stocks of oil in storage and above ground have been depleted by over 23,000,000 barrels."

GEORGE OTIS SMITH, DIRECTOR, U. S. GEOLOGICAL SURVEY, IN A LETTER TO CONGRESSMAN E. T. TAYLOR, SEPTEMBER 8, 1917

"It is true that the Government, and particularly the Geological Survey, has spent considerable time and money in the last few years in a study of the oil shale deposits. As a result of the field examinations made from 1913 to 1916 it has been clearly demonstrated that the latent potentiality of the oil shale of this region as a source of petroleum is enormous. It is also known that there is locked up in these shales a vast amount of nitrogen which can be recovered as a by-product in the refining of the shale and used in the manufacture of fertilizers and explosives."

[COPY]

THE GRAND VALLEY COMMERCIAL CLUB

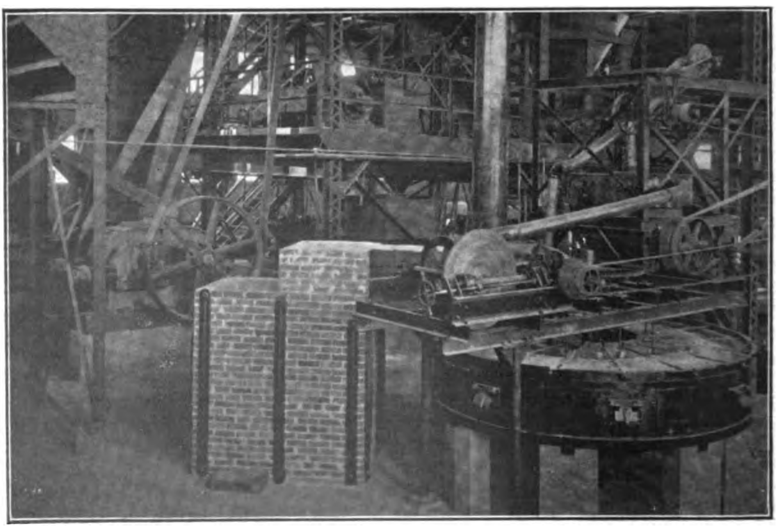
DIRECTORS

Elmer E. Wheatley, President	F. A. Wadleigh
James Brennan, Vice President	Chas. E. Cherrington
J. J. Connell, Secretary-Treasurer	James Doyle
J. E. Sipprelle, Counselor	Joseph Bellis
Hon. Edward T. Taylor	

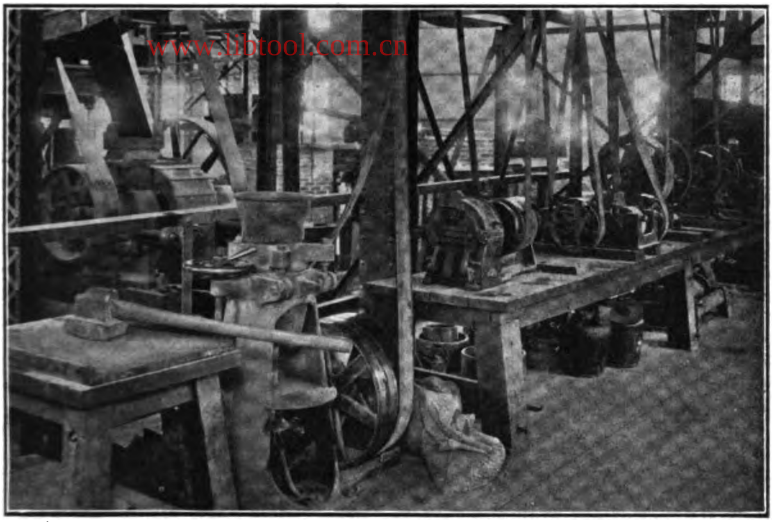
Grand Valley, Colorado,
February 24, 1918.

Dr. Victor C. Alderson, Golden, Colorado:

Dear Sir—Having been designated by the Grand Valley Commercial Club to accompany you in your investigation of the Parachute



Wilfley Hearth Roaster, Experimental Plant, Colorado School of Mines



Small Crushers, Experimental Plant, Colorado School of Mines

Creek Oil Shale District, at their request, I herewith hand you as complete a synopsis of the acreage, tonnage, future probable production, costs, and returns as is possible to prepare at the present time.

The statements herein contained are not made at random but are the results of careful surveys and years of research, and tests made in units of commercial size. The final figures on results are determined on the wholesale prices of mid-continent commodities. Denver, Salt Lake and intermountain wholesale prices are higher. However, the freight rates by the Denver & Rio Grande and Colorado Midland railroads and their connecting lines have not been definitely determined, but the lowest possible rates have been assured. We have been promised a rate of 30 cents a hundred on crude oil and 40 cents a hundred on gasoline or refined oil in tank cars, from De Beque or Grand Valley to Denver, Pueblo, or Salt Lake.

We are indebted to the following gentlemen for much of the data now available: Congressman Edward T. Taylor, Dean E. Winchester, U. S. Geological Survey; State Geologist R. D. George, D. D. Potter of Denver, J. B. Jones and W. W. Strickler of Tulsa, Okla.; F. E. Wells of Columbus, Ohio; Dr. Otto Stalmann of Salt Lake, Frank A. Wadleigh, general passenger agent, D. & R. G. R. R.; James Doyle of Denver, officials of the Garfield County State Bank of Grand Valley, and many others who have helped with the pioneer work and the many problems in connection with the oil shale industry. In referring to these gentlemen I do not intend in any way to make any one of them responsible for the following collective statement, but only to acknowledge their valuable assistance and cooperation in the development of the oil shale industry.

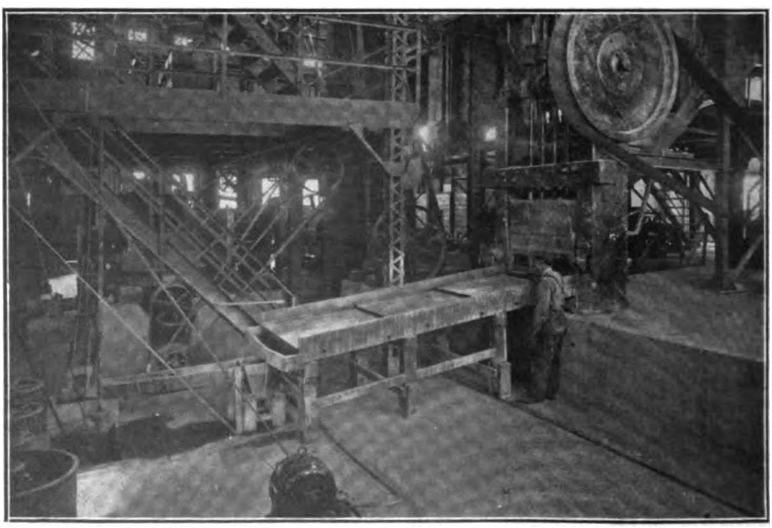
The Parachute Mining District comprises about 55,000 acres. There are sixty-nine miles of perpendicular oil shale cliffs on Parachute Creek, its three forks and several tributaries, on all of which rich, massive shale is exposed. The acreage is estimated on an extension of the strata back from the face of the cliffs a distance of only one and a quarter miles. Parachute Creek and its tributaries offer an abundance of permanent water for reduction and refining plants. Showing on the face of these sixty-nine miles of perpendicular cliffs is a continuous rich stratum of curly shale, from twelve to twenty feet in thickness, that will run better than fifty gallons of crude oil to the ton, and not less than fifteen pounds of ammonium sulphate. This same district has massive oil shale strata above and below this rich stratum, several hundred feet in thickness, that average about twenty-five gallons of oil to the ton of shale, independent of the rich stratum. Present day operations will probably be confined to the rich stratum, which occurs in a flat deposit at a distance above the valley adapted to economical mining operations.

In making the estimate of tonnage in the 55,000 acres, the rich stratum is figured at its minimum thickness of twelve feet. This gives a net result of one billion twelve million five hundred thousand tons (1,012,500,000), after deducting 25 per cent for pillars or rock supports. In estimating the amount in barrels of crude oil that this tonnage will yield, I allow as a liberal estimate 15 per cent for loss in extraction and then, for easy figuring, I reduce it still further and make the estimate one barrel, or 42 gallons, to the ton of shale, and reach 1,012,500,000 barrels of crude oil in the twelve-foot stratum for the 55,000 acres.

There are two processes for the extraction of oil from shales that seem to be a proved commercial success. Both are along the general lines of the well known Scotch methods in general principles, with improvements that have been made to adapt them to handle our much richer shales. One of these, known as the Pearse process for reduction of the oils, is under the control of the Pearse Engineering Company, New York. In connection with this process is to be used, so I am reliably informed, the Hall refining process, for refining the crude oil into marketable products, especially producing a very high percentage of gasoline.

The other process for reducing crude oil from shales was developed by Dr. Otto Stalmann of Salt Lake City, and in connection therewith is being installed the Wells refining process of Tulsa, Okla., primarily intended to develop high grade lubricating oils.

There is considerable controversy among the oil shale operators as to whether lubricants or gasoline will give the better returns. The Stalmann-Wells process will yield from the crude oil 40 per cent of



Stamp Battery and Amalgamating Plates, Experimental Plant, Colorado School of Mines

lubricants that show a viscosity test of 225 at 70° Fahr. This is a fine automobile oil, and oil refiners assert that it will always command at least 25 cents a gallon. As an example of what this combination of processes will do, I recite that the crude oils from Stalmann's retort are refined by the Wells process with the following results: First cut 15 per cent straight-run gasoline, 460 end point; 26 per cent, called gas oil, yielding 13 per cent of gasoline by "cracking" and 5 per cent fuel oil; next cut 45 per cent, being 40 per cent lubricants and 5 per cent paraffin wax; and last, 10 per cent residue; probable loss 4 per cent. After these various cuts have been made, they can all be put together again without cracking up the 26 per cent cut, and we have the same crude oil that we started with, less about 4 per cent loss. As between a sample of crude that was separated and another sample just as it comes from the Stalmann retort no difference can be detected. It is a demonstration that the molecular construction of the oil and its content has not been disturbed or harmed. This may become a very important feature independent of the value and benefit it is to the lubricant content, because it is my opinion that we can use all that is left after taking away the first two cuts and make therefrom a very fine substitute for rubber.

However, returning to the estimates of costs of production for well known commercial commodities and the returns to be expected therefrom, I make the following estimates based on the Stalmann-Wells process:

ESTIMATES

Gross value of each ton of oil shale (estimated 1 barrel, 42 gallons)		
Ammonium sulphate, 15 lbs. at 5 cents (present price, 7.3 cents)		.75
Gasoline, 11 gal. at 18 cents (present price, 25 cents)		1.98
Lubricants, 16 gal., at 20 cents (present price, 35 cents; testing 225 at 70 Fahrenheit)		3.20
Paraffine wax, 16 lb., at 10 cents (present price, 14 cents; melting point above 130 Fahrenheit)		1.60
Gross return per ton	$	7.53
Estimated tonnage (or barrels)		1,012,500.000
Return per ton (or barrel)		$7
Gross value of 55,000 acres		$7,087,500,000
Cost of mining, reduction, and refining—$4, a maximum		4,050,000,000
Net profit of commodities at the plant		$3,037,500,000

These estimates are based upon a plant of not less than 500 tons daily capacity with a complete distilling process.

Very truly yours,

(Signed) JOSEPH BELLIS.

SUMMARY

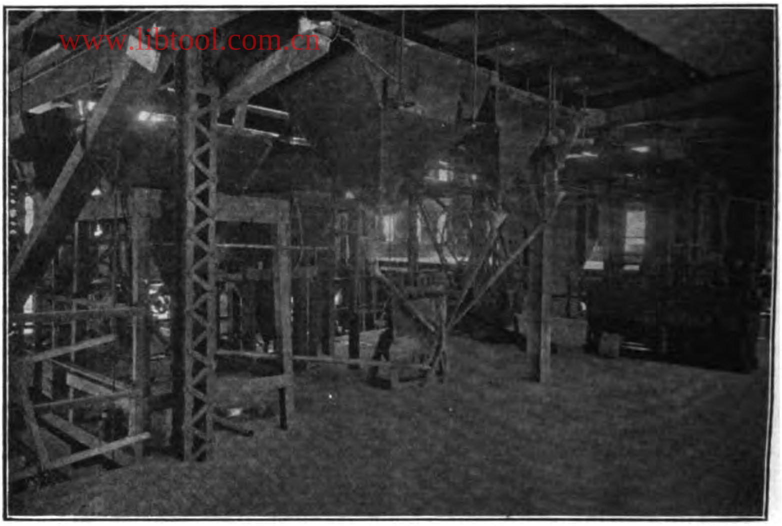
1. The oil shale industry has reached its greatest development in Scotland, where it was established in 1850. Next in importance comes France and then New South Wales.

2. In Scotland the technical and chemical problems of the industry have been carefully solved and, on the whole, the industry has been commercially profitable.

3. The Scotch shale beds are comparatively thin, irregular, steeply inclined, deep, and expensive to work.

4. The oil content of the Scotch shales is now much less than formerly and the shale could not be worked profitably if it were not for the ammonium sulphate produced as a by-product.

5. The production of crude oil alone from shale probably cannot



Classifiers and Jigs, Experimental Plant, Colorado School of Mines

now compete commercially with oil from wells. However, the increased demand for oil, the decreasing production, the steadily enhanced price on the one hand will be met by an almost inexhaustible supply of oil shale, cheap mining, improved methods of distillation and valuable by-products, which will undoubtedly, in the very near future, make the oil shale industry a strong competitor of the oil well and in the by no means distant future its successor.

6. The oil shale industry is not, in ordinary parlance, "a poor man's game." The technical and chemical problems are numerous and require a high grade of scientific ability for their solution.

7. A plant of 500 tons daily capacity is as small as can be operated permanently and successfully, as the profits will depend chiefly on the large tonnage handled. In this respect the oil shale industry bears the same relation to oil that Utah Copper and the other copper porphyries bear to copper.

8. An investment of $150,000.00 is as small as can be safely counted upon to make a single project successful.

9. Labor is cheaper in Scotland than in the United States; the Scotch shale produces more ammonium sulphate than the Colorado shale. These are the only factors favorable to the Scotch shale; all other elements that enter are distinctly in favor of Colorado shale.

10. The favorable features in the oil shale industry in Colorado are:

a. The enormous extent of the deposits.

b. The great thickness both of the medium and high grade shale.

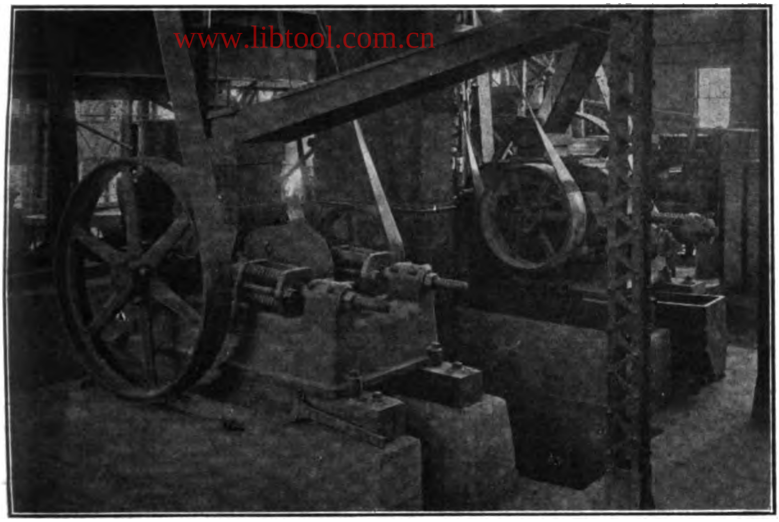
c. The horizontal position of the strata and their height above the level of the creeks—a combination that affords cheap mining.

d. Adequate water supply for the condensing and cooling systems of both the distilling and refining plants.

e. Accessibility and nearness to railroads and markets.

f. The great richness of the shale.

These features combine to make the oil shale deposits of Colorado the most valuable deposit of their kind in the world.



Rolls and Bucket Elevator, Experimental Plant, Colorado School of Mines

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Volume Thirteen Number Three

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QUARTERLY

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Vol. Thirteen JULY, 1918 Number Three

Common Methods of Determining Latitude and Azimuth Useful to Engineers and Surveyors

COMPILED BY HARRY J. WOLF.
Professor of Mining.

I. LATITUDE.

1. By Observing Altitude of the Sun at Noon.

(a) Set up transit before local apparent noon. The standard time corresponding to local apparent noon at the point of observation may be found by adding or subtracting from 12 h the equation of time as directed in the Nautical Almanac or Solar Ephemeris.

(b) Find the maximum altitude of the upper or lower limb of the sun by keeping the middle horizontal cross hair tangent to the limb as long as it continues to rise. When the observed limb begins to drop below the cross hair read the vertical angle.

(c) Level the telescope and determine the index error. Apply this error to the observed vertical angle to obtain the true vertical angle.

(d) From a table of refractions in altitude determine the refraction correction for the vertical angle obtained, and subtract this correction from the true vertical angle to obtain the altitude of the limb observed.

(e) From a table of semi-diameters of the sun determine the semi-diameter for the date of observation, and add this correction if the lower limb was observed, or subtract it if the upper limb was observed, to obtain the altitude of the sun's center.

(f) From a table of the sun's parallax determine the parallax for the observed altitude, and add this correction to obtain the true altitude of the sun's center. In view of the limits of accuracy of the surveyor's transit this correction is usually neglected.

(g) From the Nautical Almanac or Solar Ephemeris determine the sun's declination at the instant the altitude was taken. If the longitude of the place is known, increase or decrease the declination for the instant of Greenwich apparent noon by the hourly change multiplied by the number of hours in longitude. If the longitude is not known, but standard time is known, increase or decrease the declination for the instant of Greenwich mean noon by the hourly change multiplied by the number of hours since Greenwich mean noon.

(h) Latitude $= 90° -$ Altitude $+$ N. Declination, or
Latitude $= 90° -$ Altitude $-$ S. Declination.

EXAMPLE:

(a) Transit was set up before local apparent noon on June 26, 1918. From Solar Ephemeris the equation of time is 2 m·27.73 s, and the difference for 1 h is 0.525 s. Transit was set up about 11:50 A. M., which was 12 m to 13 m before the sun's meridian transit.

(b) Upper limb of the sun was observed.

The vertical angle was =	73° 54′ 30″
(c) Telescope was leveled. Index error =	30″
True vertical angle =	73° 54′ 0″
(d) The refraction correction was =	17″
Altitude of sun's upper limb =	73° 53′ 43″
(e) Sun's semi-diameter was =	15′ 46″
Altitude of sun's center	73° 37′ 57″
(f) Sun's parallax was =	3″
True altitude of sun's center =	73° 38′ 0″
(g) Sun's apparent declination at Greenwich apparent noon on June 26, 1918 =	N. 23° 23′ 14.2″
The longitude of the place is 105° 32′ 33″, which = 7.04 h (15° = 1 h). Difference in declination = 7.04 x 4.38″ =	—30.8″
Sun's apparent declination at point of observation =	N. 23° 22′ 43.4″

(h) Compute latitude by formula: Lat = 90°— Alt + N. Dec.

	90″ 0′ 0″
Subtract altitude =	73° 38′ 0″
	16° 22′ 0″
Add N. Declination =	23° 22′ 43″
Latitude of place =	N. 39° 44′ 43″

2. By Observing Altitude of Polaris at Culmination.

(a) Set up transit before upper or lower culmination. The standard time of culmination may be found by interpolation from a table of time of culmination of Polaris in the Nautical Almanac.

(b) Focus on the star and follow it with the horizontal cross hair as long as it continues to rise if upper culmination is observed, or as long as it continues to fall if lower culmination is observed. When the desired culmination is reached read the vertical angle.

(c) Level the telescope and determine the index error. Apply this error to the observed vertical angle to obtain the true vertical angle.

(d) From a table of refractions in altitude determine the refraction correction for the vertical angle obtained, and subtract this correction from the true vertical angle to obtain the altitude of the star.

(e) From the Nautical Almanac or Ephemeris determine the polar distance of Polaris, either from a table of polar distances or by subtracting the apparent declination from 90°.

(f) Latitude = Altitude of the Pole.

Latitude = Altitude of Polaris at upper culmination — polar distance.

Latitude = Altitude of Polaris at lower culmination + polar distance.

EXAMPLE:

(a) Transit was set up before lower culmination on June 1, 1918. From a table of culminations of Polaris, the local mean time of lower culmination is 8 h 51.3 m P. M. for longitude 90° W. For longitude 105° 32′ 33″ W. the time would be 8 h 51.1 m P. M. (0.16 m earlier for each 15°). The transit was set up about 8:30 P. M. which is about 20 m before lower culmination.

(b) Observed vertical angle =	38° 39′ 0″
(c) Index error =	1′ 0″
True vertical angle =	38° 38′ 0″
(d) Subtract refraction correction =	1′ 13″
Altitude of Polaris =	38° 36′ 47″
(e) Polar distance on June 1, 1918	1° 8′ 0″
Latitude of place (altitude of N. Pole) =	N. 39° 44′ 47″

II. AZIMUTH.

1. By Observing Altitude of the Sun.

(a) Observe the sun at any time except when it is within 10° of the horizon (because the refraction is relatively large and uncertain) or when it is near the meridian (because small errors in observed altitude produce relatively large errors in azimuth). Set up transit over one end of the line whose azimuth is desired. Sight along the line with the verniers set at 0°. With the lower clamp tightened and the upper clamp loosened sight on the sun with a colored shade glass on the eye piece or focus the sun's disc, and the cross hairs of the instrument, on a screen held behind the eye piece.

If the observation is made in the forenoon place the sun's disc in the upper left-hand quadrant, and tangent to the vertical and middle horizontal cross hairs, and record the vertical and horizontal angles and the time. Then reverse the instrument and make similar observations with the sun's disc in the lower right hand quadrant. If the observation is made in the afternoon, place the sun's disc first in the upper right-hand quadrant and then, with the instrument reversed, in the lower left-hand quadrant. The mean of the vertical angles and the mean of the horizontal angles may be assumed to correspond to the position of the sun's center at the instant indicated by the mean time reading.

The direct and reversed observations should be made within a short period of time, say 2 or 3 minutes. If the instrument is in perfect adjustment, the observation may be simplified by centering the intersection of the vertical and middle horizontal cross hairs on the sun's disc, with the assistance of diagonal cross hairs, stadia hairs, or concentric circles placed on a screen upon which the sun's disc is focused.

(b) From a table of refractions in altitude determine the refraction correction for the mean vertical angle of the sun's center, and subtract this correction from the vertical angle to obtain the altitude of the sun's center.

(c) From a table of the sun's parallax determine the parallax for the observed altitude, and add this correction to obtain the true altitude of the sun's center. In view of the limits of accuracy of the surveyor's transit this correction is usually neglected.

(d) From the Nautical Almanac or Solar Ephemeris determine the sun's declination at the instant the altitude was taken. If the longitude of the place is known, increase or decrease the declination for the instant of Greenwich apparent noon by the hourly change multiplied by the number of hours in longitude. If the longitude is not known, but standard time is known, increase or decrease the declination for the instant of Greenwich mean noon by the hourly change multiplied by the number of hours since Greenwich mean noon.

(e) The azimuth of the sun from the NORTH may be computed from any one of the following formulæ:

Where A_n = sun's azimuth from north

$$S = \tfrac{1}{2}\,(\text{codec} + \text{colat} + \text{coalt})$$

$$(1)\quad \sin \tfrac{1}{2} A_n = \sqrt{\frac{\sin(S - \text{colat})\ \sin(S - \text{coalt})}{\sin \text{colat} \sin \text{coalt}}}$$

$$(2)\quad \cos \tfrac{1}{2} A_n = \sqrt{\frac{\sin S\ \sin(S - \text{codec})}{\sin \text{colat} \sin \text{coalt}}}$$

$$(3)\quad \tan \tfrac{1}{2} A_n = \sqrt{\frac{\sin(S - \text{colat})\ \sin(S - \text{coalt})}{\sin S \sin (S - \text{codec})}}$$

Or from any one of the following formulae:

where A_n = sun's azimuth from north

$$s = \tfrac{1}{2}\,(\text{codec} + \text{lat} + \text{alt})$$

$$(4)\quad \sin \tfrac{1}{2} A_n = \sqrt{\frac{\sin \tfrac{1}{2}\,(\text{lat} + \text{coalt} - \text{dec}) \cos \tfrac{1}{2}\,(\text{lat} + \text{coalt} + \text{dec})}{\cos \text{lat} \sin \text{coalt}}}$$

$$(5)\quad \sin \tfrac{1}{2} A_n = \sqrt{\frac{\sin\ (s - \text{alt})\ \sin\ (s - \text{lat})}{\cos \text{lat} \cos \text{alt}}}$$

$$(6)\quad \cos \tfrac{1}{2} A_n = \sqrt{\frac{\cos s\ \cos(s - \text{codec})}{\cos \text{lat} \cos \text{alt}}}$$

$$(7)\quad \tan \tfrac{1}{2} A_n = \sqrt{\frac{\sin(s - \text{lat})\ \sin(s - \text{alt})}{\cos s\ \cos(s - \text{codec})}}$$

$$(8)\quad \text{vers } A_n = \frac{\cos(\text{lat} - \text{alt}) - \sin \text{dec}}{\cos \text{lat} \cos \text{alt}}$$

The azimuth of the sun from the SOUTH may be computed from any one of the following formulae:

where A_s = sun's azimuth from south

$$S = \tfrac{1}{2}\,(\text{codec} + \text{colat} + \text{coalt})$$

$$(9)\quad \sin \tfrac{1}{2} A_s = \sqrt{\frac{\sin(S - \text{codec})\ \sin(S - \text{colat}}{\sin \text{codec} \sin \text{colat}}}$$

$$(10)\quad \cos \tfrac{1}{2} A_s = \sqrt{\frac{\sin S\ \sin(S - \text{coalt})}{\sin \text{codec} \sin \text{colat}}}$$

$$(11)\quad \tan \tfrac{1}{2} A_s = \sqrt{\frac{\sin(S - \text{codec})\ \sin(S - \text{colat})}{\sin S\ \sin(S - \text{coalt})}}$$

$$(12)\quad \cos A_s = \frac{\pm \sin \text{dec}}{\cos \text{lat} \cos \text{alt}} \mp \tan \text{lat} \tan \text{alt}$$

Note—If the observation is made north of the equator the declination is + when north and — when south. If the observation is made south of the equator the declination is + when south and — when north. If the sun is observed when north of the prime vertical in the northern hemisphere, or south of the prime vertical in the southern hemisphere, the first term will be greater than the second term. Equation (13) is another form of equation (12).

$$(13)\quad \cos A_s = \frac{\pm \sin dec - \sin lat \sin alt}{\cos lat \cos alt}$$

$$(14)\quad vers\ A_s = \frac{\cos(lat + alt) + \sin dec}{\cos lat \cos alt}$$

The azimuth of the sun from the NORTH may be computed from the following formulae:

where A_n = sun's azimuth from the north

$$(15)\quad \cos A_n = \tan C_1 \tan lat = \tan C_2 \tan lat$$

$C_1 = \frac{1}{2}\text{coalt} + \frac{1}{2}(C_1 - C_2)$

when latitude is less than declination and on the same side of the equator.

$C_2 = \frac{1}{2}\text{coalt} - \frac{1}{2}(C_1 - C_2)$

when latitude is greater than declination and on the same side of the equator, or when latitude and declination are on opposite sides of the equator.

$$\tan \tfrac{1}{2}(C_1 - C_2) = \cot \tfrac{1}{2}(lat + dec) \tan \tfrac{1}{2}(lat - dec) \cot \tfrac{1}{2}\text{coalt}$$

EXAMPLE:

(a) Transit is set up over B.M. on June 4, 1918.
Sighted on Flagstaff with verniers at 0°.
Telescope pointed at sun, and the following observations recorded

Quadrant	Time	Horizontal Angle	Vertical Angle
Upper right........	2:52 P. M.	294° 15′	50° 3′
Lower left..........	2:54 P. M.	295° 34′	49° 6′
Sun's center.......	2:53 P. M.	294° 54′ 30″	49° 34′ 30″

(b) Refraction correction = 49″

Altitude of sun's center = 49° 33′ 41″

(c) Parallax correction = 6″

True altitude of sun's center = 49° 33′ 47″

(d) 1. If the Solar Ephemeris gives the sun's declination at Greenwich MEAN noon proceed as follows:

Sun's apparent declination at Greenwich MEAN noon on June 4, 1918 = N. 22° 22′ 22.0″. The difference in declination for 1 h = 18.03″.

The place of observation is west of longitude 105° W. and 105th meridian time is used. 105° = 7 h. The standard time of the observation was 2 h 53 m P. M. = 2.883 h, which is 7 h + 2.883 h = 9.883 h after Greenwich Mean Noon. The difference in declination at the instant of observation is 18.03" x 9.883 = 178.2" = 2' 58.2". The declination at the instant of observation is 22° 22' 22.0" + 2' 58.2" = N. 22° 25' 20.2". The difference is added because the north declination is increasing.

(d) 2. If the Solar Ephemeris gives the sun's declination at Greenwich APPARENT Noon, proceed as follows:

Sun's apparent declination at Greenwich APPARENT Noon on June 4, 1918 = N. 22° 22' 21.4". The difference in declination for 1 h = 18.03". The equation of time is 2 m 1.51 s, and the difference in the equation of time for 1 h = 0.416 s. The place of observation is west of longitude 105° W. and 105th meridian time is used. 105° = 7 h. The standard time of the observation was 2 h 53 m P. M. = 2.883 h, which is 7 h + 2.883 h = 9.883 h after Greenwich Mean Noon. The equation of time at the instant of observation was 2 m 1.51 s — (0.416 s x 9.883) = 1 m 57.4 s = 0.033 h, which must be applied to standard time to obtain apparent time. The difference in declination at the instant of observation is 18.03" x 9.883 + 0.033) = 178.8" = 2' 58.8". The declination at the instant of observation is 22° 22' 21.4" + 2' 58.8" = N. 22° 25' 20.2". The difference is added because the north declination is increasing.

By previous observation, or from a map, the latitude of the place of observation has been determined = N. 39° 44' 45".

(e) 1. Computation by formula (2)

$$\cos \tfrac{1}{2} A_n = \sqrt{\frac{\sin S \sin(S - \text{codec})}{\sin \text{colat} \sin \text{coalt}}}$$

$$S = \tfrac{1}{2}\,(\text{codec} + \text{colat} + \text{coalt})$$

codec =	67° 34' 40"
colat =	50° 15' 15"
coalt =	40° 26' 13"
2S =	158° 16' 8"
S =	79° 8' 4"

log sin S	= 9.9921434
log sin (S — codec)	= 9.3017612
colog sin colat	= 0.1141368
colog sin coalt	= 0.1880158
	2)9.5960572
log cos ½ A_n	= 9.7980286
½ A_n	= 51° 5' 24"

A_n =	102° 10' 48"
horizontal angle =	294° 54' 30"
	397° 5' 18"
	— 360°
Bearing =	N. 37° 5' 18" W.

(e) 2. Computation by formula (12)

$$\cos A_s = \frac{+\sin \text{dec}}{\cos \text{lat} \cos \text{alt}} - \tan \text{lat} \tan \text{alt}$$

log sin dec	=	9.5814136
colog cos lat	=	0.1141368
colog cos alt	=	0.1880158
log 1st term	=	9.8835662
log tan lat	=	9.9198979
log tan alt	=	0.0694691
log 2nd term	=	9.9893670
2nd term	=	— 0.975814
1st term	=	+ 0.764832
nat cos A_s	=	— 0.210982
log cos A_s	=	9.3242454
A_s	=	77° 49′ 12″
horizontal angle	=	294° 54′ 30″
		217° 5′ 18″
		— 180°
Bearing	=	N. 37° 5′ 18″ W.

Note: It is customary to make a series of five observations, compute the azimuth indicated by each, and take as the azimuth required the average of not less than three computations that check within one minute of arc. For this purpose formula (12) is the most convenient.

(e) 3. Computation by formula (15)

$$\cos A_n = \tan C_2 \tan \text{lat}$$

$$C_2 = \tfrac{1}{2} \text{coalt} - \tfrac{1}{2}(C_1 - C_2)$$

$$\tan \tfrac{1}{2}(C_1 - C_2) = \cot \tfrac{1}{2}(\text{lat} + \text{dec}) \tan \tfrac{1}{2}(\text{lat} - \text{dec}) \cot \tfrac{1}{2} \text{coalt}$$

alt	=	49° 33′ 47″
coalt	=	40° 26′ 13″
dec	=	N. 22° 25′ 20″
lat	=	N. 39° 44′ 45″
(lat + dec)	=	62° 10′ 5″
(lat — dec)	=	17° 19′ 25″
½ (lat + dec)	=	31° 5′ 2.5″
½ (lat — dec)	=	8° 39′ 42.5″
½ coalt	=	20° 13′ 6.5″

log cot ½ (lat + dec)	=	0.2197847
log tan ½ (lat — dec)	=	9.1828120
log cot ½ coalt	=	0.4338048
log tan ½ $(C_1 - C_2)$	=	9.8364015

$\frac{1}{2}(C_1 - C_2) = 34° 27' 17.6''$

$\frac{1}{2}$ coalt $= 20° 13' 6.5''$

$C_2 = -14° 14' 11.1''$

log tan C_2 = 9.4043466

log tan lat = 9.9198979

log cos A_n = 9.3242445

A_n = 102° 10' 48"

horizontal angle = 294° 54' 30"

397° 5' 18"

— 360°

Bearing = N. 37° 5' 18" W.

2. By Equal A. M. and P. M. Altitudes of the Sun.

(a) Set up transit over one end of line whose azimuth is desired. Sight along the line with the verniers at 0°. With the lower clamp tightened and the upper clamp loosened sight on the sun. If the upper and left-hand limbs are sighted in the forenoon, then sight on the upper and right-hand limbs in the afternoon. Use the same vertical angle in both observations, and record the horizontal angle and the time in each case. The mean of the two horizontal angles, corrected for the effect of change in declination, is the desired azimuth from the south.

(b) The angle between the meridian and the mean of the two horizontal angles is found by the formula:

$$\text{Correction} = \frac{\text{Half the change in declination between the two observations}}{\text{cos lat} \times \text{sin half the hour angle between the two observations}}$$

EXAMPLE:

Latitude = N. 39° 45' 36" Date = July 11, 1918.

Observations:	A. M.	P. M.
Angle on desired course =	0°	0°
Vertical angle on upper limb =	63° 18'	63° 18'
Horizontal angle =	240° 3' (left)	352° 18' (right)
Time of observation =	10h 30m	1h 12m

Half the time between observations, or hour angle = 1h 21m
= 1.35h
= 20° 15'

Half the change in declination = 19.37" x 1.35h = 26.15"

log 26.15" = 1.4174717

colog cos lat = 0.1142261

colog sin 20° 15' = 0.4607770

log correction = 1.9924748

correction = 98.282" = 1' 38"

mean horizontal angle = 63° 49' 30"

corrected angle = 63° 47' 52"

Bearing = S. 63° 47' 52" W.

Note: It is customary to take a series of observations in the forenoon at suitable intervals, and corresponding observations in the afternoon, in order to check their accuracy and increase precision.

3. By Observing Polaris at Elongation.

(a) Set up transit over one end of the line whose azimuth is desired, about half an hour before elongation, and sight along the line with the verniers set at 0°. The standard time of elongation may be found by interpolation from a table of the time of elongation of Polaris. If such a table is not available, then the hour angle may be computed by the following formula:

$$\cos \text{hour angle} = \frac{\tan \text{latitude}}{\tan \text{declination}}$$

This hour angle may be converted into sidereal time by the following formula:

Sidereal time = hour angle + right ascension.

This sidereal time may be converted into local mean time by the following formula:

Local mean time = sidereal time — mean sun's right ascension — increase in sun's right ascension.

This local mean time may be converted into standard time by expressing the longitude between the local meridian and the standard meridian in units of time (15° = 1h), and adding this correction if the local meridian is west of the standard meridian, or subtracting the correction if the local meridian is east of the standard meridian.

The declination and right ascension of Polaris, and the mean sun's right ascension and the increase in sun's right ascension, may be found in the Nautical Almanac.

(b) Focus on the star and follow it with the vertical cross hair as it moves towards its greatest elongation. Near the elongation the star appears to move vertically. When the desired elongation is reached read the horizontal angle.

(c) From a table of azimuth of Polaris at elongation determine the azimuth corresponding to the latitude of the place of observation. If such a table is not available, then the azimuth may be computed by the following formula:

$$\sin \text{azimuth} = \frac{\sin \text{polar distance}}{\cos \text{latitude}}$$

$$\text{or } \sin \text{azimuth} = \frac{\sin \text{codeclination}}{\cos \text{latitude}}$$

(d) Bearing = horizontal angle + azimuth at W. elongation.
or Bearing = horizontal angle — azimuth at E. elongation.

EXAMPLE:

(a) Transit is set up over point A, July 16, 1918, in latitude N. 39° 44′ 45″. From a table of elongations of Polaris the time of western elongation is found by computation to be 11h 59.3m P. M. Point B is sighted with the verniers set at 0°.

(b) With the lower clamp tightened and the upper clamp loosened the star is observed at western elongation, and the horizontal angle is 86° 47′ 30″.

(c) From a table of azimuth of Polaris at elongation the azimuth for latitude N. 39° 44′ 45″ is 1° 28′ 27″. Or the azimuth may be computed as follows:

Polar distance = 1° 8′ 2″.	log sin polar distance	= 8.2964195
Latitude = 39° 44′ 45″.	log cos latitude	= 9.8858632
	log sin azimuth	= 8.4105563
	azimuth	= 1° 28′ 27″

(d) Horizontal angle = 86° 47′ 30″
Azimuth at W. elongation = 1° 28′ 27″

Bearing of line A-B = N. 88° 15′ 57″ W.

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4. By Observing Polaris at Culmination.

(a) Compute the exact standard time of culmination, and provide a watch reading correct standard time. Set up transit, before upper or lower culmination, over one end of the line whose azimuth is desired. Sight along the line with the verniers set at 0°. With the lower clamp tightened and the upper clamp loosened observe the star.

(b) Focus on the star and follow it with the vertical cross hair until an assistant reading the watch calls the time of culmination. The horizontal angle is the desired azimuth from the north.

EXAMPLE:

(a) Transit is set up before lower culmination on June 1, 1918. From a table of culmination of Polaris, the local mean time of lower culmination is 8h 51m 18s P. M. for longitude 90° W. For longitude 105° 32′ 33″ W. the local mean time would be (0.16m earlier for each 15°) 8h 51m 8s P. M. The longitude between the local meridian and the standard meridian (105°) is 32′ 33″, which expressed in units of time (15° = 1h) = 2m 10s. Standard time = 8h 51m 8s + 2m 10s = 8h 53m 18s.

(b) The horizontal angle at 8h 53m 18s P. M. is 88° 16′. Hence the desired bearing is N. 88° 16′ W.

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5. By Observing Polaris at Any Hour Angle.

(a) Set up transit, at any time when Polaris is visible, over one end of the line whose azimuth is desired. Sight along the line with the verniers set at 0°. With the lower clamp tightened and the upper clamp loosened observe the star.

(b) Focus on the star and follow it with the intersection of the vertical and the middle horizontal cross hairs. Take a series of readings and record the time, horizontal angle, and vertical angle for each observation. Determine the index error of the transit if necessary. If the instrument is not in perfect adjustment, make the observations in pairs, with telescope direct and inverted, and average the two sets of angles, and determine the mean time.

(c) The azimuth may be computed by the following formulæ:

$$\sin \tfrac{1}{2} \text{ hour angle} = \sqrt{\frac{\sin \tfrac{1}{2}(\text{coalt} + \text{lat} - \text{dec}) \sin \tfrac{1}{2}(\text{coalt} - \text{lat} + \text{dec})}{\cos \text{lat} \cos \text{dec}}}$$

$$\text{and } \tan \text{azimuth} = \frac{\sin \text{hour angle}}{\cos \text{lat} \tan \text{dec} - \sin \text{lat} \cos \text{hour angle}}$$

EXAMPLE:

Transit is set up at 8:30 P. M., June 27, 1918. Observations are made from 8:40 P. M. to 9:20 P. M. At 9:00 P. M. standard time in longitude 105° 32′ 33″ W., the observed horizontal angle was 88° 56′, and the observed vertical angle was 38° 45′. The refraction correction is 1′ 12″. Hence the true altitude is 38° 45′ — 1′ 12″ = 38° 43′ 48″.

Coaltitude = 90° — 38° 43′ 48″ = 51° 16′ 12″

Latitude = N. 39° 44′ 45″

Declination = 90° — 1° 8′ 3″ = 88° 51′ 57″ (Refer to table of polar distances or declinations of Polaris)

Computation for hour angle:

½ (coalt + lat — dec) = 1° 4′ 30″. log sin = 8.2732604
½ (coalt — lat + dec) = 50° 11′ 42″. log sin = 9.8854899
colog cos lat = 0.1141368
colog cos dec = 1.7034741

2) 9.9763612

log sin ½ hour angle = 9.9881806

½ hour angle = 76° 41′ 36″
hour angle = 153° 23′ 12″

Computation for azimuth:

log sin hour angle = 9.6512462

log cos lat = 9.8858632
log tan dec = 1.7002091

1.5860723 = log 38.55426

log sin lat = 9.8057611
log cos hr = 9.9513618

9.7571229 = log .57164

log 37.98262 = 1.5795849
log tan azimuth = 8.0717613

azimuth east of meridian = 0° 40′ 33″
horizontal angle to star = 88° 56′ 0″

horizontal angle to pole = 88° 15′ 27″
Bearing of line = N. 88° 15′ 27″ W.

Note: Culminations of Polaris for latitude, or elongations of Polaris for azimuth, may be observed without knowledge of the time if advantage is taken of the fact that Zeta Ursa Majoris (the star at the bend in the dipper handle), the north pole, Polaris, and Delta Cassiopeiæ (the star at the bottom of the first stroke of the W) are nearly in a straight line, with Polaris between the pole and Delta Cassiopeiæ. When this line is horizontal Polaris is at elongation, and when the line is vertical Polaris is at culmination, the elongation or culmination being in the direction towards Delta Cassiopeiæ.

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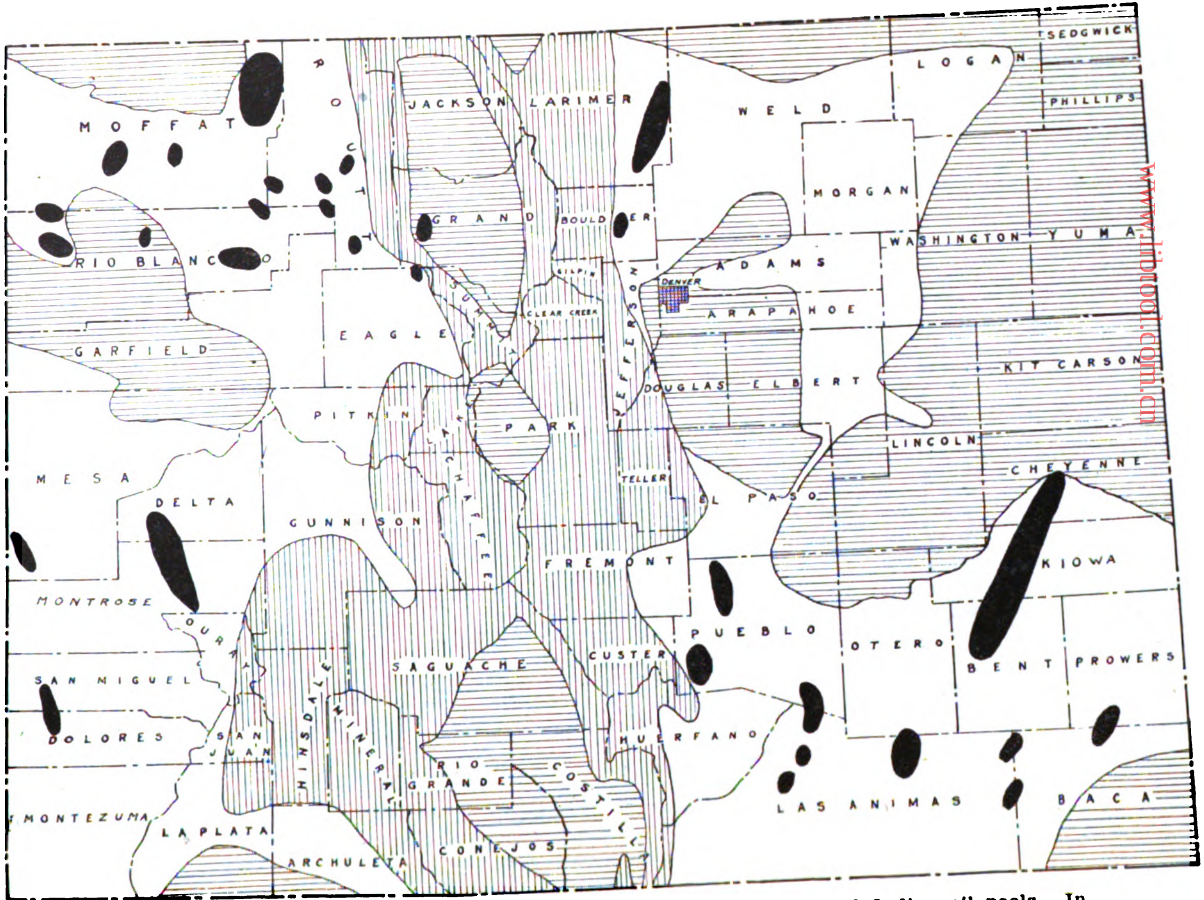

Fig. 1. Map of Colorado showing by shading the probabilities of finding oil pools. In the unshaded area the chances are fair to good; in the area lined horizontally the chances are poor; in the area with vertical lines the chances are negligible. The black areas show the location of known structures, in most cases domes. They are not necessarily of promise as possible oil producers.

Colorado's Future as an Oil Producer

BY VICTOR ZIEGLER

PROFESSOR OF GEOLOGY AND MINERALOGY, COLORADO SCHOOL OF MINES

PURPOSE AND SCOPE OF THE PAPER

The possibilities of oil production in Colorado have aroused a widespread and general interest among all the people of the state during this past year. Because of the intensive development of the Wyoming, Kansas, and Oklahoma fields, there has been a general feeling of over-exuberant optimism regarding the possibilities of production in Colorado. This has been fostered and encouraged by many unscrupulous "promoters" and "would-be geologists." "Colorado has greater possibilities of oil production than Wyoming or Kansas," "We have fifty structures in Colorado that are certain to carry more oil than any fifty in Wyoming," and "Colorado will be the great oil producer of the future," are newspaper headlines that have gained widespread credence in this state. Such propaganda undoubtedly serves a useful purpose in that it stimulates vigorous prospecting. Thus an active drilling campaign has begun in Colorado. About fifty prospect wells are being drilled at the present time in every part of the state, and many more are contemplated. By far the greater proportion of these wells are drilled in locations where the chances of success are negligible or are not clearly understood by those interested. In most cases failure is assured. The inevitable result of working in an atmosphere of over-enthusiasm and exaggerated and unfounded hopes is disgust on the part of the investor. He realizes that he has been misled, and he refuses to participate in further legitimate development work in this state. A clear understanding of conditions in Colorado, an unprejudiced and unbiased view of our chances of finding commercial oil pools, will put oil prospecting in this state on a safe basis.

In the nature of things most oil work is highly speculative. The ultimate returns to be expected should, therefore, be proportionate to the risks involved. The possibility of getting a return of ten dollars for every dollar invested does not justify the taking of a one in one hundred chance. The writer will, therefore, attempt to answer in an unbiased way the questions: "What are the chances of making Colorado an important oil producer?", and, "What geological formations are the most likely to carry oil in commercial quantities, and in what parts of the state are the chances best of finding oil pools?" This article has been prepared for the people of the state and investors elsewhere who have no or only little training in the principles of geology. It is not intended for the specialist in this subject. Every attempt will, therefore, be made to present the subject matter as free from scientific terms as possible and in a manner intelligible to the layman.

GENERAL THEORETICAL CONSIDERATIONS

In discussing the possibility of oil production in Colorado, it is necessary to call attention to a number of general features regarding the occurrence and origin of oil. A clear understanding of scientific considerations of this nature is an indispensable aid in any correct conclusions as to the probabilities of finding oil pools of commercial importance in our state.

The Rocks That Carry Oil

Not all rocks carry oil. The so-called "crystalline rocks," *i. e.*, the igneous rocks and the metamorphic rocks, such as granite, nowhere produce commercial quantities of either oil or gas. These rocks can be recognized by their crystalline texture, by their superior hardness, and by their massive structure. The accompanying map of Colorado shows in black the areas underlain by crystalline rocks. To prospect these areas for either oil or gas would be an absolute waste of time and money. There is no probability of ever obtaining production of oil or gas except from the sedimentary rocks.

The sedimentary rocks represent materials deposited in layers which we call beds or strata. They are usually formed under water, more rarely are they accumulated by the wind, or by ice, or precipitated from solutions in lakes. The more important sedimentary rocks are shales, sandstones, conglomerates, and limestones. The shales represent consolidated muds; the sandstones, consolidated sands; the conglomerates were originally gravels which are now consolidated; while the limestones represent chiefly the accumulated and more or less broken shells and skeletons of marine animals, such as molluscs, corals, and stone lilies.

MARINE SEDIMENTS

As indicated above, not all sedimentary rocks have the same origin. Those that are the result of accumulation in comparatively shallow ocean water have so far proved to be the most favorable for the occurrence of oil and gas. These rocks are included among the class of "marine sediments." They are usually characterized by dull colors—gray, black, brown, or dark green. The bright-colored sedimentary rocks, especially the brilliant red ones, are distinctly unfavorable to oil production. Marine strata above or below red colored sediments may be productive, as are the Embar and Tensleep formations below the "Red Beds" of Wyoming.

THE ORIGIN OF OIL

The intimate and virtually invariable association of marine sediments with oil and gas is simply a result of the origin of the oil. The most generally accepted theory of oil origin postulates a derivation from the dead remains of animals and plants which become buried in the sediments at the time they are deposited in the form of mud or sand on the ocean floor. Because of this burial, and in part by the salinity of the ocean water, or perhaps by excessive coldness, they are protected from rapid decomposition. Subsequently there is a sort of selective putrefaction followed and accompanied by deeper and deeper burial under the accumulating sediments. As a result, perhaps of increasing pressure and temperature, the partially putrefied animal and plant remains are distilled into oil and gas. It is of interest to note that a number of different chemists have succeeded in making oils from mixture of plant and animal remains which were virtually identical with natural oils. Other explanations of the origin of oil have been advanced, for a discussion of which the reader is referred to special treatises on oil geology. It is certain, however, that the organic origin of oil, as above outlined, is best supported by the facts of geology and chemistry. Every evidence goes to show that the oil and gas of all commercially important fields is derived from organic matter.

Reservoirs of Oil and Gas

Oil is not present under the earth's surface in lakes or streams, but is contained in minute crevices and cracks and, in greater extent, in the pore spaces between the grains of a rock. It is well to realize that marine sediments can be considered favorable as oil producers only when they carry rocks suitable as oil reservoirs that are at the same time surrounded by suitable enclosing beds. Any rock that is capable of containing oil and gas in commercial quantities is known as a "reservoir." The most common types of reservoir rocks are: first, sandstones; second, limestones; and third, shales. These will be discussed briefly.

SANDSTONES

Sandstones are the most common type of reservoir rocks. The amount of oil that any sandstone may carry is determined by the number and size of openings it contains, or, in other words, its porosity. Cement is quite important in determining porosity because it clogs up the interstices between the grains to a greater or less degree. A well-cemented sandstone is hard; a loosely cemented one, soft and friable; that is, it may be crumbled in the hands.

In color oil sands vary decidedly. Usually they are darker in color than the barren sands. Asphalt oils leave yellow to brown stains on the rock and impart to it the odor of petroleum. The paraffin base oils are so light and evaporate so readily that frequently no trace is visible in the outcropping oil sands.

SHAPE OF RESERVOIR

Certain sandstones occur in well-defined strata that are more or less constant in thickness, and that extend over very large areas. An example of such is the Dakota sandstone which is known to extend over an area of two thousand by one thousand miles. More frequently sandstones are lenticular in structure. They are limited in areal distribution and thin out, or "pinch out" laterally. The entire sandstone bed must not be thought of as being a reservoir. There are certain portions that may be incapable of holding either oil or water because of the fact that they are tightly cemented, or perhaps made up of excessively fine grains. The reservoir is confined to the porous part of the sandstone where the grains are coarser, and consequently the interstitial cavities are larger, or where the cement is poorer and does not completely fill the room between the grains.

LIMESTONES

Limestones are essentially calcium carbonate. When pure they are ordinarily unfavorable as oil reservoirs. Certain limestones, known as dolomitic limestones, or dolomites, carry varying amounts of magnesium. These are usually porous and contain oil or gas in a number of prominent fields, such as the Lima field of Ohio and Indiana, Spindle Top and other fields in Texas, and Maiden-i-Napthun in Persia.

Pure limestones are quite easily soluble. Consequently circulating water will dissolve out caves and channels which may occasionally act as reservoirs. This is true in certain of the Mexican fields. Limestones are not likely to become important as reservoir rocks in Colorado.

SHALES

The older geologists emphasized the importance of rock fractures and fissures as oil containers, and believed these to be far more important than the interstitial cavities between sand grains. At the present time this idea is applied to but a few pools. For example, at Florence, Colorado, oil is found in open fissures and fractures in a thick bed of shale. Several other localities, such as West Salt Creek, in Wyoming, and a few areas in Pennsylvania, show a similar type of accumulation. Generally, however, it may be said that such occurrence is unimportant and unreliable.

THE ENCLOSING BEDS OF RESERVOIRS

Reservoir rocks must be retained between rocks impervious to the circulation of oil, as, without these, we could expect no commercial accumulation. The most common type of enclosing beds are water-wet, fine-grained rocks, such as clays and shales. Occasionally, the enclosing rocks are similar to the reservoirs, but either so tightly cemented or so excessively fine-grained as to make the movement of oil through them impossible.

THE MIGRATION OF OIL AND GAS

In the preceding discussion we concluded that oil and gas are formed by distillation of plant and animal remains which are buried in the rocks by natural causes at the time of their deposition. Of all sediments, muds are most prolific in organic remains. It seems highly probable, therefore, that by far the greater part of oil and gas was originally formed in shales. Since neither oil nor gas occur in any great quantity in this rock, we are driven to the conclusion that they have migrated from shale and have been concentrated in rocks more suitable as reservoirs.

CAUSES OF MIGRATION

A number of different causes have probably been active in forcing such migration, chief among which we may mention the following:

1. Differences in specific gravity of gas, oil, and water.
2. Head of ground water.
3. Gas pressure.
4. Rock pressure.
5. Earth movement.
6. Heat gradient.
7. Capillary attraction.

Within the limits of this paper it is impossible to discuss these fully. For such a discussion the reader is referred to the more elaborate treatises or special articles listed in the appended bibliography.

DIFFERENCES IN SPECIFIC GRAVITIES It is a well-known fact that gas is lighter than oil, and oil lighter than water. Oil and water are not miscible. Oil floats, therefore, on the surface of the water. Consequently, wherever oil and water are mixed in rocks under the earth's surface oil should be on the top, and wherever water moves through rocks, oil must be driven ahead of it.

HEAD OF GROUND WATER The water in the rocks of earth's crust is known as ground water, or underground water. The head is the pressure determining the height to which water will rise. Head, therefore, causes water to flow, and for the reasons already mentioned, oil and gas are driven ahead of the water through the rocks.

GAS PRESSURE The gas associated with oil is frequently under very great pressure. This pressure is of necessity exerted in all directions and may to some extent force oil to move through rocks. Gas pressure is of great importance in certain oil fields because it may be sufficiently great to force the oil through the well up to the surface of the earth and so produce flowing wells or gushers. Gas migrates in all directions far more easily than oil. Gas fields, therefore, are of larger extent than oil fields, and may be entirely distinct from them.

ROCK PRESSURE Rocks underneath the earth's surface are under pressure equivalent to the weight of the column of rocks above them. With increasing depth this pressure may be so great that no openings can exist, and that the rocks will flow like wax.

The effect of rocks whose pores and openings are saturated with oil or water will be similar to that of a sponge saturated with water and subject to pressure. The liquid and lighter material will be gradually squeezed out and forced towards the surface. Below four thousand feet, rock pressure is probably the most important cause of movement.

EARTH MOVEMENTS Earth movements, such as folding and faulting and tidal deformations, set up stresses and strains in the interior of the earth which have some stimulating effect on oil migration. Their importance is probably very slight.

HEAT GRADIENT As we descend from the earth's surface, we find that the temperature increases at a more or less regular rate of 1° C for every fifty to one hundred feet. This regularly increasing temperature may have a slight stimulating effect on circulation. The general tendency will be to drive the liquids upward. Its importance is probably very slight, because of the great depth required for an effective temperature increase. Thus a burial of one mile is only equivalent to a temperature increase of 50° to 100° C.

CAPILLARY ATTRACTION The tendency of liquids to ascend minute openings and pores, such as those in sponges, is a result of capillary attraction. The effective pressure that forces liquids to ascend such tubes is capillary pressure. Water exerts a capillary pressure three times as great as that of crude oil.

Considering the fact that a mixture of oil and water is disseminated through the rocks of the earth's crust, it will be evident that the differences in surface tension will cause a selective segregation of oil and water. The water, because of its superior surface tension, occupies the pores of smaller diameter; the oil is driven into the openings of larger size. Capillary pressure is virtually negligible in rocks at a depth of several miles.

Summary

When the muds are originally deposited they carry occluded fragments of plants and animals which are subsequently altered and changed into oil. Due to the original compacting of the muds by "rock pressure" and the selective action exerted by capillary pressure, the oil produced is concentrated into the more porous and more resistant reservoir rocks, especially sandstones. In these reservoir rocks we have a mixture or emulsion of both oil and water. This becomes separated due to a circulation of underground water, the immiscibility of oil and water, and the fact that oil being the lighter, rises to the top of the water surface. The structural conditions necessary to cause a commercial accumulation will be described in the following paragraph.

GENERAL DIRECTION OF MIGRATION

The primary concentration of oil and gas is effected by rock pressure and by capillary pressure. The result of these two causes will be to promote the movement of oil and gas especially in an upward direction. This may have a decided effect in determining the relative productive capacity of reservoir rocks. Thus we may consider as an example the case of two oil sands lithologically alike and equally favorably located from the structural standpoint: One of these sandstones is below the series of shales in which the oil has been formed and the other sandstone is directly above the shale. Because of the more active movements upward there will be a greater concentration of oil into the upper sandstone which will, therefore, be the more promising from the standpoint of future production, all other conditions remaining the same.

The Structure of Rocks

The arrangement and attitude of rocks in the earth's surface is called structure. This is of the utmost importance in oil work. Special structural conditions or arrangements of rocks are needed to insure a commercial accumulation of oil.

As a rule we do not find the sedimentary rocks flat and undisturbed as they were originally deposited, but we find the rocks folded and wrinkled much like the quilt on our bed after a night's sleep. The upfolds or arches are anticlines; the downfolds or troughs are synclines. The higher parts of the folds, which experience has shown to be the more likely to carry oil, are then known as "anticlines." This rule of association of oil pools and anticlines is called the "anticlinal theory." It is the most important principle of oil geology, and should govern all prospecting and examination of oil lands. The accumulation of oil in the higher parts of the folds—or in the anticlines—is explained as follows: The sandstones which act as oil and gas reservoirs are, in most cases, saturated with water. They are overlaid and underlaid by shale or some other rock which forms a practically impervious cover. Oil and water, even if vigorously stirred up and shaken in a bottle, will not mix, but will separate in two layers according to their weight—the oil on top, the water below. Similarly, in the oil sand such a separation will take place. If the sand be completely saturated or filled with water, the oil will rise to the highest part of the reservoir—which is the very top or crest of the anticline. If the sands are only partially saturated, the oil will accumulate on top of the water level along the sides of the folds. If the sands are dry, the oil of necessity will be found in the bottom of the troughs—or, to use the geologic term, the syncline. In by far the great majority of cases we have the oil sands completely saturated and, therefore, find the oil in the crest of the anticlines. These are the conditions met with in most sands of Wyoming, California, and the Appalachians. Whether or not a sand is saturated can only be determined with certainty by drilling. Common experience in a field is the only reliable guide. The geologist is of value because he can pick out that part of the structure which holds out the greatest chance for success under the conditions prevalent in that field.

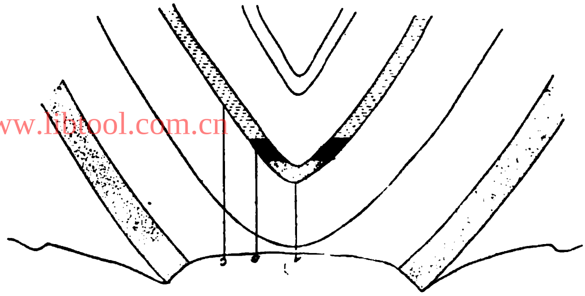

Fig. 2. A vertical section through an anticline illustrating the occurrence of gas, oil and water in the same reservoir sand. A is a gas well; B an oil well; and C a water well.

In many fields noticeable quantities of gas accompany the oil. This being the lightest constituent present, rises to the top of the oil. Hence, the occurrence of gas wells and water wells on the same structure is explained by the fact that the oil sands are struck at different elevations; the gas well at the highest; the oil well at an intermediate, and the water well at a lower elevation. The diagrams make this clear.

There are other arrangements of rocks besides the anticline that afford a chance for the formation of oil pools. Thus, the ideal structure is the "dome," which is a fold shaped like an inverted bowl. Domes may be circular in ground plan, highly elongated, oval, or eccentric. Most of the producing Wyoming oil fields are domes.

Horizontal rocks are usually unfavorable. There are rare exceptions, as in Mexico, where as a result of the intrusion of a dyke, or plug of lava, or igneous rock, the sediments are sufficiently disturbed and tilted to form a reservoir.

Rocks dipping or inclined in one direction only, are usually unfavorable. The oil rising upward seeps out on the surface and is lost. This is the case in the light oil fields of Wyoming and Colorado. Certain oils are so heavy and viscous that upon rising towards the surface they harden and clog up the pores of the sandstone. In this way the bituminous and asphalt bearing rocks like those of California and Oklahoma are formed. These frequently form the cover or seal of an oil pool. Again, slight warping may affect the slope of the rocks and form a trap in which oil and gas collect. Of such nature are the "structural terraces" of the Ohio, Indiana, and Kansas-Oklahoma fields.

There are many other structural conditions favorable to oil accumulation. Faults—that is, fractures along which movement of the rocks has taken place—often localize oil accumulation. This is apparently true in West Salt Creek, Wyoming. At other places faults destroy commercial possibilities. No matter what the structure may be, we must have porous rock, usually a sandstone, capable of acting as a reservoir, and inclosed in relatively impervious rock, usually shale. The arrangement of rocks must be such that there exists an opportunity for the accumulation of commercial quantities of oil and gas. The most important single factor in the locating of an oil well is, therefore, the geologic structure. The chief value of the geologist is his ability to determine the structure from the distribution and arrangement of rocks at the surface, and to locate the favorable areas for testing.

"Favorable Indications"

A great many popular misconceptions center about the so-called "favorable indications." Among these we may include the following:

1. Oil and gas seeps at the surface.
2. The presence of oil residue in rocks at the surface.
3. Traces of gas and oil in wells.
4. The presence of salt water.
5. The presence of "oil shale."

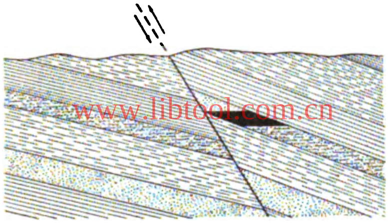

Fig. 3. A vertical section through a fault showing an oil pool (black) sealed in by the fault plane.

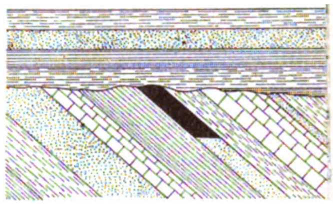

Fig. 4. A section through a conformity, showing an oil below.

The first three "indications" are only of value in proving the fact t certain formation carries oil. They do not indicate commercial accumul under the surface. Drilling should be undertaken only on a favorable ge ical structure in rocks proved petroliferous. The frequent association of with oil has led to the popular belief that salt water invariably indicate presence of oil. This is by no means true. Brines may or may not be ac panied by oil. The presence of salt water is, therefore, of no parti diagnostic value.

"OIL SHALES"*

Oil shales are clay rocks rich in bituminous terial which, on destructive distillation, yield oi gas. Considerable heat is necessary to obtain oil. Probably by far the greater part is not present as oil but as an org residue which breaks up into oil when heated. This is corroborated by fact that shales which carry as much as eighty gallons of oil to the ton not in the least greasy and do not show visible oil. The oil shale of Green River formation covers large areas in northwestern Colorado, s western Wyoming, and northeastern Utah. The shales are at the ea surface exposed to erosion, and have probably no significance whatev far as possible oil fields are concerned.

Summary

Attacking the subject under discussion from the theoretical standp we have arrived at the following conclusions:

1. That only marine sediments can be considered favorable source oil and gas, because they originally contained the raw materials from w oil and gas have been formed by distillation.

2. That to deserve exploitation such marine sedimentary rocks contain suitable "reservoir rocks" which are capable of carrying and y ing commercial quantities of oil and gas. Such reservoir rocks are ch "open" sandstones, but may be porous limestones, or very rarely fiss shales.

3. That commercially valuable accumulation of oil and gas need be expected where the attitude or structure of the rocks is such as to them. Such structural conditions are afforded by domes, and to a le extent by anticlines, terraces, and faults.

Carrying in mind these fundamental principles, we can now deal their application to Colorado conditions.

GEOLOGY OF COLORADO

As stated before, all the geological formations are deposited accor to age, with the oldest at the bottom. The included table shows the geol cal formation of Colorado arranged according to geological age.

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*For a full discussion of oil shales in Colorado see Colorado School of M Quarterly, Vol. 13, No. 2, April, 1918, entitled "The Oil Shale Industry," Victor C. Alderson.

TABLE OF GEOLOGICAL FORM

The following symbols are used: s. s.—sandsto

...IODS	EPOCHS	FORT COLLINS	DENVER	COLORADO SPRIN...	
...sent		Alluvium—Along Streams			
... or	Pleistocene Pliocene Miocene Oligocene Eocene	(Absent)	Denver— Arapahoe— s. s., congl. and tuffs.	Dawson—1000 feet White and gray kose and clays.	
	Laramie	Laramie — 1000-1500 feet. Gray s. s. and sandy shales with coal seams.	Laramie—1200 feet. See preceding column.	Laramie—250-300 f White to light g s. s. with shale n top and thin c seams.	
	Montana	Fox Hills — 800-1200 feet. Friable s. s., fine grained, with fossils. Pierre—4000 ft. (?). Dark gray to black shale weathering greenish buff. Interbedded Hygiene s. s. 100 to 300 feet thick. O. & G.	Fox Hills — 800-1200 feet. See preceding column. Pierre—4000 feet. See preceding column. s. s. less prominent and gives way to sandy shale. Thin l. s. lenses near top. Production at Boulder	Fox Hills—600 feet. Dark gray to brow ish gray s. s. Pierre—2500 feet. Dark gray to d shales, local sa layers. Thin l. near top. O. & C	
	Colorado	Niobrara—400-600 ft. Thin blocky limestone beds and hard calcareous shales. Minor hogbacks, bituminous l. s. O. & G. Benton—400 feet. Dark gray to black shale. Fish scales near base. Thin bituminous l. s. O. & G.	Niobrara—400-600 ft. See preceding column. Benton—400 feet. See preceding column.	Niobrara—400-580 ft. Gray shale near top, pale gray l. s. near base. O. & G. Carlile—60 feet. Black shale, s. s. 10-20 ft. thick at top. O. Greenhorn—50 feet. Bluish gray l. s. and calc. shale. Graneros—200 feet. Gray and drab shale. O. & G.	Niobrar Gray thin bott Carlile Gray s. s. Greenh Gray Graner Gray
	Dakota	Dakota—50 feet. Hard blocky s. s., gray, weathers rusty.	Dakota—40 feet. See preceding column. Asphalt.	Dakota—100 feet. Gray and buff fine-grained s. s. Asphalt seep.	Dakota Gray and O. well
...hean or Cretaceous		Fuson—75 feet. Sandy shales, shaly s. s., and thin clays. Lakota—60 feet. Hard, quartzitic s. s., gray, weathers rusty. High hogback.	Fuson—100 feet. See preceding column. Lakota—75 feet. See preceding column. Asphalt and oil seeps.	Purgatoire— Glencairn member—50-150 ft. shale. Lytle member—145 feet. Coarse pebbly s. s.	
		Morrison—200 feet. Variegated clays and marls, s. s. at base.	Morrison—250-300 ft. See preceding column. Asphalt.	Morrison—225 feet. Maroon and olive clays, light l. s. and s. s. near base.	Morriso Vari shal s. s Oil s
		Lykens—600 feet. Bright red shales, thin shaly s. s. and gypsum beds, thin l. s. near base.	Lykens—400-600 feet. (Upper Wyoming). See preceding column.	Lykens—180 feet. Red sandy shales with gypsum beds and thin l. s. near base.	
	Permian	Lyons—50 feet. Exact age (?) Hard quartzitic crossbedded sandstone, pale gray to buff in color.	Lyons—200 feet. Exact age (?) See preceding column.	Lyons—800-850 feet. White to pink uniform s. s., brick red s. s. near base.	
...rous	Pennsylvanian	Fountain—1200 feet. Exact age (?) Bright red s. s. with minor shale and cong. Arkose.	Fountain—1200 feet. See preceding column.	Fountain — 800-4500 Red, maroon and white s. s., arkose and congl. with minor shale.	Fount May and Red felds red s
	Mississippian				Millsap Gray and show
				(Absent)	
		(Absent)	(Absent)		Harding Whit
...n				Manitou—50-250 feet. Red-gray and blue-gray l. s.	
				Sawatch—45 feet. White fine-grained s. s.	
...brian		Schists and granites.	Gneisses and schists. O. (Golden Gate Canyon).	Chiefly granite.	Schists

. O—congl.—conglomerate, O—oil seep, G—gas seep.

...	TRINIDAD	ASPEN	GUNNISON	DURANGO	...
...0 ft. grav...	Nussbaum—30 feet. Huerfano, Cuchara, Poison Canyon { Total 5000 feet (Eocene) } Chiefly s. s.		West Elk—3000 feet. Breccias and tuffs. Ruby—2500 feet. Exact age (?) Probably Eocene Congl. and s. s. Ohio—200 feet. Exact age (?) Probably Eocene s. s.		Gree... s. sh... Was... s. & in... Ohio... W...
	Laramie — 1500-2200 feet. Alternating s. s. and shale, good coal near base.	Laramie—500-600 ft. Chiefly s. s., white or gray.	Laramie—2000 feet. s. s. and shale and good coals.		
...ales. ... in ...on at	Trinidad—150-170 ft. Massive s. s., G. in well. Pierre—1300-1700 ft. Light gray, yellow, to dark shale. Shows oil and gas in well.	Montana— Gray to black shales and thin impure l. s. Sandy near top. O. & G.	Montana—2800 feet. 300 ft. yellow s. s. at top, rest leaden gray shale with thin l. s. beds. O. & G.	Lewis—200 feet. Gray to drab shale and impure l. s. Mesaverde—1000 feet. Gray-buff s. s. and shale and coals. G. Mancos—1200 feet. Gray to black shales and impure l. s. O. & G. shows.	Mesa... s. pr... Manc... Da... ch... zo...
...—600-700 ft. ... calc. shales, ...l. s. at top and ...	Apishapa—500 feet. Sandy shales. O. & G. Timpas—190 feet. Calc. shale and thin l. s.	Niobrara—100 feet. Dense gray-blue l. s. and shaly l. s.	Niobrara—100-200 ft. Gray calc. shale and l. s. at base.		
...—210 feet. ... shale. 20-foot ...at top. O. & G. ...—40 feet. ... l. s. and shale. ...—200 feet. ... shale.	Carlile—170 feet. Gray shale capped by s. s. O. & G.	Benton—350 feet. Black calc. shale and thin l. s. O.	Benton—150-300 feet. Black shale, thin l. s. O. & G. show in wells.		
...—300-650 feet. ... and white s. s. ... beds of shale. ... G. show in ...	? (Not exposed)	Dakota—250 feet. Massive white s. s.	Dakota—40-300 feet. White quartzite, congl. and local fire clays.	Dakota—100-300 feet.	Dakot... Co...
...—70-400 feet. ...gated clays and ..., thin l. s., ... and gypsum. ...seep.		Gunnison—300 feet. Variegated clays, gray to yellow s. s. at base.	Gunnison—350-500 ft. Variegated clays and s. s.	McElmo—400-500 ft. s. s. and variegated shales. LaPlata—300-400 ft. Very massive white s. s.	Gunnis... Vari... shal...
		Triassic—2000 feet. Probably including some Carboniferous. Bright red s. s. chiefly.	(Absent?)	Dolores—2000 feet. Red s. s., grits and congl.	Red B... 4... Red...
...—2100 feet. ... include Lyons ...ykens in part. ... and white ...thic s. s. and ...ales and congl.		Maroon—4,000 feet. Calc. s. s., grits and shaly l. s. Dull reddish brown. Weber—1000 feet. Dark gray to black shale and carbonaceous l. s.	Maroon—4500 feet. Congl. and s. s., yellowish gray, red to chocolate color on top. Weber—100-550 feet. Dark gray to black shale and thin l. s.		
...—200 feet. ... to purple l. s. ... shale. Slight oil ... in well.		Leadville—200-450 ft. Blue l. s., massive; brown weathering dolomite.	Leadville — 400-525 Gray to brown to blue l. s. Massive near top.		
(Absent)		Parting Quartzite—40-90 feet. s. s., quartzite and shales.	(Absent)		
...—80 feet. ... s. s.		White Limestone—250-400 feet. Light gray dolomitic l. s.	Yule—350-450 feet. l. s. and yellow shale.		
(Absent)			(Absent)		
		Sawatch—200-400 ft. Congl., arkose and quartzite.	Sawatch—50-350 feet. Chiefly quartzite.		
... and granites.		Granite.	Granite, gneiss and schists.		

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It will be noted that the names of the formations change to some extent ι place to place. This is due to the fact that we are unable to determine certainty the equivalency of some formations in widely separated local· : In this table there are also indicated the formations that have pro d oil or gas, or from which seeps or "shows" are known.

sible Oil Horizons in Colorado

Rocks of three different ages hold out some possibilities of production. ;e are in order of importance:

1. The Cretaceous.
2. The Tertiary.
3. The Carboniferous.

Oil and gas seeps also occur in several other horizons, as for example, the ·ison formation on Oil Creek near Canon City, the Archean in Golden Canyon near Golden, the Jurassic in the northwest part of the state and near Delta, and the Morrison formation near the town of Morrison. rrences such as these are somewhat puzzling to the geologist because of haracter of the rocks in which they occur. The Morrison and the equiv- ; Jurassic formations are chiefly variegated clays, marls, and sandstones of marine origin. These rocks are chiefly sediments that were deposited terior basins under arid or semi-arid conditions such as prevail over the er part of the "Great Basin" region of the United States today. Sedi- ts accumulating under such conditions are virtually devoid of animal or t remains and consequently do not contain the raw materials necessary he production of oil and gas. The Archean is made up entirely of crystal- rocks, both igneous and metamorphic, in which an oil seep is entirely pected. The writer has had the opportunity to study several seeps in formations mentioned above and has found proof that the oil is not genous to these formations, but is present because of special structural litions at the locality of the seep. In the cases studied, the oil was ally derived from the overlying Cretaceous, and transported along fault es into the rock where observed. These seeps do, therefore, not indi- that these formations are petroliferous in general. As a matter of fact, eful study of their outcrops will convince anyone that they are unfavor- from the standpoint of petroleum production. This has also been borne by drilling, as several unsuccessful wells have been put down in these lations.

Cretaceous

The rocks of Cretaceous age comprise a thick series of marine sediments continental deposits near the top, that are prominently developed over entire Great Plains region and over much of the area of the Rocky Moun- s clear to the Pacific Coast. North and south they extend from Mexico Alaska. The various formations included in the Cretaceous of Colorado shown in the accompanying table. The rocks are chiefly shale which esent muds originally deposited in comparatively shallow ocean water. olor the shales are dull gray, drab to almost black. The greater part of shale is pure clay shale, but much is quite sandy, and some is highly ıreous. The fossils of marine animals, chiefly molluscs, are quite abun- , while certain layers, especially near the base, abound in fish scales, all ing mute evidence of the large amount of dead animals originally en- ed in these rocks. Interbedded with these shales, but of very minor im- ance, occur a few poorly cemented sandstones. These become more abun- near the top, until they make up nearly all of the upper part of the aceous series. These sandstones are yellowish white to buff in color. carry many casts of plant remains, and also contain a majority of the rtant coal seams of the Rocky Mountain region. A few impure lime- es occur interbedded in the shales. These are of very minor importance he North but increase much in thickness and purity to the South and hwest (Texas and Mexico). Frequently these limestones are a solid mass ssil oyster shells, or of large coiled or straight shelled cephalopod mol- which resemble snails. These are usually found in the center of large, d, boulder-like masses which we call concretions. Because of superior hardness these concretions weather more slowly than the surrounding shales and hence form little, nearly circular mounds and pinnacles called "Tepee Buttes" in many parts of the foothills region of Colorado. In many districts these fossils weather out readily from the shales and still show on fresh surfaces the original luster of mother of pearl. Carloads of such can be seen along the Cheyenne and White Rivers in South Dakota, along the Powder River and North Platte in Wyoming, along Ralston Creek near Golden, and many other localities in Colorado.

The following Cretaceous formations have excited interest as possible oil horizons:

1. Dakota sandstone.
2. Several sandstones in the Benton.
3. Limestones in the Niobrara.
4. Several lenticular sandstones in the Pierre shale.
5. Several sandstones near the top of the Cretaceous (in the Laramie and Mesaverde).

These will be discussed briefly in the order given.

DAKOTA SANDSTONE

This is one of the most uniform and widely distributed sandstones in western North America. It represents the basal sandstone of the Cretaceous, that is, the first sands deposited by the Cretaceous sea when it advanced over the site of the present Great Plains and the Rockies, which are of much later geologic age. The practical oil men frequently use the term Dakota loosely for all the sandstones at the base of the Cretaceous shales. Used in this sense it includes a thin shale and a heavy massive, frequently highly cemented and quartzitic sandstone of Lower Cretaceous or Commanchean age. This usage is shown in the following table:

	Black Hills	Colorado Springs	Wyoming	Oklahoma
Dakota Group	Dakota sandstone Fuson shale Dakota sandstone	Dakota sandstone Purgatoire sandstone	Cloverly	Trinity ↓

On the whole, the Dakota is a fairly well cemented to very hard sandstone, especially on the east side of the Rockies of Colorado. The porosity is, therefore, not very large, and it is, hence, a reservoir of very limited capacity. Occasionally small, well-rounded pebbles become so abundant as to make it a conglomerate.

Oil seeps occur in a number of localities along the foothills of the entire Rocky Mountains, from Canada into Texas. The most extensive seeps known occur along the Athabasca River in Canada. Prominent seeps of oil occur in a number of localities in Montana, Wyoming, South Dakota along the Black Hills, and Nebraska. Seeps and impregnations with residual oil are known near Morrison, on Ralston Creek near Golden, near Pueblo, and near Canon City. These seeps in every case carry a heavy black oil or an inspissated asphaltic residue. A number of wells have been drilled through the Dakota. A small production is obtained from this sand near Greybull in the Bighorn Basin of Wyoming. It is also reported that a well good for about eight hundred barrels has been brought in within the last few days on the Dakota on Buck Creek near Lusk, Wyoming. A very small production is maintained from the Trinity sand, which occupies a roughly similar stratigraphic position at Madill, Oklahoma. There are a great many other localities where this sandstone has been drilled in structures but failed to yield wells. It is also worth noting that this sandstone is the one from which the majority of the artesian wells of the Great Plains region derive their water. The total daily production of oil derived from this sand in all the fields of North America amounts to much less than one thousand barrels. The average initial flow of producing wells has been between five and ten barrels.

In passing it is perhaps well to call attention to the fact that in Wyoming the Dakota is underlain by about seven hundred feet of Jurassic strata of marine origin which are full of fossil remains. These marine strata may well be the source of the oil which after formation travels upward through the more or less porous Morrison formation into the Dakota where it is retained because of the thick clay shales of the Benton which overlie the Dakota sands. The marine Jurassic (the Sundance) is dominantly sandstones. This accounts for the small quantities of oil in the Dakota, as the greater proportion of the oil was probably lost at the time of its formation in the porous Sundance. In the Madill field in Oklahoma, the Trinity rests unconformably on the truncated edges of the oil-bearing formations of Pennsylvanian age. The oil produced from the Trinity is derived by seepage from the Pennsylvanian sands.

In Colorado, the Dakota rests on a very thick series of continental deposits, the Morrison and the Red Beds, which in places attain a combined thickness of more than three thousand feet. These beds are nearly all sandstones and carry no or very few fossils, and cannot, therefore, be considered probable sources of oil and gas. Below the Red Beds, we have Palezoic limestones which may have originally contained oil and gas. The greater part of this, however, must have been wasted during the deposition of the overlying Red Beds, and the rest dissipated in traveling through the thick sandstones above.

DAKOTA STRUCTURES

Structures are known to exist in the Dakota near Pueblo in southeastern Colorado, near Eads, in several localities on the western slope. The Dakota has been drilled on structures in all of these localities with disappointing results.

SUMMARY

1. The Dakota is fairly hard and well cemented in Colorado, therefore, only a poor reservoir.

2. There are no rocks directly below the Dakota formation in Colorado that would serve as sources of oil and gas, as is true in several producing localities in Wyoming, and at Madill, Oklahoma.

3. Several oil seeps occur, but those examined show oil conducted into the Dakota by faults from the overlying Cretaceous.

4. Results obtained in drilling, not only in Colorado but elsewhere in the Rocky Mountain region, have been highly disappointing both from the number of producing wells obtained as well as from the standpoint of initial production. This has been true in the case of exceptionally large promising structures. For the above reasons we can safely conclude that the chances of getting large production from the Dakota formation in Colorado are very small. The best we can hope for is small production with the chances of getting this against us.

The Benton Formation

This formation rests directly upon the Dakota sandstone. East of the Front ranges it can usually be divided into three members, the Graneros shale at the base, the Greenhorn limestone in the center, and the Carlile shale near the top. Such a threefold division can readily be made from Denver south to the New Mexico line. The division is less marked from Denver north to the Wyoming line.

The Graneros is a gray to dark colored shale, sometimes almost black. averaging about two hundred feet in thickness. This frequently shows a paperlike cleavage. Locally thin and usually bituminous limestones occur near the top. An oily, fetid odor becomes prominent when these limestones are freshly broken or struck with a hammer. The shale weathers into almost structureless masses of clay which are used in a number of localities for brick, as for example at Colorado Springs and at Boulder.

The Greenhorn consists of a series of thin dove-colored to gray jointed and blocky limestones separated by darker shale partings. It varies from about twenty-five to sixty feet in thickness. The limestones are quite characteristic everywhere south of Denver, but decrease in prominence north of this city. The limestones are frequently bituminous.

The Carlile consists essentially of gray to black shale from eighty to two hundred feet thick, frequently carrying concretions and septaria, and usually capped by sandy shales or a thin yellow to buff friable sandstone.

This is most prominently developed in the region from Colorado Springs southward. Here it varies from four to twenty feet in thickness. Locally it is absent and represented only by a sandy shale zone. The sandstone is fairly uniform in grain, bright yellow to buff in color, and very porous, consequently is ideally suited for an oil and gas reservoir. In a few localities it is overlain by a thin, strongly bituminous limestone. This sandstone is the only member of the Benton group east of the Front ranges that deserves careful consideration as a possible oil sand. Samples of this sandstone collected near Colorado Springs, and west and also south of Pueblo, when tested with ether gave strong reactions for oil residues. In stratigraphic position this sandstone is roughly equivalent to the Wall Creek sandstone which furnishes the major part of the production in Wyoming. It cannot be considered to be as favorable as the Wall Creek from the geological standpoint for the following reasons:

1. The Wall Creek sandstone is from four to twenty times as thick.

2. The Benton in Wyoming is generally much thicker and more bituminous than in Colorado.

3. The Wall Creek sandstone is much more persistent and more widely distributed.

4. Folding and structural disturbances are much more pronounced in Wyoming, while in Colorado the Benton, with the exception of a very narrow belt paralleling the Front range, is usually nearly horizontal.

The last feature is one especially noteworthy, because in our western oil fields we find that decided flexures seem to be necessary in order to cause concentration of oil and gas. Very broad and gentle folds such as characterize the Kansas and Oklahoma fields have proved unproductive wherever drilled in the Rockies.

The Benton has been drilled through in a number of places and, in several, very promising shows of oil have been developed in the sandstone mentioned. There are a number of structures in southeastern Colorado that affect the Carlile. In most cases, however, the Carlile has been eroded off the top and the older underlying formations have been exposed. Oil seeps and small "shows" in wells have been encountered down dip, that is, on sides of these structures. The chances of getting commercial production in these cases is very slight. There is, however, good reason for the belief that favorable structures with the Carlile below the surface, exist in this part of Colorado. They are difficult to locate because of the overlying rocks which are so readily eroded that they yield few outcrops. The Benton formation is also present on the Western Slope and in the San Juan region. Here it consists essentially of dark gray to black shales which can hardly be separated from the overlying Niobrara. In the White River country there are a few very thin and usually rusty weathering sandstone streaks present in the Benton. Usually these are absent and the shales are remarkably uniform. Thin bituminous limestone streaks occur rarely.

SUMMARY The only probable oil reservoir known in the Benton is a thin sandstone at the top of the Carlile. This must be considered a much more promising horizon than the Dakota. This sandstone attains a maximum of about twenty feet in thickness. It is prominently developed in southeastern Colorado from Colorado Springs, Pueblo and Trinidad east, about to the Kansas line. Within this territory a structure which carries the Carlile at sufficient depth holds out good chances of obtaining a small production of high grade oil.

The Niobrara Formation

Resting directly upon the Benton we have, east of the Front ranges, a series of calcareous shales and thin limestones usually light gray in color, which are included under the term Niobrara. Frequently both the Benton and the Niobrara are included under the term Colorado formation. Occasional bituminous shale or sand streaks occur. The limestones occur in beds up to fifty feet in thickness, and are more abundant in the lower part to which the name Timpas formation is applied in the region south and east of Colorado Springs. The upper part which is dominantly shale is known as the Apishapa formation. On the Western Slope and in the San Juan region the Niobrara is essentially dark shale occasionally calcareous and not clearly divisible on lithological grounds from the Benton below and the Pierre above. It is usually included with both under the term Mancos shale.

While there are oil and gas seeps in the Niobrara, and while bituminous limestones are characteristic, the Niobrara may be considered unfavorable as a possible oil producer because it carries no rock capable of acting as a reservoir.

The Pierre Shale

The Pierre shale comprises, as the name implies, a thick series of gray to dark gray to almost black shales which carry a few sandy streaks, occasional layers of concretions, and a few impure limestone lenses near the top. The upper part weathers into a greenish yellow porous and spongy soil. East of the Front Range the thickness varies from 1,200 to well above 3,500 feet. From the vicinity of Denver northward there is a well-defined sandy zone from 1,000 to 1,700 feet above the base. This consists of a series of highly lenticular sandstones rather than a continuous persistent bed. These sandstone lenses are usually brownish buff where weathered, are fairly uniform in grain and quite friable. The name Hygiene sandstone has been applied to such a sandstone near Boulder, and the term is frequently used for all the lenticular sandstones at about this general horizon. Such sandstones have furnished much of the production of the old Boulder field and must be considered possible future producers. These sandstones are roughly in the same horizon as the Shannon sandstone of Wyoming, which furnishes most of the shallow production at the Big Muddy Field and at Lost Soldier, Wyoming. The chief difficulty in Colorado is the generally unfavorable attitude of the Pierre shale which, except for a very narrow strip in the foothills, lies usually horizontal or at an inclination so low that the oil is not concentrated. Again, the shale overlying the sandstone lenses is so readily eroded as to leave no outcrops, and so mask more or less completely any structures that might be present.

On the Western Slope and in southwestern Colorado the Pierre is essentially shale and no sandstone capable of acting as a reservoir is known. Here, all the Cretaceous shale are usually not subdivided but included under the term Mancos.

Much of the production of the old Florence oil field is obtained from the Pierre shale. This has been fissured to some extent and the fissures have become filled with oil. This accumulation is so erratic and unusual that only an accident can lead to the discovery of similar conditions elsewhere.

SUMMARY The Hygiene sandstones of the Pierre may be considered possible reservoirs of oil and gas. They are of prominence only in the area north and east of Denver. Here, however, the structure is generally unfavorable, and no large production need be expected, unless a large, well-defined structure can be found, which is unlikely.

The Upper Cretaceous Sandstones

The Pierre shale is followed by a thick series of sandstones alternating with minor layers of shale. East of the Front Range we find the Fox Hills sandstones, a fine-grained yellow sandstone carrying marine fossils. This is frequently included with the Pierre shale under the term Montana group. South of Pueblo, this sandstone is known as the Trinidad formation. The Fox Hills varies from 150 to 600 feet in thickness. The Laramie formation rests upon the Fox Hills. It consists of a series of alternating massive gray sandstones, shaly sandstones and shales with interbedded coal beds. Virtually all important coal beds of Colorado are in the Laramie. The thickness varies from 250 to over 2,000 feet. Shows of gas are of common occurrence.

In Gunnison County the Fox Hills is a fine-grained yellow sandstone about 300 feet thick, the Laramie is about 2,000 feet thick and is followed by more sandstone and conglomerate series known as the Ohio and Ruby formations, totaling about 2,800 feet. Over much of the Western Slope and in the San Juan region, thick sandstone series appear, about equivalent in age to the top of the Pierre shale east of the Front Range. These are included under the term Mesaverde. They vary locally from 1,000 to 4,000 feet. They are usually an alternation of yellow, buff, or gray sandstone and shale which are frequently variegated red and purplish, and which are characterized by coal seams in the middle portion. The Mesaverde carries gas and shows of oil in many widely separated localities.

Locally shale beds become abundant enough to seal in certain sands, especially those near the top of the Mesaverde. Fair shows of oil up to a production of ten barrels per day has been obtained from these sands near DeBeque.

SUMMARY Much of the gas encountered in the Laramie and in the Mesaverde is derived from the associated coals, and does not, therefore, indicate the presence of oil. On the whole, these sandstones are unfavorable to oil accumulation because they lack the necessary impervious enclosing beds. Any oil and gas contained in them is not concentrated but is disseminated through the entire formation. The chances of obtaining commercial production are, therefore, slight, and only wells of small capacity and probably very high grade oil need be expected.

The Tertiary Formation

Large areas of the northeastern part of the state are covered by Tertiary formations. These are chiefly unconsolidated or loosely cemented sandstones and shales. In Logan, Washington, Yuma, Sedgwick and Phillips counties, they are present and cover the underlying Cretaceous so as to mask any structure and make improbable any discovery of oil pools except through pure accident. In the vicinity of Denver we have similarly the so-called Arapahoe and Denver formations, south near Castle Rock and Colorado Springs, the Dawson, and from Pueblo south to the New Mexico line, the Nussbaum. All of these are loosely cemented sandstones and conglomerates equally unfavorable to oil and gas. In the San Juan region, the Tertiary consists chiefly of a thick series of volcanic flows, tuff and breccias often resting directly on the Mancos or underlying rocks. These offer no chance of finding oil and gas. Farther north on the Western Slope we find locally the Fort Union, Wasatch, and the Green River formations. The first two carry coal seams. The Green River carries the important oil shale beds. The Wasatch is the more important from the oil standpoint. Oil shows and gas seeps often furnishing enough gas for domestic purposes for a ranch or two are known along the White River near Meeker, on Turkey Creek, and Beaver Creek, near DeBeque, at Rangeley and elsewhere. The Wasatch consists of an alternation of sandstones, shaly sandstones and sandy shales. The shales are more abundant and more argillaceous in the upper portion and appear to be sufficient to form a seal on the underlying sands. A good structure in the upper part of the Wasatch should, therefore, be considered promising as a possible producer. Small wells only need be expected.

The Green River formation is a series of shales much of which is so carbonaceous as to afford possibilities of commercial treatment for the extraction of oil. Many shale beds are capable of yielding from fifty to eighty gallons per ton. The oil is not present as such, but rather as partially altered organic remains which, upon destructive distillation, are broken up into oil. The chances of finding commercial oil pools in this shale are very slight. Locally oil seeps occur and near Dragon, Utah, a very small production is obtained from tunnels driven into the shale.

SUMMARY The Wasatch is the most promising of the Tertiary formations for the occurrence of oil pools. The widespread occurrence of oil seeps and the strong gas shows, coupled with the results of past drilling, all seem to indicate that a good structure would be likely to yield commercial wells of small capacity. Of all the formations mentioned, it ranks next to the Benton and Hygiene as a possible producer.

The Carboniferous

By far the greater part of the oil production of Kansas, Oklahoma, Illinois, and the north of Texas is derived from the rocks of Carboniferous age. There is also a small production of heavy black oil from the Carboniferous of Wyoming at Thermopolis and in the Lander oil fields. It is natural, therefore, that the Carboniferous formations of Colorado should attract attention. Much interest has been aroused in the southeastern part of the state which undoubtedly deserves careful investigation. In this part of the state, also, the Cretaceous formations are the most promising. The Carboniferous, however, have attracted the most attention, and the nearness to the Oklahoma line is frequently cited as a proof of the likelihood and even the certainty of the existence of oil pools. As a matter of fact, northwestern Oklahoma does not contain any important oil and gas fields. A number of wells have been drilled there without success. We may safely conclude that the chances of getting commercial production in the Carboniferous in southeastern Colorado are no better than in northwestern Oklahoma. An additional element of uncertainty is the lack of knowledge of the character of the Carboniferous rocks. The possible oil-bearing horizons are not exposed nearer than the foothills of the Front Range to the west and the central part of Oklahoma to the east. There has been a great change in the lithological character of these formations between these two points. The marine series of shales and sandstones at the top of the Carboniferous in Oklahoma and Kansas have given place to the series of "Red Beds" of Colorado deposited under conditions of aridity and, therefore, distinctly unfavorable to oil. The lower part of the Carboniferous in both localities consists essentially of marine limestones. No production of any consequence has been encountered in these. The existence of oil reservoirs in the Carboniferous in southeastern Colorado is, therefore, problematical. Any attempt to drill to this horizon should only be undertaken by those abundantly able to bear the financial burden, with the full knowledge that the chances for success are less promising than could be desired, and probably not commensurate with the risks involved, because of great depth of drilling and the excessive cost.

The Carboniferous is also attracting interest at present in the vicinity of Pueblo, where several wells are being drilled to a depth of about three thousand five hundred feet. Several are located on well-defined structures, and should result in a thorough test of this formation, although the writer believes that here also the chances for success are slight, because of formational characteristics.

CONCLUSION

NATURE OF RESERVOIR SANDS

Colorado lacks persistent sands capable of acting as reservoirs. Those present are either very thin or very much restricted laterally. The most promising sands for oil production are in order:

1. Sandstone at the top of the Carlile.
2. Hygiene sands in the Pierre.
3. Sands in the Wasatch.
4. Carboniferous.

Actual production or very promising shows are or have been obtained from the Pierre at Florence, near Boulder, and near Rangeley; from the Wasatch near DeBeque and White River; from the Mesaverde near DeBeque; and from the Carlile near Eads.

STRUCTURES IN THE STATE

The structure of the most important potential oil producer—the Cretaceous rocks—is relatively simple in the localities where suitable sands are present, as southeastern Colorado, east of Pueblo, or northern Colorado from Denver north to the Wyoming line. Consequently, the possibilities of structural arrangement favorable to oil accumulation are small.

While there are a number of large and well-defined structures in the state, it is unfortunately true that the more promising horizons of the Cretaceous are eroded off the surface, or are absent, or are so deeply buried as to be out of reach of the drill. Large fields need, therefore, not be expected in Colorado. The chances are bright of finding a few widely scattered fields with wells of small capacity, yielding a high-grade oil.

REFERENCES

This list includes a few of the more important publications on the subject to which the reader is referred for detailed information.

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SCHOOL OF MINES
COLORADO

QUARTERLY

Vol. XIV No. 1

CATALOGUE EDITION

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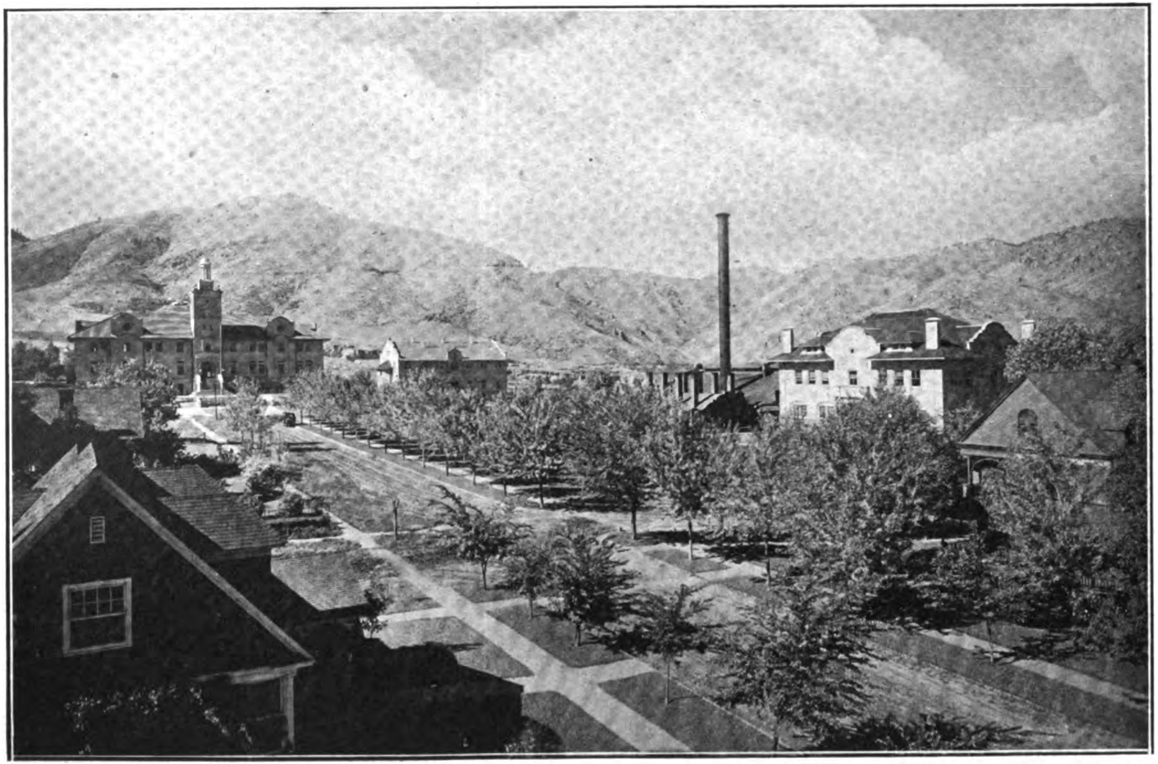

The Campus

QUARTERLY

OF THE

COLORADO SCHOOL OF MINES

Vol. XIV No. 1

Catalogue Edition

GOLDEN, COLORADO

1919

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CALENDAR

1919

January 4, Saturday	Christmas Recess ends
January 18, Saturday	First Semester ends
January 20, Monday	Second Semester begins
February 12, Wednesday	Lincoln's Birthday (a holiday)
February 22, Saturday	Washington's Birthday (a holiday)
May 23, Friday	Second Semester ends Commencement Exercises
May 26, Monday	Summer Field Work begins
July 5, Saturday	Summer Field Work ends
July 14, Monday	Summer School begins
August 23, Saturday	Summer School ends
August 27, Wednesday August 28, Thursday August 29, Friday	Examinations for entrance to the Class of 1922 and re-examination of matriculated students.
September 1, Monday September 2, Tuesday	Registration
September 3, Wednesday	Opening of the First Semester of the Academic Year 1919-20
November 27, Thursday November 28, Friday November 29, Saturday	Thanksgiving Recess
December 22, Monday	Christmas Recess begins

1920

January 3, Saturday	Christmas Recess ends
January 17, Saturday	First Semester ends
January 19, Monday	Second Semester begins

BOARD OF TRUSTEES

The regular meetings of the Board of Trustees are held in Golden at the School of Mines on the second Thursday of each month.

HONORARY DEGREES

The honorary degree of E.M. (Engineer of Mines) has been conferred as follows:

CAPTAIN E. L. BERTHOUD, 1890
Golden, Colo.
Deceased.

GENERAL IRVING HALE, 1895
Denver, Colo.

A. A. BLOW, 1897
Ware Neck, Va.
Deceased.

FRANK BULKLEY, 1898
Denver, Colo.

JOHN HAYS HAMMOND, 1909
New York, N. Y.

WALTER G. SWART, 1917
Duluth, Minn.

H. G. HARDINGE, 1917
New York, N. Y.

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President Emeritus
Special Lecturer in Metallurgy and Chemistry

PAUL MEYER, Ph. D., (Giessen)
Professor Emeritus of Mathematics

WILLIAM JONATHAN HAZARD, E. E., (Colorado School of Mines)
Professor of Electrical Engineering
(On leave of absence, 1918-19)

HARRY JOHN WOLF, E. M., M. S., (Colorado School of Mines)
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Joseph A. Holmes, Memorial Professor of Safety and Efficiency Engineering;
Professor of Coal Mining.

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(On leave of absence, 1918-19)

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(On leave of absence, 1918-19)

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(On leave of absence, 1918-19)

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President Denver Engineering Works Company
The Development of Modern Mill Systems
Recent Advances in Coarse Crushing

WALTER G. SWART, Duluth, Minn.
Mining Engineer
Recent Developments in Dry Milling
Modern Practice in Zinc Metallurgy
Electrostatic Ore Separation

THOMAS B. CROWE, Victor, Colo.
Superintendent New Portland Mill
The Metallurgy of Cripple Creek Ores

JOHN A. TRAYLOR, New York, N. Y.
President Traylor Engineering Works Co.
Jigs

L. S. PIERCE, Denver, Colo.
The Pierce Amalgamator

W. H. TRASK, Jr., Denver, Colo.
Central Colorado Power Co.
Hoisting

JOHN L. MALM, Denver, Colo.
Metallurgical Engineer
The Future of Chemical Engineering

JAMES M. McCLAVE, Denver, Colo.
Metallurgist
Ore Concentration

PHILIP ARGALL, Denver, Colo.
Consulting Metallurgist
The Flotation Process

WAYNE C. WILLIAMS, Denver, Colo.
State Industrial Commission
The Colorado Workmen's Compension Act

NEWCOMB CLEVELAND, Denver, Colo.
Ocean Accident and Guarantee Co.
The Insurance Angle of Our Workmen's Compensation Act

H. S. SHELDON, Denver, Colo.
Vindicator Consolidated Gold Mining Co.
Gold Mining Camps in Colorado

JAMES H. PLATT, Toluca, Mexico
Mining Engineer
Mining Conditions in Mexico

DR. HENRY M. PAYNE, New York, N. Y.
Consulting Engineer, Goldfields Consolidated Co.
Alaska Gold Placers
Siberian Gold Placers

FRED CARROLL, Denver, Colo.
State Commissioner of Mines
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American Red Cross Society
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CHAUNCEY E. TENNANT, M. D., Denver, Colo.
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United States Bureau of Mines
Miner's Consumption

R. M. SHUMWAY, Denver, Colo.
Rocky Mountain Fuel Co.
Coal Deposits and Coal Mining in Colorado

CAPTAIN GODFREY L. CARDEN, U. S. A.
Service in the U. S. Coast Guard

REV. CHAS. L. MEAD, Denver, Colo.
The Y. M. C. A. Work in France

BENEDICT SHUBART, Denver, Colo.
Lindrooth, Shubart & Co.
Coal Cutting Machinery

RICHARD A. PARKER, Denver, Colo.
Suggestions to Young Mining Engineers

A. J. R. CURTIS, Chicago, Ill.
Portland Cement Association
Concrete Ships

M. G. HODNETTE, Denver, Colo.
German Propaganda

LOCATION AND DESCRIPTION, HISTORY, ORGANIZATION, AND FINANCIAL SUPPORT

LOCATION AND DESCRIPTION The Colorado School of Mines is in the south central part of the City of Golden, Jefferson County, Colorado. It occupies a plat of approximately twenty-three acres, picturesquely situated about 200 feet above the bed of Clear Creek, at the base of the scenic front range which lies about fifty miles to the east of the main range of the Rocky Mountains. Farther east, about thirteen miles, lies the city of Denver which can be reached by three railway lines: the Denver and Intermountain Railroad, Arapahoe Street Station; the Denver and Northwestern Railway, Arapahoe Street Station, or Union Depot; or the Colorado & Southern Railway, Union Depot.

Golden has about three thousand inhabitants and is one of the oldest cities in Colorado. The altitude is five thousand seven hundred feet above sea level, or about four hundred fifty feet above Denver. The climate is invigorating and bracing, with open winters and a large proportion of clear days.

The Colorado School of Mines is particularly fortunate in its natural surroundings and proximity to a rich, practical laboratory. The state of Colorado is famous for its basic industries, the mining of gold, silver, and the baser metals, all of which, together with their allied branches of industry, are highly developed within a relatively small area, of which every part is easily accessible from Golden. In addition, the vanadium, tungsten, uranium, and radium fields are better represented here than in any other part of the world. In view of its great number and variety of mining and metallurgical enterprises, the state offers unexcelled opportunities for practical study.

The school is fortunately situated for the geologist. The surrounding formations not only present the strikingly clear features so characteristic of the west, but also occur in great profusion and variety. In addition, certain features peculiar to this locality afford sufficiently complicated problems to be of great value to the student of geology. It is possible, therefore, without going more than a mile or two from the school, to illustrate effectively most geological problems so that field geology can be carried on at the same time with class instruction.

In the immediate vicinity of Golden are numerous clay mines which produce pottery clay and fire clay; also lime and stone quarries. Within a few miles are extensive coal mines well equipped with hoisting and power machinery; and the sites of dredging and placer operations.

In Clear Creek Canon, a short distance west of Golden, are the historic mining Camps of Central City, Black Hawk, Idaho Springs, and Georgetown, where placer drift mining is carried on in the old river beds, and a great variety of lode mines and milling plants are in operation. The ores of this district vary from free-milling gold quartz to complex silver-lead-zinc ores.

Farther west is the camp of Breckenridge, where placer mining is carried on, and the mining camps of Montezuma, Kokomo, and Robinson. To the southwest is the famous Leadville district, well known for its rich lead and zinc ores. West of Leadville is the once renowned silver mining camp of Aspen, and to the north of Leadville are the lead-zinc camps of Redcliff and Gilman.

At the Globe plant of the American Smelting and Refining Company in Denver the treatment of lead ores and dry ores of gold and silver is illustrated. Here, also, the many mining and metallurgical machinery plants afford an excellent opportunity for the study of recent improvements in metallurgical design.

West of Colorado Springs are located the Portland, the Standard, and the Golden Cycle Mills, which treat ore from the Cripple Creek district. Farther west are the prominent camps of Victor and Cripple Creek, in which are located some of the famous gold mines of the world. Near Victor are the well known Independence, the Portland, and the Ajax Mills, where low-grade Cripple Creek ores are successfully treated.

The plant of the Colorado Fuel and Iron Company, at Pueblo, possesses many approved devices for the production of iron and steel and for the working of these products into marketable forms. At Pueblo are located the Pueblo lead smeltery and the zinc smeltery of the United States Zinc Company. At Canon City is the plant of the Empire Zinc Company. The Ohio and Colorado smeltery is located at Salida, and the Arkansas Valley smeltery at Leadville.

In the southwestern part of Colorado is the famous San Juan mining district, which includes the well known camps of Ouray, Telluride, Silverton, and Lake City, where many great mines are located and some of the most efficient milling plants in the world are to be found.

Coal mining is well represented in Colorado by the bituminous mines of the northern coal fields, the anthracite fields of

Glenwood Springs, the coal fields of Trinidad, and numerous smaller fields. Oil fields are being developed and operated at Florence and at Boulder.

Many prominent mining camps in neighboring states are easily reached from Golden. Among these are the great copper districts of Montana, Utah, and Arizona, where the latest mining, milling, and smelting operations are in progress: the iron mines of Wyoming; and the gold mining camps of South Dakota.

No other mining school in the world has within easy access such a wide variety of mining properties, or such excellent opportunities for observing the latest and best milling and smelting operations.

HISTORY The Colorado School of Mines was established by an act of the Territorial Legislature, approved February 9, 1974. Since that time the School has enjoyed a strong and steady growth in buildings, in equipment, in students, in faculty, and in the strength and rigor of its courses. Additions were made to the original buildings in 1880, by the building of 1882, and by the building of 1890, all of which are now united and called the Hall of Chemistry. The Hall of Physics was erected in 1894, the Assay Laboratory in 1900, and Stratton Hall in 1904. The Heating, Lighting, and Power Plant was completed in 1906. The Administration Building, named Simon Guggenheim Hall for the donor, was also erected in 1906. The Gymnasium was completed in 1908. The Experimental Ore Dressing and Metallurgical Building was completed in 1912.

ORGANIZATION The general management of the School is vested by statute in a Board of Trustees, which consists of five members appointed by the Governor of the state, with the advice and consent of the Senate. The members of the Board of Trustees are appointed in alternating sets of two and three, and hold their office for a period of four years and until their successors are appointed and qualified. The Constitution of Colorado recognizes the School of Mines as an Institution of the State.

FINANCIAL SUPPORT The Colorado School of Mines is supported by the income derived from an annual mill tax of the state. This is known as the "School of Mines Tax:"

BUILDINGS

SIMON GUGGENHEIM HALL —Administration Building This building, the gift of Senator Simon Guggenheim, was erected and furnished at a cost of $80,000. The corner-stone was laid by the A. F. and A. M. of Colorado, October 3, 1905. It is 164 feet long by 57 feet wide and is surmounted by an ornate tower. The first floor is devoted entirely to the department of geology and mineralogy, and includes lecture room, laboratory, offices, two work rooms, and a public museum; the second floor contains the library, the offices of the President and Registrar, the Faculty and Trustees' room; the third floor contains the Assembly Hall, two lecture rooms for mathematics, an office, and the Tau Betá Pi room. The building was dedicated October 17, 1906.

HALL OF CHEMISTRY This is a continuous group of brick buildings which comprise the buildings of 1880, 1882, and 1890. The combined buildings of 1880 and 1882 contain the main chemical laboratories. In the building of 1890 are the office and laboratory of the professor of chemistry, the chemical lecture room, the chemical store room, the physics laboratory, three recitation rooms, the laboratories for gas, fuel and spectroscopic analysis, the freshman and sophomore drawing room, and the safety efficiency laboratories.

ASSAY BUILDING This building, forty-six by ninety-two feet, was built in 1900 with funds contributed by the late W. S. Stratton, and enlarged in 1905. The design and equipment of this building make it one of the best of its kind in the country.

GYMNASIUM This building, costing $65,000, was completed in September, 1908. The first floor contains a large swimming pool, shower bath, and locker room, finished in white marble and tiling. The second floor contains the offices of the athletic director, athletic board and secretary of the Y. M. C. A.; the Theta Tau room and the Integral Club room. The entire third floor is occupied by the gymnasium room proper. This contains fifty-two hundred square feet of clear floor space and a balcony which provides accommodations for two hundred spectators.

HEATING, LIGHTING, AND POWER HOUSE The power plant, erected at a cost of $40,000, is designed to furnish light, heat, and power to the entire school. It is a simple but artistic brick building, eighty-three by one hundred twenty-two feet, with concrete floors and tile roof. The building is divided lengthwise into an engine room thirty-four feet wide, and a boiler room forty-five feet wide. A brick-lined steel stack one hundred twenty-five feet high carries all smoke to the upper air and away from the buildings.

STRATTON HALL The corner-stone of this building was laid by the A. F. and A. M. of Colorado, on November 20, 1902, and the building was completed in January, 1904. The first floor contains two large lecture rooms, each with apparatus room and private office. One-half of the second floor accommodates the surveying and mechanics in one large lecture room, with apparatus room and private office, and the other half contains a class room. The third floor is devoted entirely to a large drafting room for the junior and senior classes. The structure was named in honor of the late W. S. Stratton, who contributed $25,000 toward its cost.

THE EXPERIMENTAL ORE DRESSING AND METALLURGICAL BUILDING This building, 100 by 150 feet, erected in 1912, was made possible by an appropriation of $100,000 by the legislature of Colorado. It is situated a short distance from the campus, on the bank of Clear Creek. It is intended to be not only a laboratory for the use of the students in ore dressing and metallurgy, but also a testing plant for the benefit of the mining industry. It is the largest and most complete plant of its kind in the United States.

RESIDENCE OF THE PRESIDENT This is a brick building of two and one-half stories. It was built in 1888.

CARPENTER SHOP This is well equipped for the special demands which are continually arising in a technical school. The work varies from ordinary repair work to the careful construction of special apparatus needed in the various laboratories.

MACHINE SHOP This contains the necessary machinery for the maintenance and repair of equipment, and also for the construction of such apparatus as is required for carrying on any new or original work.

LABORATORIES AND EQUIPMENT

THE EXPERIMENTAL ORE DRESSING AND METALLURGICAL PLANT

The Building The experimental plant is situated on the bank of Clear Creek, a few blocks from the campus of the school. The building is ninety-eight by one hundred forty-one feet eight inches on the ground floor. The framework is of structural steel resting on concrete foundations which have been carried down to a substantial bed of gravel. The walls consist of two and one-half inches of cement mortar, reinforced by "hy-rib," and are of natural cement color. The roof is of elaterite resting on a two-inch sheathing of matched Oregon fir. The ground floor is concrete and is divided into three benches. Above the ground floor, but covering only a part of the area, are two suspended floors of reinforced concrete, supported by steel framework. The building is well lighted and is properly ventilated.

Power All machinery and apparatus requiring power are operated by alternating current motors supplied with current from the power house. For the generation of the current required, a producer gas-power generator unit of 100 kv-a. capacity has been installed in the power house. This unit is of Westinghouse design and consists of a bituminous suction gas producer, a vertical three-cylinder gas engine, and a direct-connected alternating current generator.

The producer has a number of noteworthy features. The principal one, and the one which contributes so largely to its success, consists of the two distinct fire zones. This feature makes it possible to operate successfully on very low-grade fuel, and eliminates the difficulties usually arising from the tar and hydrocarbons given off and deposited during the process of gas making. Ordinary Colorado lignite coal is used. From this is produced a cool, clean gas with a heat value of from 115 to 130 B.t.u. a cubic foot. To eliminate the loss of power on account of a reduced intake pressure, a motor-driven, positive-pressure type of exhauster is used. This draws the gas from the producer and delivers it to the engine at a pressure corresponding to about four inches of water.

The engine is of the standard Westinghouse vertical three-cylinder type, single acting, and using a four-stroke cycle. The cylinders are 15-inch diameter by 14-inch stroke. At a speed of 257 revolutions a minute, the engine operating on the producer gas, delivers 118 b.h.p. Compressed air is used for starting, and both engine and producer can be started readily, even though they have stood idle for several days.

Direct-connected to the engine through a spring coupling is a 100 kv-a, 2,300-volt three-phase, 60-cycle generator. The current is transmitted at this voltage to the experimental plant where it is stepped down to the working voltage of 440. The installation is such that the 100 kv-a. machine can be operated in parallel with a steam turbine in the power house. In case of an emergency all power can be supplied from the turbine alone.

Sections The plant contains four sections or units—sampling, concentration, cyanidation, and a fourth devoted to roasting and special features such as magnetic and electrostatic separation and flotation. For general equipment the plant contains a Curtis air compressor, bucket elevator, two motor operated platform elevators which give control over all the floors, a Ruggles-Cole's dryer, ore bins, track scales, turn tables, and ore cars.

Sampling. This section contains the following equipment: one Vezin sampler, one Brunton sampler, one portable feed hopper, one set of 8 by 20 inch Traylor rolls, one dust collector, accessories for finishing the sample, such as laboratory crushers and pulverizers, bucking board, and sample riffles, one complete crude oil assay furnace outfit, and equipment for chemical analysis.

Concentration. This section contains: one 7 by 10 inch Blake crusher, one 2 D Gates gyratory crusher, one set of 14 by 30 inch P. and M. M. rolls, one set 12 by 24 inch P. and M. M. rolls, one 3.5-foot Huntington mill, one 3.5-foot Akron Chilean mill for regrinding, one Richards pulsator jig, one Harz jig of one compartment, one Harz jig of four compartments, one No. 6 Wilfley table, one Deister sand table, one Deister slime table, one Richards pulsator classifier, one Johnston vanner, one three compartment classifier, two Callow cones, five 850 lb. gravity stamps equipped with amalgamating plates, one 2 foot amalgamating pan made by the Denver Engineering Works Co., Pierce amalgamator, and clean up pans, also grizzlies, impact and revolving screens, sand pumps, elevators, and concentrate driers.

For preliminary concentration: one Callow miniature ore testing plant, which includes one 24 inch Wilfley table, one two compartment jig, one set hydraulic classifiers, one 6 in. by 4 ft. amalgamating plate, one quarter-size Butchart table, one-quarter size Wilfley table, and one-quarter size Card table.

Cyanidation. This section contains: one 3.5 by 10 foot Pachuca tank, one Paterson agitator, one Dorr classifier, one Dorr thickener, one Butters filter, one 2 by 3 foot Oliver filter, one Gould wet vacuum pump, one 4 by 10 foot Denver Engineering Works tube mill, one thickening cone, one six compartment zinc box, one lead lined acid tank, one filter press for zinc slime, solution storage tanks; also small scale apparatus in the shape of agitators and precipitating devices.

Special Section. This section contains one Wetherill electromagnetic separator, one Dings electromagnetic separator, one Huff electrostatic separator, two laboratory size Callow pneumatic flotation cells, three laboratory size flotation machines, mineral separation type, one 6-cell Minerals Separation flotation machine, one Jones-Belmont laboratory size flotation machine.

Provision is made in this section for the installation of special machinery whereby its efficiency may be tested and comparison made with standard apparatus: for testing by roasting and magnetic or electrostatic separation, by dry tabling, and by such new processes and apparatus as may, from time to time, come before the metallurgical and mining public.

Research Features Besides supplying the students of the school with a splendid laboratory and thereby increasing the efficiency of their studies, the plant can be used as a research laboratory by the faculty and the alumni of the school.

COLLECTION OF COMMERCIAL ORES Most collections of ores are classified according to their mineral contents, but the department of mining is pursuing the policy of gathering average ore samples from every mining district. These are arranged geographically so that the typical ores of each mining district are placed together. Such an arrangement is found to be of great educational value to the classes in mining. The collection now numbers about 1,250 specimens.

MINERALOGICAL AND GEOLOGICAL LABORATORY AND CABINET Under the name cabinet is embraced not only the display collections, which may perhaps be called the cabinet proper, but also the other collections that have been prepared mainly for the purpose of class instruction. These collections are necessarily changing from year to year, as new material is constantly being added. This new material is obtained partly by purchase, but mainly by direct collecting, by gifts, and by means of exchange with other institutions. The display collections are not thoroughly classified, but are arranged in different cases with a view to displaying certain groups of minerals, or minerals from certain localities. The various collections, which together contain sixty-six thousand specimens, consist of display, type, and working or study collections of minerals, fossils, rocks, and ores. The rock collections include a general collection from different countries, one devoted to Colorado localities, and still others that cover particular countries or localities.

MINERALOGICAL LABORATORY Aside from the special advantages due to location, the department of geology is well equipped for practical teaching. The entire first floor of Guggenheim Hall is occupied by this department. The south end of the building is occupied by a commodious lecture room, with a seating capacity of more than a hundred, and by a separate mineralogical laboratory with table space for between fifty and sixty students, also by two small recitation rooms. On the extreme north end of the building is the public museum, devoted to a display of fine minerals. Additional space is provided for working rooms, office, packing, and storage rooms.

METALLURGICAL COLLECTIONS The School has a fine collection of models from the works of Theodore Gersdorf, Freiberg, Saxony, which illustrate types of furnaces in this and other countries. Each model is made to scale and is complete in every detail. In addition to these models are the following to illustrate the best modern practice: working model of a twenty-stamp mill, on a scale of one and one-half inches to the foot; working model of crushing rolls; working model of a Dodge crusher; model of modern blast furnace for lead-silver ores, with water jackets, smaller models, such as the complete set used in the famous Keyes and Arents lead-well suit. There is also a large collection of ores, ore dressing and metallurgical samples and products.

METALLURGICAL LABORATORY This laboratory is equipped with apparatus for the study of the quantitative relations of the various agencies taking part in metallurgical changes. The Junker, the Mahler Bomb, and the Parr calorimeters, the Wanner optical, the Le Chatelier, and Bristol electrical pyrometers, together with several electrical furnaces and a Hoskin gasoline furnace, are used for obtaining the desired temperature for experimentation. Desks and apparatus are provided for small-scale work in concentration, amalgamation, chlorination, and cyanidation. Ten separate flotation cells of the Minerals Separation Company's type and a Callow pneumatic cell, all power driven, are provided for the experimental work in the flotation process. The necessary chemical equipment for analyses is also provided. For the physical examination of ores and metallurgical products, five small dissecting, two Leitz, and one Bausch and Lomb compound metallographic microscopes are provided. The necessary standard screens are available. Provision for large scale work is made in the experimental ore dressing and metallurgical plant.

ASSAY LABORATORY This laboratory is divided into parting, balance, furnace, storeroom, and office. It is equipped with thirty-two coal-fired muffle furnaces, seven Case distillate furnaces, one gasoline furnace, two Braun cupel machines, two Iler cupel machines, and two bullion rolls, one of which is of the Braun type. In order to avoid dust, change of temperature, and direct sunlight, the balance room has no outside walls, and is lighted by means of skylight. The equipment includes seven special pulp balances, five silver balances, three gold balances, one Thompson multiple rider balance, and one Mine & Smelter Supply Company button balance, Wilfred Heusser type, No. 1000, sensitive to .002 milligram. This variety is selected in order to acquaint the student with the various mechanisms and adjustments in assay balances. Each student has his own muffle, with his own coal bin, pulp balance, and desk, conveniently arranged with regard to his furnace; he has also access in the balance room to the best type of assay and pulp balances.

SURVEYING EQUIPMENT The equipment of the department for surveying is well adapted to the practical course given. For transit work there are twenty-four light mountain transits, of which eleven are equipped for underground surveys. There are also three heavy transits, one of which is of English and one of German make. In addition to the transits there are three plane tables for taking topography. For leveling, seven wye levels and five dumpy levels of standard manufacture are used. The department is well supplied with leveling rods of various makes and types, stadia rods, tapes, hand levels, pocket transits, range poles, and other accessories. The instruments are manufactured by such well known firms as C. L. Berger & Sons, Buff & Buff, Heller & Brightly, Eugene Dietzgen & Co., Peter Herr & Co., W. and L. E. Gurley, Keuffel & Esser, William Ainsworth & Sons, Weiss & Heitzler, Young & Sons, Negretti & Zambra (English), and Max Hildebrand (German).

CHEMICAL LABORATORIES The freshman, sophomore, and junior laboratories accommodate two hundred and fifty students, and are equipped with especially designed tile-topped oak desks, provided with low reagent shelves, gas, water, filter pumps, and large porcelain sinks. The balance rooms are equipped with Sartorius, Becker, Ainsworth, and Spoerhave balances. Gas is supplied to the building from a 300-light Detroit gas machine, which is connected with buried supply tanks outside the buildings. Good ventilation is obtained by means of two Sturtevant fans.

HYDRAULIC LABORATORY The hydraulic laboratory contains weirs and orifice tanks for the determination of coefficients of discharge, calibrated tanks for water measurements, a steel pressure tank for artificial heads, pumps for water supply, and gages for pressure. A hydraulic ram is used to illustrate this class of apparatus and for testing. A long, sheet-iron trough with a car over it is used for calibrating current meters. Water wheels and centrifugal pumps are tested for efficiency under various conditions of head and load. A swinging tank is used to measure jet reactions. Friction losses in pipes and elbows are measured. Hook gages are used for the accurate determination of low heads. Streams and ditches in the vicinity of Golden are gaged by means of the current meter, by rod floats, by slope, and by a Pitot tube. A two-inch Venturi meter and manometer set is used in measuring pipe flow.

PHYSICAL LABORATORIES The physical laboratory is in the basement of the Chemistry Building. Adjoining the main laboratory is a balance and instrument room, and a dark room containing a complete Lummer-Brodhun photometer and an optical bench. The equipment is particularly adapted to the instruction of students of engineering, and is designed to teach the principles of elasticity and efficiency of machines, composition and resolution of forces, various forms of motion, density, velocity and pitch of sound, focal length of lenses, magnifying power, and the principles of the construction of telescopes. The heat equipment is particularly well adapted for calorimetry, heat expansion determinations, and for the determining of the mechanical equivalent of heat. A complete line of galvanometers, standard resistances, condensers, ammeters, voltmeters, dynamometers, permeameters, potentiometers, standard cells, and a Kelvin balance compose the electrical apparatus; in magnetism all the principles which underlie the construction of magnets for lifting purposes and for the separation of ores are demonstrated in the laboratory.

TESTING LABORATORY The laboratory is provided with a motor-driven 100,000-pound Riehle testing machine arranged for experiments in tension, compression, shearing, and flexure of materials. Extensometers for measuring elongations and compressions are employed. Numerous steel sections provide useful problems in determining centers of gravity and moments of inertia.

The equipment for cement testing includes a 2,000-pound Riehle testing machine, and a 2,000-pound Olsen automatic shot cement-testing machine for testing briquettes in tension. The specific gravity of cement is determined by means of the Le Chatelier apparatus. A nest of fineness sieves and a set of very sensitive scales equip the student for the fineness test. Setting is determined by means of the complete Vicat apparatus. Trowels, spatulas, large slate mixing boards, beakers, moulds, damp box, and immersing vats, provide apparatus for the making and setting of briquettes and for the soundness tests. Moulds are used for making cubes and cylinders of concrete for compression tests. The use of reinforced concrete is illustrated by complete models of forms for the manufacture of reinforced concrete columns and beams, and by numerous samples of various kinds of reinforcing bars.

ELECTRICAL LABORATORY This laboratory is equipped with standard makes of volt-meters, ammeters, and watt-meters, inductive and non-inductive resistances for artificial loads, a Thomson apparatus for induction experiments, a slip indicator for induction motors, an automatic speed recorder which can be used for finding the acceleration curves of motors, an Alden absorption dynamometer for motor testing, a contact apparatus for alternating current and voltage wave form, and a split phase rotary field apparatus. The generators available for laboratory work include a 100 kv-a, 2,300 volt, 60 cycle, 3 phase Westinghouse alternator, driven by a Westinghouse producer gas engine, a 75 kw. 230 volt, 3 wire, d.c. Westinghouse generator, driven by a 112 h.p. 2,300 volt, 3 phase, synchronous motor, a 75 kw. Bullock twin unit continuous current generator set, driven by a 110 h.p. De Laval turbine, a 30 kw. 1,100 volt, 125 cycle, single phase General Electric alternator, a 15 kw. 130 volt compound, continuous current generator designed and built at the school, an 8 kw. Crocker-Wheeler generator, a 6 kw. 130 volt Westinghouse generator, a 7.5 kw. 125 volt compound machine, a 3 kw. 5 and 10 volt electrolytic generator, a small single phase rotary converter, a 2 kw. 120 volt compound Brush machine, a series arc light machine, and a small Edison shunt generator. The Bullock generators can be connected at the switchboard to supply the 120-240 volt 3 wire lighting and power circuits, or they can be put in parallel and thus supply more than 600 amperes for electrothermic work. The motors include a 10 h.p. 220 volt, 60 cycle, 3 phase constant speed induction motor of General Electric make, two 5 h.p. series motors with controllers, a 5 h.p.

3 phase, two-speed induction motor, used for electric drilling, a 4 h.p. single-phase Wagner motor, a 400-2,000 rev. per min. adjustable speed experimental motor designed and built at the school, a 20 h.p. series motor, and a large number of 3 phase motors and shunt machines of standard makes in daily use about the shops and buildings. The storage batteries of 54 cells each are in daily use and are available for study. In addition to these generators and motors, a modern 5 panel d.c. switchboard and 7 panel a.c. and d.c. switchboard with the usual instruments, switches, and auxiliaries, afford excellent opportunities for the study of electric plant equipment. The engine room is utilized as a part of the dynamo laboratory, but the laboratory in Stratton Hall, equipped with numerous circuit outlets and portable instruments, is used chiefly for the study of motors and their auxiliaries. At present there are 78 generators and motors available for study. Transformers up to 80,000 volts are in use.

MINING LABORATORY The laboratory work in mining is carried on principally at the tunnel belonging to the school. The equipment here consists of numerous drills which are taken apart, reassembled, and used by the student; forges, anvils and tools for blacksmithing; the air receiver, valves, gages, fuses and switches connected with the compressed air and electric power transmission from the power plant; two mining cars; materials for track laying, and all other supplies usually found at a tunnel house. Among the makes of rock drills used by the students are Rand, Ingersoll, Sergeant, Leyner, McKiernan, Wood, Hardsocg, Shaw, Ingersoll-Leyner, Dreadnaught, Waugh, and Temple-Ingersoll. All of the mountings, such as bars, tripods, and arms, and a supply of drill steel, are also provided. For the measurement of air consumption in drilling operations, the Clark, Drillometer, and displacement meters are installed. Batteries, galvanometers, and rheostats are provided in connection with electric shot firing. In the laboratory at the school are two working size models of the Bleichert system of aerial trams; numerous models of mines; an explosive tester; a collection of rock cores taken by diamond drills; models of timbering methods; many mine maps; instruments for measuring ventilation; lantern slides illustrating mining operations; samples of wire ropes and drill steels; lamps of the open and safety patterns; a dry placering machine; and many photographs of mines and operations.

MECHANICAL ENGINEERING LABORATORY The heating, lighting, and power plant is well equipped for mechanical engineering laboratory practice. The boiler room contains the following principal equipment. One 200 h.p. and one 100 h.p. Babcock & Wilcox water tube boilers, each equipped with a chain grate; one 80 h.p. tubular boiler equipped with plain grate; Green Engineering Company fuel economizers; Babcock & Wilcox independently fired super-heater; Webster feed-water heater, boiler feed and vacuum pumps and injectors; one Wilcox water weigher; a 125 by 5-foot self-supporting steel stack supplemented by a steam-driven 42-inch Sirocco fan for induced draft; eight 25-ton steel bunkers for coal storage; and a 125 h.p. Westinghouse double-flow gas producer equipped with wet and dry scrubbers, mixing and gas storage tank, and motor-driven exhauster.

The engine room contains the following principal apparatus: 10 by 12-inch high speed Russell engine; 6 by 9-inch throttling Sturtevant engine: 75 kw. De Laval steam turbine geared to twin generators; 7 by 6-inch two-cylinder vertical Westinghouse Jr. engine; 15 by 14-inch three-cylinder vertical Westinghouse gas engine direct connected to alternator; 6.75 by 14-inch single Fairbanks, Morse & Company gas engine; 8.75 by 14-inch Priestman oil engine; a Studebaker four-cylinder automobile motor; a J. George Leyner Engineering Works two-stage air compressor, capacity 275 cubic feet of free air per minute; and a small Westinghouse air-brake.

The laboratory is well equipped with auxiliary apparatus such as indicators, prony brakes, Orsat apparatus, calorimeters and manometers, for conducting experimental work.

SAFETY ENGINEERING LABORATORY The equipment consists of six sets Draeger breathing apparatus, two-hour type; one set Draeger breathing apparatus, one-half hour type; five sets Fluess breathing apparatus, two-hour type; three sets Westfalia breathing apparatus, two-hour type; one set Westfalia breathing apparatus, one-half-hour type; all equipped with extra oxygen cylinders, various accessories, and supplies; four large oxygen cylinders for storage; one refilling pump; one pulmotor; one lungmotor; Edison, Manlite, and Wico electric lamps, with charging station; electric flash lights; various types of safety lamps; stretchers, splints, bandages, compresses, and all other necessary first aid material; fuse, squibs, electric detonators, and shot-firing batteries; mine telephones, mine signs, and other safety and efficiency appliances.

DRAWING ROOMS

Freshman and Sophomore This occupies the upper floor of the Hall of Chemistry. The floor area is about four thousand square feet. It is lighted by windows on the north, east, and west, and by eight large skylights in the roof. A suitable office for the instructors is in a central position, in which all drawings are filed and all records are kept. Each student is provided with a drawing table, a drawer, a drawing board, and a stool. The present equipment accommodates about one hundred fifty students. There are many models to aid the students in their work.

Junior and Senior The entire third floor of Stratton Hall is used for the junior and senior drawings. The room is 90 by 60 feet, lighted by windows and a large skylight. Each student is provided with a drawing table, a drawer, a drawing board, and a stool. Most of the drawing tables are independent and adjustable. The room has recently been equipped with especially constructed tables for the advanced work of the seniors. The present equipment accommodates about 160 students. There is a blue-print room fully equipped with an adjustable printing frame and all other necessary appliances. In one corner of the room is the office of the instructors, where all drawings and records are filed. There are for the use of the students a complete set of trade catalogues and a large number of blue prints from industrial corporations. These are kept up to date.

REQUIREMENTS FOR ENTRANCE

FRESHMAN CLASS

Unit Course. A unit course of study is defined as a course covering a school year of not less than thirty-six weeks, with five weekly periods of at least forty-five minutes each.

Fifteen units are required for entrance, of which ten are specified and five may be chosen from a list of electives.

Specified Units

Essentials of Algebra	1	unit
Advanced Algebra	½	unit
Plane Geometry	1	unit
Solid Geometry	½	unit
English	3	units
History	2	units
Physics	1	unit
Chemistry	1	unit
Specified Units	10	
Elective Units	5	
Total Units for Entrance	15	

Elective Units

The five elective units may be selected from the following list: Drawing, Shop Work, Mathematics, Latin, Greek, French, Spanish, History, English, Science, Psychology, Political Economy. In allowing credit for drawing and shop work two forty-five minute periods will be regarded as equivalent to one forty-five minute period of classroom work. Half units are accepted in all studies except in physics and chemistry, provided that not less than one full unit shall be accepted in language.

Entrance

(a) By Certificate.

A graduate of an accredited high school in the State of Colorado will be admitted without examination upon the presentation of proper credentials from the principal of his high school, provided that the studies he has successfully completed cover the requirements for entrance. Blanks for this purpose will be sent, on application to the Registrar.

Graduates of accredited high schools in other states will be accepted in the same manner as graduates of accredited high schools in Colorado.

(b) By Examination.

All other candidates for admission will be required to pass entrance examination. These examinations are held in Golden.

For the benefit of any student who cannot take the examination in Golden, conveniently, on account of the distance, arrangements will be made so that he may take the examination under the direction of some responsible person at his own home, or near it.

Entrance examinations for the class of 1923 will be held in Golden on Wednesday, Thursday, and Friday, August 27, 28 and 29, 1919.

It is the opinion of the Faculty of the Colorado School of Mines that every candidate for the freshman class should have taken a thorough course of at least four years in a good high school, or its equivalent, and during the last year of his preparation should have had a thorough review of mathematics. Special attention should be given to the preparation in chemistry and physics.

If a first year student is found to be deficient in any of the subjects required for entrance, the faculty reserves the right to require such student to remove his deficiency before proceeding with his regular work.

REGISTRATION

The first Monday and Tuesday of September are the registration days for the first semester; and the first day of the second semester is the registration day for that semester.

DESCRIPTION OF THE UNITS REQUIRED FOR ENTRANCE

ENGLISH (3 Units)

(a) **Grammar** The student should have a sufficient knowledge of English grammar to enable him to point out the syntactical structure of any sentence which he meets in the prescribed reading. He should also be able to state intelligently the leading grammatical principles when he is called upon to do so.

(b) **Reading** The books prescribed by the Joint Committee on Uniform Entrance Requirements in English form the basis for this part of the work.

The list is divided into two parts: the first consists of books to be read with attention to their contents rather than to their form; the second consists of books to be studied thoroughly and minutely.

The lists thus divided are as follows:

I Books prescribed for reading

Group I (Two to be selected)

Shakespeare's *As You Like It*, *Henry V*, *Julius Caesar*, *The Merchant of Venice*, *Twelfth Night*

Group II (One to be selected)

Bacon's *Essays;* Irving's *Life of Washington; The Sir Roger de Coverly Papers* in *The Spectator; Franklin's Autobiography*

Group III (One to be selected)

Chaucer's *Prologue;* Spencer's *Faerie Queéne* (selections); Pope's *The Rape of the Lock;* Goldsmith's *The Deserted Village;* Palgrave's *Golden Treasury* (*First Series*), *Books II and III*, with especial attention to Dryden, Collins, Gray, Cowper and Burns

Group IV (Two to be selected)

Goldsmith's *The Vicar of Wakefield;* Scott's *Ivanhoe;* Scott's *Quentin Durward;* Hawthorne's *The House of the Seven Gables;* Thackeray's *Vanity Fair;* Mrs. Gaskell's *Cranford;* Dickens' *A Tale of Two Cities;* George Eliot's *Silas Marner;* Blackmore's *Lorna Doone*

Group V (Two to be selected)

Irving's *Sketch Book;* Lamb's *Essays of Elia;* De Quincey's *Joan of Arc* and *The English Mail Coach;* Carlyle's *Heroes and Hero Worship;* Emerson's *Essays;* Ruskin's *Sesame and Lilies*

Group VI (Two to be selected)

Coleridge's *The Ancient Mariner;* Scott's *The Lady of the Lake;* Byron's *Mazeppa* and *The Prisoner of Chillon;* Palgrave's *Golden Treasury* (*First Series*), *Book IV*, with especial attention to Wordsworth, Keats, and Shelley; Macaulay's *Lays of Ancient Rome;* Poe's *Poems;* Lowell's *The Vision of Sir Launfal;* Arnold's *Sohrab and Rustum;* Longfellow's *Evangeline;* Tennyson's *Gareth and Lynette*, *Lancelot and Elaine*, and *The Passing of Arthur;* Browning's *Cavalier Tunes*, *The Lost Leader*, *How They Brought the Good News from Ghent to Aix*, *Evelyn Hope*, *Home Thoughts from Abroad*, *Home Thoughts from the Sea*, *Incident of the French Camp*, *The Boy and the Angel*, *One Word More*, *Herve Riel*, *Pheidippides*

II Books prescribed for study and practice

Shakespeare's *Macbeth*, Milton's *Lycidas*, *Comus*, *L'Allegro*, and *Il Penseroso;* Burke's *Speech on Conciliation with America*, or Washington's *Farewell Address* and Webster's *First Bunker Hill Oration;* Macaulay's *Life of Johnson*, or Carlyle's *Essay on Burns*.

(c) **Composition** Regular and persistent training in both written and oral composition should be given throughout the entire school course. The topics should be so chosen as to give practice in the four leading types of prose discourse, namely, description, narration, exposition, and argument

(d) **Rhetoric** The instruction in this subject should include the following particulars: Choice of words, structure of sentences and paragraphs, the principles of narration, description, exposition, and argument.

The teacher should distinguish between those parts of rhetorical theory which are retained in text books merely through the influence of tradition and those which have a direct bearing upon the composition work. The former may be safely omitted.

HISTORY (2 Units)

Any two of the following periods may be offered:

I Ancient History, with special reference to Greek and Roman History, with a short introductory study of the more ancient nations and the chief events of the early middle ages, down to the death of Charlemagne

II Mediaeval and Modern European History, from the death of Charlemagne to the present time

III English History

IV American History, or American History and Civil Government

MATHEMATICS (3 Units)

The courses offered by the school are so exacting that a thorough training in the following subjects is essential:

I **Essentials of Algebra** (1 Unit) The four fundamental operations for rational algebraic expressions; factoring; complex fractions; the solution of equations of the first degree containing one or more unknown quantities; radicals; theory of indices; quadratic equations and equations containing one or more unknown quantities that can be solved by the methods of quadratic equations; problems dependent on such equations.

II **Advanced Algebra** (½ Unit) This course should begin with a thorough review of the essentials. Later work should cover an introduction to the graphical representation of linear and simple quadratic expressions; ratio and proportion; variation; binomial theorem; the progressions; and logarithms.

III **Plane Geometry** (1 Unit) Completed, with the solution of original exercises and numerical problems.

IV **Solid Geometry** (½ Unit) Properties of straight lines and planes; of dihedral and polyhedral angles; of projection; of polyhedrons, including prisms; of pyramids and the regular solids; of cylinders, cones, and spheres; of spherical triangles, and the mensuration of surfaces and solids.

CHEMISTRY (1 Unit)

The equivalent of Brownlee's **Elementary Chemistry**, Bradbury's **Elementary Chemistry**, or McPherson and Henderson's **First Course in Chemistry**, with experiments.

PHYSICS (1 Unit)

The equivalent of Carhart and Chute's **High School Physics**, or Gage's **Principles of Physics**, together with systematic laboratory practice such as is outlined in Crew and Tatnall's **Laboratory Manual in Physics**.

The two units required in languages other than English may be offered in Greek, Latin, French, or Spanish.

ADMISSION TO ADVANCED STANDING

Applicants who are graduates of technical or scientific schools or colleges of good standing will be admitted without examination upon the presentation of proper credentials. They will be permitted to take any subject taught in connection with the regular courses, provided, in the opinion of the instructor, their previous experience and training will enable them to pursue the subject with profit. Each case will be judged on its own merits, but applicants will be advised to become candidates for a degree and to complete one of the regular courses of the school.

Applicants who have partly completed the course in technical or scientific schools or colleges of good standing will be admitted without examination upon the presentation of proper credentials. Due credit will be allowed for the successful completion of work which is equivalent to that given in the Colorado School of Mines. Plates of drawings, laboratory note books, and catalogues of the institution attended, should be submitted with applications for advanced standing. All credits given to advanced standing students are given provisionally, with the understanding that such credits may be withdrawn at any time in case a student fails to maintain a creditable standing. Application blanks will be furnished, on request to the Registrar.

DEGREES

The degree of E. M. (Engineer of Mines) will be conferred upon a candidate who fulfils the following conditions:

(a) He must complete the prescribed work of the freshman and sophomore years.

(b) He must complete the required work in one of the groups: Metal Mining, Coal Mining, Metallurgy, or Mining Geology, and enough additional elective work to make a total of one hundred credit hours. The presentation of a thesis is optional, but if presented six credit hours are allowed for it.

No diploma will be delivered until the full requirements of the course of study are satisfied, and all accounts with the school are settled.

The degree of M. S. (Master of Science) may be conferred upon a candidate who already holds a degree from this school or an equivalent degree from a similar institution of good standing, and whose application for such degree shall have been approved by the faculty; provided, that the candidate completes work equivalent to fifty credit hours, chosen with the approval of the faculty, and presents an acceptable thesis. Before being accepted as a candidate the applicant must file a record of his previous attainments.

DEPARTMENTS OF INSTRUCTION

COURSES OF INSTRUCTION

TABULAR VIEW

FRESHMAN YEAR

FIRST SEMESTER	Page	Lect. Hr.	Lab. Hr.	SECOND SEMESTER	Page	Lect. Hr.	Lab. Hr.
Required				**Required**			
Mathematics I.........	74	3		Mathematics III.......	75	3	
Mathematics II........	75	2		Mathematics IV.......	76	2	
Chemistry I............	44	5		Chemistry II..........	44	5	
Chemistry III..........	44	1		Chemistry IV..........	45	1	
Chemistry V...........	45		6	Chemistry VI.........	45		6
Mechanical Engineering I	78	2		Mechanical Engineering III	78	2	
Mechanical Engineering II	78		6	Mechanical Engineering IV	79		6
Geology and Mineralogy I	68	3		Geology and Mineralogy II	68	3	
Physical Training......				Civil Engineering I....	50	1	
Military Art				Physical Training			
				Military Art			
Elective				**Elective**			
Spanish I..............	113	2		Spanish II............	113	2	

Civil Engineering II (page 51) is given during six weeks of the summer following the close of the freshman year.

TABULAR VIEW

SOPHOMORE YEAR

FIRST SEMESTER	Page	Lect. Hr.	Lab. Hr.	SECOND SEMESTER	Page	Lect. Hr.	Lab. Hr.
Required				**Required**			
Mathematics V........	76	3		Mathematics VI	77	3	
Physics I.............	103	5		Physics III...........	104	5	
Physics II............	104		6	Physics IV...........	104		6
Chemistry VII........	46	1		Chemistry VIII........	46	1	
Chemistry IX..........	46		6	Chemistry X...........	46		6
Mechanical Engineering V	79	2		Mechanical Engineering VII	80	2	
Mechanical Engineering VI	79		3	Mechanical Engineering VIII	80		3
Geology and Mineralogy III	69	2	6	Geology and Mineralogy IV	69	2	6
Metal Mining I	92	1		Metal Mining II.......	93	1	
Physical Training				Physical Training......			
Military Art				Military Art			
Elective				**Elective**			
Spanish III............	114	2		Spanish IV............	114	2	
Mathematics VII.......	77	2		Mathematics VIII......	77	2	

Metal Mining III (page 93) is given during the four weeks of the summer following the close of the sophomore year.

Metal Mining IV (page 94) is given for two weeks of the summer following the close of the sophomore year.

TABULAR VIEW

GROUP I METAL MINING

JUNIOR YEAR

FIRST SEMESTER	Page	Lect. Hr.	Lab. Hr.	SECOND SEMESTER	Page	Lect. Hr.	Lab. Hr.
Required				**Required**			
English I	65	1		Civil Engineering III	51	3	
Mechanical Engineering IX	80	1		English II	65	1	
Mechanical Engineering X	81		6	Geology and Mineralogy VII	71	1	3
Metallurgy I	85	1		Mechanical Engineering XI	81	1	
Metallurgy II	85		9	Mechanical Engineering XII	81		6
Metallurgy III	86	5		Metallurgy IV	86	3	
Metal Mining V	94		3	Metal Mining VII	95	2	
Metal Mining VI	95	2		Metal Mining X	96	3	
Metal Mining VIII	96	2					
Metal Mining IX	96	1					
Physics V	105	3					
Elective				**Elective**			
Chemistry XV	48	2		Chemistry XIII	47	1	
Coal Mining I	56	2		Chemistry XIV	48		6
Geology and Mineralogy V	70	3		Civil Engineering IV	52		6
Geology and Mineralogy VI	70	2		Coal Mining II	56	2	
Electrical Engineering I	61	3		Electrical Engineering III	62	3	
Electrical Engineering II	61		3	Electrical Engineering IV	62		3
Physics VI	105	2		Metallurgy VI	87	2	
Military Art				Military Art			
Safety Engineering I	109	1		Physics VIII	106		3
Safety Engineering II	110		3	Safety Engineering III	111	1	
Spanish V	114	1		Safety Engineering IV	112		3
				Spanish VI	114	1	

TABULAR VIEW

GROUP I METAL MINING

SENIOR YEAR

FIRST SEMESTER	Page	Lect. Hr.	Lab. Hr.
Required			
English III	65	1	
Mechanical Engineering XIV	82	2	
Mechanical Engineering XV	83		6
Metallurgy VII	87	4	
Metallurgy VIII	87		6
Metal Mining XI	97	2	
Metal Mining XIII	98	2	
Elective			
Chemistry XVI	48		3
Civil Engineering VII	53		6
Electrical Engineering V	63	2	
Electrical Engineering VI	63		6
Geology and Mineralogy X	72	2	
Hygiene and Camp Sanitation I	73	1	
Mechanical Engineering XIII	82	2	
Mechanical Engineering XVI	83	2	
Metallurgy XIV	90	2	
Metallurgy XVII	91	1	
Military Art			
Mining Law I	102	1	
Physics IX	106	1	
Thesis. Credit three hours.			

SECOND SEMESTER	Page	Lect. Hr.	Lab. Hr.
Required			
English IV	66	1	
Metal Mining XII	98	2	
Metal Mining XIV	99	1	
Metal Mining XV	100	1	
Elective			
Chemistry XVII	49		3
Civil Engineering V	52	2	
Civil Engineering VI	53		3
Civil Engineering VIII	54		6
Civil Engineering IX	54		6
Coal Mining V	58	2	
Coal Mining VI	59	2	
Coal Mining VII	59	1	
Coal Mining VIII	60		3
Coal Mining IX	60		3
Elec. Engineering VII	64	2	
Elec. Engineering VIII	64		6
Geology and Mineralogy XI	72	2	
Geology and Mineralogy XII	72	3	
Mech. Eng. XVII	83	2	
Mech. Eng. XVIII	84		6
Metallurgy X	88	3	
Metallurgy XI	89		3
Metallurgy XVI	90		3
Military Art			
Mining Law II	102	1	
Physics X	106	1	
Physics XI	107	2	
Physics XII	107		3
Thesis. Credit three hours.			

TABULAR VIEW

GROUP II COAL MINING

JUNIOR YEAR

FIRST SEMESTER	Page	Lect. Hr.	Lab. Hr.
Required			
Coal Mining I	56	2	
English I	65	1	
Metallurgy I	85	1	
Metallurgy II	85		9
Metallurgy III	86	5	
Metal Mining V	94		3
Metal Mining VI	95	2	
Physics V	105	3	
Safety Engineering I	109	1	
Safety Engineering II	110		3
Elective			
Electrical Engineering I	61	3	
Electrical Engineering II	61		3
Geology and Mineralogy V	70	3	
Geology and Mineralogy VI	70	2	
Mechanical Engineering IX	80	1	
Mechanical Engineering X	81		6
Metal Mining VIII	96	2	
Metal Mining IX	96	1	
Military Art			
Physics VII	105		3
Spanish V	114	1	

SECOND SEMESTER	Page	Lect. Hr.	Lab. Hr.
Required			
Civil Engineering III	51	3	
Coal Mining II	56	2	
English II	65	1	
Mechanical Engineering XI	81	1	
Mechanical Engineering XII	81		6
Metallurgy IV	86	3	
Metal Mining VII	95	2	
Safety Engineering III	111	1	
Safety Engineering IV	112		3
Elective			
Civil Engineering IV	52		6
Geology and Mineralogy VII	71	1	3
Electrical Engineering III	62	3	
Electrical Engineering IV	62		3
Metal Mining X	96	3	
Metallurgy VI	87	2	
Military Art			
Physics VIII	106		3
Spanish VI	114	1	

TABULAR VIEW

GROUP II COAL MINING

SENIOR YEAR

FIRST SEMESTER	Page	Lect. Hr.	Lab. Hr.	SECOND SEMESTER	Page	Lect. Hr.	Lab. Hr.
Required				**Required**			
English III	65	1		English IV	66	1	
Coal Mining III	57	2		Coal Mining V	58	2	
Coal Mining IV	58		3	Coal Mining VI	59	2	
Mechanical Engineering XIV	82	2		Coal Mining VII	59	1	
Mechanical Engineering XV	83		6	Coal Mining VIII	60		3
				Coal Mining IX	60		3
Elective				**Elective**			
Chemistry XVI	48		3	Chemistry XVII	49		3
Civil Engineering VII	53		6	Civil Engineering V	52	2	
Electrical Engineering V	63	2		Civil Engineering VI	53		3
Electrical Engineering VI	63		6	Civil Engineering VIII	54		6
Geology and Mineralogy X	72	2		Civil Engineering IX	54		6
Hygiene and Camp Sanitation I		1		Elec. Engineering VII	64	2	
Mechanical Engineering XIII	82	2		Elec. Engineering VIII	64		6
Mechanical Engineering XVI	83	2		Geology and Mineralogy XI	72	2	
Metallurgy VII	87	4		Geology and Mineralogy XII	72	3	
Metallurgy VIII	87		3	Mechanical Engineering XVII	83	2	
Metallurgy XIV	90	2		Mechanical Engineering XVIII	84		6
Metallurgy XVII	91	1		Metallurgy X	88	3	
Metal Mining XI	97	2		Metallurgy XI	89		3
Military Art				Metal Mining XII	98	2	
Mining Law I	102	1		Metal Mining XIV	99	1	
Physics IX	106	1		Metal Mining XV	100	1	
Thesis. Credit three hours.				Military Art			
				Mining Law II	102	1	
				Physics X	106	1	
				Physics XI	107	2	
				Physics XII	107		3
				Thesis. Credit three hours.			

TABULAR VIEW

GROUP III METALLURGY

JUNIOR YEAR

FIRST SEMESTER	Page	Lect. Hr.	Lab. Hr.	SECOND SEMESTER	Page	Lect. Hr.	Lab. Hr.
Required				**Required**			
Chemistry XI..........	47	1		Chemistry XIII........	47	1	
Chemistry XII.........	47		6	Chemistry XIV........	48		6
English I..............	65	1		Civil Engineering III...	51	3	
Metallurgy I...........	85	1		English II.............	65	1	
Metallurgy II..........	85		9	Metallurgy IV.........	86	3	
Metallurgy III.........	86	5		Metallurgy VI.........	87	2	
Metal Mining VI.......	95	2		Metallurgy IX.........	88		3
Physics V.............	105	3		Metallurgy XII........	89	1	
				Metallurgy XIII........	89		3
				Metal Mining VII......	95	2	
Elective				**Elective**			
Chemistry XV.........	48	2		Civil Engineering IV...	52		6
Coal Mining I.........	56	2		Coal Mining II.........	56	2	
Electrical Engineering I	61	3		Electrical Engineering III	62	3	
Electrical Engineering II	61		3	Electrical Engineering IV	62		3
Geology and Mineralogy V	70	3		Geology and Mineralogy VII	71	1	3
Geology and Mineralogy VI	70	2		Metal Mining X........	96	3	
Mechanical Engineering IX	80	1		Military Art			
Mechanical Engineering X	81		6	Physics VIII...........	105		3
Metal Mining VIII.....	96	2		Safety Engineering III.	111	1	
Military Art				Spanish VI............	114	1	
Physics VI............	105	2					
Physics VII...........	105		3				
Safety Engineering I...	109	1					
Spanish V.............	114	1					

TABULAR VIEW

GROUP III METALLURGY

SENIOR YEAR

FIRST SEMESTER	Page	Lect. Hr.	Lab. Hr.
Required			
English III	65	1	
Metallurgy VII	87	4	
Metallurgy VIII	87		6
Metallurgy XIV	90	2	
Metallurgy XV	90		3
Elective			
Chemistry XVI	48		3
Civil Engineering VII	53		6
Coal Mining III	57	2	
Electrical Engineering V	63	2	
Electrical Engineering VI	63		6
Geology and Mineralogy X	72	2	
Hygiene and Camp Sanitation I	73	1	
Mechanical Engineering XIII	82	2	
Mechanical Engineering XVI	83	2	
Metallurgy XVII	91	1	
Metal Mining XI	97	2	
Metal Mining XIII	98	2	
Military Art			
Mining Law I	102	1	
Physics IX	106	1	
Thesis. Credit three hours.			

SECOND SEMESTER	Page	Lect. Hr.	Lab. Hr.
Required			
English IV	66	1	
Metallurgy X	88	3	
Metallurgy XI	89		3
Elective			
Chemistry XVII	49		3
Civil Engineering V	52	2	
Civil Engineering VI	53		3
Civil Engineering VIII	54		6
Civil Engineering IX	54		6
Coal Mining V	58	2	
Coal Mining VI	59	2	
Coal Mining VII	59	1	
Coal Mining VIII	60		3
Coal Mining IX	60		3
Elec. Engineering VII	64	2	
Elec. Engineering VIII	64		6
Geology and Mineralogy XI	72	2	
Geology and Mineralogy XII	72	3	
Mech. Eng. XVII	83	2	
Mech. Eng. XVIII	84		6
Metallurgy XVI	90		3
Metal Mining XII	98	2	
Metal Mining XIV	99	1	
Metal Mining XV	100	1	
Military Art			
Mining Law II	102	1	
Physics X	106	1	
Physics XI	107	2	
Physics XII	107		3
Thesis. Credit three hours.			

TABULAR VIEW

GROUP IV MINING GEOLOGY

JUNIOR YEAR

FIRST SEMESTER	Page	Lect. Hr.	Lab. Hr.	SECOND SEMESTER	Page	Lect. Hr.	Lab. Hr.
Required				**Required**			
English I	65	1		Civil Engineering III	51	3	
Geology and Mineralogy V	70	3		English II	65	1	
Geology and Mineralogy VI	70	2		Geology and Mineralogy VII	71	1	3
Metallurgy I	85	1		Metallurgy IV	86	3	
Metallurgy II	85		9	Metal Mining VII	95	2	
Metallurgy III	86	5					
Metal Mining V	94		3				
Metal Mining VI	95	2					
Physics V	105	3					
Elective				**Elective**			
Chemistry XI	47	1		Chemistry XIII	47	1	
Chemistry XII	47		6	Chemistry XIV	48		6
Chemistry XV	48	2		Civil Engineering IV	52		6
Coal Mining I	56	2		Coal Mining II	56	2	
Mechanical Engineering IX	80	1		Electrical Engineering III	62	3	
Mechanical Engineering X	81		6	Electrical Engineering IV	62		3
Metal Mining VIII	96	2		Mechanical Engineering XI	81	1	
Metal Mining IX	96	1		Mechanical Engineering XII	81		6
Military Art				Metallurgy VI	87	2	
Physics VI	105	2		Metallurgy IX	88		3
Physics VII	105		3	Metallurgy XII	89	1	
Safety Engineering I	109	1		Metallurgy XIII	89		3
Safety Engineering II	110		3	Metal Mining X	96	3	
Spanish V	114	1		Military Art			
				Physics VIII	106		3
				Safety Engineering III	111	1	
				Safety Engineering IV	112		3
				Spanish VI	114	1	

Geology and Mineralogy XIII (page 73). Credit three hours. This course is required and is given for four weeks during the summer following the close of the junior year.

TABULAR VIEW

GROUP IV MINING GEOLOGY

SENIOR YEAR

FIRST SEMESTER	Page	Lect. Hr.	Lab. Hr.	SECOND SEMESTER	Page	Lect. Hr.	Lab. Hr.
Required				**Required**			
English III	65	1		English IV	66	1	
Geology and Mineralogy VIII or IX	71		6	Geology and Mineralogy XI	72	2	
Geology and Mineralogy X	72	2		Geology and Mineralogy XII	72	3	
Elective				**Elective**			
Chemistry XVI	48		3	Chemistry XVII	49		3
Civil Engineering VII	53		6	Civil Engineering V	52	2	
Coal Mining III	57	2		Civil Engineering VI	53		3
Coal Mining IV	58		3	Civil Engineering VIII	54		6
Electrical Engineering V	63	2		Civil Engineering IX	54		6
Electrical Engineering VI	63		6	Coal Mining V	58	2	
Hygiene and Camp Sanitation I	73	1		Coal Mining VI	59	2	
Mechanical Engineering XIII	82	2		Coal Mining VII	59	1	
Mechanical Engineering XVI	83	2		Coal Mining VIII	60		3
Metallurgy VII	87	4		Coal Mining IX	60		3
Metallurgy VIII	87		6	Elec. Engineering VII	64	2	
Metallurgy XIV	90	2		Elec. Engineering VIII	64		6
Metallurgy XVII	91	1		Mech. Eng. XVIII	84		6
Metal Mining XI	97	2		Metallurgy X	88	3	
Metal Mining XIII	98	2		Metallurgy XI	89		3
Military Art				Metallurgy XVI	90		3
Mining Law I	102	1		Metal Mining XII	98	2	
Physics IX	106	1		Metal Mining XIV	99	1	
Thesis. Credit three hours.				Metal Mining XV	100	1	
				Military Art			
				Mining Law II	102	1	
				Physics X	106	1	
				Physics XI	107	2	
				Physics XII	107		3
				Thesis. Credit three hours.			

CHEMISTRY

Clayton Winfield Botkin, Associate Professor
Lewis Dillon Roberts, Assistant Professor

The courses in Chemistry are arranged especially for the needs of the mining and metallurgical engineer. These branches of engineering demand a thorough understanding of the laws and theories of inorganic chemistry, and the ability to apply this knowledge to analytical and industrial problems.

I GENERAL CHEMISTRY Lectures

The fundamental principles of Chemistry are taught in this course. Emphasis is laid upon the nature of chemical reactions and the forces which influence them. The work also includes a study of the non-metallic elements and compounds, with special reference to their production and industrial uses.

Prerequisites: Entrance requirements.

Text: Smith, General Chemistry for Colleges

Lectures and recitations five hours a week during the first semester of the freshman year.

Required of all students. (L. D. Roberts.)

II GENERAL CHEMISTRY Lectures

This course is a continuation of Course I and deals with the chemistry of the metallic elements and their compounds. The cement, glass, clay, and alkali industries are considered, and elementary metallurgy is introduced in connection with the more important metals.

Prerequisite: Course I

Text: Smith, General Chemistry for Colleges

Lectures and recitations five hours a week during the second semester of the freshman year.

Required of all students. (L. D. Roberts.)

III QUALITATIVE ANALYSIS Lectures

The principles of qualitative analysis are emphasized in this course, and consideration is given to the relative solubility of substances, oxidation and reduction reactions, and the reactions involved in the systematic analysis of the common inorganic substances. The aim of this course is to teach rapid, accurate analytical analysis methods and to serve as an introduction to quantitative analysis.

Prerequisite: Entrance requirements

Texts: A. A. Noyes, **Qualitative Analysis**
Treadwell-Hall, **Analytical Chemistry, Vol. 1**

One hour a week during the first semester of the freshman year

Required of all students. (L. D. Roberts.)

IV QUALITATIVE ANALYSIS **Lectures**

This is a continuation of Course III and deals with the problems involved in the solution of minerals, alloys, industrial and commercial products and with their special methods of analysis.

Prerequisites: Courses I and III

Texts: A. A. Noyes, **Qualitative Analysis**
Treadwell-Hall, **Analytical Chemistry, Vol. 1**

One hour a week during the second semester of the freshman year.

Required of all students. (L. D. Roberts)

V QUALITATIVE ANALYSIS **Laboratory**

This covers the separation and detection of the cations and anions involved in the analysis of solutions and dry substances.

Prerequisite: Entrance requirements

Texts: A. A. Noyes, **Qualitative Analysis**
Treadwell-Hall, **Analytical Chemistry, Vol. 1**

Six hours a week during the first semester of the freshman year.

Required of all students. (L. D. Roberts, Botkin)

VI QUALITATIVE ANALYSIS **Laboratory**

This is a more advanced qualitative analysis and includes the separations and detections involved in the analysis of ores, slags, alloys, industrial and commercial products, and some of the rarer elements.

Prerequisites: Courses I, III, and V

Texts: A. A. Noyes, **Qualitative Analysis**
Treadwell-Hall, **Analytical Chemistry, Vol. 1**

Six hours a week during the second semester of the freshman year.

Required of all students. (L. D. Roberts, Botkin)

VII QUANTITATIVE ANALYSIS **Lectures**

The aim of this course is to study the general principles of gravimetric analysis as applied to simple precipitation methods, and the principles of volumetric analysis as applied to titration methods which involve the use of acids and alkalies.

Prerequisites: Courses IV and VI

Texts: Olsen, **Quantitative Analysis**
Botkin, **Quantitative Determinations**

One hour a week during the first semester of the sophomore year.

Required of all students. (Botkin)

VIII QUANTITATIVE ANALYSIS **Lectures**

This course involves a study of oxidation, reduction, electrolytic methods and the application of the methods most frequently used in the analysis of ores, slags, alloys, and industrial products.

Prerequisite: Course VII

Texts: Olsen, **Quantitative Analysis**
Botkin, **Quantitative Determinations**

One hour a week during the second semester of the sophomore year.

Required of all students. (Botkin)

IX QUANTITATIVE ANALYSIS **Laboratory**

Simple salts are analyzed gravimetrially; standard solutions are prepared and unknown substances are determined by titration methods.

Prerequisites: Courses IV and VI

Tests: Olsen, **Quantitative Analysis**
Botkin, **Quantitative Determinations**

Six hours a week during the first semester of the sophomore year.

Required of all students. (L. D. Roberts, Botkin)

X QUANTITATIVE ANALYSIS **Laboratory**

The course deals with mineral analysis, including mainly volumetric methods and their application to industrial and smelter practice. Simple alloys, ores of the common metals, slags, and mattes are analyzed.

Prerequisites: Courses VII and IX

Texts: Olsen, **Quantitative Analysis**
Botkin, **Quantitative Determinations**

Six hours a week during the second semester of the sophomore year.

Required of all students. (L. D. Roberts, Botkin)

XI ADVANCED QUANTITATIVE ANALYSIS Lectures

Credit one hour

This work is an extension of the quantitative analysis of the sophomore year and includes determinations of sulphur, silica, phosphorus, chromium, molybdenum, tungsten, vanadium, titanium, and uranium in ores, and the analysis of waters and boiler scale.

Prerequisites: Courses VIII and X

Text: Low, Technical Methods of Ore Analysis

References: Lord and Demorest, Metallurgical Analysis

One hour a week during the first semester of the junior year.

Required in Group III. (Botkin)

XII ADVANCED QUANTITATIVE ANALYSIS Laboratory

Credit two hours.

Laboratory practice to cover subjects treated in Course XI.

Prerequisites: Courses VIII and X

Text: Low, Technical Methods of Ore Analysis

Reference: Lord and Demorest, Metallurgical Analysis

Six hours a week during the first semester of the junior year.

Required in Group III. (Botkin)

XIII METALLURGICAL ANALYSIS Lectures

Credit one hour.

This course is to familiarize the student with the analytical methods used in conjunction with metallurgical processes. The subjects taught are the technical methods connected with the metallurgy of iron and steel, zinc, lead, copper, bismuth, mercury, cadmium, tin, nickel, cobalt, and the rarer elements of commercial importance.

Prerequisites: Courses VIII and X

Text: Lord and Demorest, Metallurgical Analysis

References: Johnson, Chemical Analysis of Special Steels, Steel-Making Alloys and Graphites

Scott, Standard Methods of Chemical Analysis

One hour a week during the second semester of the junior year.

Required of Group III. (Botkin)

XIV METALLURGICAL ANALYSIS **Laboratory**

Credit two hours.

Laboratory practice to cover subjects treated in Course XIII

Prerequisites: Courses VIII and X

Text: Lord and Demorest, **Metallurgical Analysis**

References: Johnson, **Chemical Analysis of Special Steels, Steel-Making Alloys and Graphites**

Scott, **Standard Methods of Chemical Analysis**

Six hours a week during the second semester of the junior year.

Required of Group III. (Botkin)

XV PHYSICAL CHEMISTRY **Lectures** (Elective)

Credit two hours.

A study of the laws and theories underlying chemical phenomena from the standpoint of their application to the problems of the chemist and the metallurgist. Some of the subjects considered are: theories of atomic structure and properties; the periodic law; solutions; electrolytes; colloids; chemical equilibrium; velocity of chemical action; catalysis and thermo-chemistry.

Prerequisites: Courses VIII and X

Text: Walker, **Introduction to Physical Chemistry**

References: Senter, **Outlines of Physical Chemistry**

Washburn, **Principles of Physical Chemistry**

Two hours a week during the first semester of the junior year. (Botkin)

XVI OIL AND OIL SHALE ANALYSIS **Laboratory** (Elective)

Credit one hour.

This course includes a study of the distillation of oil shale and of the refining methods for shale oil and petroleum. In the laboratory oil shales are analyzed for yield of oil and ammonium sulphate. Tests are made on crude petroleum and shale oil to determine the specific gravity, flash point, viscosity, solidifying point, per cent of water and sulphur, yield of gasoline, kerosene, lubricating oil, paraffin, coke, asphalt, and aromatic hydrocarbons.

Prerequisites: Chem. VIII and X

References: Bulletin 641F, U. S. G. S.
Bulletin 581A, U. S. G. S.
Lunge, Vol. III, Part I
Bacon and Hamor, Vol. I and II

Three hours a week during first semester of the senior year.
(Botkin)

XVII ROCK ANALYSIS Laboratory (Elective)

Credit one hour.

Analysis of rocks, clays and the materials used in the potash industry.

Prerequisites: Courses VIII and X

References: Hillebrand, The Analysis of Silicate and Carbonate Rocks
Washington, Manual of the Chemical Analysis of Rocks

Three hours a week during the second semester of the senior year. (L. D. Roberts)

CIVIL ENGINEERING

James Ferris Seller, Assistant Professor

The aim of this department is to train the student in such subjects of civil engineering as may be required of a mining engineer. This includes a knowledge of plane surveying, analytical and applied mechanics, structural design, and hydraulics.

I THEORY OF PLANE SURVEYING **Lectures**

In this course the student is first made familiar with the various kinds of surveying instruments and their uses. Careful instruction in the elementary principles of surveying, supplemented with numerous examples covering every phase of the work is designed to make the student both rapid and accurate in the calculations of the various kinds of problems likely to be met with in this work. The course is systematically arranged, taking up first general methods of measurement by means of the steel tape or chain, comparison to a standard unit at a given temperature, followed by examples in the making and reduction of transit and level notes, together with a brief study of stadia and plane table methods. City, land, and railroad surveying are taken up in turn, together with parting of land, traverses, and the more simple cases of triangulation; also the reduction of solar observations for a true meridian. The student is especially impressed with the importance of minute observation and the keeping of clear and concise notes.

Prerequisites: Math. I and II

Text: Breed and Hosmer, **Plane Surveying, Vol. I**

References: Johnson and Smith, **Theory and Practice of Plane Surveying**
Breed and Hosmer, **Higher Surveying, Vol. 2**
Wilson, **Topographic Surveying**
Tracy, **Plane Surveying**

One hour a week during the second semester of the freshman year.

Required of all students. (Seller)

II PRACTICE OF PLANE SURVEYING **Lectures and Field Work**

The field work in plane surveying is conducted in the vicinity of Golden and takes up the actual work of chaining, the running of peg and profile levels, triangulation, traversing, and numerous exercises with the transit. A topographical map of an extended territory is made by each squad with the transit and stadia. In addition, several days are spent with the plane table in rapid mapping. At all times the combination of accuracy with economy of time is emphasized. Lectures are held as often as necessary to give detailed instruction in the adjustment and manipulation of instruments.

Prerequisite: Course I

References: Searles, **Field Engineering**
Pence and Ketchum, **Surveying Manual**
Johnson and Smith, **Theory and Practice of Plane Surveying**
Breed and Hosmer, **Higher Surveying, Vol. 2**
Wilson, **Topographic Surveying**

Six weeks in the summer following the close of the freshman year.

Required of all students. (Seiler)

III MECHANICS OF ENGINEERING **Lectures**

Credit three hours.

This course comprises a study of elastic bodies; stresses and strains; compression, shear; torsion and flexure; combined stresses; safe loads; oblique forces; long columns; hooks; simple and continuous beams. The course also includes a brief study of the graphical method of determining the elastic curve and deflection of beams under load, and long columns under eccentric loading.

Prerequisite: Physics V

Texts: Boyd, **Strength of Materials**
Greene, **Structural Mechanics**

References: Merriman, **Mechanics of Materials**
Burr, **Elasticity and Resistance of the Materials of Engineering**
Lanza, **Applied Mechanics**
Cambria and Carnegie **Handbooks**

Three hours a week during the second semester of the junior year.

Required in Groups I, II, III, and IV (Seiler)

IV TESTING LABORATORY (Elective)

Credit two hours.

In this course tests are made to determine the strength and resistance of building materials, such as cast iron, wrought iron, steel, plain and reinforced concrete, and wood in tension, compression, and shearing. Stone and brick are examined for abrasion, absorption, disintegration, and other qualities which determine their economic values. Morever, a wide range of experiments are made on statically indeterminate structures to find the reactions, for which empirical formulae are deduced. Earth pressures on retaining walls are experimented with and methods for proper designs are developed. Tests of cement are made as specified by the American Society for Testing Materials.

Prerequisite: This course must be taken in conjunction with, or subsequent to, Course III

References: Merriman, **Mechanics of Materials**
Burr, **Elasticity and Resistance of the Materials of Engineering**
Lanza, **Applied Mechanics**
Martens, **Handbook of Testing Materials**
Hatt and Schofield, **Laboratory Manual of Testing Materials**

Six hours a week during the second semester of the junior year. (Seiler)

V HYDRAULICS **Lectures** (Elective)

Credit two hours.

This course opens with a brief treatment of hydrostatics, taking up the properties of fluids in motion, and includes the flow of liquids through pipes and orifices and over weirs; fluid friction and consequent losses of head. Special emphasis is placed on Bernoulli's Theorem or the theorem of conservation of energy, as the basis for the solution of all problems relating to the flow of water in pipes and channels. The student is made familiar with empirical formulae which have been deduced through experiment by recognized authorities on hydraulics and numerous and varied problems involving the flow of water through pipes, are solved, and graphical methods for solving resultant equations which cannot be evaluated analytically are illustrated. The impulse and resistance of fluids is studied; the action of pumps and rams; the impulse water motor; overshot, breast, and undershot water wheels; back water; theorem for flow in revolving pipe; turbine and reaction wheels.

Prerequisite: Physics V

Text: Daugherty, Hydraulics

References: Merriman, Treatise on Hydraulics
Hughes and Safford, Hydraulics
Russell, Textbook on Hydraulics
Church, Hydraulics

Two hours a week during the second semester of the senior year. (Seiler)

VI HYDRAULICS Laboratory (Elective)

Credit one hour.

Measurements are made of flow over weirs, through orifices, and through flumes and ditches. The determination of the experimental law of flow in pipes also forms part of the course. Water-wheels and centrifugal pumps are tested and their efficiency under various conditions is determined.

Prerequisite: This course can be taken only in conjunction with Course V

References: Church, Hydraulics
Merriman, Treatise on Hydraulics
Williams and Hazen, Hydraulic Tables
King, Handbook of Hydraulics

Three hours a week during the second semester of the senior year. (Seiler)

VII ENGINEERING CONSTRUCTION Lectures and Drawing (Elective)

Credit two hours.

In this course instruction is given in graphical analysis of the stresses of framed structures of the simpler forms. Comparison is made with the algebraic solutions of the same problems as far as possible. The design of roof and bridge trusses in steel is then taken up from the theoretical and practical points of view. Steel mill buildings are thoroughly discussed, an analysis of all stresses involved is made, and a complete design is required from each student. In connection therewith the forms, covering, lighting, ventilation, erection, and similar topics are carefully considered. The design and construction of steel head-frames and ore bins are taken up in detail.

Prerequisite: This course may be taken only with the consent of the instructor

Texts: Ketchum, Steel Mill Buildings
Lecture Notes

References: Ketchum, Structural Engineer's Handbook
Morris, Designing and Detailing Simple Steel Structures
Cambria Steel

Lectures and drawing six hours a week during the first semester of the senior year. (Seiler)

VIII STRUCTURAL DETAILS Lectures and Drawing (Elective)

Credit two hours.

This course is a study of the methods of framing heavy timber. The student is first made familiar with the terms of framing, such as housing, notching, mortise and tenon, dovetailing, lag-screws, dowels and lugs, and from accepted unit stresses, he is led to design joints, splices, deepened beams, trussed beams, and head-frames from wood. A complete design of a combination wood and steel truss is required from each student. A brief study is made of the ordinary timbers used in construction, and the best modern methods of protecting them from the action of the elements and wood-destroying insects.

Prerequisite: This course may be taken only with the consent of the instructor

Texts: Jacoby, Structural Details
Lecture Notes

Reference: Kidder, Architect's and Builder's Pocketbook

Lectures and drawing six hours a week during the second semester of the senior year. (Seiler)

IX HYDRAULIC INVESTIGATIONS Lectures, Laboratory, and Field Work (Elective)

Credit two hours.

This is an advanced course in hydraulics, in which the student is led into the more practical field of making investigations of water power and various other hydraulic installations. Practical problems omitted in previous courses because of their greater difficulty are here dealt with in a practical way and according to latest and best engineering practice. Water pipe problems met with in various engineering installations are taken up and solved. Several streams and water power sites within a radius of 100 miles are examined and reports as to power available and feasibility of development, are submitted, while the student is made familiar, in the lecture room and in discussions, with the great variety of conditions which may affect any installation and its construction. Various kinds of water wheels are examined and the student made to understand why certain types are adapted to certain conditions, and what are the main features which enter into their design. Finally the student is required to make a survey of a water power site, execute a map or drawing showing a complete general design and layout of installation, accompanied with a full report covering all details of design, power available, income of plant, initial and operative costs, and thus arrive at the charge to be made for power developed.

Prerequisite: This course may be taken only with the consent of the instructor.

References: King, Handbook on Hydraulics
Mead, Water Power Engineering
Marks, Mechanical Engineer's Handbook
Williams and Hazen, Hydraulic Tables
American Civil Engineers' Pocketbook
Vol. 12, Transactions, American Society of Civil Engineers

Laboratory and field work six hours a week during the second semester of the senior year. (Seiler)

COAL MINING

James Cole Roberts, Professor

I PRINCIPLES OF COAL MINING **Lectures**

Credit two hours.

The subjects discussed in this course are: distribution and occurrence of coal; the world's production and available supply of coal and coke, with special reference to that of the different states; the losses each year as compared with production: the origin of coal; classification; general geological features of coal-bearing areas, together with the geological and structural features bearing on the economical mining of coal; the prospecting of coal-bearing areas by surface examinations, prospect machines, drifts, and drill holes; the different types of drilling machines with the rate and cost of boring in different strata; examination and reporting on developed and undeveloped coal properties; preparation of coal by wet and dry processes; ultilization of fuels; manufacture, handling, and utilization of wood, charcoal, peat, lignite, bituminous and anthracite coals, coke, petroleum, natural and artificial gas. Students are required to visit and witness actual mining operations.

References: Hughes, **Textbook of Coal Mining**
Redmayne, **Modern Practice in Mining**
Mayer, **Mining Methods in Europe**
Beard, **Mine Ventilation**
Beard, **Mine Gases and Explosion**
Wilson, **Mine Ventilation**
Wabner, **Ventilation of Mines**
Somermeier, **Coal, its Composition, Analysis, Utilization, and Valuation**
Coal Miners' Pocketbook
United States Bureau of Mines, **Publications**

Two hours a week during the first semester of the junior year.

Required in Group II. (J. C. Roberts)

II METHODS OF COAL MINING **Lectures**

Credit two hours.

Methods of development and operation of coal mines are taken up in this course. Drifts, slopes, and shafts are discussed and compared; the dip and thickness of coal seams; character of roof and floor or walls of vertical seams; driving and sinking through rock and coal; surface stripping and mining by steam shovels; longwall, room and pillar, panel, and other systems; advancing and retreating systems; the driving of entries, rooms, and crosscuts; width of rooms and pillars in thick and thin seams of coal; drawing of pillars; the proportion of coal that can be safely and economically taken in advance work; methods of working thick and thin seams, lying flat, rolling, pitching, or vertical; methods of working overlying seams with special reference to the recovery of the largest possible yield of coal to the acre; shooting off the solid; undercutting of coal by hand (pick mining) and by machines; the operation of the various types of coal cutters, punches, and shearers, with special reference to the economy of each type and the conditions under which each may be used to advantage; single, double, and multiple entry systems compared; surface subsidence; culm flushing as practiced in the anthracite regions of Pennsylvania.

References: Hughes, **Textbook of Coal Mining**
Redmayne, **Modern Practice in Mining**
Mayer, **Mining Methods in Europe**
Beard, **Mine Ventilation**
Beard, **Mine Gases and Explosion**
Wilson, **Mine Ventilation**
Wabner, **Ventilation of Mines**
Somermeier, **Coal, Its Composition, Analysis, Utilization, and Valuation**
Coal Miners' Pocketbook
United States Bureau of Mines, **Publications**

Two hours a week during the second semester of the junior year.

Required in Group II. (J. C. Roberts)

III PRACTICES OF COAL MINING **Lectures**

Credit two hours.

Timbering of shafts, slopes, drifts, entries, rooms, and crosscuts, by the use of wood, steel, and concrete, with the relative merits and costs of each; haulage systems; hand tramming; mules or horses; rope; compressed air; electric and gasoline locomotives, hoisting; operation of various types of hoisting engines, using steam, compressed air, or electricity; cages; head-frames and tipples; drainage; sources of mine water, its control and ejectment.

References: Hughes, Textbook of Coal Mining
Kerr, Practical Coal Mining
Redmayne, Modern Practice of Mining
Duncan and Penman, Electrical Equipment of Collieries
Shearer, Electricity in Coal Mining
Pamely, Colliery Managers' Handbook
Coal Miners' Pocketbook
United States Bureau of Mines, Publications

Two hours a week during the first semester of the senior year.

Required in Group II. (J. C. Roberts)

IV COAL MINING Laboratory

Credit one hour.

This course consists of field work in prospecting and examining coal-bearing lands, following outcrops with actual practice in operating prospecting drills, and visits to points where drilling operations are carried on; sampling of outcrops and coal in the mine; sampling of carload lots of coal in the yards, and on the tipple of operating mines; cutting down and preparing samples for analysis, the analysis of the samples is taken up under C. M. IX. Each student is required to undercut, shoot, and load out a coal face by hand (pick mining) and by each type of machine, to familiarize himself with the different types.

References: Hughes, Textbook of Coal Mining
Kerr, Practical Coal Mining
Redmayne, Modern Practice in Mining
Duncan and Penman, Electrical Equipment of Collieries
Shearer, Electricity in Coal Mining
Pamely, Colliery Managers' Handbook
Coal Miners' Pocketbook
United States Bureau of Mines, Publications
The Trade Catalogues

Three hours a week during the first semester of the senior year.

Required in Group II. (J. C. Roberts)

V PRACTICES OF COAL MINING Lectures

Credit two hours.

This course is a continuation of Course III.

Two hours a week during the second semester of the senior year.

Required in Group II. (J. C. Roberts)

VI COAL MINE EQUIPMENT Lectures

Credit two hours.

This course includes a study of typical mine constructions, such as headframes, tipples, breaker machinery, rolls, screens, and various types of coal cutting machines, mechanical devices for loading coal into pit cars; types of pit cars, with special emphasis on tight end cars and rotary dumps; various types of mine fans and their housing; automatic weighing devices; box car loaders.

References: Hughes, Textbook of Coal Mining
Kerr, Practical Coal Mining
Redmayne, Modern Practice in Mining
Duncan and Penman, Electrical Equipment of Collieries
Shearer, Electricity in Coal Mining
Pamely, Colliery Managers' Handbook
Coal Miners' Pocketbook
United States Bureau of Mines, Publications
The Trade Catalogues

Two hours a week during the second semester of the senior year.

Required in Group II. (J. C. Roberts)

VII ECONOMICS OF COAL MINING Lectures

Credit one hour.

The subjects taken up in this course are: general conditions that should precede the opening of coal mines, such as topography, title, climatic conditions, transportation facilities, possible townsite and living quarters for workmen and their families, available water supply, administration and superintendence: contract system as opposed to day labor; costs of operation; maintenance, depreciation, and amortization; methods of acquiring coal lands from the government and individuals; leasing of coal lands; market and trade conditions; preparation of coal for different markets: selling price of coal as compared with cost at the mines; freight rates to various markets and cost of coal to the consumer; company charges for insurance, physicians, and hospitals; disposal of unsalable products.

One hour a week during the second semester of the senior year.

Required in Group II. (J. C. Roberts)

VIII COAL MINING Laboratory

Credit one hour.

This course is a continuation of Course IV and includes in addition a critical study of typical mine constructions, with preparation of working drawings of cages, cars, headframes, and tipples.

References: Trade Catalogues

Three hours a week during the second semester of the senior year.

Required in Group II. (J. C. Roberts)

IX FUEL AND GAS ANALYSIS Laboratory

Credit one hour.

This course consists of the proximate and ultimate analysis of coal; the calorific value of gaseous, liquid, and solid fuels; the analysis of natural and artificial gas, flue gas, mine, and furnace gases.

References: Gill, Gas and Fuel Analysis for Engineers.
U. S. Bureau of Mines Publications

Three hours a week during the second semester of the senior year.

Required in Group II. (J. C. Roberts)

ELECTRICAL ENGINEERING

Frank E. E. Germann, Professor of Physics and Electrical Engineering

Joseph William Gray, Assistant Professor of Electrical Engineering

It is the desire of the department to make the electrical courses as independent as possible, that the student may have considerable freedom in the choice of his work. Since there is a logical sequence of studies in principle, practice, and design, it is highly desirable that the student elect his courses in groups. Though not required, it is strongly recommended that those who select Groups I, II or IV should elect E.E. Courses I to VI, inclusive.

I DIRECT CURRENT MACHINERY **Lectures** (Elective)

Credit three hours.

This course includes a study of the operating principles of direct current generators, motors, meters, switchboards, and auxiliaries, field and usefulness of each type, methods of connection and control, use and care of storage batteries, and the calculation of circuits.

Prerequisites: Physics III and IV

Text: Gray, **Principles and Practice of Electrical Engineering**

References: Morse, **Storage Batteries**
Crocker and Arendt, **Electric Motors**
Lyndon, **Storage Battery Engineering**
Langsdorf, **Principles of Direct Current Machines**
Franklin and Esty, **Elements of Electrical Engineering, Direct Currents**

Three hours a week during the first semester of the junior year. (Gray)

II DIRECT CURRENT MACHINERY **Laboratory** (Elective)

Credit one hour.

In this work the common types of voltmeters, ammeters, and wattmeters are studied and calibrated; and the common generators and motors, including the three wire and interpole machines, are studied. Series-parallel and standard mining locomotive controllers are wired up and used with two series motors.

Prerequisites: Registration in Course E.E. I or an equivalent preparation

References: Swenson and Frankenfield, **Testing of Electromagnetic Machinery, Vol. 1**

Karapetoff, **Experimental Electrical Engineering, Vol. 1**

Three hours a week during the first semester of the junior year. (Gray)

III ALTERNATING CURRENT MACHINERY **Lectures** (Elective)

Credit three hours.

The plan of this course is similar to that of Course I, but treats of alternating current principles and apparatus, generators, and motors with their auxiliaries and characteristics, transformers, rectifiers, and converters, and the calculation of single and three phase circuits.

Prerequisites: Physics III and IV

Text: Gray, **Principles and Practice of Electrical Engineering**

References: Miller, **American Telephone Practice**

Van Deventer, **Telephonology**

Lawrence, **Principles of Alternating Current Machinery**

Bailey, **The Induction Motor**

Franklin and Esty, **Elements of Electrical Engineering, Alternating Currents**

Jansky, **Electrical Meters**

Three hours a week during the second semester of the junior year. (Gray)

IV ALTERNATING CURRENT MACHINERY **Laboratory** (Elective)

Credit one hour.

A study is first made of the alternating current instruments which are subsequently used in the experimental work. This is followed by a variety of experiments on inductive circuits. Transformers are connected and used in many ways. The starting and running characteristics of induction motors are studied under normal conditions and under some abnormal conditions that are frequent causes of trouble. Synchronizing is done in several ways.

Prerequisites: Registration in Course E.E. III or an equivalent preparation

References: Swenson and Frankenfield, Testing of Electromagnetic Machinery, Vol. 2
Karapetoff, Experimental Electrical Engineering, Vol. 2

Three hours a week during the second semester of the junior year. (Gray)

V ELECTRICITY APPLIED TO MINING Lectures (Elective)

Credit two hours.

The characteristics of electrical machines and auxiliaries which are adapted to the needs of the various operations of mining and milling are first discussed and then problems based upon these principles are given. The applications discussed, include surface plants, air compression, fans, drilling, coal cutting, shot firing, lighting, haulage, hoisting, pumping, dredging, and signaling. Foundations for electrical machines are designed and circuits discussed. In connection with electricity applied to metallurgical work, the discussion includes motor applications, control and protection, the production of current for electrolytic processes and furnaces, magnetic separation, electrostatic separation and precipitation. All of the above subjects are, of course, discussed in detail by the special departments concerned and only the electrical features are considered in this course.

Prerequisites: E.E. I and II, or III and IV

References: Croft, American Electrician's Handbook
Davies, Foundations and Machinery Fixing
Standard Handbook for Electrical Engineers
Koester, Hydroelectric Developments and Engineering
Underhill, Solenoids, Electromagnets, and Electromagnetic Windings
Coombs, Pole and Tower Lines
Rosenthal, Transmission Calculations
Lundquist, Transmission Line Construction
Shearer, Electricity in Coal Mining
Duncan and Penman, Electric Equipment of Collieries

Two hours a week during the first semester of the senior year. (Gray)

VI APPLIED ELECTRICITY Laboratory (Elective)

Credit two hours.

This is the laboratory course accompanying E.E. V. It includes a study of the standard hand operated compensators with "no voltage" and "overload" releases, resistance starters, automatic contactor starters, motor driven fans, and various tests of generators and motors.

Prerequisites: E.E. I and II, or III and IV

Six hours a week during the first semester of the senior year. (Gray)

VII ELECTRICAL INSTALLATIONS **Lectures** (Elective)

Credit two hours.

This is primarily a design course in small installations, though the work may be varied to suit the needs of the individual student. Course VIII should be taken in conjunction with it.

Prerequisite: E.E. V

Text: Brown, **Electrical Equipment**

References: **Electrical Handbooks**
Trade Bulletins
Catalogues

Two hours a week during the second semester of the senior year. (Gray)

VIII ELECTRICAL INSTALLATIONS **Drawing** (Elective)

Credit two hours.

This is a drawing course to accompany E.E. VII

Prerequisite: Registration in E.E. VII

References: **Electrical Handbook**
Trade Bulletins
Catalogues

Six hours a week during the second semester of the senior year. (Gray)

ENGLISH

Leslie Fairbanks Paull, Assistant Professor of Modern Languages

I ENGLISH COMPOSITION Lectures

Credit one hour.

This course is designed to train the student in the essentials of English composition. Practical exercises are given to develop orderly arrangement and clear expression of thought. A study is made of the relation of the general to the particular and its practical application in writing paragraphs and subject outlines.

Texts: Alderson, Miscellaneous Faulty Expressions
Wooley, Handbook of Composition

One hour a week during the first semester of the junior year.

Required in Groups I, II, III, and IV. (Paull)

II BUSINESS CORRESPONDENCE Lectures

Credit one hour.

This course is a continuation of Course I. It aims to give a practical grasp of business correspondence and to familiarize the student with the type of English composition requisite as a basis for professional report writing.

References: Lewis, Business English
Gallagher and Moulton, Practical Business English
Wooley, Handbook of Composition

One hour a week during the second semester of the junior year.

Required in Groups I, II, III, and IV. (Paull)

III REPORTS Lectures

Credit one hour.

This course is designed as a preparation for technical writing. The fundamentals of the subject are studied and reports upon assigned topics are required from the students.

References: Sypherd, Handbook of English for Engineers
Earle, Theory and Practice of Technical Writing
Rickard, A Guide to Technical Writing
Watt, Composition of Technical Papers

One hour a week during the first semester of the senior year.

Required in Groups I, II, III, and IV. (Paull)

IV TECHNICAL WRITING Lectures

Credit one hour.

This course is a continuation of Course III. The principal object is to outline the best methods of presenting technical subjects for publication and for private reports.

References: Sypherd, Handbook of English for Engineers
Earle, Theory and Practice of Technical Writing
Rickard, A Guide to Technical Writing
Watt, Composition of Technical Papers

One hour a week during the second semester of the senior year.

Required in Groups I, II, III, and IV. (Paull)

FINANCE

Victor C. Alderson, President

I FINANCE **Seminar** (Elective)

Credit one hour.

It is a well-known fact that engineers frequently fail to appreciate the financial aspect of their work. To obviate the defect the President offers this course in the form of a seminar. Attention is called to the great world movements that cause variations in the market value of securities, the minor market movements, and the general trend of the prices of commodities.

Members of the class follow closely the market value of a group of selected securities on the New York Exchange. At each meeting one member analyzes a security and endeavors to decide whether the quoted price is above, below, or at its real value. The Wall Street Journal, the Magazine of Wall Street, John Moody's Investment Service, besides many works on finance are available in the Library. A strong effort is made to get the student interested in financial matters, to induce him to read financial literature, and to form his own opinion of the results of the forces at work to determine the market value of securities.

One hour a week during the first semester of the senior year.

This course may be taken only with the consent of the instructor. (Alderson)

II FINANCE **Seminar** (Elective)

Credit one hour.

This is a continuation of Course I.

One hour a week during the second semester of the senior year. This course may be taken only with the consent of the instructor. (Alderson)

GEOLOGY AND MINERALOGY

Victor Ziegler, Professor
F. M. Van Tuyl, ~~Assistant~~ Associate Professor
H. G. Schneider, Instructor

The college is very fortunately situated for the geologist. The surrounding formations present the strikingly clear features so characteristic of the West. In addition certain features peculiar to this particular location afford sufficiently complicated problems to be of great value to the student of geology. It is possible, therefore, without going more than a mile or two from the school, to illustrate very effectively most geological problems so that field geology can be carried on at the same time as class instruction.

I GENERAL GEOLOGY Lectures

The aim of this course is to present the fundamentals of geology by means of lectures supplemented by the study of the textbook, and by assigned readings. It comprises a brief survey of the rocks and minerals of the earth's crust and a comprehensive study of the surface features of the earth, with emphasis on the forces and agents which have produced these results and are still bringing about slow changes. Occasional field trips are required.

Prerequisites: Entrance requirements

Text: Pirsson and Schuchert, A Textbook of Geology, Part I

Lectures three hours a week during the first semester of the freshman year.

Required of all students. (Van Tuyl)

II GENERAL GEOLOGY Lectures

This course is a continuation of Course I. It is a study of primary and secondary rock structures, with emphasis on the secondary features resulting from earth movements, such as faults and folds, and the value of their proper interpretation to the mining engineer.

Prerequisite: Course I

Text: Pirsson and Schuchert, A Textbook of Geology, Part I

References: Leith, Structural Geology
Lahee, Field Geology
Grabau, Principles of Stratigraphy

Lectures three hours a week during the second semester of the freshman year.

Required of all students. (Van Tuyl)

III MINERALOGY Lectures and Laboratory

This course in mineralogy is essentially an introduction to Descriptive Mineralogy of the second semester. It comprises a discussion of the principles of crystallography and of blowpipe analysis. Only such portions of crystallography are emphasized as are of practical value in the determination and proper understanding of minerals. In the laboratory work a very thorough drill is given in the more practical portions of the subject. The course includes work with wooden crystal models, and the determination of the forms on a large and representative series of natural crystals. The laboratory work in crystallography is followed by a thorough drill in the methods of blowpipe analysis, with practice in the determination of unknown minerals. The lecture time is devoted to a discussion of the fundamental principles of descriptive mineralogy.

Prerequisites: Chemistry I and II

Texts: Lewis, Determinative Mineralogy
Patton, Lecture Notes on Crystallography

Lectures two hours, laboratory six hours, a week during the first semester of the sophomore year.

Required of all students.

(Ziegler, Van Tuyl, Schneider)

IV DESCRIPTIVE MINERALOGY Lectures and Laboratory

About three hundred of the more important mineral species are presented by lectures, in which special emphasis is placed on the recognition of minerals by means of their physical properties. Every attempt is made to make the course thoroughly practical so as to enable the student to recognize at sight such minerals as are met in mining operations. With this object in view, as thorough a drill as the time will allow is given to the actual handling and determining of minerals in the laboratory. In this work each student is expected to handle, to determine, and to be questioned and examined on approximately two thousand five hundred individual specimens.

Prerequisite: Course III

References: Fords, Dana's Manual of Mineralogy
Dana, System of Mineralogy
Lewis, Determinative Mineralogy

Lectures two hours, laboratory six hours, a week during the second semester of the sophomore year.

Required of all students.

(Ziegler, Van Tuyl, Schneider)

V HISTORICAL GEOLOGY Lectures

Credit three hours.

A study of earth history with emphasis on the North American continent. The theories of the origin of the earth are discussed and the succession of events in its known history as revealed by the rocks are traced. Special attention is given to the changes in relation of land and sea, the character and distribution of the deposits, the orogenic movements, volcanic activity, economic products, and dominant life forms of each geological period.

Prerequisites: Courses I and II

References: Pirsson and Schuchert, A Textbook of Geology, Part II
Chamberlin and Salisbury, Geology, Vol. II and III
Rice, Adams, and Others, Problems of American Geology

Lectures three hours a week during the first semester of the junior year.

Required in Group IV (Van Tuyl)

VI STRUCTURAL GEOLOGY Lectures

Credit two hours.

This course covers practically Mining Geology. It includes a comprehensive study of rock structures with special emphasis on features important to the mining engineer. The graphic study of folds and faults and the interpretation of structure from maps receive special attention.

Prerequisites: Courses I to V inclusive.

References: Leith, Structural Geology
Geikie, Structural and Field Geology
Hayes, Handbook for Field Geologists
Gunther, The Examination of Prospects
Tolman, Graphical Solution of Fault Problems

Lectures two hours a week during the first semester of the junior year.

Required in Group IV (Ziegler, Schneider)

VII LITHOLOGY Lectures and Laboratory

Credit two hours.

The object of this course is to present all the more commonly occurring rocks in such a way as to render their identification at sight reasonably accurate. The methods pursued are purely those applicable to the hand specimen without the aid of microscopic sections. The collection of the school is especially rich in those rocks that are usually encountered in mining operations in Colorado and adjacent states. Special emphasis, therefore, is laid upon such rocks and upon their various alteration forms.

Prerequisite: G. and M. IV

Lectures one hour, laboratory three hours, a week during the second semester of the junior year.

Required in Groups I and IV (Ziegler, Schneider)

VIII MICROSCOPIC PETROGRAPHY

Credit two hours.

In this course the study of rocks and rock-forming minerals is carried on with the help of the petrographic microscope. It covers (a) the study of the optical properties of minerals with a view to their identification, and (b) systematic petrography or the identification of rock types by means of their structures and mineral components.

Laboratory six hours a week during the first semester of the senior year.

Required in Group IV

Course IX may be substituted. (Ziegler)

IX INDEX FOSSILS OF NORTH AMERICA Lectures and Laboratory

Credit two hours.

A course planned to meet the needs of students who desire to fit themselves for work in oil geology and stratigraphy. Only the more important guide fossils of each system are studied. Special attention is given to the fossils characteristic of western formations of economic importance.

Prerequisite: Course V

References: Shimer, An Introduction to the Study of Fossils

Grabau and Shimer, Index Fossils of North America

Six hours laboratory a week during the first semester of the senior year.

Required in Group IV

Course VIII may be substituted. (Van Tuyl)

X ORE DEPOSITS Lectures

Credit two hours.

This course treats of the nature, origin, and occurrence of ore deposits. Among other subjects the criteria useful in the recognition of the various types of ore deposits, the changes in the character of ores with depth, and mineral associations and alterations, are discussed. Those features likely to be of use in the examination of mining prospects receive special attention.

Prerequisites: Courses I, II, III, IV, and VII

References: Beyshlag, Vogt, and Krusch, **Deposits of Useful Minerals and Rocks**
Lindgren, **Mineral Deposits**

Lectures two hours a week during the first semester of the senior year.

Required in Group IV (Ziegler)

XI ECONOMIC GEOLOGY Lectures

Credit two hours.

This course includes a discussion of the more important mining districts of North America. In addition to ore deposits, the more important non-metallic products and their distribution are included.

Prerequisite: Course X

References: Lindgren, **Mineral Deposits**
Beyshlag, Vogt, and Krusch, **Deposits of Useful Minerals and Rocks**

Lectures two hours a week during the second semester of the senior year.

Required in Group IV (Ziegler)

XII OIL AND GAS Lectures

Three credit hours.

The chemistry and physics of the natural hydrocarbons, their origin, type of occurrence, and geologic setting are discussed in detail. Emphasis is placed on the principles and laws of oil accumulation applicable to all fields. An effort is made to train the student in the interpretation of the structural and geological phenomena characteristic of oil and gas fields.

Prerequisites: Course I to VII inclusive

References: Johnson and Huntley, Oil and Gas Production
Hager, Practical Oil Geology
Engler and Hoefer, Das Erdol
Bacon and Hamor, the American Petroleum Industry

Three hours a week during the second semester of the senior year.

Required in Group IV (Ziegler)

XIII FIELD GEOLOGY

Credit three hours.

This course is intended to give field practice in geologic mapping and in the working out of structural details. The area selected is divided among individual squads and a complete map with structural sections is prepared through cöoperation of the different squads. The work covers four weeks at the close of the junior year. Camping equipment and instruments are furnished by the school. The student is expected to furnish bedding. The expense of the course varies somewhat according to the location of the area worked. Ordinarily forty to forty-five dollars should cover all actual field expenses.

Prerequisites: Courses V, VI, and VII

Four weeks of the summer at the close of the junior year.

Required in Group IV (Ziegler, Van Tuyl, Schneider)

HYGIENE AND CAMP SANITATION

Dr. Louis A. Packard, Medical Director and Director of Physical Training

I HYGIENE AND CAMP SANITATION Lectures (Elective)

Credit one hour.

General principles of personal and public hygiene; preventive measures and prophylaxis; industrial hygiene with special regard to mining camps and mills; camp sanitation, sewage, and garbage disposal, water supply, and general health measures.

One hour a week during the first semester of the senior year.

(Packard)

MATHEMATICS

Thomas Orr Walton, Professor
James Ferris Seller, Assistant Professor of Civil Engineering and Mathematics

The courses in this department have been arranged to meet the extensive needs of students in the various branches of engineering. The subjects are treated so as to give the student both logical training and power of application. The principles which are of greatest value in engineering work are particularly emphasized. The courses offered serve as a sufficient prerequisite for the work in mathematical physics, physical chemistry, engineering and applied mechanics; and they mark the minimum of mathematical attainments that an engineer ought to possess. A special feature of the work is the early introduction of the calculus, the principles of which are introduced with those of analytic geometry and developed as needed, thus disregarding, to a certain extent, the traditional barrier that has existed between these subjects. By this means, the principles of the calculus are allowed to develop slowly, their sphere of usefulness is widened, the student gains a better grasp of mathematics as a whole, and is able, early in his course, to make direct application of his knowledge of mathematics to practical problems.

I COLLEGE ALGEBRA

This course begins with a rapid review of the fundamental operations as far as quadratics. Graphical work is early introduced in the belief that the illumination which it affords greatly enlivens the entire presentation of the subject and brings algebra into closer relationship with the other mathematical courses. Quadratics are given special emphasis. The progressions, inequalities, mathematical induction, proportion, variation, theory of limits, series, the binomial theorem, logarithms, exponentials, and determinants are all amply treated. Methods of approximating the roots of numerical equations are especially emphasized.

Much time is given to drill work in calculations involving formulas often met in engineering work. A special feature of the course is the persistent use of graphic methods in presenting facts—a practice which is becoming an indispensable requisite in engineering.

Prerequisites: Entrance requirements.

Text: Rietz and Crathorne, College Algebra

Three hours a week during the first semester of the freshman year.

Required of all students. (Walton, Seiler)

II TRIGONOMETRY

The general formulas of plane and spherical trigonometry are developed. Inverse functions, identities, and trigonometric equations are carefully considered. Much practice is given in the use of tables and the applications of trigonometry to mensuration in general. The astronomical triangle and such problems relating thereto as occur in surveying are dwelt upon particularly and graphical representation is given its needed emphasis.

Prerequisites: Entrance requirements

Texts: Crawley, Short Course in Trigonometry
Hodgman, Surveyor's Tables

Two hours a week during the first semester of the freshman year.

Required of all students. (Walton, Seiler)

III ANALYTIC GEOMETRY

This course begins with the Cartesian coordinates of a point. Graphs of algebraic and transcendental functions follow. Loci in general, the straight line, conic sections, and cycloids are taken up in detail.

The methods and notation of the calculus are introduced early and are employed in the study of tangents and normals. The parametric equations of the conics and cycloids are developed and many applications to locus problems are introduced and discussed. The student is made familiar with the polar equations of the conics, spirals, ovals, and other plane curves. Emphasis is given to the graphical representation of the trigonometric, logarithmic, exponential, and other transcendental functions.

The analytic geometry of space is deferred until the second year when it is needed in the development of the calculus.

Prerequisites: Courses I and II

Text: Smith and Gale, New Analytic Geometry

Three hours a week during the second semester of the freshman year.

Required of all students. (Walton, Seiler)

IV CALCULUS

This course introduces the student to the elements of the calculus. The language, the symbols, and the first processes of the infinitesimal analysis are explained and many illustrations in geometry, physics, engineering, and applied mechanics are introduced. The fundamental principles of continuity, limiting values, and the theory of infinitesimals are established. The differentiation of all the fundamental forms and the application of the differential calculus to problems involving maxima and minima, rates, and to the theorems of analytic geometry comprise a large part of the course. Integration is introduced as the inverse operation of differentiation and is applied to numerous problems involving areas, velocities, and geometry.

Prerequisites: Courses I and II

Text: Granville, Differential and Integral Calculus

Two hours a week during the second semester of the freshman year.

Required of all students. (Walton, Seiler)

V CALCULUS

This course is a continuation of Course IV, in which students are made familiar with the elementary processes and applications of the differential calculus. A special feature of this course consists in carrying on the differential and integral calculus together. This method of instruction enables the student to grasp the more difficult notions of the subject in their inherent relations, and at the same time to apply this knowledge, early in the course, to the solution of engineering problems. The conception of the definite integral and its many applications are early introduced. The aim is to make clear the *rationale* of each process, and to arouse an early interest in the usefulness of the subject. The theory of single and multiple integration is applied to the principal methods of rectification and quadrature, and to the calculation of surfaces and volumes of solids of revolution.

Prerequisites: Courses I to IV, inclusive

Text: Granville, Differential and Integral Calculus

Three hours a week during the first semester of the sophomore year.

Required of all students. (Walton)

VI CALCULUS

This course is a continuation of Course V. The elements of solid analytic geometry are introduced to assist in the proper development of the calculus of functions of two or more variables. Simple differential equations are introduced in close connection with integration. Multiple integration in rectangular, polar, and cylindrical co-ordinates is taken up and many applications are made to problems in areas, volumes, moments of inertia, centers of gravity, and pressure. Solids of revolution, cylinders, space curves, ruled and quadric surfaces are all given their needed emphasis as applications of the calculus. The last part of this course is pre-eminently a problem course. The aim is to review, in a practical way, the mathematics of the last two years and thereby encourage the student to look upon his mathematics as an instrument of power and usefulness, rather than one merely of mental development and culture.

Prerequisites: Courses I to V, inclusive

Text: Granville, Differential and Integral Calculus

Three hours a week during the second semester of the sophomore year.

Required of all students. (Walton)

VII PROBABILITY AND LEAST SQUARES (Elective)

Credit two hours.

This course includes the development of the method of Least Squares and its application to practical problems in Physics, Astronomy, and Surveying.

Prerequisite: Course IV

Two hours a week during the first semester of the sophomore year. (Walton)

VIII ADVANCED CALCULUS (Elective)

Credit two hours.

This course consists of subjects in calculus which are not included in the regular course or whose further development may be useful to the engineer, such as, Taylor's Theorem, finite differences, ordinary differential equations, definite and elliptic integrals.

Prerequisite: Registration in Course VI

Two hours a week during the second semester of the sophomore year. (Walton)

MECHANICAL ENGINEERING

James L. Morse, Professor of Mechanical Engineering
James Ferris Seller, Assistant Professor of Civil Engineering and Mathematics

I DESCRIPTIVE GEOMETRY **Lectures**

This course includes problems relating to the point, line, plane, surfaces, intersection of solids and the development of their surfaces, and numerous practical applications to mine surveying and machine design.

Prerequisites: Entrance requirements

Text: Church and Bartlett, **Descriptive Geometry**

Two hours a week during the first semester of the freshman year.

Required of all students. (Seller)

II DESCRIPTIVE GEOMETRY **Drawing**

At the beginning of the course considerable time is given to the use of instruments, geometrical constructions, and lettering; then follows the direct application of the problems that are taken up in the lecture work.

Prerequisites: Entrance requirements

Text: Church and Bartlett, **Descriptive Geometry and Plates**

French, **Mechanical Drawing and Elementary Machine Design**

Six hours a week during the first semester of the freshman year.

Required of all students. (Seller)

III ELEMENTARY MACHINE DESIGN **Lectures**

This course includes a study of machine elements, the nature of materials entering into machine construction, and elementary calculations which involve the correct proportion, by empirical methods, of various machine parts and their application to mining and manufacturing.

Prerequisites: Courses I and II

Text: French, **Mechanical Drawing and Elementary Machine Design**

Two hours a week during the second semester of the freshman year.

Required of all students (Morse)

IV GENERAL ELEMENTARY DRAWING AND DESIGN

Drawing

The object of this course is to give the student the principles of orthographic projection when applied to machine drawings executed according to modern drafting and shop practice. Considerable time is devoted to correct methods of lettering and dimensioning of drawings and free-hand sketching. Working drawings are submitted from the following list: anchor-bolts, shaft-couplings, hangers, pipe-joints, valves, machine elements, hoisting machinery, mine timbering, and simple engine parts. A portion of the semester is devoted to drawing land, city, and topographical maps.

Prerequisites: Courses I and II

Text: French, **Mechanical Drawing and Elementary Machine Design**

Six hours a week during the second semester of the freshman year.

Required of all students. (Morse)

V MACHINE DESIGN **Lectures**

This is a continuation of Course III. A brief outline of the various principles of mechanics, so necessary for the work, is here taken up. Special attention is given to problems which involve the transmission of power and the best solution of these from both the theoretical and practical point of view. All problems are of a practical nature and are based upon first-class commercial practice, with special reference to mining and transportation.

Prerequisites: Courses III and IV

Text: Nachman, **Elements of Machine Design**

Two hours a week during the first semester of the sophomore year.

Required of all students. (Morse)

VI MACHINE DESIGN **Drawing**

This is a continuation of Course IV. The work is extended to include more complex problems. Complete working drawings of some of the following are submitted: shafting layouts; belt, fibrous, and wire rope drives; machine parts, shop and hoisting machinery, conveyors, and conveyor systems.

Prerequisites: Courses III and IV

Text: Nachman, **Elements of Machine Design**

Three hours a week during the first semester of the sophomore year.

Required of all students. (Morse)

VII KINEMATICS OF MACHINERY **Lectures**

This course begins with the theoretical analysis of mechanism and extends to the practical application of these principles to such problems as arise in practice. Special attention is given to the analysis of linkages, belting: shop, mining and mill machinery: cams, gears, and other contact mechanisms.

Prerequisites: Courses V and VI

Text: Schwamb and Merrill, **Elements of Mechanism**

Two hours a week during the second semester of the sophomore year.

Required of all students. (Morse)

VIII KINEMATICS OF MACHINERY **Drawing**

This course supplements and is directly dependent upon the lecture work. This work is taken up from a practical point of view and applies such theory as is consistent with the most approved method of design. Designs and complete working drawings are made of machine parts, gears, cams, and various systems and devices used for the transmission of power, with special emphasis upon the correct velocities and co-ordination of the relative motion and balance of parts.

Prerequisites: Courses V and VI

Text: Schwamb and Merrill, **Elements of Mechanism**

Three hours a week during the second semester of the sophomore year.

Required of all students. (Morse)

IX HEAT POWER PLANT ENGINEERING **Lectures**

Credit one hour.

The greater portion of the semester is devoted to steam boiler subjects. After a brief historical treatment of the subject, the lectures cover the theory, principles of design, and construction of modern boilers. Numerous practical problems are assigned from time to time so that the student becomes thoroughly familiar with the design and operation of the leading types of boilers.

Prerequisites: Courses VII and VIII

Text: Allen and Bursley, **Heat Engines**

One hour a week during the first semester of the junior year.

Required in Group I (Morse)

X HEAT POWER PLANT ENGINEERING **Design**

Credit two hours.

The drafting room work is devoted principally to the design of power plant apparatus and to such other machinery as is usually to be found in a mine plant. Boilers, steam engines, hoists, conveying systems, and mill installations are designed and complete sets of detailed working drawings are required in all cases. The value of time is impressed upon the student and all work is done in accordance with the most approved manufacturing methods.

Prerequisites: Courses VII and VIII

Text: Allen and Bursley, **Heat Engines**

Nachman, **Elements of Machine Design**

References: Marks, **Mechanical Engineering Handbook**

Catalogues and Mechanical Engineering Journals.

Six hours a week during the first semester of the junior year.

Required in Group I (Morse)

XI HEAT POWER PLANT ENGINEERING **Lectures**

Credit one hour.

The lectures of this course embrace principally the subject of steam engines. The development of the steam engine is first carefully traced out, after which attention is given to thermodynamics and the fundamental principles which underlie the steam engine. Practical problems are assigned the student and great stress is laid upon all matters pertaining to the economical side of the subject.

Prerequisites: Courses VII and VIII

Text: Allen and Bursley, **Heat Engines**

One hour a week during the second semester of the junior year.

Required in Groups I and II (Morse)

XII HEAT POWER PLANT ENGINEERING **Design**

Credit two hours.

This course is a continuation of Course X, and enables the student to undertake and complete some of the more advanced problems in the design of power plant, and other machinery.

Prerequisites: Courses VII and VIII

Text: Allen and Bursley, **Heat Engines**

Nachman, **Elements of Machine Design**

References: Marks, Mechanical Engineering Handbook
 Catalogues and Mechanical Engineering Journals.

Six hours a week during the second semester of the junior year.

Required in Groups I and II (Morse)

XIII COMPRESSED AIR Lectures (Elective)

Credit two hours.

This course includes a study of the theory and practice of air compression. At the beginning considerable time is given to the study of such thermodynamics as is necessary to a successful pursuit of the course. After this the work comprises a study of the following principal items: single and multiple stage compression; absorption of heat during compression; transmission of power by compressed air; draining of moisture from pipe lines; reheating; the use of compressed air in motors and the various valve-gears used. The application of compressed air to pumping, hoisting, drilling, and conveying. Compressor catalogues and trade journals form a part of the subject matter of the course.

Prerequisites: Courses VII and VIII

Texts: Peele, Compressed Air
Trade Catalogues

Two hours a week during the first semester of the senior year. (Morse)

XIV POWER PLANT DESIGN Lectures

Credit two hours.

This course includes a detailed study of the units and auxiliaries necessary to a power plant and their various connecting links. After this, problems affecting the type and location of power plants are taken up and then the work is extended to problems involving the best selection and number of units, location and arrangement, connection with auxiliaries, and the necessary housing for equipment. The items of first cost, operating cost, and depreciation are carefully considered.

Prerequisites: Courses XI and XII

Text: Gebhardt, Power Plant Engineering

Two hours a week during the first semester of the senior year.

Required in Groups I and II.. (Morse)

XV POWER PLANT DESIGN **Drawing**

Credit two hours.

The work in this course includes working drawings of some of the power plant equipment taken up and studied in detail in the lecture course. Such problems as the following are assigned: detail of piping systems, including live and exhaust steam, for a certain size plant; foundations for units and auxiliaries; flues and stacks; coal and ash handling machinery, and complete power plants.

Prerequisites: Courses XI and XII

Six hours a week during the first semester of the senior year.

Required in Groups I and II. (Morse)

XVI GAS ENGINES **Lectures** (Elective)

Credit three hours.

This course is intended to give the mining engineer both a theoretical and practical knowledge of the gas engine. The theory and thermodynamics of the gas engine are carefully considered, together with the conditions affecting efficiency and operation. The best types of modern engines together with auxiliary apparatus are taken up and discussed with regard to special features and advantages. Each student is assigned a seminar paper upon some special subject of investigation. At the conclusion of the course these papers are presented before the class. A portion of the course is devoted to practice in operating and running the engines found in the laboratories.

Prerequisites: Courses VII and VIII

Text: Streeter, **The Gas Engine**

Two hours a week during the first semester of the senior year. (Morse)

XVII PUMPING MACHINERY **Lectures** (Elective)

Credit two hours.

This course includes the principles, design, and operation of all kinds of pumping machinery. Special attention is given to the selection and installation of steam, electric, and compressed air pumps for mine service. Problems involving the calculations of capacity, slip, and duty of pumping engines are assigned to the students. Along with the study of pumping machinery considerable time is devoted to the study of air-lifts.

Prerequisites: Courses VII and VIII

Text: Greene, **Pumping Machinery**

Two hours a week during the second semester of the senior year. (Morse)

XVIII MECHANICAL ENGINEERING Laboratory (Elective)

Credit two hours.

It is the purpose of this course to familiarize the student with the apparatus used in testing and engineering investigation. The practice work includes indicator practice: study of reducing motions; dynamometers; determination of the quality of steam; flue gas analysis; calibration of gages; valve setting; testing of boilers, engines, turbines, and air compressors. A complete written report of each test or experiment is required of all students taking this work.

Prerequisites: Courses VII, VIII, IX and XI, and XIII

Text: Moyer, Power Plant Testing

Reference: Smallwood, Mechanical Laboratory Methods

Five hours a week during the second semester of the senior year. (Morse)

METALLURGY

Irving Allston Palmer, Professor
Samuel Zettler Krumm, Instructor

I ASSAYING Lectures

Credit one hour

This course includes a discussion of the underlying principles of fire assaying, its relation to chemistry and metallurgy, the reasons for its use, and its application to the determination of metals in ores and metallurgical products. The methods, reagents, furnaces, and apparatus used in commercial work are described. It is aimed to make the course as practical as possible.

Prerequisites: Physics III and IV
Geology and Mineralogy IV
Chemistry VIII and X

Text: Fulton, Manual of Fire Assaying

References: Brown, Manual of Assaying
Furman-Pardoe, Manual of Practical Assaying

Lectures one hour a week during the first semester of the junior year.

Required in Groups I, II, III, and IV (Palmer)

II ASSAYING Laboratory

Credit three hours.

In this course the student is required to put into practice what he has learned in the lectures. The stock room of the laboratory has a large supply of assayed and analyzed pulp and bullion samples from various mining, milling, and smelting companies, and a given number of these samples are submitted to the students for assay. The work is continued until results are obtained closely checking those reported by the companies donating the samples. Special attention is paid to minor points in manipulation and to the attainment of speed as well as accuracy. This course may be taken only in conjunction with Course I.

Laboratory nine hours a week during the first semester of the junior year.

Required in Groups I, II, III, and IV

(Palmer, Krumm)

III GENERAL METALLURGY AND THE METALLURGY OF IRON AND STEEL

Credit five hours.

In this course there are taken up for consideration the general principles of metallurgy; the production, properties, and uses of the more important metals; alloys and metallic compounds; ores of the common metals; fuels, refractories, furnaces, and apparatus; metallurgical processes; and a detailed study of the metallurgy of iron and steel.

Prerequisites: Chemistry VIII and X
Physics III and IV, G. and M. IV

Text: Hofman, **General Metallurgy**

References: Fulton, **Principles of Metallurgy**
Stoughton, **Metallurgy of Iron and Steel**
H. H. Campbell, **The Manufacture and Properties of Iron and Steel**
J. E. Johnson Jr., **Blast Furnace Construction in America**
Principles, Operation and Products of the Blast Furnace

Five hours a week during the first semester of the junior year.

Required in Groups I, II, III, and IV (Palmer)

IV METALLURGY OF LEAD **Lectures**

Credit three hours.

The metallurgy of lead is considered in the following order: properties of lead and its alloys and compounds; ores of lead; sampling and purchasing of lead ores; fluxes and fuel; smelting in the ore hearth; roasting of ores, including the chemistry of the roasting process; blast furnace smelting, including construction, chemistry of the blast furnace, calculation of furnace charges, treatment of products; softening, desilverization, and refining of base bullion; Pattinson process; Parkes process; Betts process; German and English cupellation.

Prerequisite: Course III

Text: H. O. Hofman, **The Metallurgy of Lead**

Reference: H. F. Collins, **The Metallurgy of Lead**

Three hours a week during the second semester of the junior year.

Required in Groups I, II, III, and IV (Palmer)

VI METALLURGY OF ZINC **Lectures**

Credit two hours.

The subject is treated in the following order: production and uses of zinc; chemical and physical properties; alloys and compounds; ores; calcination; roasting; smelting; the manufacture of retorts and condensers; retort and furnace fuels; types of roasting and retort furnaces; refining; and electrolytic recovery of zinc.

Prerequisite: Course III

Text: W. R. Ingalls, **The Metallurgy of Zinc and Cadmium**

References: L. S. Austen, **The Metallurgy of the Common Metals**
H. C. Hofman, **General Metallurgy**

Two hours a week during the second semester of the junior year.

Required in Group III (Palmer)

VII ORE DRESSING **Lectures**

Credit four hours.

This course is designed to give the student a good general idea of the modern theory and practice of ore dressing. The underlying principles are discussed, and the application of these principles to the concentration of ores is illustrated by references to laboratory experiments and to commercial work. Emphasis is placed upon the economic side of the subject. On account of the rapid changes in ore dressing practice only the more modern milling plants are taken up for detailed examination and study.

Text: Richards, **Textbook of Ore Dressing**

References: Wiard, **Theory and Practice of Ore Dressing**
Rickard and Ralston, **Flotation**
Hoover, **The Flotation Process**
A. W. Fahrenwald, **Testing for the Flotation Process**

Four hours a week during the first semester of the senior year.

Required in Groups I and III (Palmer)

VIII ORE DRESSING **Laboratory**

Credit two hours.

This course is designed to supplement the lectures on the subject by giving the student practice in the handling of ore dressing equipment. The first part of the course is devoted to laboratory experiments, illustrating general principles, and to the study of the construction, capacity, efficiency, and power consumption of such machines and other apparatus as are available. This work is followed by the testing of ores. Visits are made to commercial milling plants and the information thus gained incorporated in reports prepared by the student.

Six hours a week during the first semester of the senior year.

Required in Groups I and III (Palmer, Krumm)

IX METALLURGY **Laboratory**

Credit one hour.

This course is intended to supplement the lecture work of the junior year and includes high temperature measurements with optical radiation, base metal couples and rare metal couple pyrometers; seger cones; melting points of common metals; heat treatment of steel; the thermit process, and the desilverization of base bullion.

Three hours a week during the second semester of the junior year.

Required in Group III (Krumm)

X METALLURGY **Lectures**

Credit three hours.

Gold and Silver. This course covers the following: metallurgy of gold and silver, with special attention to stamp milling, amalgamation and cyanidation; the parting of gold and silver bullion by various commercial methods, with special attention to electrolysis and the sulphuric acid treatment. The various modifications of the cyanide process receive particular attention.

Copper. A study of the principles of copper metallurgy as exemplified by the best modern practice, including the roasting of ores, blast and reverberatory smelting, pyritic smelting, converting of matte, refining of copper, treatment of oxidized ores, and hydrometallurgical methods.

Text: Hofman, **The Metallurgy of Copper**

References: Peters, **Principles of Copper Smelting**
Practice of Copper Smelting
Clennell, **The Cyanide Handbook**
Rose, **The Metallurgy of Gold**

Three hours a week during the second semester of the senior year.

Required in Group III (Palmer)

XI METALLURGY Laboratory

Credit one hour.

This work includes the testing of gold and silver ores by amalgamation and cyanidation; experimental roasting and leaching of zinc ores; the leaching of oxidized copper ores; and the laboratory study of such standard processes as lend themselves to small scale treatment.

References: Clennell, The Cyanide Handbook
Megraw, Details of Cyanide Practice
Current Publications

Three hours a week during the second semester of the senior year.

Required in Group III (Krumm)

XII. METALLOGRAPHY Lectures

Credit one hour.

This course comprises a study of the general methods of investigating metals and alloys; the experimental determination and plotting of cooling curves; the physical mixture, including a consideration of aqueous solutions, fused salts and alloys; a discussion of freezing point curves and diagrams; the preparation of the sample and development of the structure by various etching media; the use of the microscope and methods of making microphotographs.

References: Howe, The Metallography of Steel and Cast Iron
Sauveur, The Metallography and Heat Treatment of Iron and Steel
Bullens, Steel and Its Heat Treatment

One hour a week during the second semester of the junior year.

Required in Group III (Krumm)

XIII METALLOGRAPHY Laboratory

Credit one hour.

This course is intended to supplement the lectures, and includes the application of principles in every day commercial practice from the initial heating of the steel for forging to the cooling in the final heat treatment process; the examination of heat-treated steels and the photomicrographing of the specimens.

Three hours a week during the second semester of the junior year.

Required in Group III (Krumm)

XIV ELECTROMETALLURGY Lectures

Credit two hours.

This course is divided into three parts and covers the following subjects: (a) the electrolytic winning and refining of metals and the parting of gold and silver bullion; (b) the electric furnace; (c) the electrometallurgy of iron and steel.

This is a course of lectures and recitations on modern practice in electric smelting and refining, in which the various types of furnaces and other equipment and their underlying principles are discussed and comparisons made with ordinary fire methods, followed by the direct application to the reduction and refining of metals.

References: Stansfield, The Electric Furnace
Rodenhauser and Shoenawa, The Electric Furnace in the Iron and Steel Industry

Two hours a week during the first semester of the senior year.

Required in Group III (Krumm)

XV ELECTROMETALLURGY Laboratory

Credit one hour.

This course is intended to supplement the lectures and includes the electrolytic winning of zinc, parting of gold and silver bullion, construction and operation of laboratory size electric furnaces.

Three hours a week during the first semester of the senior year.

Required in Group III (Krumm)

XVI ORE DRESSING Laboratory (Elective)

Credit one hour.

During the second semester of the senior year a practical course in ore dressing is given at the experimental plant. This plant contains standard-sized machinery and ores can be run in lots of several tons each. The students are thus made familiar with actual milling operations. Ores are concentrated by various methods, and the relative merits of different machines and processes are determined. It is aimed to keep in touch with the most recent progress in ore dressing, and the newer ideas are tried out as nearly as possible under actual working conditions.

Three hours a week during the second semester of the senior year. (Palmer, Krumm)

XVII METALLURGICAL PROBLEMS Lectures (Elective)

Credit one hour.

This course is designed to include not only a discussion of the more important technical metallurgical problems in connection with the extraction and refining of metals, but in the larger sense the economic problems, so as to include a consideration of such questions as labor, transportation, fuel supplies, location of plants, relation of metallurgy to civilization, importance of metallurgy in the waging of war, technical education, and the organization and management of metallurgical companies.

One hour a week during the first semester of the senior year.

(Palmer)

METAL MINING

Harry John Wolf, Professor

The courses given in this department are intended to instruct the student in the theoretical as well as the practical subjects that are necessary to a thorough comprehension of the mining industry. The subjects range from the most elementary to those that teach the principles of mining, the various schemes or methods of developing and working mines, and the actual or practical operations involved in mining. Throughout these courses it is aimed to present the most approved ideas and to have the student feel that he is receiving instruction that is revised up to the time of presentation.

I MINERAL LAND SURVEYING Lectures

This course covers instruction in the methods of acquiring title to mineral lands in the United States and in foreign countries. Special attention is given to practice in the western United States. Determination of meridian and latitude by solar and stellar observation is explained. Methods of sub-dividing the public lands and the regulation of land offices and Surveyors General are discussed and explained. Instruction is given in the preparation and filing of the documents used in acquiring title to lode and placer claims; mill and tunnel sites; timber, coal, and stone lands; water rights; dam and reservoir sites; and ditch, flume, and pipe lines. The duties of the United States Deputy Mineral Surveyors are explained and the student is familiarized with the field methods and office practice involved in obtaining United States patent to mineral lands. This course makes the student competent to pass the examination given by the Surveyor General to applicants for commissions as mineral surveyors.

Prerequisites: C.E. I and II

References: Underhill, Mineral Land Surveying
Hodgman, Land Surveying
General Land Office, Manual of Instructions for the Survey of the Mineral Lands of the United States

One hour a week during the first semester of the sophomore year.

Required of all students. (Wolf)

II MINE SURVEYING **Lectures**

This course includes the theory involved in mine surveying. Among the subjects discussed are the following: the adjustment and uses of top and side telescopes and other transit accessories used in underground work; surface and underground surveys and traverses; carrying the meridian underground; underground connections; plumbing vertical shafts; determination of dip, strike, and thickness of mineral deposits from results of development, including drill-hole data; survey and measurement of stopes, rooms, and pits; methods of recording surveys in field books and office records; methods of mapping, including plans, elevations, and sections of underground workings, and the design and uses of mine models.

Prerequisites: C.E. I and II

References: Trumbull, **Manual of Underground Surveying**
Durham, **Mine Surveying**
Brough, **Mine Surveying**
Shurick, **Coal Mine Surveying**

One hour a week during the second semester of the sophomore year.

Required of all students. (Wolf)

III MINE SURVEYING **Field Work**

This course embraces practice in laying out mining claims on the ground and in surveying underground workings. The students are organized in suitable squads for efficient work in the field. Each squad is required to survey a lode claim, placer claim, mill site, and tunnel site; locate and mark all corners, as required by law in the case of an actual survey; tie the surveys to proper section corners, or other monuments, and obtain all field data required for the calculation of intersections with conflicting claims. The practice in surface and underground work is given in one of the neighboring mining districts where typical mines are selected which provide a variety of problems common to mine surveying, such as shaft plumbing, adit and drift traversing, and making connections through shafts, tunnels, drifts, raises, winzes, and stopes. The student receives practice and acquires skill in the use of instruments, the taking of measurements, and the securing of important data under the numerous disadvantages and disagreeable conditions common to underground work. The location of water rights and the surveying of ditches, flumes, pipelines, and aerial tramways are included in this course.

Prerequisites: Courses I and II

References: Underhill, Mineral Land Surveying
General Land Office, Manual of Instructions for the Survey of the Mineral Lands of the United States
Field Notes
Plats and Mine Maps

Four weeks in the summer following the close of the sophomore year.

Required of all students. (Wolf)

IV MINING LABORATORY

Credit two hours.

The work in this course is performed in a mine located on Mt. Zion, about three-quarters of a mile from the campus, where the school has built and equipped a mine shop and has driven a 7 by 8-foot adit. The shop is equipped with a forge and tools for blacksmithing, timbering, track-laying, piping, and repair work; also drill steel, machine drills, mine cars, and other apparatus used in the underground work. The students work in squads of three or four and perform all of the usual duties involved in the driving of a tunnel, such as track-laying, timbering, drilling by hand and with machine drills, blasting, mucking, and tramming. Under the instruction of a practical miner the students learn to temper and sharpen their own steel to suit the varying conditions of ground and for the different makes of drills. Opportunity is afforded students to do extra work investigating the efficiency and power consumption of different makes of drills and the relative advantages of various brands of high explosives.

Two weeks in the summer following the close of the sophomore year.

Required of all students. (Wolf)

V MINE MAPPING Drawing

Credit one hour.

This is a drafting room course wherein the student is required to perform all office work necessary in connection with the surveys made in Course III, Mine Surveying Field Work, including the preparation of plats, field notes and reports required by Land Office Directors and Surveyors General, and the drawing of accurate maps of all mine surveys and water rights.

Prerequisite: Course III

References: Field Notes
Mine Maps

Three hours a week during the first semester of the junior year.

Required in Groups I, II, and IV (Wolf)

VI PROSPECTING AND THE LOCATION AND EXPLORATION OF MINING CLAIMS Lectures

Credit two hours.

This course is introductory to all the following metal mining courses. Following a presentation of the elementary and fundamental principles of mining, the great mining districts of the world, and famous individual mines and mineral discoveries, are described and discussed. The general principles of exploitation of mineral deposits are presented. Representative mining costs are reviewed and compared with reference to the conditions under which they obtain.

The course also involves a presentation of the regulations of the Land Office and Surveyors General, together with instruction in the approved methods of acquiring title to mineral lands with a view to avoiding legal entanglements and gaining maximum advantage to the locator. The course includes an elementary discussion of mining laws and regulations of the United States and foreign countries.

Two hours a week during the first semester of the junior year.

Required in Groups I, II, III and IV (Wolf)

VII PRINCIPLES OF MINING Lectures

Credit two hours.

This course is designed to give the student a general view and conception of the mining industry from a business man's viewpoint. Many of the prominent features of other mining courses are presented, with suitable discussion, but a study of technical details is avoided. The chief object of the course is to supply the needs of the student who requires a general knowledge of mining, but does not intend to specialize in metal mining.

Two hours a week during the second semester of the junior year.

Required in Groups I, II, III, and IV (Wolf)

VIII MINE ACCOUNTING Lectures

Credit two hours.

This course begins with the fundamental principles of bookkeeping. The student is taught how to use the various books, records, and blanks involved in standard systems of accounting. The course is designed to impart a clear knowledge of double entry bookkeeping. Special attention is given to systems employed in dealing with the accounts of mining corporations, classification of mine, mill, and smeltery accounts, and the distribution of mining expenditures. The student is taught how to analyze costs, compile an operating statement, take off a trial balance, and prepare a financial report. Each student is required to enter in a set of blank forms the transactions covering a month's operations of a mining company.

References: Carlton, American Mine Accounting
Lawn, Mine Accounts and Mine Bookkeeping
Greendlinger, Accounting Theory and Practice
Wallace, Simple Mine Accounting
Wolf, Notes on Mine Accounting

Two hours a week during the first semester of the junior year.

Required in Group I (Wolf)

IX MINING CORPORATIONS Lectures

Credit one hour.

This course covers the essentials of corporation law involved in the organization and operation of industrial corporations, particularly those engaged in mining. The various steps in the life of a mining corporation are discussed and analyzed, and the ordinary vicissitudes and the usual methods of facing them are illustrated by typical examples. Methods of recording a corporation's activities in the general books of accounts are explained.

References: Lough, Corporation Finance
Bush, Uniform Business Law
Wolf, Notes on Mining Corporations
Corporation Laws

One hour a week during the first semester of the junior year.

Required in Group I (Wolf).

X PLACER MINING Lectures

Credit three hours.

This course covers the theory and practice involved in the recovery of precious metals from sand and gravel deposits. Among the subjects discussed are: panning, rocking, sluicing; methods of extracting gravel for sluicing; hydraulicing; drift mining; dry placering; dredges and their operation; thawing frozen ground. Typical operations are considered in detail, and special attention is paid to capacity of machinery and operating costs.

References: Longridge, Hydraulic Mining
Longridge, Gold and Tin Dredging
Wilson, Hydraulic and Placer Mining
Weatherbee, Dredging for Gold in California
Aubury, Gold Dredging in California

Three hours a week during the second semester of the junior year.

Required in Group I (Wolf)

XI METAL MINING Lectures

Credit two hours.

This course begins with a discussion of surface prospecting in various countries, the methods employed and the equipment required; and prospecting for ore, oil, and water by means of churn drilling and core drilling. Next, the methods of opening and developing the different types of mineral deposits are considered and compared. The various methods of excavating earth and rock are discussed and the different tools employed are described. Shaft sinking and tunnel driving are described, and the different systems of stoping are explained. The course includes the consideration of mine timbering; the kinds and properties of timber, and special methods of framing; methods of supporting vein walls with ore and waste filling; hand and machine drills and drilling methods; the different kinds of explosives and their use in blasting; underground haulage; hoisting; surface transportation; wire rope tramways; pumping; ventilation; lighting; and sanitation.

References: Hoover, Principles of Mining
Young, Elements of Mining
Storms, Timbering and Mining
Brinsmade, Mining Without Timber
Sanders, Mine Timbering
Brunswig, Explosives
Dana and Saunders, Rock Drilling
Brunton and Davis, Modern Tunneling
Lauchli, Tunneling
Crane, Ore Mining Methods
Gillette, Handbook of Rock Excavation
Ihlseng and Wilson, Manual of Mining
Peele, Mining Engineer's Pocketbook

Two hours a week during the first semester of the senior year.

Required in Group I (Wolf)

XII METAL MINING **Lectures**

Credit two hours.

This course includes the discussion and solution of a variety of practical mining problems which the student is likely to encounter in practice. Knowledge gained in previous mining courses is applied to problems in haulage, hoisting, surface tramming, and pumping. The selection and arrangement of surface and underground equipment is discussed. The various forms of power used in mining operations are discussed and their applications and relative advantages explained. Some of the lectures are illustrated by lantern slides of various mine structures and machinery installations; the subjects so illustrated are discussed and the engineering principles considered in their selection and involved in their operation are explained.

References: Hoover, **Principles of Mining**
Young, **Elements of Mining**
Walker, **Electricity in Mining**
Redmayne, **Modern Practice in Mining**
Tinney, **Gold Mining Machinery**
Ketchum, **Design of Mine Structures**
Peele, **Mining Engineer's Pocketbook**
Handbook of Mining Details
Details of Practical Mining

Two hours a week during the second semester of the senior year.

Required in Group I (Wolf)

XIII MINE VALUATION **Lectures**

Credit two hours.

This course includes a detailed discussion of the methods of mine sampling. The sampling of fissure veins, placer deposits, and coal seams is carefully explained. The measurement of ore bodies and the methods of estimating tonnage are described; the systems of classifying ore are discussed. The course includes an analytical study of the following subjects: factors influencing payability of ore; relation between vein width and stoping width; underground wastes and losses; mining costs; influence of mineralogical composition; losses and deductions involved in metallurgical treatment; milling, transportation, and smelting costs; valuation of ore bodies; valuation of surface and underground equipment; appraisement of water rights and other privileges; investigation of geological features and the probabilities and possibilities of extension of ore bodies; calculation of maintenance and depreciation of equipment; and amortization of capital. Methods of recording assays, tabulating calculations, and compiling data in comprehensive form, are described. Suggestions are given for the arrangement and presentation of the essential information required in mine reports.

References: Rickard, Sampling and Estimation of Ore in a Mine
Burnham, Modern Mine Valuation
Gunther, Examination of Prospects
Herzig, Mine Sampling and Valuing
Somermeier, Coal, Its Composition, Analysis, Utilization, and Valuation
Spurr, Geology Applied to Mining
Eckel, Iron Ores
Hoover, Principles of Mining
Denny, Diamond Drilling for Gold and Other Minerals
Wolf, Notes on Mine Valuation

Two hours a week during the first semester of the senior year.

Required in Group I (Wolf)

XIV ECONOMICS OF MINING Lectures

Credit one hour.

This course begins with a brief review of the fundamental principles of political economy. Then follows an analytical discussion of the underlying factors which influence the operation of the various types of industrial enterprises, with special attention to mining corporations. The different classes of corporate securities are described and the factors which influence the value of mining securities are discussed. Mining costs are classified and analyzed. The application of business principles to mining is explained and emphasized.

References: Babson, Business Barometers
Rickard, Economics of Mining
Finlay, Cost of Mining
Skinner and Plate, Mining Costs of the World
Fish, Engineering Economics
Conway, Investment and Speculation
Walker, Political Economy
Seager, Economics
Meade, Economics
Bullock, Selected Readings in Economics

One hour a week during the second semester of the senior year.

Required in Group I (Wolf)

XV MINE MANAGEMENT Lectures

Credit one hour.

This course includes a discussion of the following topics: personal qualities involved in efficient management: value of versatile technical knowledge and experience; general and department organization of working forces; application of the principles of efficiency engineering; value of business ability and diplomacy; influence of ideals, enthusiasm, loyalty and esprit de corps; systems of labor compensation; classification of labor and efficiency reward; contracts and specifications; leasing systems; marketing mine and mill products; analysis of smeltery contracts; analysis and distribution of mining cost; purchase of supplies; care and maintenance of surface and underground equipment; developing and operating policies; and compilation of periodical operating reports.

References: Emerson, The Twelve Principles of Efficiency
Taylor, The Principles of Scientific Management
Parkhurst, Applied Methods of Scientific Management
Gilbreth, Motion Study
Galloway, Business Organization
Gestenberg and Hughes, Commercial Law
Brinton, Graphic Methods of Representing Facts
Wolf, Notes on Mine Management

One hour a week during the second semester of the senior year.

Required in Group I (Wolf)

MILITARY ART

Students' Army Training Corps

On September 12, 1918, the Board of Trustees passed the following resolution making military drill compulsory:

"That on and after September 1, 1918, military drill and instruction be required of all students in the school not physically disqualified, or excused by the president of the faculty with the concurrence of the commanding officer assigned by the War Department."

The War Department accepted the school as a unit of the Students' Army Training Corps and military instruction is given under the direction of the following corps of officers of the United States Army:

HERBERT J. SHEPHERD, 1st Lieut. U. S. A.
Commanding Officer

GLENN B. LITTON, 2nd Lieut. U. S. A.
Adjutant

CARL B. JOHNSON, 2nd Lieut. U. S. A.
Personal Adjutant

ALBERT F. CORFMAN, 2nd Lieut. U. S. A.
Supply Officer

FLOYD M. BILYEU, 2nd Lieut. U. S. A.
Assistant Supply Officer

ARTHUR R. FISH, 2nd Lieut. U. S. A.
Detachment Commander

MINING LAW

Joseph S. Jaffa, Professor

I MINING LAW (Elective)

Credit one hour.

a. Status of the law previous to the discovery of gold in California in 1848.

Organization of mining districts in California and other states; Federal legislation; subsequent state legislation.

b. Lode claims under the act of 1872.

Valuable mineral deposits; surveyed and unsurveyed land; vein or lode; in place; apex; mining claims and location.

c. Important requisites of a valid lode location.

Discovery and location; sinking of shaft; posting of notice and recording; size of location; apex within the location; end lines; side lines; side-end lines; overlapping.

One hour a week during the first semester of the senior year. (Jaffa)

II MINING LAW (Elective)

Credit one hour.

d. Extralateral rights under the act of 1872.

Broad lodes; vein entering and leaving on same side line; vein crossing both parallel side lines; vein crossing end lines and side lines; miscellaneous cases.

e. Secondary veins.

f. Discussion and interpretation of Federal and State Courts of Sec. 2336 U. S. Rev. Statutes as to "the Space of Intersection".

g. Placer claims:

What is locatable as placer; acts of location; known lodes within placers.

h. Tunnel sites.

Location; location of blind veins in tunnel sites; rights of way through prior patented or unpatented claims.

i. Mill sites.

j. Annual labor or assessment work.

k. Abandonment, forfeiture, and relocation.

l. Patent.

One hour a week during the second semester of the senior year. (Jaffa)

PHYSICS

Frank E. E. Germann, Professor of Physics and Electrical Engineering.

Joseph William Gray, Assistant Professor of Electrical Engineering.

The courses in Physics are intended to give the student a broad, general knowledge of the whole subject, as well as the knowledge most essential to his work as a mining or metallurgical engineer. Special attention is given to the general laws underlying the science, and the history of the development of the more important discoveries is carefully studied. In the laboratory courses, the purpose is to excite in the student an interest in experimentation and to develop the ability for careful observation. Special attention is given to report writing and the graphical interpretation of results.

I GENERAL PHYSICS **Lectures**

Mechanics of solids and fluids; sound; heat.

A course of lectures, illustrated by experiments, and recitations with assigned problems. The subjects treated are mechanics, including the elements of kinematics, dynamics, and hydrostatics; the properties of matter; heat, including thermometry and expansion, calorimetry, change of state, conduction, radiation, kinetic theory of gases, and the elements of thermodynamics; sound, including wave motion in general, production and propagation of sound waves.

Prerequisites: Mathematics I to IV, inclusive, and registration in Mathematics V.

Text: Kimball, **Textbook of Physics**

References: Preston, **Theory of Heat**
Edser, **Heat for Students**
Barton, **Textbook of Sound**

Three lectures and two recitations a week during the first semester of the sophomore year.

Required of all students. (Germann)

II ELEMENTARY PHYSICAL MEASUREMENTS **Laboratory**

This course is arranged to accompany Course I. A selected group of experiments in mechanics, sound, and heat are performed, and a complete report on each experiment is presented. It is the aim to train the student to write clear, concise reports on the work performed, and to give a complete analysis and discussion of results. Whenever possible curves are plotted and interpreted. The aim of the course is to teach the student the necessity of careful work as well as to have him acquire skill in physical measurements.

Prerequisite: Registration in Course I

Laboratory Manual: Nichols and Blaker

Six hours a week during the first semester of the sophomore year.

Required of all students. (Germann, Gray)

III GENERAL PHYSICS **Lectures**

Electricity, magnetism, and light.

This course is a continuation of Course I. The subjects treated are electricity and magnetism, including electrostatics, electrokinetics, thermo-electricity, magnetic induction, electromagnetism, electrolysis, the electro-magnetic theory, and electric oscillations; conduction of electricity through gases, and radioactivity; light, including propagation reflection, refraction, dis-

Prerequisites: Mathematics V
Physics I and II

Text: Kimball, **Textbook of Physics**

References: Wood, **Physical Optics**
Starling, **Electricity and Magnetism**

Three lectures and two recitations a week during the second semester of the sophomore year.

Required of all students. (Germann)

IV ELEMENTARY PHYSICAL MEASUREMENTS **Laboratory**

A continuation of Course II

Prerequisites: Course II and registration in Course III

Laboratory Manual: Nichols and Blaker

Six hours a week during the second semester of the sophomore year.

Required of all students. (Germann, Gray)

V ANALYTICAL MECHANICS **Lectures**

Credit three hours.

This course consists of the study of the fundamental and derived laws of matter, force, and motion, with their application to engineering problems. The chief topics treated are composition and resolution of forces; solution of framed structures; center of gravity; moment of inertia; kinetics of a particle; projectiles; work; power; energy; friction; kinetics of rigid bodies; and impact. The course is taught by text assignments, with lectures and recitations. Special emphasis is placed upon problem work.

Prerequisites: Math. V and VI; Physics I and II

Text: Fuller and Johnston, **Applied Mechanics**

References: Minchin, **Treatise on Statics**
Routh, **Dynamics**
Ziwet, **Theoretical Mechanics**
Church, **Mechanics of Engineering**
Maurer, **Technical Mechanics**
Church, **Notes and Examples in Mechanics**

Three hours a week during the first semester of the junior year.

Required in Groups I, II, III, and IV (Germann)

VI ELECTRON THEORY AND RADIOCTIVITY **Lectures** (Elective)

Credit two hours.

This course consists of lectures illustrated by experiments in the laboratory. The subjects considered are: conduction of electricity through gases; properties of Röntgen, Lenard, and Canal rays; study of X-ray spectrometry; methods used in the determination of the mass and charge of the electron; radioactive substances and their transformations, together with a study of the various laboratory methods of measuring the activity of radioactive minerals.

Prerequisite: Course III

Two hours a week during the first semester of the junior year. (Germann)

VII ELECTRICAL MEASUREMENTS **Laboratory** (Elective)

Credit one hour.

This course deals with the theory of the absolute and relative measurements of the various electrical and magnetic quantities and includes the actual measurement of these quantities in the laboratory.

Prerequisite: Course III

Three hours a week during the first semester of the junior year. (Germann)

VIII ALTERNATING CURRENTS Laboratory (Elective)

Credit one hour.

The subjects considered are: e.m.f. and current curves; the harmonic e.m.f. and current; circuits containing capacity; power in alternating circuits; graphical method of investigating harmonic e.m.f. and currents; parallel circuits; polyphase e.m.f. and currents; the two-phase system; the three-phase system; delta and star connections; the alternating current transformer; general equations; solution of equations under various conditions; transformer theory as applied to a. c. motors.

Prerequisite: Course III

Three hours a week during the second semester of the junior year. (Germann)

IX ELECTROLYTES AND ELECTROLYSIS Lectures (Elective)

Credit one hour.

A detailed study of the mechanics of electrolysis, the theory of electrolytic dissociation, polarization, diffusion of electrolytes, and contact difference of potential between liquids. The analysis of simple and complex mixtures of chemical compounds by electrolytic conductivity and single potential method is also studied at length. The course serves as an introduction to Course X, and is a prerequisite to it.

Prerequisites: Courses I, II, III, and IV

One hour a week during the first semester of the senior year. (Germann)

X PRIMARY AND REVERSIBLE BATTERIES Lectures (Elective)

Credit one hour.

A continuation of Course IX. The theory and practice of batteries is taken up in the light of the work covered in Course IX. The lectures cover depolarizers, positive and negative temperature coefficients, calculation of electro motive forces from thermo-chemical data; standard cells; and the care of batteries.

Prerequisite: Course IX

One hour a week during the second semester of the senior year. (Germann)

XI CHEMICAL PHYSICS Lectures (Elective)

Credit two hours.

This course is given to prepare the student for a clear understanding of the underlying physico-chemical principles of crystallography, metallography, and metallurgy. The influence of temperature and pressure on chemical composition, crystal form, and allotropic modifications of the elements is studied in connection with their bearing on the geological and mineralogical formation of the earth's crust. The solution of gases in metals, adhesion, absorption, and occlusion, together with the phenomenon of "spitting" is also considered. Fusion and solidification, vaporization and condensation, solid and colloidal solutions, are all given special attention. In connection with colloidal solutions, questions of flotation are taken up.

Prerequisites: Physics I, II, III, and IV and Chemistry I and II

Two hours a week during the first semester of the senior year. (Germann)

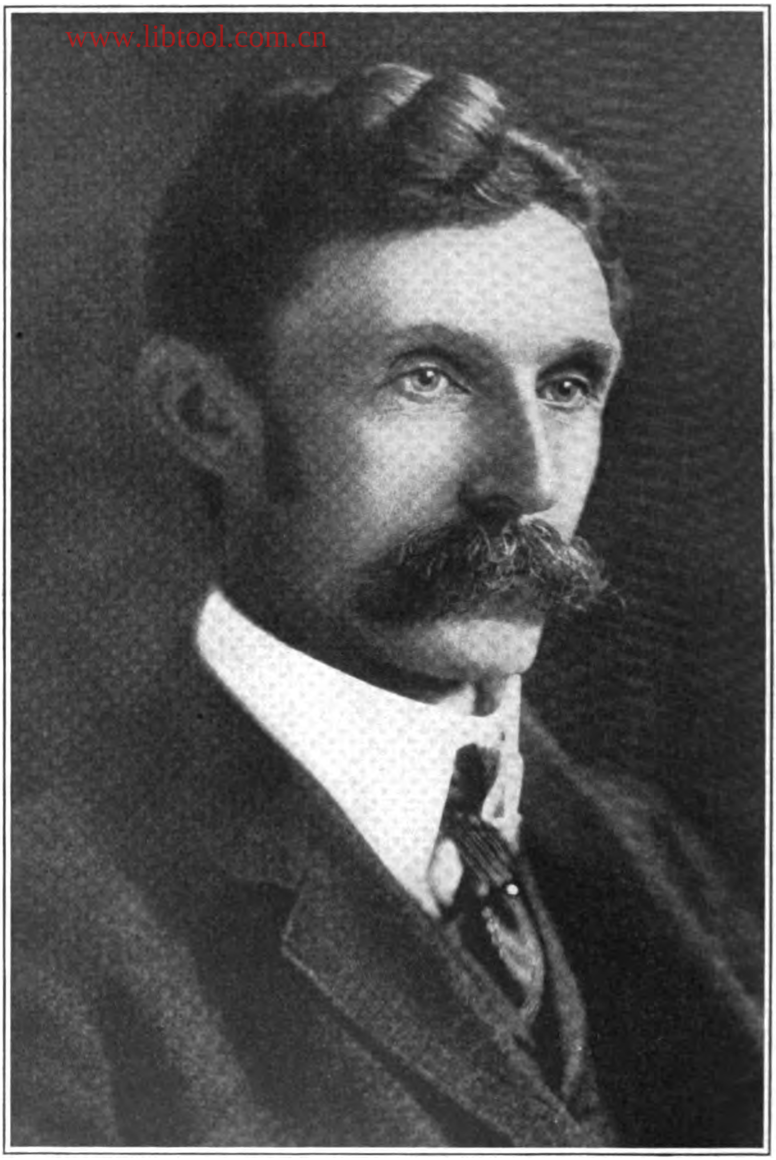
XII CHEMICAL PHYSICS Laboratory (Elective)

Credit one hour.

A group of selected experiments closely paralleling the work of Course XI and illustrating some of the simpler chemico-physical phenomena are performed.

Prerequisite: Registration in Course XI.

Three hours a week during the second semester of the senior year. (Germann)



DR. JOSEPH AUSTIN HOLMES
Late Director, United States Bureau of Mines

SAFETY AND EFFICIENCY ENGINEERING

James Cole Roberts, Professor

On August 12, 1915, the Board of Trustees passed the following resolution:

Whereas, the late Joseph A. Holmes, Director of the United States Bureau of Mines from the date of its creation, May 16, 1910, until his death in Denver, July 13, 1915, devoted his life to the advancement of safety and efficiency in the mining and metallurgical industries of the entire country; and

Whereas, it is meet and proper that a lasting memorial of him should be established and maintained; therefore

Be It Resolved by the Board of Trustees of the Colorado School of Mines that there be and hereby is created a full chair in this institution to be known as the Joseph A. Holmes Professorship of Safety and Efficiency Engineering.

I SAFETY AND EFFICIENCY ENGINEERING Lectures

Credit one hour.

The subjects in this course are taken up with respect to their bearing on safety and efficiency as applied to mining, milling, and smelting operations.

Illumination: the importance of efficient lighting in mine, mill, and smelteries; use of oil, acetylene, gasoline, gas, arc, and incandescent lights; candles, carbide, safety, and portable electric lamps; the importance of efficient lighting around shafts and tipples.

Ventilation: deleterious and harmful gases found in coal and metal mines; approved methods of ventilation.

Explosives: the various types of explosives are discussed from the standpoint of safety and efficiency; safety measures involved in the storage, handling, and use of explosives; approved types of magazines and thaw houses; blasting and shot-firing by squibs, fuse, and electric detonators; tamping and tamping materials, and the placing of holes.

Mine fires: history of some of the important mine fires; storage of oil, oiling and greasing cars underground; explosions; gas and dust explosions, and incendiarism.

Methods of fire prevention: fire patrols; systematic examination of all places where fires are likely to occur; doors; permanent stopings and bulkheads of non-combustible material; organization of fire fighting crews with fire drills.

Fire-fighting equipment: ample water supply; air line convertible into water line; sprinkling device in shaft; water plugs; fire extinguishers; telephones; fire signals; fire pumps; fire doors; ventilating fans; water barrels and fire buckets.

Methods of extinguishing fires: use of fire extinguishers; fighting fire directly with water; sealing off the fire zone, and introducing gases and steam; bulkheading and flooding; hydraulic flushing; use of rescue apparatus and gas analysis, as an aid in fighting fires.

Gas and dust explosions: the excessive danger of gas and dust in coal mines; a brief history of some of the important explosions; means of preventing explosions; use of inert stone or adobe dust; Taffnell and Rice stone dust barriers.

References: Haldane, **Investigation of Mine Air**
Beard, **Mine Gases and Explosions**
Lamphrecht, **Recovery Work After Pit Fires**
Garforth, **Rules for Reçovering Coal Mines After Explosions and Fires**
United States Bureau of Mines, **Publications**
United States Geological Survey, **Bulletins**
Cowee, **Practical Safety Methods and Devices**

One hour a week during the first semester of the junior year.

Required in Group II. (Roberts)

II SAFETY AND EFFICIENCY ENGINEERING **Laboratory**
Credit one hour.

In this course thorough instruction and training is given in the care, testing, and handling of all lights used in the mines, such as candle, carbide, safety, and electric lamps. The students are required to make inspection trips to operating mines, mills, and smelteries and inspect and report on them as to safe and efficient methods and practices. Instruction and training is also given in the various types of rescue apparatus—the lungmotor and pulmotor and other mechanical respiratory devices—and in the repair, upkeep, and maintenance of this equipment and accessory apparatus. The rescue training is conducted in the mine in irrespirable gases, and smoke, and under conditions which would exist in case of an actual mine fire or after an explosion. Students are required to build brattices and bulkheads, saw and set timbers and props, put out fires with hose and fire extinguishers, and carry injured men from mine workings filled with smoke and gases. Special attention is paid to mine rescue and recovery practices of the government, states, and mining companies. Each student is required to undergo a rigid physical and medical examination before he is permitted to take this training.

Reference: United States Bureau of Mines, Publications

Three hours a week during the first semester of the junior year.

Required in Group II. (Roberts)

III SAFETY AND EFFICIENCY ENGINEERING Lectures

Credit one hour.

This course is a continuation of Course I and takes up the following subjects: laws of the various states relative to safety; policing and inspection of mines by federal and state officials and by company inspectors; industrial accident commissions and compensation laws of the different states; inspection and merit-rating systems as practiced by the Associated Insurance Companies; accidents, their causes, classification, and means of prevention; sanitation and health conditions; education and social welfare, night schools, mining institutes, moving pictures, and entertainments; trade agreements and relations between employers; unionism versus open shop; miners' organizations; discipline; reporting of unsafe or inefficient practices or conditions; safeguarding all machinery; careful investigation of all accidents immediately after their occurrence; public meetings of employers and employees in the interest of safety and efficiency; suggestion boxes and bulletin boards; bonus system; personal instruction to employees; statistics with methods of obtaining and recording them and their value from the standpoint of safety and efficiency; purchasing, storing, checking, and issuing materials and supplies; careful inspection of all tools and equipment; labor conditions; proper treatment of employees by employers; cooperation.

References: Haldane, Investigation of Mine Air
Beard, Mine Gases and Explosions
Lamphrecht, Recovery Work After Pit Fires
Garforth, Rules for Recovering Coal Mines After Explosions and Fires
United States Bureau of Mines, Publications
United States Geological Survey, Bulletins
Cowee, Practical Safety Methods and Devices

One hour a week during the second semester of the junior year.

Required in Group II (Roberts)

IV SAFETY AND EFFICIENCY ENGINEERING Laboratory

Credit one hour.

This course involves a practical study of physiology, anatomy, and hygiene, and is followed by thorough instruction and training in the care and transportation of persons injured in and about mines, mills, and metallurgical plants. Students are required to become proficient in the use of compresses, tourniquets, bandages, splints, and stretchers.

References: Lauffer, Electrical Injuries
United States Bureau of Mines, Publications
American Red Cross, Textbook on First Aid
Johnson, First Aid Manual
Manson, Tropical Diseases
Kober and Hanson, Diseases of Occupation and Vocational Hygiene

Three hours a week during the second semester of the junior year.

Required in Group II (Roberts)

SPANISH

Leslie Fairbanks Paull, Assistant Professor of Modern Languages

The purpose of these courses is to familiarize students who expect to do professional work in Spanish-American countries with the fundamental principles of the grammar; with the sound of the spoken language; and with the forms of business correspondence and of technical writing in current use in those countries.

I SPANISH (Elective)

Credit two hours.

This consists of a study of elementary grammar, accompanied by copious written exercises outside the class, and by practice in pronunciation and simple translation in the class. Spanish conversation will be introduced gradually, with constantly increasing use of the language in conducting the class.

Text: Hills and Ford, **First Spanish Course**

Two hours a week during the first semester of the freshman year. (Paull)

II SPANISH (Elective)

Credit two hours.

This course is a continuation of Course I. It consists of advanced study of Spanish grammar and its application to Spanish composition. Classes are conducted as completely as possible in Spanish.

Prerequisite: Course I

Texts: Hills and Ford, **First Spanish Course**
Crawford, **Spanish Composition**

Reference: "**La Revista del Mundo.**" (Current issues)

Two hours a week during the second semester of the freshman year. (Paull)

III SPANISH (Elective)

Credit two hours.

Prerequisite: Course II

This course is conducted as completely as possible in Spanish. It consists of three parts:

1. Advanced composition.
2. Commercial correspondence.
3. Practice, written and oral, in the use of technical words, phrases, and idioms relating to mining and engineering, and reading and reports based upon Hispano-American journals.

Texts: Harrison, Spanish Correspondence
Espinosa, Advanced Spanish Composition and Conversation

References: Graham and Oliver, Spanish Commercial Practice
Halse, Dictionary of Spanish-English Mining and Metallurgical Terms

Two hours a week during the first semester of the sophomore year. (Paull)

IV SPANISH (Elective)

Credit two hours.

Continuation of Course III

Prerequisite: Course III

Two hours a week during the second semester of the sophomore year. (Paull)

V SPANISH (Elective)

Credit one hour.

This course is intended for irregular students who have only a brief time in which to get a start in the knowledge of the language.

Text: Hall, All Spanish Method

One hour a week during the first semester of the junior year. (Paull)

VI SPANISH (Elective)

Credit one hour.

This is a continuation of Course V

Prerequisite: Course V.

Text: Hall, All Spanish Method

One hour a week during the second semester of the junior year. (Paull)

INSPECTION TRIPS

The same importance is attached to the inspection trips as to class-room and laboratory work. Grades are given on reports submitted and satisfactory results are required for graduation.

METALLURGICAL TRIPS The study of various metallurgical processes and plants may be prosecuted with great benefit in Colorado. Beginning with the junior year and continuing throughout the senior year, inspection trips are taken for the purpose of supplementing the laboratory work and for illustrating the lecture courses. Printed outlines of reports which carry out all of the important features peculiar to the plant and to the practice, are given to the students. A written report on each trip is turned in for correction and criticism.

During the junior year the following plants are visited:

The Pueblo plant of the American Smelting and Refining Company, for a study of the metallurgy of lead.

The Minnequa plant of the Colorado Fuel and Iron Company at Pueblo, for a study of the manufacture of iron and steel and for the working up of the product into commercial forms.

The Globe plant of the American Smelting and Refining Company at Denver, for a study of the metallurgy of lead.

The zinc plant of the American Smelting and Refining Company at Pueblo, for a study of the metallurgy of zinc.

During the senior year the following plants are visited:

The Jackson and other mills in Idaho Springs, for the study of ore dressing.

The various stamp mills of Black Hawk and Central City, for the study of amalgamation.

The plants of the Ferro-Alloy Co. and the Iron Mountain Alloy Co. at Denver.

The Portland and Vindicator Mills at Victor.

The Golden Cycle Mining and Reduction Co. Plant at Colorado Springs.

MINING TRIPS During the junior and senior years, the students are taken to well known Colorado mining districts for the inspection of actual mining operations. These trips are arranged in such order as to introduce different interesting features and, at the same time, to emphasize definite portions of the classroom instruction. Attention is paid to surface plants, underground equipment, mining systems, and to all the regular operations, both above and below ground. Lectures precede these trips to explain their objects, the particular properties to be visited, and the operations to be witnessed. Printed outlines are furnished and each student is required to submit a report, illustrated by his own sketches.

ELECTRICAL AND MECHANICAL POWER PLANT TRIPS In connection with the junior mining trip to Breckenridge, Colorado, a study is made of the application of electric power to dredging, milling and mining. Near the end of the junior year the class visits the plants and sub-stations of the Denver City Tramway Company and of the Denver Gas and Electric Company. Here they see in operation nearly all the electrical machinery and apparatus studied during the year. The seniors make a combined steam and electric plant trip to the station of the Northern Colorado Power Company at Lafayette, Colorado.

AVAILABLE MINING, METALLURGY, ENGINEERING, AND GEOLOGICAL TRIPS

COLORADO

PORTLAND.

Metallurgy.

Colorado Portland Cement Company: crushing and fine grinding of raw material and clinker.

CANON CITY.

Metallurgy.

Empire Zinc Company: wet and magnetic separation of zinc ores and magnetic treatment of Wilfley table middlings; experimental plant with magnetizing roaster, magnetic separators, dry and electrostatic separators, and flotation installation.

Geology.

A study of the Mesozoic sedimentary formations that are upturned in fine hog-backs in a great semicircle around the Canon City basin.

LEADVILLE.

Metallurgy.

Arkansas Valley Plant of the A. S. and R. Company: lead smelting; Benight-Lloyd and H. and H. roasting; and blast furnace treatment of silver-lead ores.

Adams Mill: wet concentration of lead ores.

Yak Mill: magnetic concentration with International separators and Cleveland-Knowles separators, after a magnetizing roast.

Mining.

The students are taken into the Yak Tunnel, through the several mines connected therewith, and are finally hoisted to the surface of Breece Hill through the shaft of the Little Jonny mine. The Moyer, Tucson, and other mines are also visited. Excellent opportunity is afforded for studying the two distinctive kinds of ore bodies for which this district is noted, and to learn, by observation, how these dissimilar ore bodies are attacked and their contents successfully extracted. Interest attaches to the unusual complexity of the ores, which contain gold, silver, and most of the base metal sulphides, oxides, and carbonates.

Engineering.

Arkansas Valley Plant, A. S. and R. Company: steam power plant; capacity 1,500 h.p.; condensing Corliss engines belted to Connersville blowers; return tubular boilers equipped with underfeed stokers.

Colorado Power Company: steam power plant; Curtis turbines, direct connected to 3-phase, 6,600 volt, 60 cycle alternators; current stepped up to 100,000 volts for long distance transmission over steel tower line; small and moderate sized units; Alberger surface condensers with independent dry vacuum pump and centrifugal circulating pump; 400 h.p. B. and W. boilers, hand fired.

Yak Tunnel: Silver Cord property; two-drum electric hoist; motor driven compressors; compressed air and electric driven pumps; continuous current haulage.

Geology.

The Paleozoic series and fault systems are studied underground and the sharply defined moraines, and other glacial phenomena, on the surface.

SALIDA.

Metallurgy.

The plant of the Ohio and Colorado Smelting Co.

SHOSHONE.

Engineering.

Central Colorado Power Company's hydro-electric plant. Water from the Grand river is conducted through a tunnel cut inside of the mountain for approximately two and one-quarter miles, delivered through penstocks to central discharge turbines under a head of 165 feet; ultimate capacity of plant approximately 25,000 h.p.; ultimate transmission voltage 100,000.

SHOSHONE AND GLENWOOD.

Geology.

Archaean gneiss and schist, uncomformable above these are the Paleozoic rocks exposed in the canyon of the Grand river; typical canon erosion and travertine deposits. At Glenwood the Mesozoic rocks.

UTAH.

BINGHAM.

Mining.

This district permits the study of three distinct systems of mining, namely, the overhead stoping, the caving, and the open pit. The extensive properties of the Utah Consolidated Mining Company and the Utah Copper Mining Company are open to the unrestricted inspection of the class. Further interest in this district comes from the opportunity to study aerial tram systems, difficult railroad engineering, and the operations of single companies under different systems.

Geology.

The Carboniferous quartzite and limestone, with intruded igneous masses that have marmorized the limestone at contact; the relationship of the ore bodies to these contact phenomena.

BINGHAM JUNCTION.

Metallurgy.

United States Smelting Company: special roasting devices for lead ores, with neutralization and bag-housing of fumes.

GARFIELD.

Metallurgy.

Utah Copper Company: coarse crushing and roll crushing of Bingham ores with tabling, vanning and flotation methods of concentration.

Engineering.

Utah Copper Company: steam power plant; capacity 10,000 boiler h.p.; 500 h.p. Heine boilers equipped with underfeed stokers; forced draft; concrete stacks; large cross compound Allis and Nordberg engines direct connected to a.c. generators; Wheeler surface condensers with independently driven Edwards air pumps.

American Smelting and Refining Company; steam power plant; large horizontal blowing engines; single stage air compressors driven by cross compound Corliss engines; Worthington surface condensers with Blake air and circulating pump; 500 h.p. Stirling boilers equipped with plain grates.

SALT LAKE CITY.

Metallurgy.

General Engineering Company: special devices for screening, classifying, and concentration of ores.

Geology.

Excursion into the Wasatch range, to see the great synclinal fold and the Wasatch fault; very recent faults and glacial features; Lake Bonneville terrace formations.

MONTANA.

BUTTE.

Metallurgy.

The Precipitation plants: recovery of dissolved copper from mine waters; leaching and recovery of soluble values from dumps.

The Butte and Superior Mill; Timber Butte Mill.

Mining.

The mines of this district exhibit modern practices of lode mining in high grade copper ore. Among the noteworthy mining features studied are: deep mining with the involved difficulties of drainage, ventilation, and timbering; steel surface structures; automatic loading and dumping of ore; rapid hoisting; mechanical framing of timbers; handling of large volumes of acid water; square set stoping; the driving of working levels in country rock; the naturally high temperatures of the working places; and the systematic recording of every operation. Mine and geological underground surveying are exemplified in the practices of the Amalgamated Copper Company.

Geology.

Secondary enrichment of original sulphide ores; the relationship of these ore bodies to the remarkable fault systems of Butte; the study of granite, aplite, porphyry, and rhyolite rocks.

Engineering.

Anaconda Copper Company: mine plant at the New Leonard, 3,500 h.p. Nordberg hoist; 150 foot steel head frame; two stage Nordberg air compressors rope driven by induction motors; locomotive type of boilers.

Anaconda Copper Company: mine plants at the Diamond and Bell mines; very large air compressing plant; two stage compressors equipped for either steam or motor drive; 3,000 h.p. Allis hoisting engine; marine type of boilers; high steel head frame with automatic dumping attachments.

Missouri River Power Company: steam power plant; Westinghouse - Parsons turbines, connected to a.c. generators; surface condensers with independently driven air and circulating pumps; B. and W. boilers equipped with Roney stokers; high tension current station used as relay for the company's hydro-electric plants and operated in parallel with them.

ANACONDA.

Metallurgy.

New Reduction Works: track system for the delivery of ores and shipment of products; compressed air traction for yard haulage; concentrating mill of eight one-thousand ton units; bin systems; briquetting plant; largest furnaces in the world; reverberatory furnaces; converter plant; refining furnaces and casting department; arsenic plant, and flue systems. So much is to be seen here that considerably more time is spent in this plant than at any other point, and, owing to the courtesy of the management, much valuable instruction is possible.

The Anaconda Copper Mining Company: brick department; the manufacture of clay and silica brick of the highest degree of refractoriness and of all shapes.

Engineering.

New Reduction Works: general power plants; large triple expansion condensing Corliss engines belted to line shaft; two and four stage air compressors driven by cross compound Corliss engines; rotary blowers of the Connersville and Root types, direct connected to Corliss engines; rotary blowers, rope driven from induction motors; Stirling boilers equipped with plain grates; rotary converters and transformers for the high tension current brought in from the hydro-electric plants.

UNITED STATES BUREAU OF MINES

ROCKY MOUNTAIN EXPERIMENT STATION

STAFF

Richard B. Moore, B. S., D. Sc.
Samuel C. Lind, A. B., B. S., Ph. D.
Daniel Harrington, E. M.
John W. Marden, B. S., M. S., D. Sc.
John P. Bonardi, B. S.
Malcolm N. Rich, 2nd Lieut. C. W. S.
Charles W. Davis, B. S.
John E. Conley, B. S.

There are at the present time ten experimental stations belonging to the United States Bureau of Mines. These are situated at Pittsburgh, Pa.; Golden, Colo.; Salt Lake City, Utah; Tucson, Ariz.; Berkeley, Calif.; Seattle, Wash.; Fairbanks, Alaska; Minneapolis, Minn.; Urbana, Ill., and Columbus, Ohio. In the majority of cases the stations are doing direct cooperative work with the state institutions, with the object of promoting efficiency in the mining industry. Each station has assigned to it a specific field of work, to which, however, it is not absolutely confined. The work of the Rocky Mountain station covers the whole country in its particular field.

At the present time the work is confined almost exclusively to problems in connection with the production and use of various rare metals for war purposes. Special attention is being paid to the metals zirconium, vanadium, uranium, tungsten, and molybdenum. The Bureau is interested in any problems in connection with these metals, the solution of which promises increased production, a higher efficiency of treatment, or greater usefulness.

In order to extend the work of the Bureau, more particularly to problems of Colorado ores and their products, and also to assist in a closer cooperation with the School of Mines, three cooperative fellowships have been established by the School of Mines for the prosecution of research in mining, metallurgy, and industrial chemistry.

The Mines Safety work for the Rocky Mountain region is under the direction of Daniel Harrington, and also the general supervision of two Mines Safety cars. Car No. 2 has headquarters at Raton, New Mexico, and covers the territory of Arizona, New Mexico, and Colorado, and last year traveled about 10,000 miles. Car No. 5 has headquarters at Butte, Montana, serves Idaho, Montana, South Dakota and Wyoming, and traveled over the entire territory last year. On January 1, 1919, it is expected to have a new car, No. 11, with headquarters at Rock Springs, Wyoming, and will probably have as its territory Southern Wyoming, Utah and Northern Colorado.

The laboratories and offices of the United States Bureau of Mines occupy the Engineering Building. These consist of two large general laboratories on the second floor for analytical and research work; a large laboratory for technologic experimental work in the basement; and, in addition, a number of small private laboratories and rooms for special work. The equipment is adapted to investigations in connection with the rare metals, both on a small and semi-commercial scale. The technologic laboratory is equipped with leaching apparatus of various kinds, precipitating tanks, filter presses, steam-jacketed kettles, roasting, and fusing furnaces.

The equipment for work in radioactivity is excellent. Two rooms are especially reserved for this purpose. The Bureau possesses nearly two grams of radium which it has secured as its pro rata part of its cooperative work with the National Radium Institute. Five hundred milligrams of this radium is reserved at Golden for experimental work. In addition, during the past year, the Bureau has, through its research work and cooperation with the Welsbach Company, received a supply of mesothorium which will be used for further research work at the Rocky Mountain section.

COURSE FOR PROSPECTORS AND PRACTICAL MINING MEN

The Course for Prospectors and Practical Mining Men, which was inaugurated by the Colorado School of Mines in January, 1915, proved so popular and profitable to those who attended, that the course has been repeated each year since. As a result of the success which attended this innovation, it has become an established part of the work of the School of Mines and will be offered annually as long as there is any apparent need or demand. The work is planned so as to keep the men occupied throughout each day. This will be an advantage from the point of view of instruction and makes the course less expensive to those who attend.

All of the courses are of the most practical nature and comprise instruction in mineralogy, common minerals, ores, and rocks; elementary chemistry; principles of ore dressing, assaying, and the more common metallurgical processes; methods of valuing, buying, and selling ore; placer and lode mining; location of mining claims; first aid to the injured and safety engineering. They are given entirely by regular members of the faculty and consist of lectures, supplemented by practical laboratory demonstrations.

Those who expect to take advantage of this work are asked to notify the school authorities as soon as possible, in order that ample preparation can be made for the work. Address all correspondence to The Registrar, Colorado School of Mines, Golden, Colorado.

FEE

A single fee of two dollars is charged for the entire course of four weeks and is payable on registration.

Outline of Subjects

COMMON ROCKS AND MINERALS

Professors Ziegler and Van Tuyl

Three hours lecture and six hours practical laboratory work a week.

This course is devoted to the study of common minerals, ores, and rocks. The instruction includes blowpipe reactions, with apparatus and appliances. A few of the rarer ores in which prospectors are just now greatly interested, such as those of chromite, tungsten, and molybdenum, will also be considered.

GENERAL GEOLOGY; GAS AND OIL

Professors Ziegler and Van Tuyl

Three hours lecture work a week.

This course is devoted to such geological features as throw light on the origin and manner of occurrence of ore deposits and on the structural features frequently met in mining. These latter include faults and folds, strikes and dips, and the mutual relationship of rock masses. Particular attention is given to the kinds of rocks and geological conditions which appear to affect ore deposition. An important part of prospecting is to know what may be sought for in the different formations. Gas and oil geology is a feature of this course.

CHEMISTRY

Professors Botkin and L. D. Roberts

Two hours lecture and six hours practical laboratory work a week.

The object of the course is to make the prospector more familiar with the use of such apparatus and chemicals as may aid him in supplementing his field work, and to equip him with knowledge of the characteristic properties of the common metals. Some work on the commercially rare metals is also given.

METALLURGY, ORE DRESSING, AND ASSAYING

Professor Palmer

Three hours lecture and six hours practical laboratory work a week.

The following subjects are treated: principles and methods of sampling as used in mines, mills, and smelteries; methods of assaying common ores; determination of the value of ores from assay or analysis; how ores are bought and sold; the value of an ore to the producer; simple tests for the prospector; nature of ores, crushing, sizing, and classification; course and fine concentration in water; methods of dry concentration; amalgamation; flotation; electrostatic and magnetic separation; determining percentage extraction; the cyanide process; leaching copper and zinc ores; smelting lead and copper ores; simple treatment plant for prospectors.

The laboratories and experimental plant afford exceptional opportunities for demonstration and the student is given every reasonable facility to study methods and mechanical appliances.

PLACER MINING

Professor Wolf

Two hours a week.

This course includes a discussion of the theory and practice involved in the recovery of precious metals from sand and gravel deposits. Among the subjects considered are: panning, rocking, sluicing, hydraulicing, dredging, and dry placering. Typical operations are described for the purpose of illustration.

MINING CLAIMS
Professor Wolf

Three hours a week.

This course includes instruction in the methods of acquiring title to mineral lands in the United States. Practical methods of locating and surveying mineral lands are described and instruction is given in the preparation and filing of documents used in acquiring title to lode and placer claims; mill and tunnel sites; timber, stone, and coal lands; water rights. Mining laws which are important to the prospector are discussed and explained.

LODE MINING
Professor Wolf

Two hours a week.

This course includes a discussion of surface prospecting, methods employed, and equipment required. The opening and development of prospects to the best advantage are discussed; also proper methods of sampling in the mine and on the dump.

MINE SAFETY ENGINEERING
Professor J. C. Roberts

Two hours lecture and three hours practical work a week.

The course in Mine Safety Engineering includes the following:

1. General safety in mines.

2. Explosives: composition of explosives in general use in coal and metal mines and in quarries; composition of resultant gases from explosives and the danger of going back too soon after shots are fired; the proper and improper methods of handling explosives.

3. Mines gases: gases encountered in coal and metal mines, prospect holes, and shafts; their composition, methods of detecting, and removal; precautions to be taken to prevent accumulation; methods of recovering and removing men overcome.

4. Mine lighting.

5. Mine fires: their causes, methods of preventing and extinguishing.

6. Mine rescue methods and appliances, with demonstrations of various types of mine rescue apparatus in use, resuscitating devices, pulmotor and lungmotor.

7. First aid to the injured; a complete course in first aid will be given. This includes the following: the human body; wounds, with and without bleeding; bruises, sprains, and dislocations; fractures, simple and compound; bandages and splints; shock, fainting, and poisoning.

SUMMER SCHOOL

For the benefit of matriculated students who desire either to make up deficiencies or to do advanced work, and for the benefit of prospective students who have not completed the requirements for entrance, a Summer School is held annually from the middle of July to the last of August.

The following courses are usually given:

Requirements for entrance.

Review Algebra	Fee $2.00
Solid Geometry	Fee 2.00
Chemistry	Fee 7.00
Physics	Fee 4.00

College Courses:

Mathematics.

Mathematics	I	College Algebra
"	II	Plane and Spherical Trigonometry
"	III	Analytic Geometry
"	IV	Elementary Calculus
"	V	Calculus
"	VI	Calculus

The fee for each of these courses is $2.00.

Chemistry:

Lecture Courses.

Chemistry	III	Qualitative Analysis
"	IV	Qualitative Analysis
"	VII	Quantitative Analysis
"	VIII	Quantitative Analysis

The fee for each of these courses is $2.00.

Laboratory Courses:

Chemistry	V	Qualitative Analysis
"	VI	Qualitative Analysis
"	IX	Quantitative Analysis
"	X	Quantitative Analysis

The fee for each of these courses is $7.00.

Mechanical Engineering:

Lecture Courses.

Mech. Eng.	I	Descriptive Geometry
" "	III	Elementary Machine Design
" "	V	Machine Design
" "	VII	Kinematics of Machinery

Drawing Courses:

Mech. Eng.	II	Descriptive Geometry
" "	IV	Elementary Machine Design
" "	VI	Machine Design
" "	VIII	Kinematics of Machinery

The fee for each of these courses is $2.00.

Metallurgy:

Lectures.

Metallurgy I Assaying ....Fee $2.00

Laboratory.

Metallurgy II Assaying ....Fee $10.00

Instruction is given by regular members of the faculty.

A laboratory deposit, to cover the cost of material used, is required in each laboratory course. Any unused portion is returned at the end of the course.

The numbered courses are described in the catalog. The schedule of hours will be arranged on the opening day.

For further particulars address The Registrar, Colorado School of Mines, Golden, Colorado.

SCHOLARSHIPS

Scholarships are awarded to applicants for admission who show proficiency in their studies and are recommended by the proper school officials. A candidate must satisfy the requirements for entrance and file his application, with recommendations, on or before July 1 following his graduation. A scholarship relieves the holder of all tuition and laboratory fees for a period of four years, but will be terminated if the holder does not maintain a satisfactory standing in his studies, or does not comply with the requirements of the faculty or the trustees.

UNITED STATES ARMY AND NAVY SCHOLARSHIPS These scholarships are available to officers and men who are honorably discharged from the Army or Navy or the Marine Corps of the United States, and may be awarded by the President of the school to candidates who are recommended by the proper Army or Naval official. They are intended to benefit men who gave up their college career to enter the service and who, after the war, wish to complete their college course. To non-residents of Colorado these scholarships have an annual value of approximately $200.00.

UNITED STATES SCHOLARSHIPS A scholarship is awarded each year to each State in the Union on the recommendation of the State Superintendent of Public Instruction. It has an annual value of approximately $200.00.

COLORADO SCHOLARSHIPS A scholarship is given each year to each of the accredited high schools of the State of Colorado. It is awarded on the recommendation of the principal, and has an annual value of approximately $50.00.

COLORADO LABOR EDUCATION ASSOCIATION SCHOLARSHIPS Five scholarships are awarded annually on the recommendation of the Colorado Labor Education Association. They have an annual value of approximately $50.00.

FOREIGN SCHOLARSHIPS Scholarships are awarded to each of the Latin-American countries, to each of the provinces of Canada, to Cuba, Porto Rico, and to the Philippine Islands. They have an annual value of approximately $200.00. These scholarships are awarded on the recommendation of the following officials:

CENTRAL AMERICA

Costa Rica, San José..............Minister of Public Instruction
Guatemala, Guatemala............Minister of Public Instruction
British Honduras, Belize......................Inspector of Schools
Honduras (Republic), Tagucigalpa..Minister of Public Instruction
Nicaragua, Managua..
.......Minister of Foreign Relations and Public Instruction
Salvador, San Salvador..........Secretary of Public Instruction
Panama, Panama...............Secretary of Public Instruction
Porto Rico.................Superintendent of Public Instruction
Cuba.....................Superintendent of Public Instruction

SOUTH AMERICA

Argentina, Buenos Aires..........Minister of Public Instruction
Bolivia, Sucre........Minister of Justice and Public Instruction
Brazil, Rio de Janeiro....................................
.........Minister of Justice, Interior and Public Instruction
Chile, Santiago..................Minister of Public Instruction
Colombia, Bogota.................Minister of Public Instruction
Ecuador, Quito...................Minister of Public Instruction
Paraguay, Asuncion.......................................
........Minister of Justice, Worship and Public Instruction
Peru, Lima...........Minister of Justice and Public Instruction
Uruguay, Montevideo............Minister of Public Instruction
Venezuela, Caracas................Minister of Public Instruction

CANADA

Alberta, Edmonton...........Chief Superintendent of Education
British Columbia, Victoria...Chief Superintendent of Education
Manitoba, Winnipeg.....................Minister of Education
New Brunswick, Frederickton...........................
.........................Chief Superintendent of Education
Nova Scotia, Halifax.........Chief Superintendent of Education
Ontario, Toronto........................Minister of Education
Prince Edward Island, Charlottetown.....................
............Chief Superintendent of Education and Council
Quebec, Quebec...................Council of Public Instruction
Saskatchewan, Regina...................Minister of Education
Yukon Territory, Dawson...Superintendent of Public Instruction

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Philippine Islands, Manila..Superintendent of Public Instruction
Mexico, D. F............Director General de Educacion Publica

GRADUATE RESEARCH FELLOWSHIPS

The Colorado School of Mines offers fellowships in Mining, Metallurgical, and Chemical Research in cooperation with the U. S. Bureau of Mines. These fellowships are open to graduates of universities and technical schools who are qualified to undertake research. The value of each fellowship is $900.00, payable in twelve monthly installments of $75.00 each. Fellowship holders must be graduates of colleges, universities, or technical schools of good standing. During the college year they will be required to devote fifteen hours a week to the school as laboratory assistants. The remainder of the time they may pursue advanced studies and become candidates for higher degrees or may engage in research work.

The purpose of these fellowships is to undertake the solution of problems in mining, metallurgy, and metallurgical chemistry which are of special importance to the State of Colorado, and also problems in connection with the production of the rare metals of general interest. Subjects for research may be selected from the following general fields:

1. Pyrometallurgy, electrometallurgy, and other methods of metal extraction.
2. Metallography and the heat treatment of metals.
3. Ore dressing, including concentration by wet and dry methods, flotation, electromagnetic and electrostatic separation.
4. Utilization of the rare metal resources of Colorado.
5. Problems involved in the development of the Oil Shale industry.
6. Radioactivity, radioactive transformations, and the study of radioactive minerals.

Facilities of the Colorado School of Mines experimental mill and of the various chemical, metallurgical, and mechanical laboratories of the Colorado School of Mines and also of the U. S. Bureau of Mines will be available for the use of holders of the graduate research fellowships.

Applicants should send a copy of their collegiate records from the Registrar's office of the college where they have been, or will be, graduated. They should also state their professional experience and give the names and addresses of at least three persons who are familiar with the character, training, and ability of the applicant. Applications should be addressed to the President of the Colorado School of Mines, Golden, Colorado.

GENERAL INFORMATION

TUITION

The Statutes of Colorado provide as follows:

> "The said School of Mines shall be open and free for the instruction to all bona fide residents of this State, without regard to sex or color, and, with the consent of the Board, students from other states and territories may receive education thereat upon such terms and at such rates of tuition as the Board may prescribe."

The tuition for non-residents is one hundred fifty dollars a year, payable in two installments, seventy-five dollars at the beginning of each semester.

DEPOSITS.

Deposits are required to cover the cost of supplies consumed. Any unused balance is returned.

For courses in Chemistry	$10.00
For Metallurgy II	25.00
For drawing (paid only once)	2.50
For locker (paid only once)	1.00

FEES.

Fees are charged to cover not only the cost of materials and supplies furnished, but also the wear on apparatus. No part of a fee is returnable. The athletic fee, although collected by the school, is turned over to the Treasurer of the Athletic Association and is expended only for athletic purposes.

Matriculation fee	$5.00
Athletic fee (paid each semester)	5.00
Graduation fee	5.00
Thesis fee	5.00

LABORATORY FEES

Chemistry V, VI, IX, X, XII, and XIV (each)	$ 7.00
Chemistry XVI and XVII (each)	5.00
Civil Engineering II	5.00
Civil Engineering IV	2.00
Civil Engineering VI	1.00
Coal Mining IX	5.00

Electrical Engineering II, IV, VI, and VIII (each)	3.00
Geology and Mineralogy III, IV, VIII, and XIII (each)	5.00
Geology and Mineralogy VII and IX	3.00
Mechanical Engineering XVIII	5.00
Metallurgy II	10.00
Metallurgy VIII and XVI (each)	5.00
Metallurgy IX, XI, XIII, and XV (each)	3.00
Metal Mining III and IV (each)	5.00
Physics II, IV, VII, VIII and XII (each)	4.00
Safety Engineering II and IV (each)	5.00

BOARD AND LODGING

The school has no dormitory. Board can be obtained in private families for six to seven dollars a week. Students' clubs furnish board for about twenty-four dollars a month. Rooms can be obtained for eight dollars to twelve dollars a month.

OTHER EXPENSES

There are other expenses incidental to the mining, metallurgical, engineering, chemical, and geological trips, which vary so widely that they can not be estimated.

Students leaving in mid-term, except on account of severe or protracted sickness, are not entitled to the return of fees or tuition. **All charges of the school are payable strictly in advance at the beginning of each semester.** No student is allowed to be graduated while indebted to the school. The Trustees reserve the right to make incidental changes in fees and deposits without printed notice, as new and unforeseen emergencies may arise.

Students who desire to earn money to defray their school expenses are advised to limit their work to the summer vacation. The course of study is too exacting to allow much time during the college year for outside work.

The total expenses of the college year, including room and board but exclusive of tuition, need not exceed five hundred dollars, and may be reduced considerably by strict economy.

THE QUARTERLY

Four times a year, in January, April, July, and October, the school issues the Quarterly. The various numbers include the Catalog, the Book of Views, Commencement addresses, and articles of a mining or of a metallurgical nature.

METHOD OF GRADING

The following system of grading is used:

A—Excellent

B—Good

C—Fair

D—Conditioned

E—Failed or Subject Dropped

A, B, and C are passing grades.

D (Conditioned) means that the student is not passed. The deficiency may be removed by passing a re-examination or by otherwise completing the work. Unless a condition is removed before the beginning of the next school year the D becomes an E.

E (Failed or Subject Dropped) means that the subject must be taken again, and that no subject depending upon this one may be taken until the E is removed. In removing an E the student must take the subject again either at a regular period or under conditions approved by the head of the department.

Three hours of laboratory or of drawing are regarded as the equivalent of one lecture or recitation hour.

In case a student fails to complete his work in any subject the instructor may, at his discretion, report to the office not a D but an "Incomplete", which shall be designated by the letters "Inc." This is not regarded as a condition, but it becomes an E at the beginning of the next school year unless previously removed, or unless an extension of time is given by the instructor in charge.

In case a student leaves school with one or more conditions and returns after an absence of a year or more, the term "next school year" will be interpreted to mean the next school year of his attendance; but in case he leaves at the close of the first semester he may return at a similar period a year or more later, subject to the conditions under which he left, as though there had been no break in his attendance, except in case of a changed curriculum.

THE LIBRARY

The school library occupies one-half of the second floor of Guggenheim Hall. The room is well lighted and ventilated and has a seating capacity for one hundred twenty readers. The library contains about fifteen thousand volumes and several hundred pamphlets, principally of a technical nature, and is being increased in subjects corresponding to instruction given in the school. Direct access to the shelves is permitted to all students in order that they may obtain the benefit of examining the books themselves. Books which are not needed for special reference work are loaned for home use for a period of two weeks. The card catalogue includes entries under author, title, and subject, arranged on the dictionary plan. The classification is an adaptation of the Dewey decimal system to the needs of a technical library.

The library subscribes to the publications of the leading scientific societies of the world and to the chief literary and scientific periodicals. It is especially rich in files of engineering journals, the material in which is available for ready reference through excellent periodical indexes received monthly. The library is a depository for the documents of the United States Geological Survey and has an unusually complete collection of the publications issued by state geological surveys and mining bureaus both in this country and abroad. A collection of mine reports has recently been indexed and made available for reference.

During the academic year the library is open from 8 a. m. to 12:30 p. m.; from 1:30 p. m. to 5 p. m., and from 7 p. m. to 10:00 p. m., except on Saturdays and holidays. The library is closed Saturday afternoons.

Y. M. C. A.

The Y. M. C. A. of the Colorado School of Mines exists for the purpose of serving the men of the school in every possible way. When called upon to do so, the Association assists men in securing suitable boarding and rooming accommodations, and when possible, in securing employment to help them earn their expenses through school. Weekly Bible Study Classes and religious meetings are conducted during tne greater part of the year. An Advisory Board, consisting of one alumnus, one local minister, one local business man, and two faculty members supervises the work of the Association.

THE INTEGRAL CLUB

The Club Room is in the Gymnasium Building and is furnished in the ordinary style of a gentleman's club. The purpose of the Club is to foster good comradeship among the students. It is under the direct control and management of a student committee.

PRIZES

Each year, usually at commencement, prizes are awarded to certain students who have maintained an excellent scholastic record or who have submitted a meritorious thesis. These prizes may be in the form of cash, engineering instruments, books, or other suitable mementos.

At the commencement exercises, May 31, 1918, the Wolf Medal, presented by Harry J. Wolf, of the class of 1903, was awarded to Henry George Schneider, for high scholastic attainment.

Professor Victor Ziegler offers a silver loving cup to the member of the graduating class who, in the opinion of the faculty, is most worthy of special distinction because of pre-eminence in athletics, leadership in student activities, and proficiency in scholarship.

LOAN FUNDS

The following loan funds have been established to assist worthy and deserving students through school.

The Natalie H. Hammond Loan Fund of $1,000.00 was donated to the school in July, 1909, by Mr. John Hays Hammond.

The Vinson Walsh Loan Fund of $1,000.00 was donated to the school in May, 1908, by Mr. Thomas F. Walsh, in memory of his son Vinson Walsh.

The Walter Lowrie Hoyt Loan Fund of $2,000.00 was donated to the school in May, 1912, by Mrs. Mattie B. Hoyt, in memory of her husband, Walter L. Hoyt.

Thirty-nine students have received financial assistance from these funds.

ATHLETICS AND PHYSICAL TRAINING

By virtue of the athletic fee required, all students entering the School of Mines become members of the Athletic Association. The Association is supported by the student fees, gate receipts, and by contributions from the alumni and other friends of the school. The affairs of the Association are managed by a Board of Control, which consist of the Athletic Director, as Chairman; the captains of the football, baseball, basketball, and track teams; and the presidents of the junior and senior classes. The Athletic Association maintains an office in the gymnasium building, under the supervision of the athletic director. Training is required in regular gymnasium classes during the freshman and sophomore years.

ALUMNI ASSOCIATION

The aim of the Alumni Association is to promote acquaintance and friendship among the graduates, to encourage them to aid each other, and to make an organized effort to elevate and uphold the reputation and standard of their Alma Mater. To carry out these ideas, the Association, under the management of an Assistant Secretary and Treasurer, publishes monthly "The Colorado School of Mines Magazine" and conducts an employment bureau, or Capability Exchange, for the benefit of the members. This employment bureau also assists undergraduate students in securing employment during summer vacations and at other times, especially when such students are in need of funds to defray the cost of their education.

All graduates are earnestly requested to join the Association, and to keep the assistant secretary and treasurer advised of their addresses and occupations.

The officers of the Association are:

Alexander K. McDaniel, '01...........President
E. P. Arthur Jr., '95.............Vice-President
Paul Gow, '07.......................Secretary
A. C. Watts, '02......................Treasurer

Executive Committee—

Daniel Harrington, '00
Edwin H. Platt, '00
Thomas B. Crowe, '00

The association holds its annual meeting and banquet on the day following the commencement exercises, unless otherwise provided for by the Executive Committee. All graduates are eligible to membership and are invited to the annual meeting and to the banquet.

MONTANA CHAPTER OF THE ALUMNI ASSOCIATION, BUTTE, MONTANA

James W. Dudgeon, '13...............President
Harold H. Goe, '08..............Vice-President
Lester J. Hartzell, '95......Secretary-Treasurer

UTAH CHAPTER OF THE ALUMNI ASSOCIATION, SALT LAKE CITY, UTAH

James S. Thompson '99..............President
Blair S. Sackett, '09.............Vice-President
A. C. Watts, '02...........Secretary-Treasurer

COLORADO SCHOOL OF MINES SCIENTIFIC SOCIETY

This has been a local society, confined to students of the school, for many years, but now is merged with the American Society of Mining Engineers as a Junior Affiliated Society. Active membership in the Society is limited to Junior Associate members of the Institute. Students of the school who do not join the Institute may become Associate members of the Society.

The Society has for its object the presentation and discussion of technical and engineering papers. Meetings are held monthly, and papers on various topics of interest are presented and discussed by the members. From time to time lectures are delivered before the Society by leading engineers and scientific men.

The officers for the ensuing year are as follows:

William A. Conley....................President
George V. Dunn.................Vice-President
R. R. Ireland..........Secretary and Treasurer

The faculty members of the A. I. M. E. are as follows:

President Victor C. Alderson
Professor I. A. Palmer
Professor J. C. Roberts
Professor H. J. Wolf
Professor Victor Ziegler
J. C. Williams
H. G. Schneider
S. Z. Krumm

All students in the list of students marked (*) are Junior Associates of the A. I. M. E., and consequently active members of the Scientific Society.

ENROLLMENT OF STUDENTS

POSTGRADUATES

Mulliken, Clarence K. . . . . Golden, Colo.
B. S., Maryland Agricultural College
*Ornelas, Ernesto . . . . Mexico City, Mexico
M. E., Cornell University

SENIORS

*Burwell, Blair . . . . Denver, Colo.
Denver University
Chao, Y. C. . . . . Chen-Ning, Kansu, China
University of Peking
*Conley, Wm. A. . . . . Golden, Colo.
University of Arizona
Coulter, Ronald S. . . . . Denver, Colo.
*Mechin, Rene J. . . . . St. Louis, Mo.
University of Illinois
Metzger, Otto H. . . . . Meeker, Colo.
Miller, Guy E. . . . . Canon City, Colo.
*Mulford, L. D. . . . . Golden, Colo.
*Parker, R. J. . . . . Denver, Colo.
Denver University
*Romine, T. B. . . . . Walla Walla, Wash.

JUNIOR CLASS

Abadilla, Q. A. . . . . Catananan, Foyabas, P. I.
Letran College, Manila
Alvir, Antonio D. . . . . Bulacan, Bulacan, P. I.
University of the Philippines
*Bailey, Donald L. . . . . Denver, Colo.
Benbow, Jules C. . . . . Colorado Springs, Colo.
*Berkowitz, Sam . . . . Pueblo, Colo.
*Brown, Prentice F. . . . . Denver, Colo.
Bunte, Ernest B. . . . . Denver, Colo.
*Case, Wm. B. . . . . Golden, Colo.
Chow, T. Y. . . . . Shanghai, China
University of California
Davis, Ninetta A. . . . . Golden, Colo.
Dunn, George V. . . . . Golden, Colo.
*Dutton, Dewey A. . . . . Grand Junction, Colo.
Flint, Howard T. . . . . Denver, Colo.
*Gallucci, Nicholas . . . . Louisville, Colo.
Garnett, Samuel A. . . . . Pueblo, Colo.
Kiesel, Albert H. . . . . Ouray, Colo.
Klamann, Albert A. . . . . Denver, Colo.

*Levings, Wm. S	Denver, Colo.
Lichtenheld, Fred A	Denver, Colo.
*Linn, Herbert K	Denver, Colo.
*Pittser, Chester M	Gunnison, Colo.
Serrano, Juan E	Santiago, Chile, S. A.
Miami University	
*Serviss, Fred L. F	Golden, Colo.
*Sisson, Myron L	Golden, Colo.
Urtiaga, Santiago	Candela, Coah., Mexico
St. Louis College, San Antonio, Texas	
Wichman, L. E	Telluride, Colo.
Willett, R. R	Golden, Colo.

SOPHOMORES

*Adamson, John N	Morley, Colo.
Baldwin, James W	Denver, Colo.
Bengzon, Ernesto	Camilino, Tarlac, P. I.
Betton, Chas. W	Colorado Springs, Colo.
*Bevan, John G. Jr	Colorado Springs, Colo.
*Bianchi, Alfred P	Chicago, Ill.
Bilisoly, Joseph M	Golden, Colo.
Brinker, Fred A	Denver, Colo.
Casey, James W. Jr	Denver, Colo.
Chang, C. L	Nanyang, Honan, China
Government University, Peking	
Connors, Hugh M	Denver, Colo.
De Ford, Ronald K	National City, Calif.
Edgeworth, Joseph E	Denver, Colo.
*Fidel, Henry P	Grand Junction, Colo.
Frenzell, E. Herbert	Redlands, Calif.
Goodwin, George G	Denver, Colo.
*Graham, Daniel J	Mishawaka, Ind.
Hartung, Kirk G	Cheyenne, Wyo.
Hopkins, Walter	Pueblo, Colo.
Horcasitas, Javier	Los Angeles, Calif.
*Ireland, Robert R	Quincy, Ill.
Jen, T. Y	Nanyang, Honan, China
Government University, Peking	
Jenni, Alfred E	Pueblo, Colo.
Johnson, R. P	Brighton, Colo.
Kay, Fred D	Schenectady, N. Y.
*Kintz, George M	Denver, Colo.
University of Colorado	
Kirkwood, David F	Antofagasta, Chile, S. A.
Lawrence, H. W	West Stockbridge, Mass.
Lee, Y. C	Hiangcheng, Honan, China
Government University, Peking	
Likes, Myrton D	Briggsdale, Colo.
Litheredge, Robert W	Loveland, Colo.
Marvin, Theodore	Sheldon, Iowa
McKenna, Wm. J	Tooele, Utah
State Agricultural College	
Moreas, José E. A	Pernambuco, Brazil, S. A.
Bailor University and German College	
*Nelson, Fred M	St. Joseph, Mo.
Neumann, Gustave L	Denver, Colo.

*Prentiss, Louis W. .... Washington, D. C.
Robb, Andrew B. .... New Britain, Conn.

Rodriguez, Juan A. .... Oruro, Bolivia, S. A.
American Institute, La Paz, Bolivia
*Rogers, Bryant K. .... Montclair, N. J.
Schneider, George W. .... Denver, Colo.
*Seemann, Arthur K. .... Brooklyn, N. Y.
Strock, Hale McC. .... Denver, Colo.
*Surfluh, John S. .... Los Angeles, Calif.
Thomas, George D. .... Lafayette, Colo.
Thomson, Waldemar P. .... Golden, Colo.
Turner, Albert M. .... La Veta, Colo.
Valdez, Don C. .... Salida, Colo.
West, H. R. .... Rocky Ford, Colo.
Wong, Y. Y. .... Eagle Pass, Texas
St. John's University, Shanghai, China
*Woo, Y. D. .... Shanghai, China
Fuh-Tau College
Zambrano, José .... Monterrey, N. L., Mexico

FRESHMAN CLASS

Aaron, Eugene R. .... Denver, Colo.
Babcock, Lloyd .... Rocky Ford, Colo.
Bacca, Joseph P. .... Trinidad, Colo.
Bartholomew, J. A. .... Toronto, Canada
Beall, Chas. B. .... Golden, Colo.
Bergh, Stephen T. .... Hendrum, Minn.
University of Wisconsin
Bond, Frederick C. .... Wheatridge, Colo.
Bond, George F. .... Estes Park, Colo.
Boone, John H. H. .... Hutchinson, Kansas
Bragg, Conrad R. .... Augusta, Me.
Bransford, James C. .... Denver, Colo.
Brenner, I. Edward .... Chicago, Ill.
Bruhn, Frederick E. .... San Antonio, Texas
Bryan, Lewis Jay .... Golden, Colo.
Bunte, Arthur H. .... Denver, Colo.
Chang, J. K. .... Koa Shan, Shien, Honan, China
Government University, Peking
Chang, M. S. .... Yunan, Honan, China
Chang, K. Y. .... Kungsien, Honan, China
Church, Harold A. .... Rocky Ford, Colo.
Clark, William I. .... Idaho Springs, Colo.
Clopton, John H. .... San Antonio, Texas
Cochran, Harry B. .... Hutchinson, Kan.
Crawford, Joseph .... Lincoln, Ill.
Crawford, Wm. P. .... Charleston, W. Va.
Cronin, M. Bernard .... Denver, Colo.
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Davis, Donald J. .... Tacoma, Wash.
Denny, John H. .... Washington, D. C.
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Derryberry, Chas. W. .... Grand Junction, Colo.
Derryberry, Ward W. .... Grand Junction, Colo.
Dohoney, Edward N. .... Merrill, Wis.

Dorrance, James R....................Bishop, Calif.
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Fahey, Thos. P....................Leadville, Colo.
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Government University, Peking
Fryberger, Elbert L....................Loveland, Colo.
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Gochenour, Paul....................Delphi, Ind.
Gould, J. C....................Pine Bluff, Ark.
Gow, Neil W....................Golden, Colo.
Graeber, Calvert....................Arlington, Colo.
Graham, Wallace A....................Golden, Colo.
Gray, Cecil T....................Gunnison, Colo.
Gray, Thomas E....................Chicago, Ill.
Gregg, Donald C....................Denver, Colo.
Griffith, Wm. E....................Denver, Colo.
Guth, Clarence W....................Golden, Colo.
Haines, Harold F....................Tacoma, Wash.
Hakola, Samuel H....................Fairport Harbor, Ohio
Handy, Deane S....................Denver, Colo.
Haskin, Joseph A....................Chattanooga, Okla.
St. Mary's College
Henderson, J. S....................Montrose, Colo.
*Heydrick, Harold F....................Muskogee, Okla.
*Hicks, Eugene H....................St. Paul, Minn.
MacAlester College
Hurley, Keith P....................Denver, Colo.
Hyland, Norbert W....................Denver, Colo.
Jackson, Merle....................Eaton, Colo.
Jensen, Bert P....................Gary, Ind.
Johnson, Frank....................Denver, Colo.
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Klein, Henry G....................La Junta, Colo.
Knight, D. A....................Rawlins, Wyo.
Krantz, Percy R....................Dunton, Colo.
Krause, Hilmar P....................La Grange, Texas
La Follette, Bruce B....................Greeley, Colo.
Lailhacar, Albert....................Santiago, Chile, S. A.
Lascowitz, Samuel....................Denver, Colo.
Leaver, Ralph H....................Aspen, Colo.
Lee, P. H....................Chiynan, Honan, China
*Leech, Thomas B....................Muskogee, Okla.
Lindsey, Hugh R. Jr....................Flat Rock, N. C.
Lipman, Chas. H....................Chicago, Ill.
Litheredge, Roland T....................Loveland, Colo.
Lloyd, Ernest P....................Denver, Colo.
Ma, H. Y....................Anyang, Honan, China
Malinarich, Carlos....................Santiago, Chile, S. A.
Mayall, Henry H....................Boulder, Colo.

McDermott, Wm. G....Denver, Colo.
McGowan, Harold W....Denver, Colo.
McKenna, Hugh L....Breckenridge, Colo.
McKenzie, George R....Denver, Colo.
McMenemy, James ....Denver, Colo.
Merry, Albert E....Rockville Center, N. Y.
Min, Edward H. S....Seoul, Korea
Moreno, Domingo ....Santiago, Chile, S. A.
Morton, S. Sidney....Golden, Colo.
Packwood, Samuel F....St. Joseph, Mo.
Pierce, Albert Le Roy....Denver, Colo.
Quiroga, Manuel F....Huepac, Sonora, Mexico
Raiff, Ben L....Columbus, Mont.
Reed, Ethbert F....Golden, Colo.
Reynolds, William ....La Veta, Colo.
Rhodes, Louis C....Gary, Ind.
Rice, Neil A....Denver, Colo.
Roller, Wilfred L....Denver, Colo.
Rooney, Lawrence P....Denver, Colo.
Ruth, Joseph P....Denver, Colo.
Rydlund, Alfred C....Georgetown, Colo.
Santee, Leslie C....Cedar Falls, Iowa
Savage, Eros M....San Diego, Calif.
Schoder, Wm. P....Denver, Colo.
Seborg, Raymond M....Rocky Ford, Colo.
Serafini, Theodore J....Denver, Colo.
Shaw, Harold F....Grand Junction, Colo.
Shearn, Justin....Roselle Park, N. J.
*Shepard, George M....Denver, Colo.
Shih, H. P....Chiyuan, Honan, China
Pei-Yang University, Tientsen, China
Smith, Howard B....Bellevue, Pa.
Smith, Warren E....Denver, Colo.
Son, Dorsey G....Golden, Colo.
Sonneborn, Robert H....Pueblo, Colo.
Steward, La Vere....Thermopolis, Wyo.
Steward, Roscoe G....La Junta, Colo.
Stovall, Preston W....Denver, Colo.
Stong, F. Verne....Grand Junction, Colo.
Sun, Y. C....Kuei-Teh, Honan, China
Swanson, Oscar B....Canon City, Colo.
Tanner, Horace A....Golden, Colo.
Tenney, Lealon....Leadville, Colo.
Terrazas, Abel J....El Paso, Texas
Terry, Joseph W....Denver, Colo.
Treadwell, Wilbur A....Pueblo, Colo.
Wager, Maurice R....Chicago, Ill.
Walker, Carl H....Gunnison, Colo.
Wang, C. F....Hwangchwan, Honan, China
Government School, Kifeng, Honan, China
Webber, Benjamin....San Diego, Calif.
Weber, Claude A....Denver, Colo.
Welch, Leland B....Walsenburg, Colo.
Williamson, Raymond M....Golden, Colo.
Woeber, Lorenz S....Denver, Colo.
Worden, John C....Denver, Colo.
Wright, Paul W....Gunnison, Colo.
Zee, Z. S....Nanking Road, Shanghai, China

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Quarterly of the

Colorado School of Mines

Volume Fourteen
APRIL, NINETEEN-NINETEEN
Number Two

Book of Views

Entered as second-class mail matter, July 10, 1906, at the Post Office at Golden, Colorado under the Act of Congress of July 16, 1894

QUARTERLY

OF THE

COLORADO SCHOOL OF MINES

VOL. XIV APRIL, 1919 NO. 2

Book of Views

ISSUED QUARTERLY

BY THE

COLORADO SCHOOL OF MINES

GOLDEN, COLORADO

Entered as second-class mail matter, July 10, 1906, at the Post Office at Golden, Colorado, under the Act of Congress of July 16, 1894

THE Colorado School of Mines is in the south central part of the city of Golden, Jefferson County. Golden is about fourteen miles west from Denver and can be reached by the Denver and Intermountain Electric Railway and by the Denver and Northwestern Electric Railway on Arapahoe Street between Fourteenth and Fifteenth, with half-hour service, or by the Colorado and Southern Railroad from the Union Station, Denver.

The altitude of Golden is five thousand seven hundred feet above sea level, and four hundred feet above Denver. The climate is invigorating and pleasant, with open winters, and an unusually large proportion of clear days.

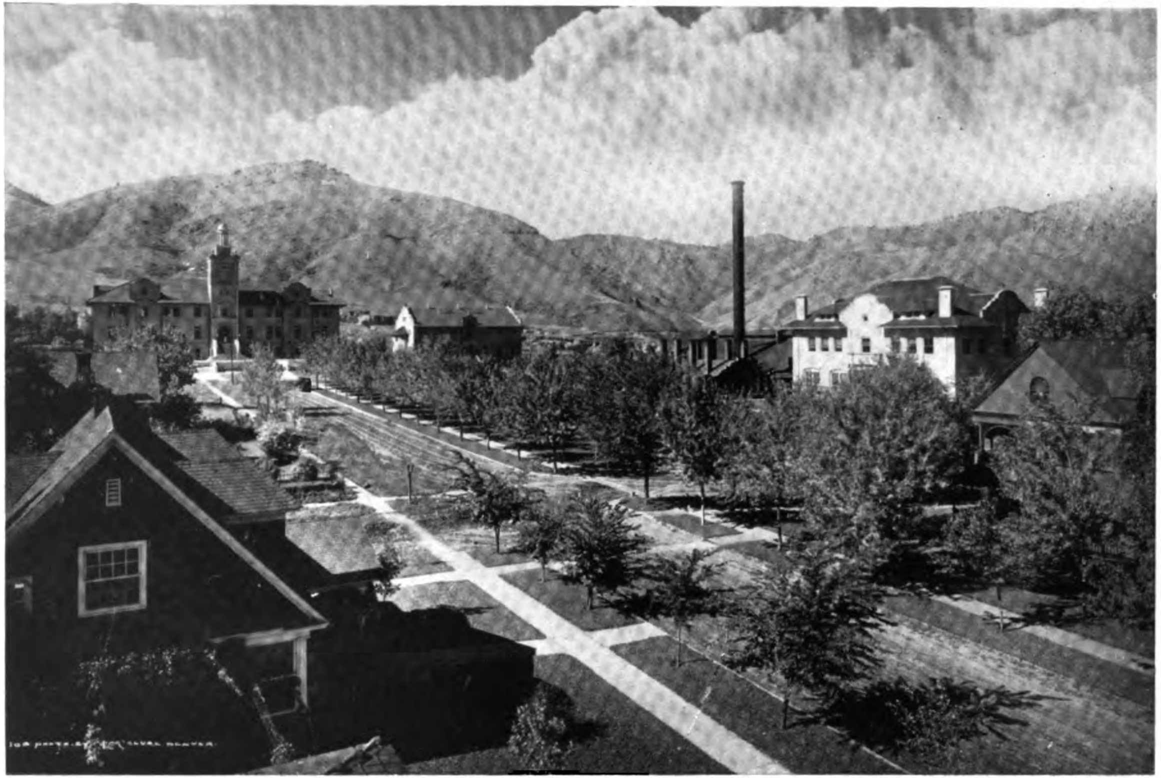
The region surrounding Golden is rich in characteristic Rocky Mountain scenery. Within a few hours' walk from the town are to be found many of the scenic spots for which Colorado is noted. The Mountain Park boulevards, part of the Denver Park system, connect Golden and Denver and provide many interesting and beautiful trips into the hills for the automobilist. The Colorado School of Mines is well situated for combining both theory and practice in teaching mining and metallurgical engineering.

The proximity of the institution to the large mines, mills, and reduction plants of the state enables its students to study operations at close hand. With the great variety of metals produced in Colorado, including gold, silver, zinc, lead, copper, iron, uranium, vanadium, radium, and tungsten, no district in the world offers better opportunities for a study of mining, metallurgy, and geology. Further, a great variety of coals, fire and plastic clays, are to be found in the vicinity of Golden.

The Experimental Ore Dressing Plant of the school serves as an exceptional laboratory for the students, and for research and testing work.

The Book of Views and Catalogue should be examined together. Copies may be had by addressing

THE REGISTRAR,
Colorado School of Mines, Golden, Colorado.



THE CAMPUS

VIEW OF THE CAMPUS FROM CASTLE ROCK

COLORADO SCHOOL OF MINES

SIMON GUGGENHEIM HALL—ADMINISTRATION BUILDING

THE LIBRARY

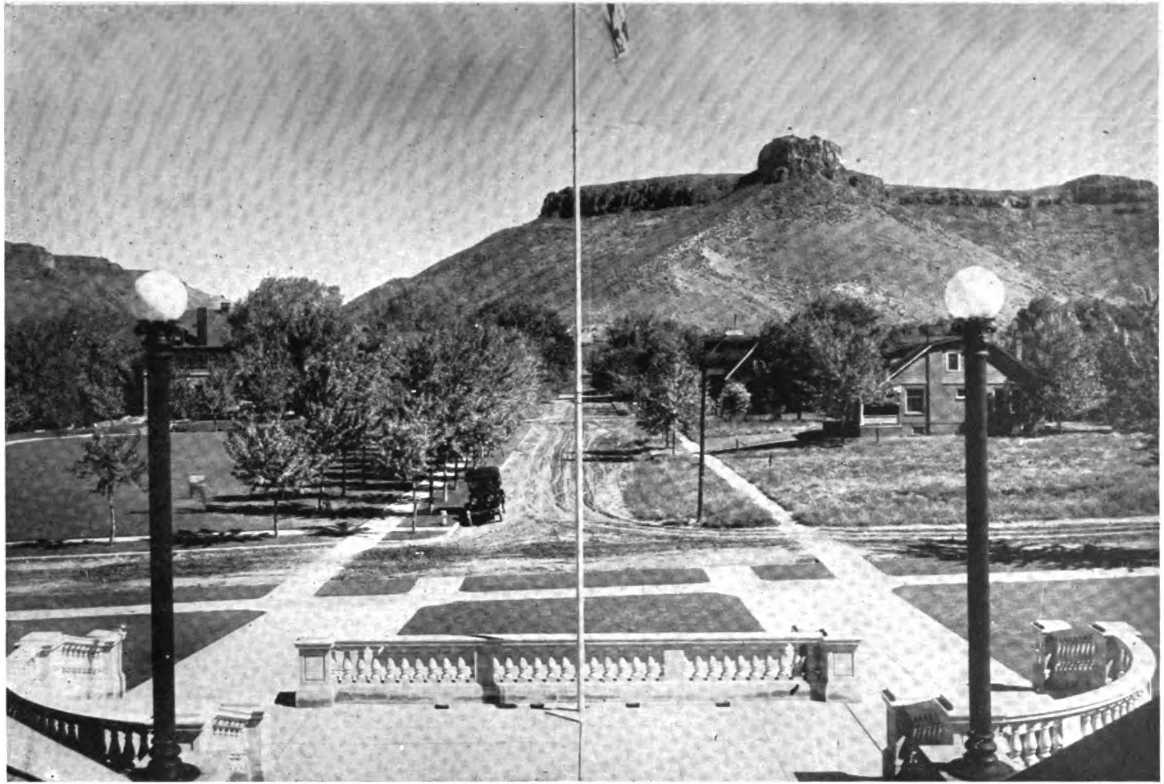
THE AUDITORIUM

Assay Laboratory Stratton Hall

A VIEW OF THE CAMPUS

Gymnasium | Assay Laboratory and Power House | Stratton Hall

A VIEW OF THE CAMPUS

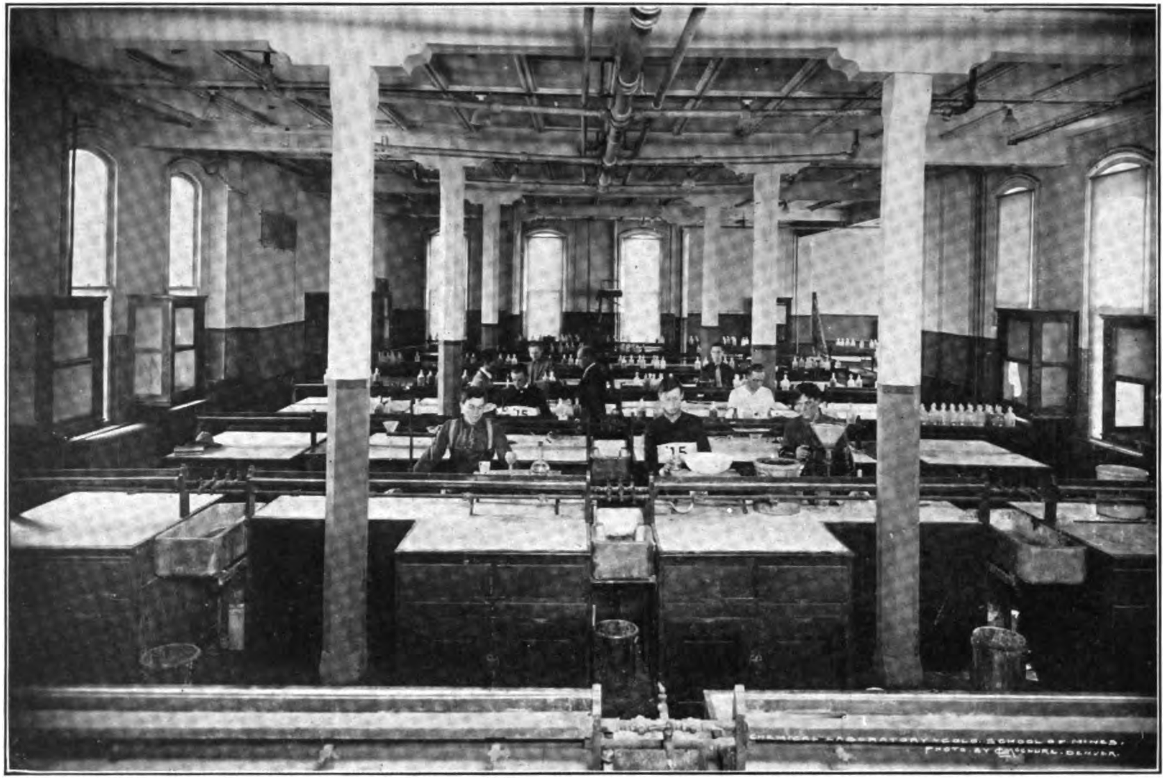


VIEW FROM GUGGENHEIM HALL—LOOKING EAST TOWARDS CASTLE ROCK

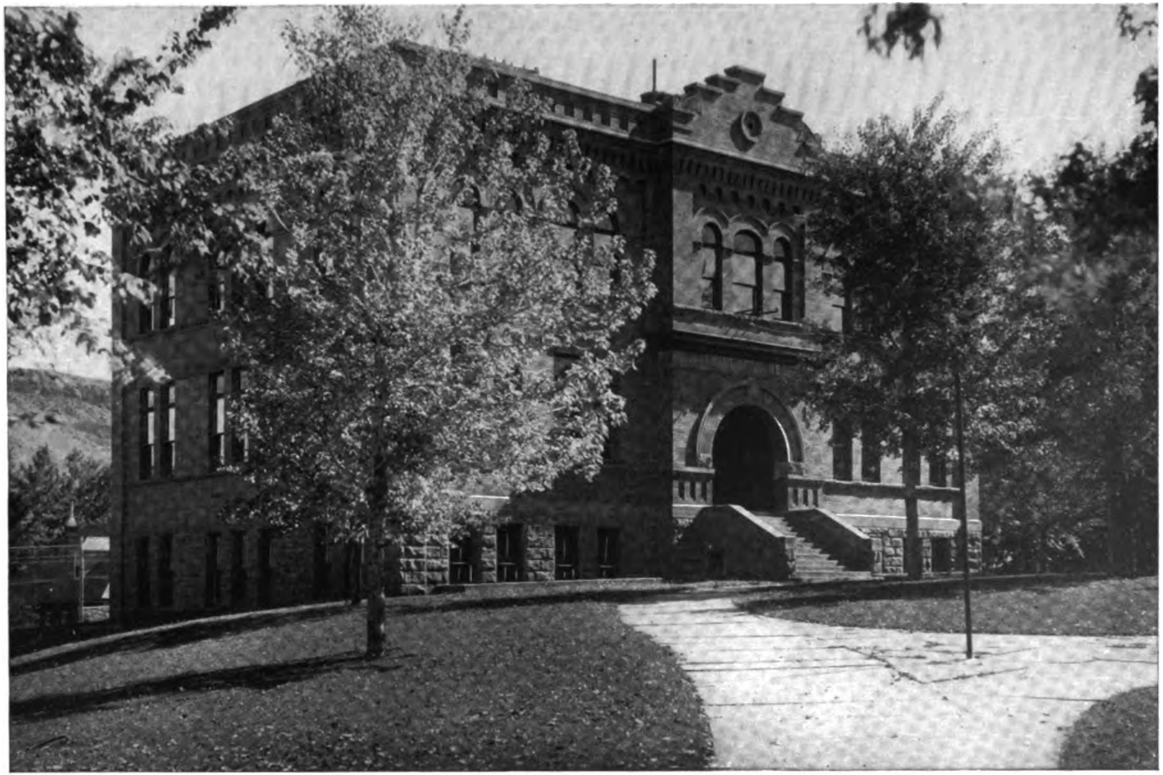
THE RESIDENCE OF THE PRESIDENT

COLORADO SCHOOL OF MINES

THE HALL OF CHEMISTRY—THE ORIGINAL GROUP OF BUILDINGS

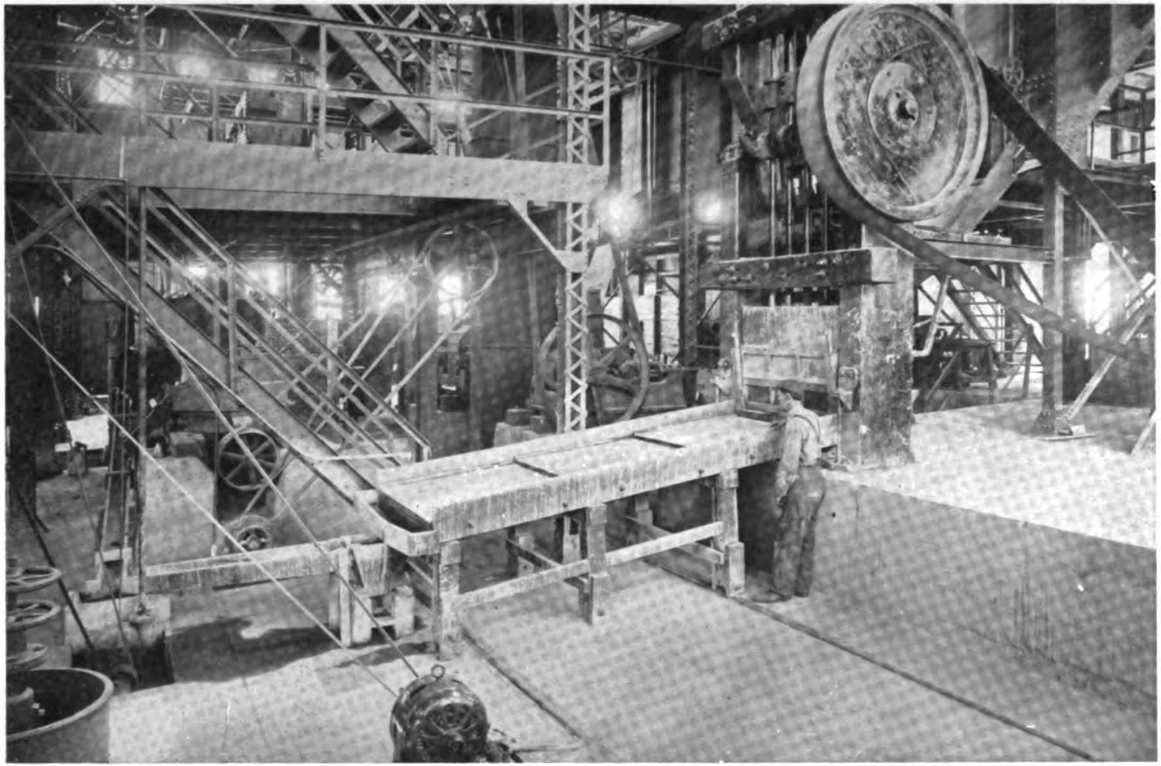


ONE OF THE CHEMICAL LABORATORIES

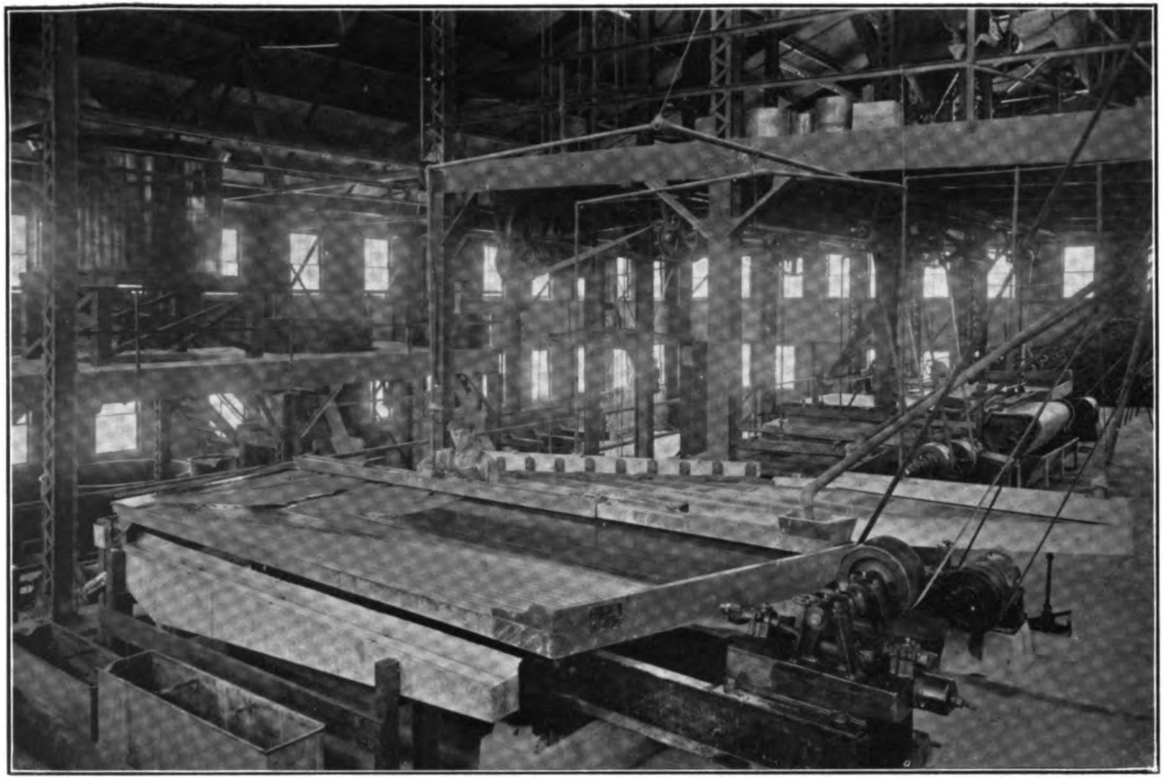


UNITED STATES BUREAU OF MINES BUILDING

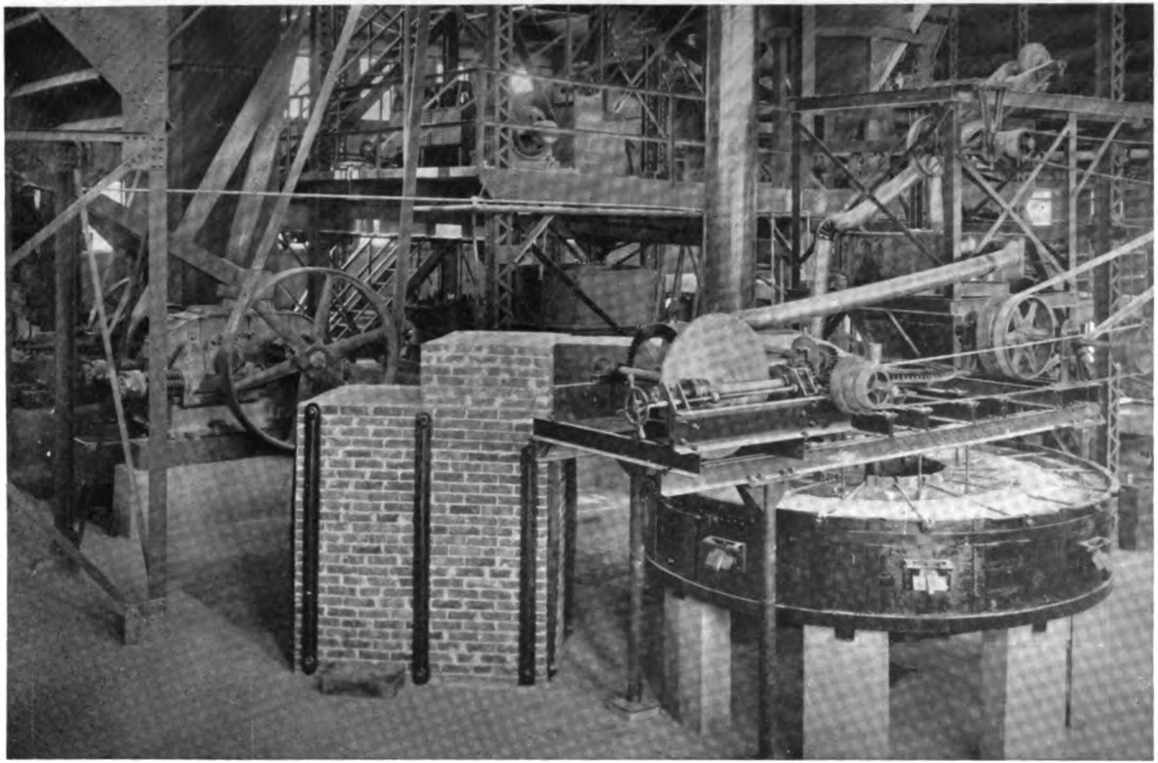
THE EXPERIMENTAL ORE DRESSING AND METALLURGICAL PLANT



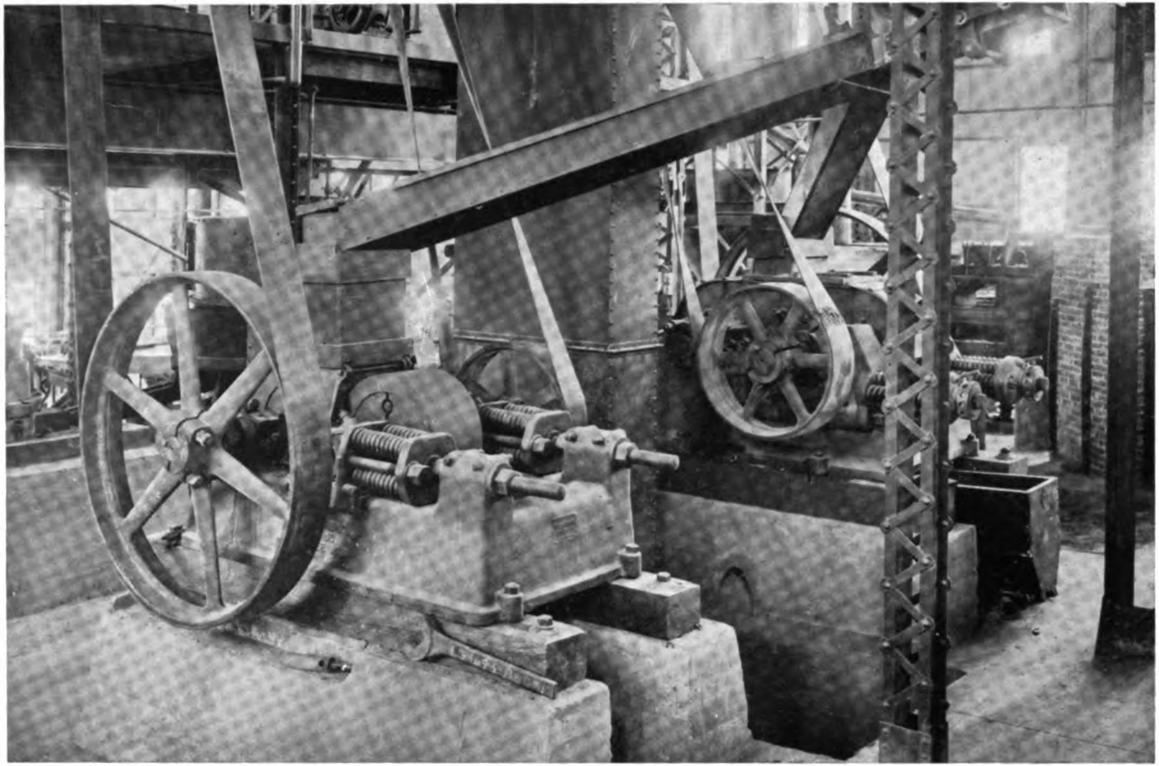
STAMP BATTERY, EXPERIMENTAL PLANT



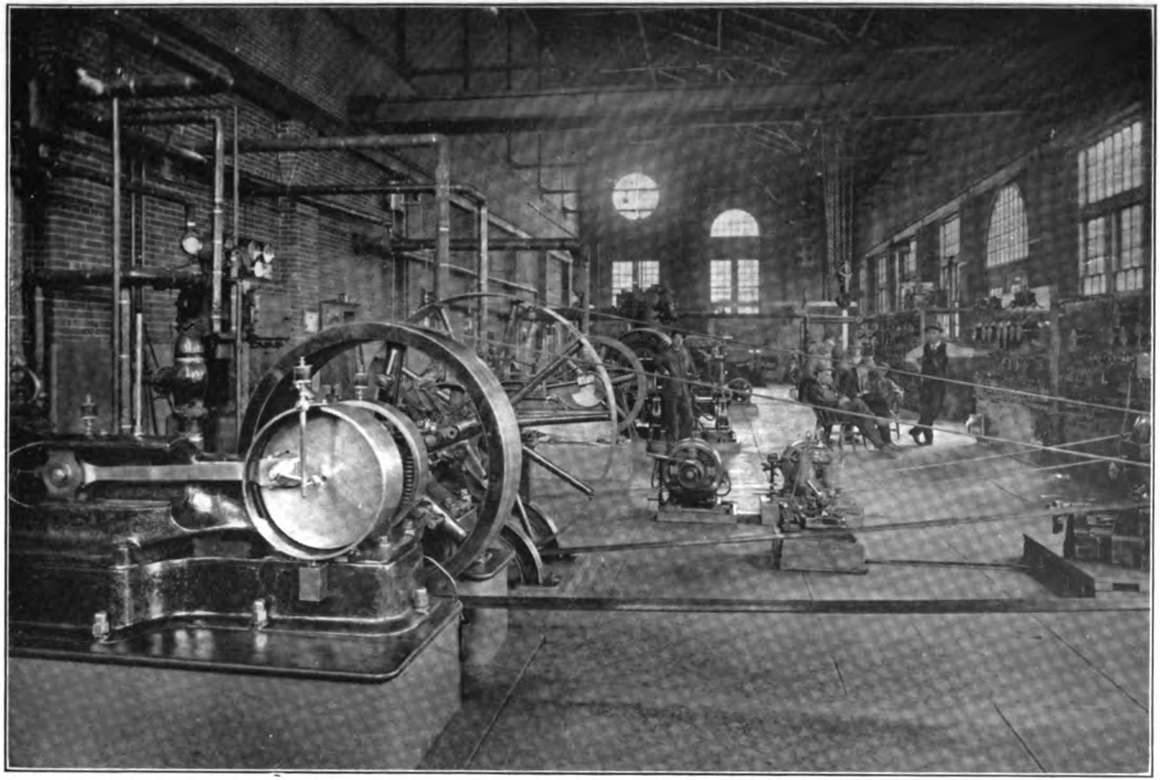
VANNER FLOOR, EXPERIMENTAL PLANT



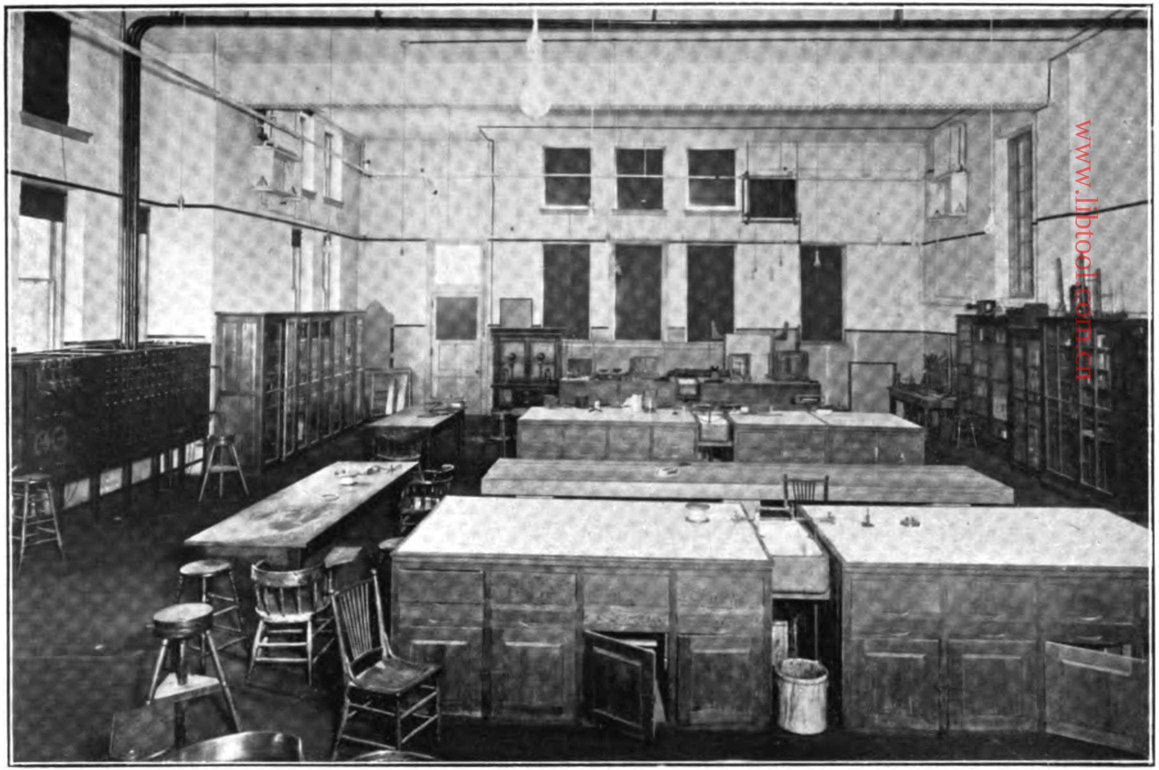
WILFLEY ROASTING FURNACE, EXPERIMENTAL PLANT



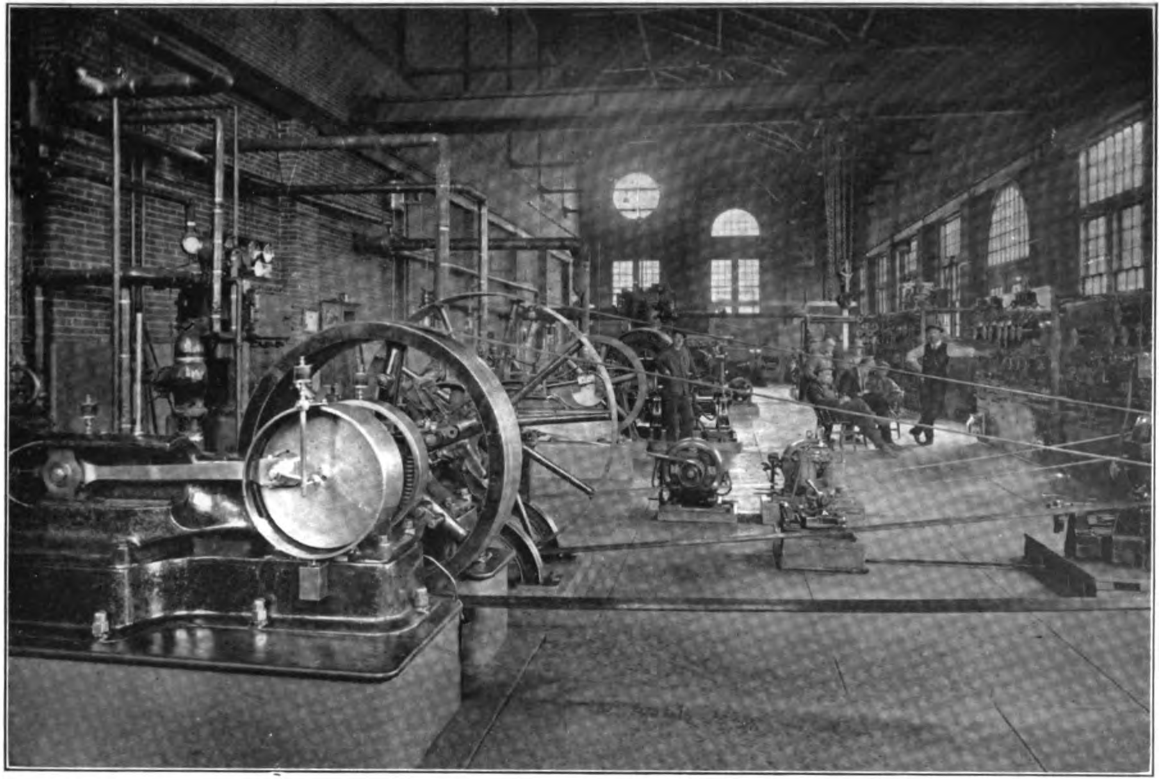
CRUSHING ROLLS, EXPERIMENTAL PLANT



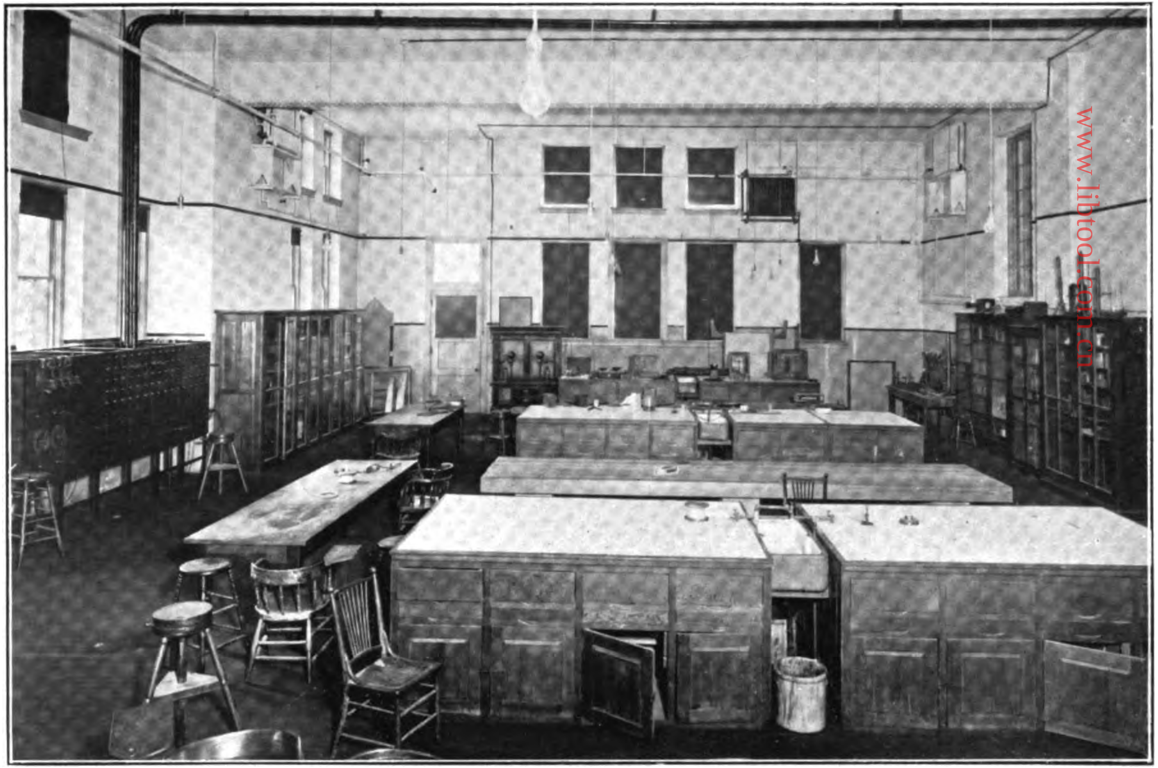
THE MECHANICAL AND ELECTRICAL ENGINEERING LABORATORY—POWER HOUSE



PHYSICS LABORATORY



THE MECHANICAL AND ELECTRICAL ENGINEERING LABORATORY—POWER HOUSE

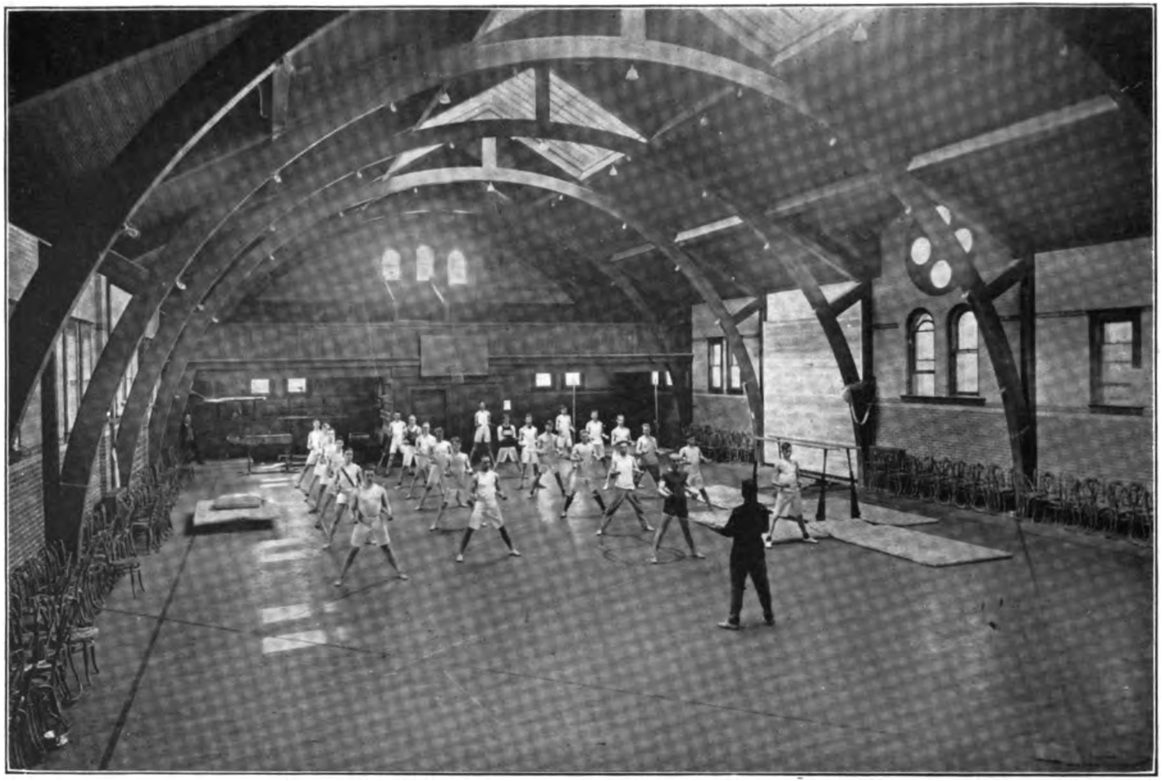


PHYSICS LABORATORY

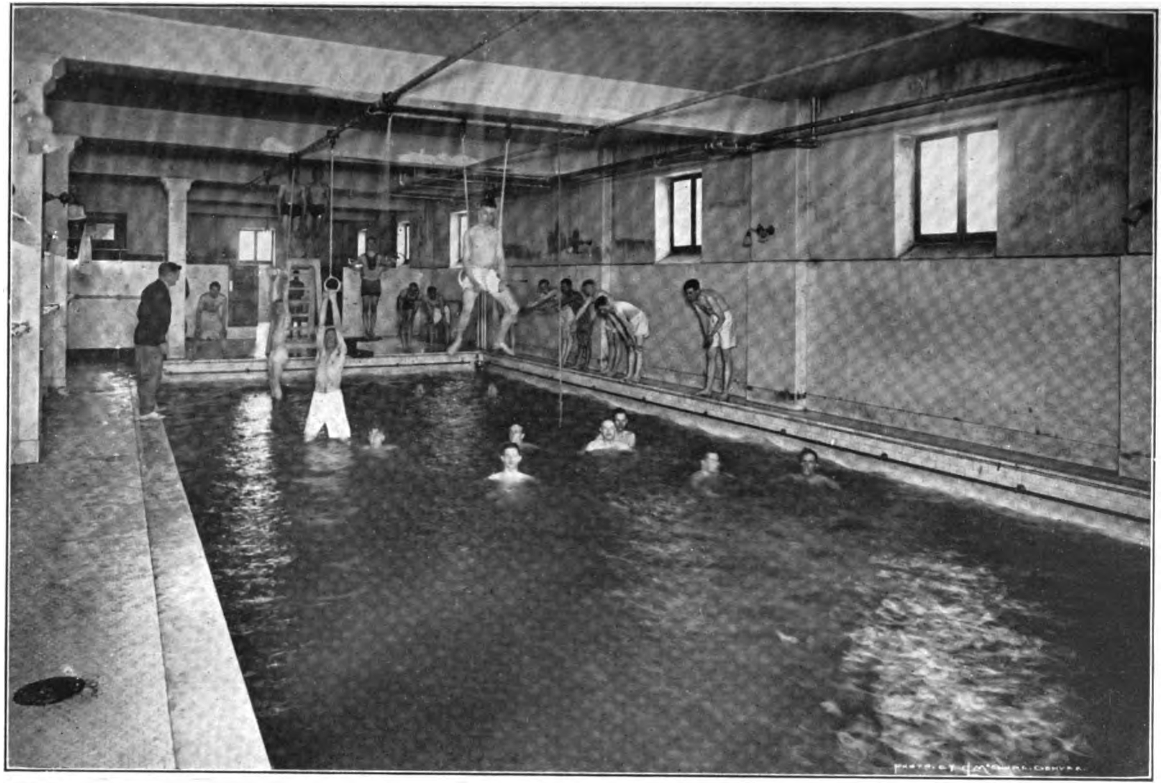
FIRST AID AND MINE RESCUE WORK

FIRST AID AND MINE RESCUE WORK

THE GYMNASIUM



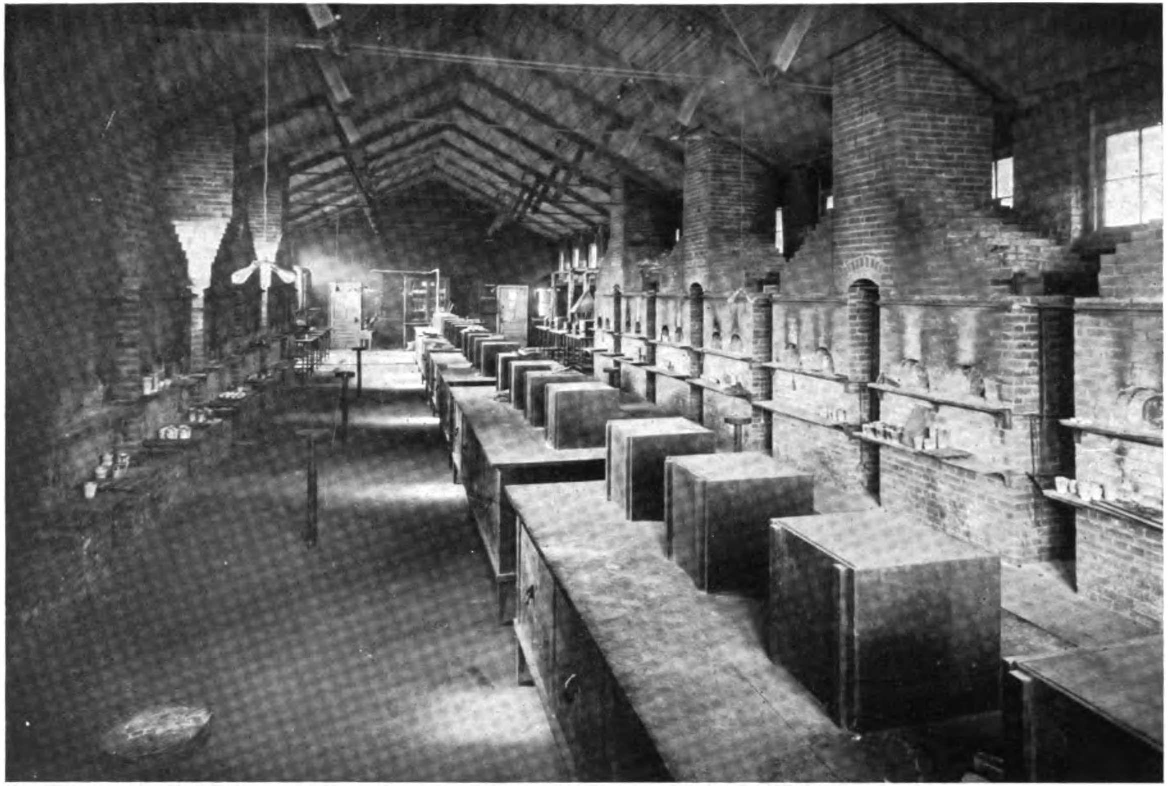
A CLASS IN PHYSICAL TRAINING



THE SWIMMING POOL

THE INTEGRAL CLUB—THE CENTER OF SOCIAL LIFE

THE INTEGRAL CLUB



THE ASSAY LABORATORY

THE C. S. M. MINE

THE C. S. M. MINE—THE ENTRANCE

MINERALOGY LABORATORY—PROSPECTORS' COURSE

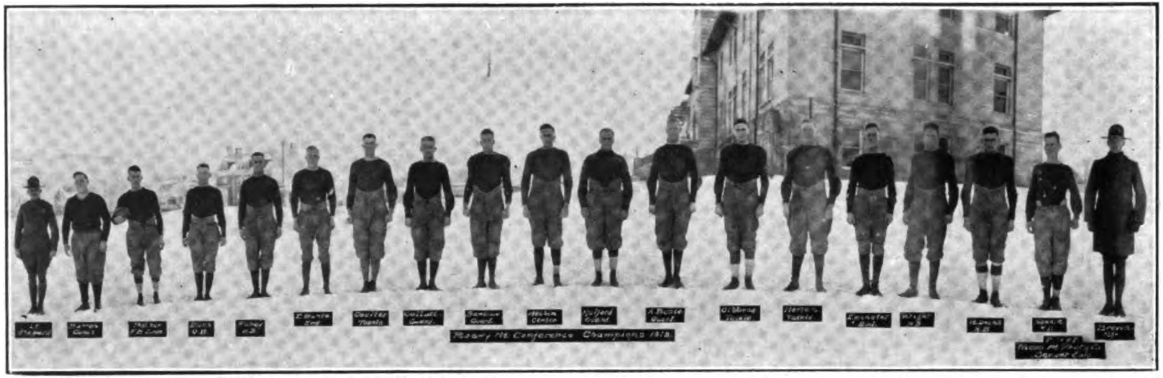
COLORADO SCHOOL OF MINES

MEMBERS PROSPECTORS' COURSE

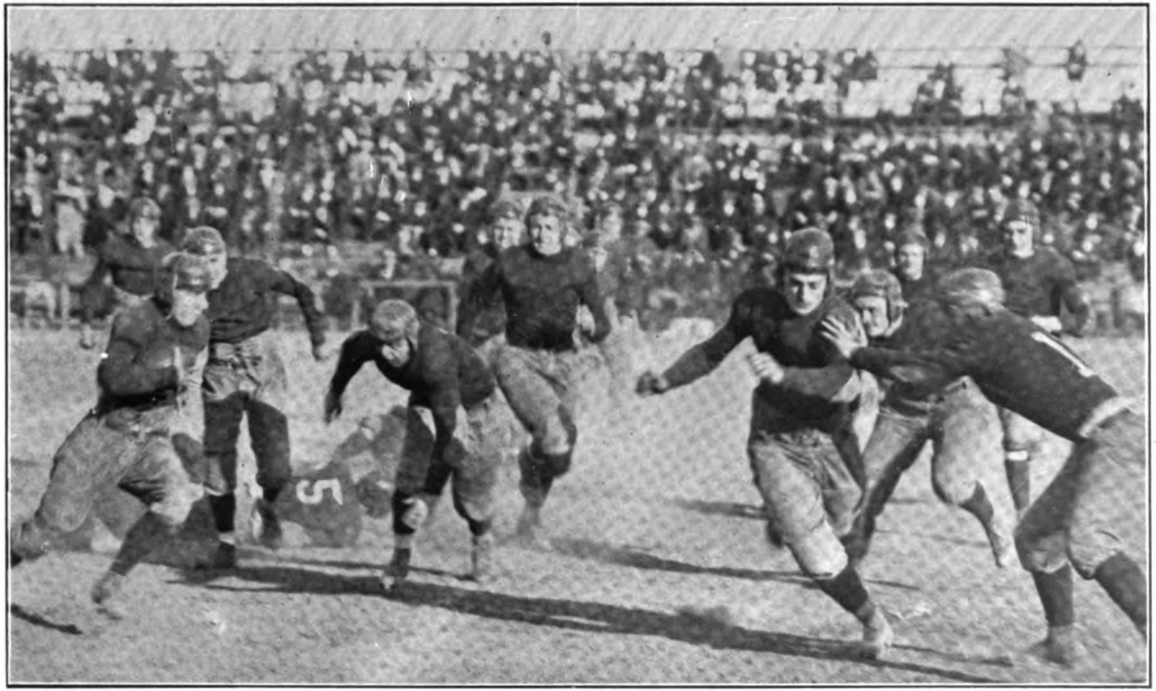
CHEMICAL LABORATORY—PROSPECTORS' COURSE

MINE SURVEYING CLASS AT IDAHO SPRINGS

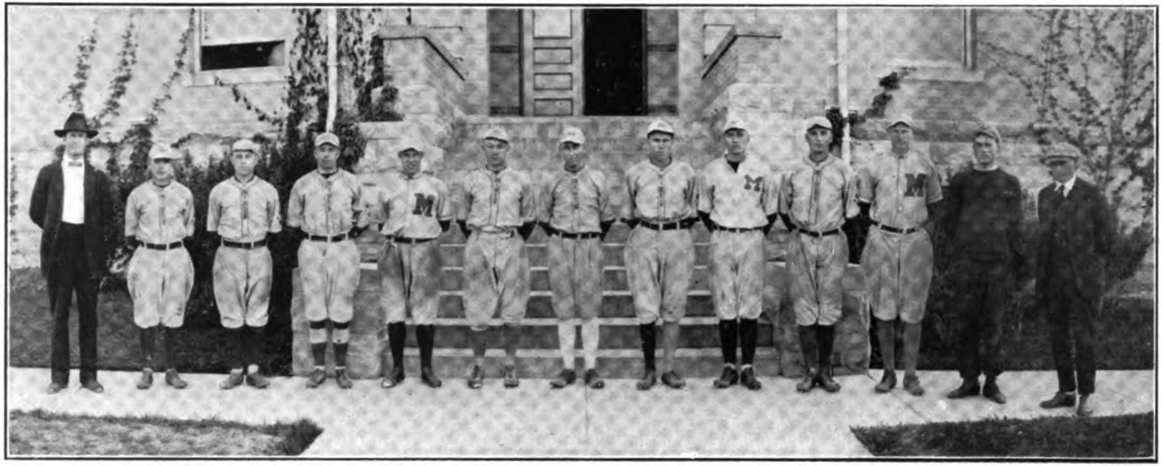
INSPECTION TRIP—SENIOR CLASS AT CASTLE GATE, UTAH



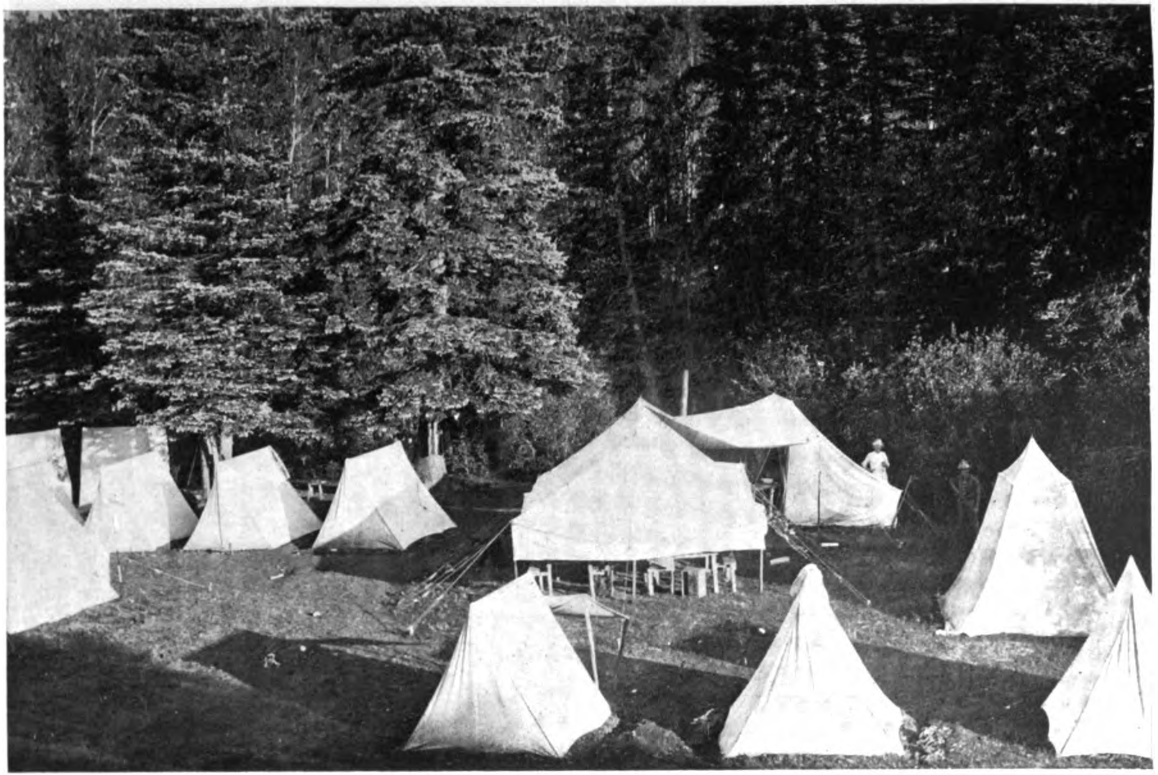
FOOTBALL—ROCKY MOUNTAIN CONFERENCE CHAMPIONS 1918



FOOTBALL



BASEBALL—ROCKY MOUNTAIN CONFERENCE CHAMPIONS 1919



GEOLOGICAL FIELD WORK—THE CAMP

Volume Fourteen Number Three

QUARTERLY

OF THE

COLORADO SCHOOL OF MINES

JULY, 1919

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Golden, Colorado

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QUARTERLY

OF THE

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Vol. Fourteen — JULY, 1919 — Number Three

The Cripple Creek District of Colorado
A Resurvey
Colorado School of Mines

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Introduction

CAPTAIN JAMES T. SMITH.

LEGEND The Mount Pisgah (promised land) territory near the southwestern slope of Pike's Peak was known to the Argonauts of 1859 as a potential placer camp. From that pioneer period until 1891, when Cripple Creek was accorded geographical distinction, prospectors drifted in and gold specimens filtered out from an area some ten miles by eight in superficial extent, very largely devoted to the feeding of range cattle and owned in part by the Denver real estate firm of Bennett and Myers. With this period of evasive dawn the names of Winfield Scott Stratton, E. M. DeLaVergne, Robert Womack, James F. Burns, and James Doyle are intimately connected. Cattle bogging in the small stream, which courses through the district from north to south and along which gold values may be traced from its source to Florence on the Arkansas river, gave rise to the name Cripple Creek—impeded in progress but never stopped. That the mines were neither true fissures, as in the pioneer and San Juan mining districts, nor flat veins in the Leadville sense, but of breccia (broken rock) formation, was a geological drawback to the early day miners, who reasoned from what they knew to what they did not know, forgetting that Nature is loaded with fresh revelations.

METALLURGICAL PROCESSES Then comes the metallurgical experiments, involving the expenditure of millions of dollars and the gains, disappointments, and failures incident thereto, since gold was recovered for the temple of Solomon from the now abandoned mines of the "dark continent," and the Aztecs of Mexico and the Incas of Peru developed their arts in the precious metals, fine in the sense of intrinsic value. Smelting, lixiviation, chlorination, cyanide, straight cyanide, the Clancey process, fireless ore treatment, and other methods within and outside the legitimate, together with up-to-date flotation, have all had their day in court with the usual verdict—the fittest have survived, as will be seen by the report of Professor Palmer, which covers the scope of present-day success, showing a high extraction of values at small cost to the ton of ore handled. In this useful application of science the names of Philip Argall and Thomas B. Crowe have won eminent distinction.

THE ROOSEVELT TUNNEL When the mines commenced to reach depth in 1908 the Roosevelt deep drainage tunnel was projected, with the completion of which—strictly on time and without accident—the names of A. E. Carlton and T. R. Countryman are creditably connected, the first providing the needed capital and his colleague the engineering skill. May 11, 1907, work on the tunnel was commenced with an appropriate celebration, the address of the day being delivered by President Victor C. Alderson of the Colorado School of Mines. The tunnel reached its objective point at the Portland mine in the last week of December, 1918, and has since blazed the trail to rich high-grade ore strikes in the Cresson and the Portland properties. The tunnel is 24,255 feet in length, has cost $817,000, and shows a gain of over $3,000,000 in the item of draining the active mines as compared with the cost of pumping. Up to the end of 1918 the tunnel had drained 40,000,000 gallons of water, the flow at the portal ranging from 17,000 at the peak down to 2,500 gallons per minute. Where it hits the Portland No. 2 shaft it is 2,133 feet below grass roots. It is properly hailed as an enterprise conceived in scientific vision and pinnacled with success.

PRODUCTION The ebb and flow of the world's standard of value from America's leading gold camp is easily gleaned from the following summary, which shows by years the bullion extracted from the ores in smelter and mill. The figures are those of the United States geological survey:

Year		Bullion Value
1891	Stamp mills and smelters	$ 200,000
1892		587,310
1893	Cyanide—Panic year	2,750,000
1894	Chlorination	3,250,000
1895	Colorado City mills	6,100,000
1896	Florence mills	8,750,000
1897		12,000,000
1898		16,000,000
1899	Bromination mills	21,000,000
1900	Mill trust plants	22,500,000
1901		24,986,990
1902		24,508,511
1903		17,630,107
1904		21,414,080
1905		22,307,952
1906		16,268,291
1907	Straight cyanide mills	13,148,152
1908	Fireless metallurgy	16,230,525
1909		15,850,000
1910	New Portland mill	11,031,555
1911		10,593,278
1912		11,049,024
1913		10,948,098
1914	World war	12,025,364
1915	Labor scarcity	13,727,992
1916	Labor scarcity	12,177,231
1917	Labor scarcity	10,400,200
1918	Spanish influenza	8,346,000
	Grand total	$367,780,650

In the past four years of turmoil the gold supply of the world has been rapidly falling off, while the paper credits placed upon gold have increased beyond the bounds of safety as measured in financial circles prior to 1914. As commodity prices—founded on the circulating medium—moved up, the relative value of gold descended, while the cost of producing the gold was increased in propertion. Under these circumstances the Cripple Creek and other gold districts were confronted with a crisis. With the triumph of American arms on land and sea this condition has happily passed, and the sun of renewed prosperity heralds the arrival of a better day. Our Liberty Bonds being a promise to redeem in gold every ton of ore recovered from the Cripple Creek mines is concrete evidence that the contract of the nation will be paid in full.

Geology and Ore Deposits

PROF. F. M. VAN TUYL.

INTRODUCTION The geology and ore deposits of the Cripple Creek district have been described in detail by Lindgren and Ransome* in their report entitled "Geology and Gold Deposits of the Cripple Creek District, Colorado" issued by the United States Geological Survey in 1906. Though thirteen years have now elapsed since the report appeared, it is still of inestimable value. However, the development work in later years has furnished valuable data, regarding the character and persistence of the ores at depth, which were not available at the time this report was prepared. A part of this later development work and its results were described by Patton and Wolf in 1915.† The present paper is an attempt to point out the bearing of the recent development work in the district on its future history rather than to bring our knowledge of the developments in recent years up to date. Before discussing the effect of the newer developments, however, a brief summary of the geology of the district, based largely upon the report of Lindgren and Ransome, is presented.

LOCATION The Cripple Creek district is situated about ten miles southwest of Pike's Peak, in the south central part of Teller county, Colorado. "All the important mines lie within a circle having a radius of about three miles" and at elevations varying from 9,400 to 10,800 feet above sea level.

RESUME OF THE GEOLOGY OF THE DISTRICT The rocks of the district consist, (1) of a series of pre-Cambrian gneisses and schists intruded by three varieties of granite and an olivene syenite, and (2) the products of a Tertiary volcano consisting of tuffs and breccias of latite-phonolite, cut by dikes and intrusive masses of phonolite and syenite. These are again traversed by younger basic dikes. The mineralization in the district is supposed to have followed closely the intrusion of the latter rocks. These Tertiary volcanics and intrusives apparenty fill the throat of an old volcano which has been planed off by erosion.

ORE DEPOSITS The ore deposits are nearly all related to fissures and are of two main types: (1) lodes or veins and (2) irregular replacement bodies, usually in granite. The fissure veins are by far the most important. These occur mainly within the volcanic neck and have a roughly radial plan. Usually they are nearly vertical and rarely exceed one half mile in length. Many of the veins in the upper levels are very short; some of them are less than three hundred feet in

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* U. S. Geological Survey, Prof. Paper 54, 1906.

† Preliminary Report on the Cresson Gold Strike at Cripple Creek, Colorado. Quarterly, Colorado School of Mines, Vol. IX, pp. 3-15, January, 1915.

length, though they may contain rich ore. The veins occur in all rocks, but favor the breccia and the granite, although many follow phonolitic and basic dikes. Most of the lodes are narrow and show a sheeted structure, but the fissures seldom show indications of faulting. It is believed that they were formed about the same time as the intrusion of the basic dikes, by compressive stresses which resulted from a slight sinking of the solidified breccia and small intrusions in the throat of the volcano. The persistence of a vein with depth is roughly proportional to its length. In general, the fissures seem to be smaller and less abundant in depth than near the surface. Within the narrow veins are occasional ore shoots of variable size. These are not confined to any particular type of rock. The shoots are generally tabular, elongated bodies varying in width from a few inches to fifty feet, with four to five feet a common size. The stope length in an ordinary shoot varies from fifty to three hundred feet. In rare cases, it may be as much as two thousand feet. The pitch varies from 45° to 90° and is generally northward. The average pitch length is five hundred feet, but it occasionally may be as much as fifteen hundred feet. When one shoot ceases with depth another may be found below it upon the same or an adjoining fissure. The largest shoots are independent of intersections, but some small ones appear to be related to crossings.

The most important ore mineral is calaverite, $Au(Te)_2$, some of which carries a small amount of silver. Small amounts of sylvanite, $(Au, Ag)Te_2$ and of Krennerite, $(Au, Ag)Te_2$ have also been recognized in the ores of the district. Native gold, with a few minor exceptions, is present only in the oxidized ore in the form of a brown spongy variety. Galena, sphalerite, tetrahedrite, stibnite, and molybdenite occur sparingly. The gangue in the fissure veins consists typically of quartz and fluorite. Occasionally dolomite also is present. In some of the veins the fluorite, quartz, and calaverite are intimately intergrown and form a fine grained purple rock. Drusy structure is commonly shown in the veins. The replacement ore occurs in red granite which often shows a drusy structure and is partly replaced by adularia, fluorite, and calaverite.

The country adjacent to the veins shows only a slight alteration as a result of the passage of the mineralizing solutions. In the tuffs and breccias, the dark silicates are transformed to carbonates, pyrite, and fluorite while the feldspars and feldspalthoids are changed to sericite and adularia. As a result of oxidation, the veins are usually considerably changed above the ground water level and in exceptional cases even to a depth of two or three hundred feet below the water level. Descending surface waters, bearing oxygen and carrying sulphuric acid, formed by the oxidation of the pyrite, disseminated through the ore and the country rock decompose the gold tellurides, forming brown spongy gold and tellurites, and change the silicates and other minerals to kaolin, quartz, manganese dioxide, and limonite. "Oxidation tends to destroy the original structure of the vein and changes the ore to a brown, soft, and homogeneous mass." In spite of the extensive oxidation effects, no evidence of secondary enrichment of the ore deposits has been found in the district.

Lindgren and Ransome favor the view that the ores were deposited by hot ascending alkaline solutions, of magmatic origin. "The waters ascended in the deeper part of the volcano with comparatively great velocity on the fewer fissures here available. Nearing the surface they spread through a larger space in a more complicated fissure system. The speed became checked and conditions for precipitation improved. Deposition and the chemical action of the country rock changed the composition of the solutions and a mingling with fresh ascending waters, possibly also with atmospheric waters, induced further precipitation. In this manner, is explained the smaller amount of ore deposited in depth and the richness and abundance of ore nearer the old surface. The portion of the volcano removed by erosion may have contained still richer deposits."

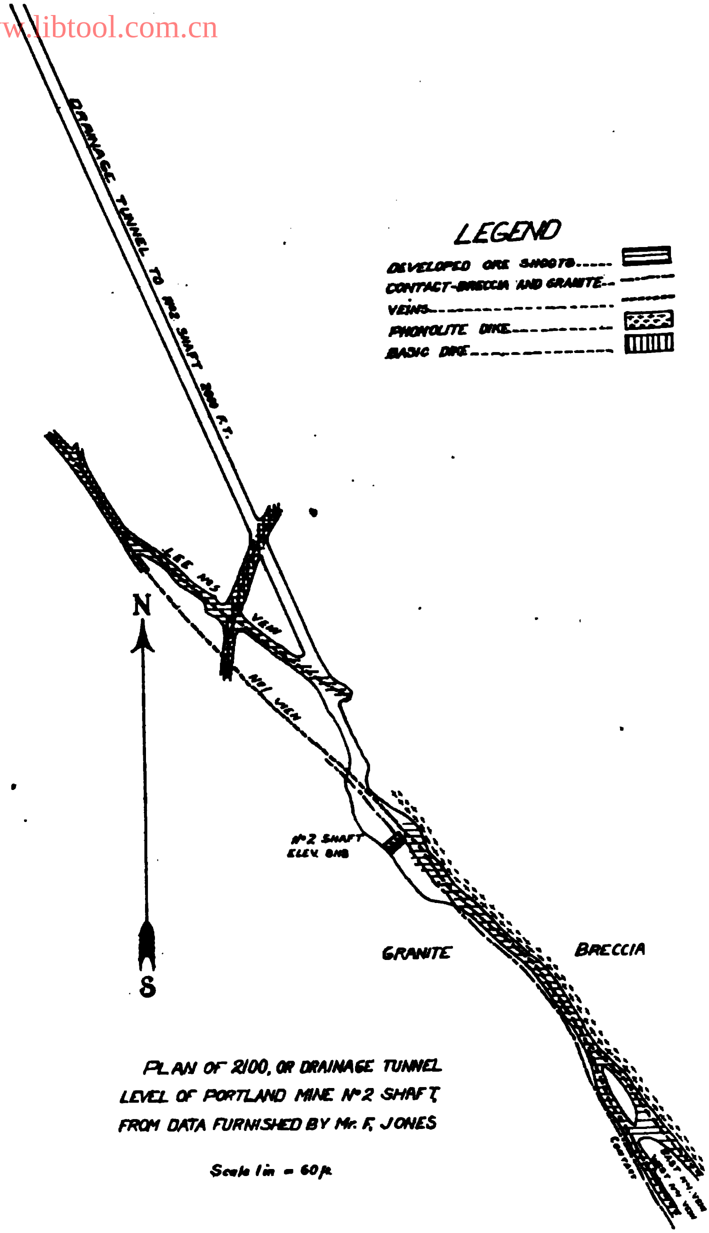
NEWER DEVELOPMENTS IN THE DISTRICT Among the newer developments of interest in the past few months are: (1) The results of deep exploration work in the Vindicator, Portland, and Cresson properties, stimulated largely by the completion of the Roosevelt tunnel. (2) The new discoveries in the Trail, Cresson, and Index mines. (3) The opening of the Rose Nicols mine. (4) The discovery and exploration of the manganese deposit on Ironclad Hill. At the present time, interest centers largely in the deeper development in the Vindicator, Portland, and Cresson mines.

The results of deep exploration in the Vindicator, located on Bull Hill, have been summarized in the annual report of the company for 1918, as follows:

"Early in 1918 development was discontinued on the twentieth level, the bottom of the Golden Cycle shaft. On this level a total of 4,240 feet of work has been done, and no ore of commercial grade exposed. This work has systematically explored the known ore zones which, at this level, should possibly produce ore. The vein systems were found in place and the fracturing was strong and well defined, and with a general physical appearance favorable to ore deposition. However, the value necessary to make commercial ore was lacking. This level is at a depth of 2,150 feet from the collar of the shaft and at an elevation of 7,920 feet above sea level. The productive areas in the property maintained well with depth to an elevation of about 8,300 feet. In sinking below this, there was a gradual but marked decrease in the production of the areas, the oreshoots being more broken up, and showing a decided decrease in the average grade of the ore produced. Extensive work has been done on the twentieth level with the view of developing ore below a possible barren zone existing at the elevation of the nineteenth level, but with negative results. There are possibly existing ore bodies at a greater depth, but it is the opinion of the operating staff, from a thorough study of the habits of the existing ore bodies, that there will not in this property be sufficient ore opened at a greater depth than that to which exploration work has been carried to warrant the expense of sinking and exploring. However, this does not mean that exploration should stop, as there is considerable area on the upper levels of the property that has not been thoroughly prospected, and it is the intention of the management to explore this ground during 1919. Due to the intense labor shortage during the year 1918, this work was impossible."

The Portland Gold Mining Company, operating on Battle Mountain, has been much more successful in its deep exploratory work. On the twenty-one hundred foot, or drainage tunnel, level, a rich ore body was recently discovered in Portland vein No. 1 near shaft No. 2. The tenor of the ore is said to average from $30.00 to $40.00 a ton and the shoot is regarded as one of the richest yet found in this vein. The vein which is nearly vertical and trends N. 35° W., on this level, parallels a phonolite dike which follows the contact between granite and Cripple Creek breccia. This ore body is not important on the nineteenth level, but is somewhat richer on the twentieth, where its width varies from five to twelve feet. On the twenty-first, where the best values are found, the width varies from four and one half feet to a maximum of more than twenty-eight feet at a point where the vein "splits" into east and west branches. The ore mineral is calaverite and the gangue minerals are quartz and chalcedony with a little fluorite. There is also considerable disseminated pyrite in the ore and the wall rock. The mineralization has affected the granite, the phonolite, and the breccia indiscriminately giving rise to rich ore in all three varieties of rock.

The Lee No. 5 promises to yield considerable commercial ore on the twenty-first level also. It is reported that the ore shoot opened in this vein on this level is richer than on the level above. The relation of the Lee No. 5 to Portland No. 1 vein is shown in the accompanying sketch.



PLAN OF 2100, OR DRAINAGE TUNNEL LEVEL OF PORTLAND MINE No. 2 SHAFT, FROM DATA FURNISHED BY Mr. F. JONES

Scale 1 in = 60 ft.

The deep development work in the Cresson mine on Raven Hill is just beginning. Several well defined veins were cut recently on this property in the cross cut connecting the Roosevelt tunnel with the nineteenth level. Some of these show considerable promise, but have not been sufficiently developed to give an idea of their extent and value. However, considerable optimism is felt concerning the persistence of the ores at depth in this mine.

The higher-level strikes in recent months on the Trail and Cresson properties have also stimulated interest. On the Trail, owned by the United Gold Mines Company, a rich ore shoot has been opened in the Dexter vein on the tenth and eleventh levels. Another strike on the fourteenth level of this mine has been reported.

In the Cresson mine, important discoveries have been made recently on the eighth, eleventh, and fourteenth levels. It has been demonstrated that the important ore shoots in this property are related to a more or less chimney-like area of shattering, roughly elliptical in plan, with a length of about a thousand, and a width of five hundred feet. The richer ore bodies tend to occur within this area or near its borders. Early in 1919 a rich shoot was found on the fourteenth level (No. 1417) in a sheeted zone in volcanic breccia just outside the area of shattering. The vein strikes N. 50°E., is five to twenty feet wide, and dips steeply to the southeast. The same shoot is said to carry commercial ore on the twelfth and fifteenth levels. During the month of March of this year a shoot was discovered just within the shattered area on the eighth level. The ore body is nearly vertical, has a general north-south trend, and is approximately sixty feet long and thirty feet wide. It is known to extend at least one hundred feet both above and below this level. The average tenor of the ore is $20.00 a ton, the higher values being found near the middle of the ore body.

Three important discoveries in the Index mine, operated by the El Paso Extension Corporation, on the southwestern slope of Gold Hill have been reported recently. One of these was made by the company on the eighth level, at a depth of approximately 1,160 feet, at the intersection of the Index vein with a cross vein. The remaining two were made by lessees on the fourth level, one to the north and one to the south of the shaft.

The Rose Nicols mine, situated on the northwestern slope of Battle Mountain, was reopened more than two years ago by the Reva Gold Mining Company and exploratory work has been carried on steadily since, chiefly upon the Lost Anne and Dexter veins. The Lost Anne vein has been explored by a drift extending from the eighth level of this mine directly to the Portland. Also the intersections of this vein with the Dexter and Hidden Treasure veins, where rich ore bodies were expected to occur, have been prospected on the seventh and eighth levels. Up to the present time no large ore bodies of considerabble richness have been discovered, but several small shoots of some importance have been located on the Dexter and Lost Anne. It is possible that future development will result in one or more rich discoveries on this property, since the vein systems are exceptionally well defined.

The discovery of a manganese deposit on Ironclad Hill and the present attempt to develop this by the Lincoln Mines and Reduction company is worthy of notice. The ore occurs in the form of psilomelane which is essentially a hydrated oxide of manganese with small amounts of barium and potassium oxides. This mineral is one of the chief sources of manganese the world over. Its occurrence at Ironclad Hill, however, is unique in that it occurs in phonolitic breccia. The productive area of the breccia appears to be confined to a belt fifty to seventy-five yards wide and about one hundred fifty yards long and trends approximately northwest-southeast. The depth to which the mineral extends apparently exceeds one hundred feet, since samples of it have been reported at the base of an inclined shaft which extends below this depth. The psilomelane does not form a continuous deposit, but occurs rather as streaks and small pockets which have an erratic distribution in the breccia. All of the local deposits contain fragments of the country rock or kaolin, derived from it by decay, and in some of them there is considerable limonite—the hydrated oxide of iron. It is believed that the richer and larger bodies of the mineral will be found relatively near the surface, but the spotted character of the deposit and the presence of considerable impurities in much of the material will render its future uncertain.

FUTURE OF THE DISTRICT The greatest problem, from a geological standpoint, which confronts the mining interests of the Cripple Creek District is the question of the persistence of the ore deposits with depth. The problem is the more acute at the present time, because many of the rich ore bodies, which have so far been discovered on the higher levels, are now either greatly depleted or have been completely removed, and in many cases the operators hesitate to carry on deep exploratory work unless they have some assurance that the chances for success on the deeper levels are proportionate to the financial risks involved. Fortunately, however, the aggressiveness of some of the larger companies in deep exploration in recent months, especially since the completion of the Roosevelt tunnel, has thrown considerable additional light upon the behavior of the veins with depth.

The apparent decrease in the number of ore bodies found on the lower levels does not warrant predictions of a brilliant future for the district. However, the discovery of well defined vein systems at the greatest depths yet penetrated in three of the largest mines, located in comparatively widely separated points in the district, suggest that the deposition of ore bodies at considerable depth has not been hampered by the lack of numerous passage ways for the ascending mineralizing solutions. But it must be considered probable that conditions did not favor the deposition of the ores to the same extent and to the same degree at the greater depths, as they did nearer the surface where more extensive mineralization must have been favored by (1) the greater decrease in temperature and pressure of the rising solutions, (2) by the checking of the velocity of their ascent due to the greater number of fissures and other openings near the surface, and (3) by their greater mingling with descending solutions of meteoric origin. But the history of the development in the district during the past few years indicates clearly that ore shoots of great richness have been formed, under certain favorable conditions, at depths surprising to many geologists and mining engineers. It is believed, therefore, that the recent strikes on the deeper levels, such as those on the twenty-first level of the Portland, should lend considerable encouragement to deep prospecting on the part of the larger companies which are in a position to undertake such work.

Mining

PROF. HARRY J. WOLF.

WAR CONDITIONS The public is not generally aware of the creditable record made by the mines of the Cripple Creek district during the war. A list of the properties that remained in active operation in spite of high wages, scarcity of labor and high cost of supplies, offers a genuine surprise to those who have accepted too hastily as truth the utterances of certain pessimistic persons. These utterances have served to convey the general impression that Cripple Creek, one of the great gold mining districts of the world, is a thing of the past. A casual investigation of the true conditions discloses the fact that more than twenty prominent mines of the district maintained regular production during the war. Among these mines were the Portland, Granite, Vindicator, Cresson, Jerry Johnson, Forest Queen, Index, Dante, Isabelle, Modoc, Dexter, Howard Shaft of the Mary McKinney, Rose Nicol, part of the Stratton Estate, El Paso, Gold Sovereign, Blue Flag, Elkton, Gold Bond, Queen Bess, Phoenix, Jo Dandy, and Block 8 of School Section 16. It is generally accepted as good practice to maintain ore reserves by pushing development work during periods of normal production. However, in the case of a gold mining district where all mining costs increased nearly one hundred per cent while the price of the product remained fixed it became expedient to curtail expenditures for development work, and direct attention to the production of such ore as could be hoisted with the minimum expenditure for all operations which were not immediately productive. The following of this practice in the Cripple Creek district has depleted reserves, and has naturally left some properties in a condition which suggests approaching exhaustion, while as a matter of fact the situation is not as bad as it looks, for recent resumption of systematic development work has resulted already, in many cases, in the discovery of numerous promising ore bodies. Among the properties which suspended operations, in whole or in part, during the war, are the following: Ajax, Elkton, Strong, Jo Dandy, Acacia, Blue Bird, Gold Sovereign, New Gold Dollar, Queen, Petrel, Bunker, Prince Albert, Ocean Wave, Tornado, Sheriff, Masterpiece, Anchoria, Leland, Victor, Pride of Cripple Creek, Millasier, Erie, Bertha B., W. P. H., White Horse, Jack Pot and Blue Bell. Several of these properties have resumed operations recently, and the Blue Bird, Maggie, Elkton, Deadwood, Free Coinage, Acacia, W. H. P. and Strong properties are preparing to operate as soon as conditions improve.

DEVELOPMENT At this time there is a growing tendency on the part of both large and small operators to undertake development work of a purely exploratory nature. Engineers familiar with the Cripple Creek geology recognize the desirability of prospecting at lower levels throughout the vein system extending from Stratton's Independence to the Forest Queen, a distance of about three miles. Prospecting below the 1,000-foot level has been limited, but the efforts of several of the larger operators at deep levels have been richly rewarded. It is of interest to refer to the successes of some of the larger producers which have been the mainstays of the camp for many years. The most noteworthy examples of development of high grade ore at deep levels are to be found in the Portland and Cresson properties.

THE PORTLAND On the Roosevelt Tunnel level, or 2,133-ft. level, of the Portland mine, one of the most spectacular discoveries of the past few years has been made. On this bottom level a shoot of rich ore over thirty feet wide has been opened. The same ore shoot was about ten feet wide at an elevation one hundred feet above. The average value of this ore body, and the possibility of its continuance downward, make it a discovery of first importance. It is of interest to note that the company performed 8,071 feet of development work during the year 1918. The total underground development to January 1, 1919, amounts to a little less than 63 miles in the Portland mine, and nearly 17 miles in the company's Independence mine, making a total of nearly 80 miles of underground workings. The company's grand total ore production to the end of 1918, is 3,949,248 tons, having a gross value of $48,773,377. To January 1, 1919, the company has paid $11,257,080 in dividends, of which amount $300,000 was distributed during the year 1918.

THE CRESSON The Cresson property has completed its connection with the Roosevelt tunnel at a depth of 1,915 feet, and has cut a shaft station on this level. Exploratory work on this bottom level is under way, and a body of high grade ore has been opened, the extent of which has not been determined. During the past few months a large body of high grade ore has been found on the eighth level. This ore body is 50 by 150 feet in horizontal extent, and is comparable in size and average value with another important ore body on the same level discovered some two years ago. These two new ore bodies are now being opened by drifts and crosscuts, and chutes are being made preparatory to stoping. During the past two years the company's underground development work has opened new ore bodies on the third, fourth, and fifth levels on the vein systems of the Funeral and Silver dykes; new ore bodies of substantial size and value on the seventh, eighth, ninth, and tenth levels, located in the center of the volcanic crater; and new ore bodies on the Roosevelt tunnel level, exceeding in both size and value the ore bodies heretofore disclosed on the sixteenth level, 175 feet above the tunnel. During the year ended August 31, 1918, the company performed development work consisting of 4,540 feet of diamond drilling, 6,472 feet of drifts and crosscuts, and 1,766 feet of raises and winzes. In addition, drifts and winzes aggregating 886 feet were driven to connect both the main shaft and the 1,600 level ore bodies with the Roosevelt Drainage tunnel. Under date of August 31, 1918, the net ore reserves were estimated at nearly $3,000,000. In the year ending August 31, 1918, there were shipped 89,730 tons of ore of the net value of $1,628,187, after deducting freight and treatment charges. It is interesting to note that the company's production for the twelve months aggregated 9,028 pounds of pure gold.

THE VINDICATOR

Another important producer of the Cripple Creek district is the Vindicator. This property has not been as fortunate as the Portland and Cresson mines in the development of rich ore bodies in its lower levels, but has operated at a profit of $544,000. The total development during the year ended December 31, 1918, amounted to 5,112.5 feet, of which 2,899 feet were driven by lessees. The total development work to date in the company's Vindicator and Golden Cycle properties amounts to nearly fifty miles. Early in 1918, development work was discontinued on the 20th level of the Golden Cycle shaft, the bottom level. On this level a total of 4,240 feet of work has been done, and no ore of a commercial grade exposed. Recently, exploration work has been resumed in the upper levels, and the results of this work have been encouraging. During 1918 the labor shortage made it impossible to accomplish much development work, and as a result the ore reserves of the company have been greatly depleted. On January 1, 1919, the ore reserves were estimated at 104,230 tons of average grade ore. The value of the crude ore mined on company account has been $6.15 a ton, and the average value of ore mined by lessees has been $9.60 a ton. The property is of special interest on account of its low mining cost of $1.60 a ton, exclusive of cost of development; the operation of its flotation plant at a cost of fifty cents a ton; and the development of interesting methods of ore sorting and the Muncaster system of inclined shrinkage stoping.

THE MUNCASTER METHOD OF STOPING

The Muncaster method of stoping has definite advantages over the ordinary methods of shrinkage stoping where the attempt is made to draw the ore out of a stope uniformly from end to end and maintain an approximately level muck line. In the inclined shrinkage system the ore is drawn off through two adjacent chutes at a time, beginning at one end of a stope and proceeding gradually toward the other end. Above the two active chutes, the material that is being drawn off is maintained at an inclination as steep as, or a little steeper than, its normal angle of repose. This condition causes the larger boulders to roll down the incline past the active chutes and into the portion of the stope from which the smaller sized and better ore has been drawn.

This action reduces the tendency of the larger rocks to clog the chutes, and the rolling of the larger rocks serves to separate them from the finer material which finds its way readily toward the chutes. At the same time the larger rocks, which are frequently not payable ore, may be retained in the stopes. Further, the operation of the stope may be inspected safely from the quiet surface of the filling above the inactive chutes.

THE ROOSEVELT TUNNEL The Roosevelt drainage tunnel has been an important factor in deep-level development of the district, for many properties could not have been operated at their present depths without its assistance. The only mines of importance which could have been operated without the tunnel are the Portland, Cresson, Strong, and Granite. The tunnel has saved millions of dollars which would have been expended in pumping. The total length of the tunnel, from portal to breast, is 24,355 feet. It taps the El Paso mine at a depth of 1,289 feet, the Elkton at 1,640 feet, the Cresson at 1,915 feet, and the Portland at 2,133 feet. The Portland and Cresson mines are connected with the tunnel by means of crosscuts. The Portland connection is 2,000 feet long from the tunnel to Portland No. 2 Shaft. The Cresson crosscut is 1,715 feet long.

LESSEES Many important mines of the district are operated by lessees. Among these properties are the American Eagle, Six Points, Longfellow, Index, Midget, Jo Dandy, and Hiawatha. Almost all the mining companies find it advantageous to lease certain blocks of ground which would be difficult to operate on company account. A leasing arrangement which has gained considerable popularity in the district is the "split check system," in which the company supplies the equipment, the lessee contributes the labor, and the net proceeds are divided between the two parties.

LABOR CONDITIONS American labor is employed almost exclusively in the Cripple Creek district, and no encouragement is given to proposals which involve the introduction of foreign labor. The district is in great need of skilled miners and other labor. Living conditions are good and high wages are paid.

Metallurgy

PROF. IRVING A. PALMER.

INTRODUCTION The proper metallurgical treatment for Cripple Creek ores is a problem that for years has absorbed the attention of some of the best engineers in the country. Many processes have been tried and a large number of reduction plants have been erected. Owing to the peculiar nature of the ores in this district, the extraction methods that have proved to be the most efficient show a considerable variation from the standard practice in other gold mining camps.

In the early days of the Cripple Creek district the greater part of the ore was sent to smelting plants for treatment. The mines were fortunate in being located comparatively close to several large lead and copper smelters at Denver, Pueblo, and Leadville. The ores were mostly high grade and needed no roasting for the smelting process. They were in demand, therefore, by the smelting companies. But the treatment charges were heavy, as the high percentage of silica and alumina in the ores necessitated the use of a large amount of iron and lime flux in the smelting mixtures. As the camp developed, a considerable tonnage of lower grade ore was produced and the necessity of a cheaper reduction method was recognized. The first attempt in this direction was the installation in the district of a number of small mills using stamp batteries and plate amalgamation. During 1892 and 1893 ten of these mills, containing a total of 270 stamps, were erected. These mills were later equipped with concentrating tables and blankets. Although the surface ores carried a considerable amount of free gold, it was found that the gold did not amalgamate well because of its rusty nature. As the mines increased in depth and the free gold was replaced by the unoxidized sulpho-tellurides the amalgamation process became less and less effective and the mills were soon entirely abandoned.

In 1893 the first chlorination plant in the district was built by Edward Holden. In 1895 another chlorination plant was built at Gillette, under the supervision of J. D. Hawkins. In 1897 the first cyanide mill was built at Mound City, under the direction of Philip Argall. In the next few years a number of large mills were erected at Florence and Colorado City, some using chlorination and others the cyanide method. The two processes vied with each other for some time, but the chlorination process finally gave way to cyanidation. The last plant to use chlorination was that of the Portland Gold Mining Company, at Colorado Springs, which converted its mill into a cyanide plant in 1912. The two developments that contributed most to the victory of the cyanide process were fine grinding and better methods for the treatment of slime. In addition to the chlorination and cyanide mills a number of smaller plants were erected from time to time, using a variety of processes. Practically all of these proved to be failures.

In recent years the tonnage and grade of the ores mined at Cripple Creek have fallen off very materially. The first result of this has been the closing of several of the large mills at Florence and Colorado Springs. The second effect has been the building of mills at Victor for the treatment of the low grade ores not rich enough to stand shipment out of the district. Still later, the conditions produced by the war have resulted in a further contraction in the mining and milling of the Cripple Creek district ores and there now remain in operation but three of the many mills erected to handle them. Two of these plants are at Victor, treating low grade ores exclusively, and the third is at Colorado Springs, treating the better grade ores, together with the concentrates, slimes, and precipitates from one of the other two mills.

The ores mined at Cripple Creek belong to the class known as sulpho-tellurides. There are practically no base metals, such as copper, lead or zinc, and the amount of silver is so small as to be of little commercial importance. The ores are mined and treated almost exclusively for their contents in gold. The gangue consists mainly of brecciated phonolite and granite. As the gangue is usually quite hard the problem of crushing the ore in the most effective way has been given a great deal of attention. At or near the surface considerable free gold is found, but on the lower levels the gold occurs largely as a telluride, usually associated with pyrite. The predominating gold mineral is sylvanite. The almost invariable presence of a greater or lesser amount of pyrite in the ore has made the problem of the proper metallurgical treatment a difficult one. Very early in the history of the district it was found that a thorough roasting of the high grade ore was necessary in order to get a satisfactory extraction of the gold, no matter what milling process might be used.

Another very important feature of the Cripple Creek ores is the occurrence of the gold minerals with relation to the gangue. For many years it has been known that the finely divided ore or screenings carried more gold than the coarser rock. The dust in sampling mills and the slimes at the bottoms of sumps were always found to be richer than the average of the ore from which the finer material came. Hand sorting has been practiced since the mines were first opened, and the reject has consisted of coarse pieces known to be low in gold. The reason for this segregation of values in the finer material is to be found in the fact that in this district not only does the gold ore usually occur in narrow veins and seams in the barren rock, but the ore itself in turn contains the gold largely in minute cracks and cleavage planes. The more of these crevices and cleavage planes in the ore, the higher the grade; the greater ease also with which it can be crushed, and consequently the greater the tendency to occur in small pieces after being mined. The large pieces that survive the blasting operations of the mine or the coarse crushing of the mill owe their size to the fact that they have fewer seams and cleavage planes. They are, therefore, lower in grade than the finer pieces. The segregation of gold in the ores is often quite apparent to the eye and enables the miner by hand sorting to discard a considerable tonnage of rock that would not pay for treatment. This feature of Cripple Creek ores is more marked in some parts of the district than in others. It is particularly characteristic of the ores of the Vindicator mine and forms the basis of a large part of the milling practice of that company. On the other hand, in the Cresson mine there is a more uniform distribution of the gold throughout the entire mass of the ore. Even here, however, there is a tendency towards segregation of gold in the fines.

Another characteristic of some of the ores of the district is the increasing percentage of carbonate of lime. This has become so marked in some cases as to necessitate a modification of the milling practice. In the roasting of these ores much of the lime carbonate is converted into sulphate which deposits in the pipes, launders, and filter leaves of the cyanide mill and adds to the mechanical difficulties of the process. This will be referred to later in connection with the Golden Cycle Mill, at Colorado Springs.

The outstanding feature of the metallurgical methods now in use at the two mills operating in Victor is the extent to which the underlying principles of ore dressing are applied; that is, the elimination by mechanical means of as much as possible of the unprofitable gangue, and the separation by mechanical means of higher grade product or concentrates from other material requiring a different metallurgical treatment. It is now recognized that in the past a considerable amount of ore has been shipped out of the district that did not pay its way. It was mixed with higher grade material, and the profit on the latter absorbed the deficit on the former. In recent years the falling off in the average grade of the ore mined and the constant increase in the cost of labor and supplies have impelled the mining companies to look into this matter very closely. A great many tests have been conducted for the purpose of ascertaining to what extent the above mentioned principles of ore dressing could be applied. These tests have resulted in a material modification of the practice at both mills, and in a gratifying increase in the financial returns. The newer methods also enable the mills to handle ore that a few years ago would have been regarded as unprofitable waste.

THE INDEPENDENCE MILL

The larger of the two metallurgical plants at Victor is the Independence mill of the Portland Gold Mining Company. This mill was formerly the property of the Stratton's Independence Mining Company. The Victor mill of the Portland Company was closed on July 30, 1918, and much of the machinery was moved to the Independence plant. All of the ore reduction operations of the company are, therefore, consolidated in one mill, the Colorado Springs plant having been closed on March 31, 1918, so far as ore treatment was concerned.

The metallurgical treatment at the Independence mill is a combination of mechanical sorting, water concentration, and slime cyanidation. Two products are shipped, concentrates and gold precipitate. Probably the most striking feature in connection with the operations is the low grade of ore treated, the mill feed for several months past having averaged in value but a little more than two dollars per ton. On this ore the average extraction of the gold is about 80 per cent, and the company makes a small profit. The successful treatment of such low grade material is certainly a tribute to the technical skill of the metallurgists in charge.

At the present time most of the ore handled comes from the dumps of the Portland and Independence mines. It is reclaimed by means of homemade drags drawn by cables which deliver the ore into glory holes leading down to shutes installed in the upper tunnel levels. From there it is trammed to the mill. The total cost of delivering the dump ore into the shutes is only ten cents a ton. On arriving at the mill the ore is subjected to the first application of the ore dressing principle by being dumped over grizzlies with 8-inch openings. The oversize of plus 8 inch material is sent to the dump. Assays of the coarse reject show it to contain about 50 to 60 cents in gold. As the total cost of milling in the district is about $1.00 per ton and the tailing rarely runs less than 40 cents per ton the wisdom of discarding the coarse rock is evident. In February, 1919, the Independence mill was receiving about 1,525 tons of low grade dump and mine ore daily. Of this about 225 tons was taken out by the grizzlies and rejected. This left 1,300 tons daily to be treated in the mill proper.

Immediately under the grizzlies are the storage bins from which the ore can be sent either to the sampling department and thence to the crushing plant, or it can be sent to the crushing plant direct. As the mill expects to handle a considerable tonnage of custom ore, there is a fully equipped sampling plant, supplied with Vezin automatic sample cutters. The company also uses the equipment at intervals for the sampling of its own ores.

The ore is delivered from the bins to the crushing department by means of conveyor belts. The coarse crushing equipment consists of two No. 7½ gyratory crushers and two sets of 72 by 20 inch Garfield rolls, each gyratory crusher and set of rolls constituting one unit. As the capacity of the crusher and rolls is about 100 tons per hour the operation of one unit for two shifts daily is sufficient to take care of all the ore that the rest of the plant can handle. The gyratory crushers deliver a product of a maximum size of 4 inches, which is further reduced by the rolls to a maximum size of 2 inches to 2.75 inches. The practice with the Garfield rolls is interesting because of the low speed at which they are operated. At some mills rolls of this size are run at from 75 to 100 revolutions per minute. At the Independence plant this speed has been reduced to between 30 and 35 revolutions with an increase in efficiency. The greater effectiveness at the lower speed is probably due to the lack of brittleness in the ore and to better gripping of the coarser particles of the feed by the surfaces of the rolls. The product of the rolls goes to storage bins whence it is delivered by an automatic tripper conveyor to the feed hoppers of 6-6 foot Wellman-Seaver-Morgan Chilian mills. The ore is fed into the mills by means of plunger feeders supplied with revolution counters. From the number of the plunger strokes registered by these counters the approximate tonnage of ore delivered can be calculated. Along with the ore there is fed mill solution containing about 0.20 per cent sodium cyanide, in the proportion of about three of solution to one of ore. From this point onward the ore is in continual contact with sodium cyanide. Five of the Chilian mills operate at a speed of 37 to 38 R.P.M. and the other one at 29 R.P.M. The power consumption on the high speed mills is about 110 h. p. each. Two of the mills are supplied with 20 mesh screens and the other four with 6 mesh screens. Each Chilian mill discharges directly into an Akins classifier, where the ground ore is separated into two products, sand and slime. The sand is sent to ball mills for further grinding, while the slime overflow is passed into primary thickeners and thence to the concentrating and cyaniding departments.

The use of Chilian mills at this point is worthy of comment because of the fact that in the opinion of many engineers they do not constitute the most effective grinding machinery. In a number of the newer milling plants there are employed for fine grinding either a combination of disc crushers and ball mills, or ball mills alone. In spite of these facts the metallurgists in charge of the Independence plant are strong in the belief that for their particular ore crushing problem the Chilian mill is the most satisfactory machine that could be installed. It must be remembered that the feed for these mills consists of a hard, tough ore, of a maximum size of 2 to 2.75 inches, and that the final crushing of the sand produced is performed in ball mills. The Portland engineers have made many tests to determine the relative efficiency of various types of grinding machinery, so that their present practice is not the result of prejudice or indifference.

The question as to what type of classifier should be used between the Chilian mills and the ball mills was also subjected to considerable experimenting. The Akins machine was installed because it is simple in construction, occupies small space, and delivers sand comparatively free from slime. Any coarse material that may escape in the overflow is caught on the tables and either goes into the concentrates or is returned as a middling product for further grinding in one of the ball mills.

In the fine grinding department there are six 6 by 6 foot Colorado Iron Works ball mills, having chilled iron liners and using two inch chilled iron balls. Five of these mills receive the sand discharge from the Akins classifiers previously mentioned and the other is used for regrinding the middlings from the concentrating department. About 60 per cent of the total amount of ore crushed goes to the ball mills. The first five mills operate in closed circuit with Akins classifiers and the sixth in closed circuit with a Dorr drag classifier. The overflow from all of these classifiers goes to thickneners and thence to the concentrating and cyaniding departments. The use of the Dorr classifier in connection with the ball mill grinding the middlings finds its justification in the very small percentage of sand passing over with the slime. As this is the final classifying machine in the mill the point is of some importance.

In the next step of the milling operations there is another example of the application of the ore dressing principle. As a large percentage of the gold in the ore occurs as telluride in close association with pyrite, it would be necessary to roast the ore in order to get a good extraction by the cyanide process. The roasting at Victor of a low grade ore, such as that treated in this mill, would be out of the question because of the additional expense involved. The greater part of the gold bearing pyrite is, therefore, removed from the slime by means of concentrating tables, only the tailings from these tables being subjected to complete cyanidation. Some of the gold is, of course, removed from the pyrite because the concentrating operations are conducted in mill solution containing sodium cyanide.

The slime overflow from the first series of Akins classifiers, after passing through the primary thickeners, where the excess water is removed, is conducted to the concentrating department at 5 per cent on 40 mesh, where the separation is effected on tables equipped with Card mechanisms and Wilfley tops. This combination has been found to be very satisfactory for this character of work. Two products are made, rougher concentrates, which go to finishing tables, and tailings, which go to thickeners in the cyanide department. On the finishing tables three products are made; concentrates, which go to the bins, preparatory to drying and shipping; middlings, which are elevated and delivered again to the finisher tables, and hence are in closed circuit; and tailings, which, as referred to above, are returned to one of the ball mills for further grinding. This reground portion or middling is thickened, given a preliminary agitation in two 30-foot Dorr agitators, and then passed to the regular slime agitation system with the bulk of the ore.

The slime overflow from the Akins classifiers in closed circuit with the ball mills, after partial thickening, is sent to another series of tables and separated into concentrates, and tailings, as in the case of the first set of Akins classifiers.

If the grade and type of ore at this point does not warrant further treatment of the granular or sand portion, classification and washing is practiced with 6 Akins classifiers and the sands discarded. Otherwise, as at present, they are sent to thickeners and agitators with the pure slimes. The use of Akins classifiers as washing devices is deserving of notice. It is a cheap and effective way of eliminating sand not rich enough to warrant further handling, and at the same time reducing the soluble gold losses to a minimum.

The finished concentrates from the various tables are collected in drying tanks, where the water is eliminated by means of canvas filter leaves under vacuum suction at the bottoms of the tanks. This method has been found to be extremely effective. The concentrates carry from $35.00 to $40.00 in gold and are shipped to the lead smelters for treatment. As the product contains a large excess of iron there is a corresponding deduction from the smelting charge. The weight of the concentrates is about one per cent of that of the original ore, while in value the gold contained amounts to 20 per cent of the total. All of the profit that the company makes is covered by the gold in these concentrates.

The cyanidation method used is the familiar all-sliming process, the available values in the sand not being sufficient to call for separate treatment. Dewatering is effected in ten 25-foot Dorr thickeners, of which six are constructed of wood and four of steel. The spigot discharge from these thickeners contains water and ore in the proportion of 1.3 to 1 and is sent to six 40 by 25 foot Dorr agitators. Here 120 pounds of sodium cyanide is added to each tank and sufficient lime to maintain an excess of about 1.7 pound CaO per ton of solution. The cyanide added is a little less than 0.25 pound per ton of solution. The ore contains only a small proportion of cyanicides, such as ferrous sulphate and sulphuric acid, and the amount of protective alkalinity required is small, but for extraction and settling purposes the demands are high. The agitation is continued for from 48 to 50 hours. The gold tellurides go into solution rather slowly and it is very important that sufficient time be allowed for the operation. From the agitators the pulp and solution go to four Merrill filter presses, each containing ninety 4 by 6 foot by 2⅞ in. frames. Here the pulp is filtered from the solution, washed first with barren mill solution, and finally with fresh water, and then sluiced out of the frames into the tailings launder. The entire operation is almost automatic, requiring the attention of but one man per shift, and is deserving of a more detained description than can be given here.

From the Merrill presses the clear solution, except the lower grade washings, which are returned to the mill circuit, is sent to the precipitation department, first passing through the Crowe vacuum system for the removal of the dissolved air. In this process the solution is run into a closed steel tank from which the air is continually exhausted by means of a vacuum pump. The release of pressure over the solution causes most of the dissolved air to escape. The solution is now ready for precipitation. This is effected by zinc dust in Merrill zinc presses. The zinc dust is fed into the solution as it comes from the vacuum tank by means of an automatic cylindrical feeder. At this stage of the process the solution carries 60 cents in gold per ton, and the amount of zinc dust required is about 0.09 pound per ton. The use of the vacuum system has enabled the Portland company to reduce the consumption of zinc and sodium cyanide at this mill very materially in each case. The gold precipitates very quickly, and almost as rapidly in the first compartment of the press as in the last. Before the use of this system the dissolved oxygen retarded the precipitation by oxidizing some of the zinc. This necessitated the use of a larger amount of zinc dust for complete precipitation. Moreover, the zinc oxide produced formed an insoluble compound with the lime in the solution and thus clogged the pores of the filter leaves. This could be overcome only by the use of more cyanide. The vacuum system is the invention of Thomas B. Crowe, superintendent of the Independence mill, and is now in use by many cyanide plants in all parts of the world. After washing, the gold precipitate is removed from the filter leaves, dewatered, and then sent to the old Portland mill at Colorado Springs, for refining. The amount of solution reaching the zinc presses is two tons for each ton of ore milled. The cyanide consumption is 0.25 pound per ton of ore, the zinc consumption is .18 pound, and the total cost of milling is about $1.00 per ton. The net recovery is about 80 per cent on $2.00 ore.

The use of pressure filters following the agitators is open to question and has been the subject of consideration by the Portland engineers. On the grade of ore treated it would seem that a filter of the Oliver type would be justified because of its cheapness and simplicity. The Portland company, however, is contemplating the milling of higher grade ore later on and thinks that the better separation of solution and pulp effected by the pressure filter justifies its continued use. Two factors that would decrease the efficiency of vacuum type filters at this plant are the considerable amount of granular matter in the slime and the high altitude.

The use of flotation in the milling of Cripple Creek ores has for some time been the subject of considerable experimenting by the Portland metallurgists. The occurrence of the gold largely as sulpho-tellurides, and the fact that the very fine slime not amenable to gravity concentration carries so much of the values, have suggested the possibility of replacing both table concentration and cyanidation by flotation. To this end a great many tests were made, and finally a 400-ton installation put into operation, and 100,000 tons treated before abandoning the process. The net result of these tests has been the decision of the company not to change its metallurgical practice, at least for the present, although some flotation experiments are being continued.

The presence of so much of the gold in the finely ground slime, which has been referred to above as having been one of the chief factors in suggesting flotation, is closely associated with the chief difficulty in the process. The colloidal material, which of course is mainly gangue, tends to go into the flotation concentrates and thus lower the grade. In the Independence mill tests it was found that in order to make a clean concentrate it was necessary to sacrifice gold in the tailings. A high recovery meant a low grade concentrate. As the concentrates must be sent to a smelter for reduction, any decrease in the grade means an increase in the freight and treatment charges. The flotation tests at the Independence plant were made largely with machines of the pneumatic type. In the opinion of a number of engineers who have studied the problem better results can be obtained by the use of agitation machines. The Vindicator Mining company is in fact using Minerals Separation equipment and is getting a good extraction of the gold. The flotation problem at Victor is an interesting one and is worthy of all the attention that is being given to it.

THE VINDICATOR MILL

The Vindicator Mill is an interesting example of an ore dressing plant pure and simple. There is no cyanidation and all the products shipped are the results of screening, sorting, washing, and flotation concentration. Here again the ore treated is of very low grade. The present practice at the mill was introduced something more than a year ago, and is the result of a great deal of experimentation on the part of the metallurgical staff. Thousands of screen tests were made with the object of determining the amount of gold in the various products of the crushing and washing operations. The tests showed conclusively that a large proportion of unprofitable rock that formerly had been shipped to

Colorado Springs could be eliminated by mechanical means, leaving a comparatively small tonnage of enriched product. This, of course, would mean a corresponding decrease in the freight and treatment charges at the reduction plant. That the change in milling practice was justified is shown by the fact that in 1918 the company saved in marketing costs of the products shipped more than $125,000, as compared with the costs of the year before. In addition, there was a decrease in operating costs of more than $8,000, because of the simplified mechanical treatment. There was a further increase of revenue due to the installation of a flotation plant to treat a portion of the reject from the screening and washing operations.

The ore as it comes from the mine, which averaged in 1918 $6.15 per ton in value, is dumped over a series of grizzlies and flat screens, placed one above another, and three sizes of screenings, 1.5 in. to .75 in., .75 in. to .25 in., and minus .25 in., are thus separated from the bulk of the ore. These screenings average about $20.00 per ton in gold and are sent to the Golden Cycle mill at Colorado Springs for treatment by cyanidation. The coarse reject falls into bins from where it is drawn off upon a belt conveyor and sent to the washing plant. As the ore is drawn from the bins it is hand sorted, the high grade material being saved for shipment to the Golden Cycle mill. The washing practice is very simple and effective. The conveyor delivers the coarse rock into a revolving trommel constructed of manganese steel and having 0.375 in. perforations. Inside the trommel jets of water at rather high pressure play upon the moving ore and wash off the fine, loosely adhering gold bearing particles and dust, being aided by the attrition of the pieces of ore grinding upon each other. The slimes thus produced and the fine ore up to 0.375 in. in diameter are washed through the trommel and pass to Bunker Hill 40-mesh screens, where there is a separation into two products, slimes or washings, which go to settling tanks, and oversize up to 0.375 in. which goes to the Golden Cycle mill direct. The settling tanks are four in number and as each is filled the excess water is drained off and the slimes dried by means of steam pipes. The material is then shoveled out and shipped to the Golden Cycle mill for treatment. The average value of these slimes is about $120.00 per ton, a very striking illustration of the tendency of Cripple Creek gold to occur in the fines. In 1918 the shipping products made by the Vindicator company in the screening, sorting, and washing departments amounted to but 6.67 per cent of the crude tonnage of ore hoisted. Including the flotation product the total shipments amounted to 9.29 per cent of the tonnage hoisted. These figures indicate the extent to which the company has benefited in reduced freight and treatment charges.

The coarse reject from the washing trommel, which now carries about $2.50 in gold, is conveyed to storage bins and thence trammed to the flotation plant. There it is mixed with some low grade ore from the Golden Cycle shaft, and the combined product subjected to a second washing process, this time in a trommel having larger perforations, about .75 in. at present. This, however, may be changed as the character of the ore changes.

The coarse reject is hand sorted, the sortings being crushed for flotation treatment, and the remainder carried to the dump by means of a belt conveyor. At present about 78 per cent of the total amount of ore received at the flotation plant is discarded in this way. The assay value of this waste material is about $1.10 per ton. The fine ore and slimes passing through the perforations of the washing trommel are prepared for flotation treatment by crushing in Garfield rolls and fine grinding in two 6 by 6 foot Stearns-Roger ball mills. The ball mills operate in series and in closed circuit with a Dorr classifier. One of the mills takes the entire feed, while the other takes the sand from the classifier. The overflow from the classifier goes to the flotation machines.

Flotation is effected in Minerals Separation machines, there being twelve 24 by 24 in. rougher cells, and five 24 by 24 in. cleaner cells. The tailings from the cleaner cells are passed over a Wilfley pilot table. The oil used per ton of ore consists of a mixture of .5 gallon Florence fuel oil and .11 gallon General Naval Stores Co. No. 8. In this mill, as at the Independence plant, considerable difficulty was experienced in the flotation treatment because of the large amount of colloidal material. To counteract the influence of this to some extent the impellers of the machines are run at high speed. At the Vindicator mill the impellers have a peripheral speed of 2,000 feet per minute. From the flotation machines the concentrates go to a Dorr thickener, where the amount of water is reduced to 50 per cent. The thickened pulp goes to a 12 by 12 foot Portland filter which reduces the water to 30 per cent. The low efficiency of the filter is accounted for by the large amount of finely divided clayey material in the pulp. The final drying is performed on a 6 by 40 foot Lowden dryer, which delivers a product carrying about 17 per cent of moisture. The difficulty of dewatering these concentrates by means of the equipment now in use is so great that the company is considering the use of steam drying tanks, such as are used for the washer slimes. The dried concentrates assay from $35.00 to $40.00 in gold and are sent to the Golden Cycle mill for treatment.

The Vindicator engineers have done a great deal of experimental work on flotation, and, while the process is a commercial success as at present operated by them, they feel that there is still room for improvement. The great difficulty is to produce a high grade concentrate, while at the same time maintaining a high percentage of recovery. The small size of plant necessary for the tonnage handled and the simplicity of the flow sheet are certainly strong arguments in favor of the process, and offer great inducements to those who are working it out.

During the year 1918 the Vindicator flotation plant received from all sources 222,626 tons of ore, of an average assay value of $2.13 per ton. Of this, 176,623 tons, averaging $1.42 per ton, was rejected by screening, and 46,003 tons, of an average assay value of $4.18 per ton, was sent to the flotation crushing department. The flotation plant produced 6,029 tons of concentrates having a gross value of $206,254.81 and a net value, after marketing charges of $171,037.92. There was a net profit of $27,955.40.

THE GOLDEN CYCLE MILL The Golden Cycle mill is the only remaining plant of the many erected outside of the Cripple Creek district for the purpose of treating the ores from that camp. It was built originally as a bromination plant, but was converted into a cyanide mill about four years later. It is now the largest mill in the world treating gold ores by a combination of roasting and cyanidation. Only the high grade ores from the mines at Cripple Creek and the concentrated products from the Vindicator mill are sent to the Golden Cycle plant. The greater richness of the material treated permits of a more elaborate extraction scheme than that of the Independence mill, but the flow sheet is a comparatively simple one. The efficiency is so high that there is practically no limit to the grade of ore received, although it is customary for the mining companies to "grade down" by mixing the very rich ore with that of lower grade before shipping. The lead smelters now receive but an insignificant tonnage of Cripple Creek ore. The Golden Cycle mill is a custom plant only, and is equipped with a very complete sampling department. Blake crushers are used, followed by coarse rolls and sample cutters of the Vezin type. The reject goes to the storage bins. All of the ore received is roasted before being cyanided, so that the next step is to crush it to the size most suitable for desulphurization. At this point it is necessary to divide the ore into two classes, according to the percentage of lime contained. The increasing amount of carbonate of lime in some of the Cripple Creek ores has been referred to above. In recent years this tendency has been so pronounced as to require a modification of the metallurgical practice at the Golden Cycle mill, because of the conversion of a part of the lime carbonate into sulphate in the roasting furnaces. Some of the ore recently mined in the Cripple Creek district has carried as much as 9 per cent CaO. At the Golden Cycle mill all ore containing not more than 2 per cent CaO is rated as class A ore, and all over 2 per cent, as class B. Class A comprises about 66 per cent of the total ore treated and class B, 34 per cent. Typical analyses of both classes are as follows:

	Class A	Class B
Insol.	86.70	75.90
Al_2O_3	2.30	3.40
Fe	3.26	3.48
CaO	1.57	5.12
S	1.79	1.80
MgO	0.21	1.08
Ignition loss	3.20	6.50
	99.03	97.28

These two classes of ore are bedded separately so as to give each class its most efficient treatment. The beds are large, about 5,000 tons each, thus avoiding frequent changes in the character of the ore going to the roasters.

The crushing for the roasting department is done in Schmidt "kominuters", a type of ball mill adapted to moderately fine, dry crushing. The discharge is put through diagonal slotted screens 9-64 by 1-2 inch, giving a product which analyzes as shown in the following table:

SCREEN ANALYSIS OF BALL-MILL PRODUCT.

Size	Old Screens		New Screens	
	Per Cent	Cum. Per Cent	Per Cent	Cum. Per Cent
Over 5-32 in.	6.1	6.1	1.1	1.1
5-32 to 1-8 in.	5.1	11.2	2.4	3.5
1-8 in. to 10 mesh	24.0	35.2	16.6	20.1
10 to 20 mesh	22.2	57.4	26.2	46.3
20 to 30 mesh	8.0	65.4	10.2	56.5
30 to 40 mesh	5.2	70.6	7.6	64.1
40 to 60 mesh	6.4	77.0	9.8	73.9
60 to 80 mesh	1.2	78.2	1.2	75.1
80 to 100 mesh	2.5	80.7	3.0	78.1
100 to 150 mesh	2.2	82.9	3.9	82.0
150 to 200 mesh	4.2	87.1	4.4	86.4
Below 200 mesh	12.9	100.0	13.6	100.0
	100.0	....	100.0	....

The use of these "kominuters" has been criticised and it would seem that machines of the disc crusher type would be more suitable for the work. The repairs on the "kominuters" are quite heavy, and as the screens wear there is a considerable variation in the fineness of the crushed product. In the dry grinding of Cripple Creek ores it is desirable to keep the percentage of very fine material as low as possible in order to decrease the dust loss in the roasters. The fines carry more gold than the coarser material, and, in addition, show a tendency to flow through the roasters without being properly overturned by the rabbles. On the other hand, too much coarse material in the product will result in faulty elimination of the sulphur.

The two classes of ore are handled separately in the roasters. Each roaster handles about 50 per cent more of class A ore than of class B, showing the importance of the amount of lime as affecting the roasting practice. The roasting is performed in 9 furnaces of the Edwards duplex 54 rabble type, supplied by the Stearns-Roger Mfg. Co. The roasting hearths are 115 by 13 feet, and the cooling hearths 44 by 13 feet. There are 27 pairs of rabbles in the roasting hearths and 11 pairs in the coolers. The rabbles inside the furnaces are water-cooled. There are three fire boxes, of the semi-gas producer type, to each roaster. The regulation of the temperature is very important and Brown indicating pyrometers are used for this purpose. Frequent chemical determinations are also made upon the roasted product. The maximum temperature attained in roasting class A ore is about 870°C and in class B about 900°C. The temperature at the discharge point of the roasters is about 485°C, and at the discharge point of the coolers about 278°C. The high lime ore requires the higher temperature because the calcium sulphate produced is thereby rendered less soluble in the mill solutions. The capacity of the roasters, for class A ores, is from 125 to 150 tons per 24 hours, and for class B ores, from 80 to 100 tons per 24 hours. The avoidance of dust losses in the roasting is very important, and the ore is subjected to the minimum amount of agitation throughout the entire operation. The slope of the hearths toward the discharge end is 0.5 in. to the foot. From the cooling hearths the roasted ore falls through a choke feeder upon a reciprocating drag conveyor at the far end of which jets of water are sprayed over the ore. The drag conveyor discharges the product now at a temperature of about 90°C, upon a rubber belt conveyor which carries the ore to the Chilian mills in the cyanide department. The total dust loss is about 0.4 per cent by weight, and the dust contains 20 per cent more gold than the ore.

In the cyanide department both sulphates and soluble sulphides are hindrances to good work. The soluble sulphides consume cyanide and attack zinc. They are active reducing agents and remove oxygen from the solutions. Acid sulphates are also cyanicides if not neutralized quickly. Calcium sulphate is a decided nuisance because of its tendency to separate out as crystals upon the pipes, launders, thickeners, filter mats, clarifying mats, filter frames and cloths, upon the zinc and in the zinc boxes. Most of the soluble calcium sulphate at the Golden Cycle mill is produced in the roasters by the sulphatizing of the carbonate of lime in the original ore. It is found, however, that if the ore is roasted at a temperature somewhat above 870°C, the calcium sulphate produced becomes practically insoluble in the mill solutions. This result is attributed to the more perfect dehydration of the sulphate at the higher temperature. Naturally, greater care must be observed in roasting the class B ore than when working upon class A ore. The low limits of insoluble sulphur and soluble sulphides in the roasted products are as follows: Class A ore—0.10 per cent each; class B ore—0.15 per cent each. At these percentages there is the maximum extraction of values. It is found that if the roasting be carried beyond these limits the residues become richer, although the cyanide treatment is simplified. In addition, the cost of roasting is greater. The following table shows in a striking manner the effect of over-roasting of class B ore, as compared with the results obtained on an average roast of the same ore:

VALUE OF SAND RESIDUES FROM CLASS B ORE.

Screen Mesh	Over-roasted Ore		Average Residue	
	Weight Per Cent	Gold, Ounce	Weight Per Cent	Gold, Ounce
Over 20	..	....	1	0.01
20 to 30	4	0.03	5	0.01
30 to 40	14	0.04	15	0.01
40 to 60	23	0.05	35	0.02
80 to 100	16	0.05	16 (bracketed with next row)	0.02
60 to 80	14	0.04		0.02
100 to 150	11	0.06	12	0.02
150 to 200	10	0.09	13	0.02
Below 200	8	0.12	3	0.04
	100	0.0571	100	0.0185

The roasting of the ores at the Golden Cycle mill is interesting and important and is closely associated with the success of the plant as a whole. It would seem that it might be possible to replace the Edwards roasters with a less expensive installation, but it must be remembered that the present equipment delivers a product low in sulphides and in soluble calcium sulphate, and that it entails a very small dust loss. These are strong points and would weigh heavily in any discussion regarding a possible change.

The roasting practice at the Golden Cycle mill is the subject of an interesting and instructive paper written by A. L. Blomfield and M. J. Trott, manager and assistant superintendent, respectively, of the plant. This paper was read at the Colorado meeting of the A. I. M. E. in September, 1918, and was published in the A. I. M. E. Bulletin for August, 1918. The writer of the present article is indebted to the above paper for much of the data given.

From the roasting department the ore goes to 7 Evans-Waddel Chilian mills for fine grinding. Here again there may be some discussion as to why ball mills are not used. One of the reasons for the present equipment is that the roasted ore does not require finer grinding than 20 mesh for satisfactory extraction, and for this maximum size of product the Chilian mill is very efficient. However, the feed is too fine for the maximum efficiency. The grinding is performed in cyanide solution, as at the Independence mill. The Chilian mills are followed by apron plates upon which are stretched cotton blankets for the purpose of catching the coarse gold in the pulp. This coarse gold is not readily amenable to ordinary amalgamation, because of the thin films of impurities upon the particles. In addition, it dissolves rather slowly in cyanide solution. The blankets are removed at frequent intervals and the gold washed off and treated with mercury in small arrastras and grinding pans. The abrasive action of the arrastras and pans polishes the gold particles and they are absorbed in the mercury. In this way a large percentage of the total gold in the ore is recovered quickly and cheaply. The tailings from the grinding pans go to the cyanide department. The amalgam is retorted in the usual manner.

From the blanket tables the pulp and solution pass to Dorr bowl classifiers where separation into sand and slime is effected. The question as to whether an all-sliming process should be used at this plant has received careful consideration, but has been decided in the negative. While there would be some simplification of the flow sheet by the adoption of a system involving slime treatment only the cost of grinding would be much greater, and there would be no corresponding increase in the metal extraction. It has already been stated that very fine grinding is not necessary on the roasted ore in order to get effective cyanidation. But for the combination process there must be a very complete separation into sand and slime. For this purpose the Golden Cycle company has recently installed a Dorr classifier with a 12 foot bowl and capable of handling the entire tonnage of the mill. This machine is intended to replace 5 smaller classifiers of the same type. So efficient is the classification that the slimes contain but 0.5 per cent of sands and the sands but 4 per cent of slimes. Good classification is so important at this plant because of the necessity of rapid leaching in the percolation tanks and of very thorough agitation and aeration in the slime treatment tanks. The reducing action of the soluble sulphides and the tendency of the calcium sulphate to crystallize are both minimized by performing the operations as rapidly as possible.

There are eleven 50 by 6 foot leaching tanks, having filter bottoms of cocoa matting. The filling of these tanks is done mechanically, and from the periphery toward the center, so as to avoid segregation of coarse and fine material. It is important also to have the sands dewatered before reaching the tanks, for the same reason. When the tanks are filled mill solution containing the proper amount of sodium cyanide is run in. As rapidly as is consistent with good extraction of the values the enriched solution is drawn off and sent to the gold storage tanks in the precipitation department. The weaker solutions are sent to the zinc presses by way of the Crowe vacuum system, and the washings into the mill circuit. After leaching the sands are flushed out by means of fire hose. Seventy per cent of the total tonnage of ore consists of sands and 30 per cent of slimes.

The slime treatment is characterized by very thorough agitation and aeration in order to oxidize soluble sulphides. The overflow from the classifiers goes to a 50 by 9 foot Dorr tray thickener. The spigot product goes to a 30 by 10 foot continuous mechanical-air agitator, and the overflow back to the Chilian mills as battery solutions. From the agitator the pulp and solution go to three 30 by 10 foot secondary Dorr thickeners. The overflow from these secondary thickeners goes to a clarifier and thence to the cold storage tanks. The spigot product is again subjected to agitation in a 37 by 23 foot Dorr continuous agitator, followed by three 30 by 10 foot intermittent mechanical agitators. From the latter the pulp and solution go to two Moore stationary 86 leaf vacuum filters. The filtered rich solution goes to the gold storage tanks and the weaker solutions to the zinc dust presses, or to the mill circuit. There is thus a rather complicated alternation of thickeners and agitators, but it is necessary in order to get the best results. In both the sand tanks and the slime treatment tanks quick change of solution is essential. All of the operations must go forward as rapidly as possible. This, of course, means that at no point in the flow sheet can there be a falling off in efficiency without seriously interfering with the work of the plant as a whole. Insufficient roasting is a fruitful source of trouble, even when it involves but a small proportion of the total tonnage of ore. It means a lower recovery of gold, increased cyanide consumption, and a greater deposition of calcium sulphate. Lime is added to the solutions to maintain the proper amount of alkalinity, although this sometimes can be omitted in the case of the high lime class B ores. Precipitation of the gold from the richer solutions from both the sand and slime treatment tanks is performed in zinc boxes by means of zinc shavings. The weaker solutions are precipitated by means of zinc dust in presses. The Crowe system is used to deoxidize all solutions before precipitation. In the melting room the gold precipitate is treated with sulphuric acid to remove the greater part of the zinc, zinc oxide and lime, and the residue then melted down in graphite crucibles heated by Case oil-fired furnaces. The resulting bullion is shipped to the U. S. Mint at Denver.

The Golden Cycle mill is a good example of a plant in which results are achieved by close attention to details that are sometimes overlooked. In 1917 the plant treated 361,000 tons of ore, of a gross value of $7,332,000, or $20.31 a ton. In 1918 the amount treated was 326,000 tons of about the same average assay.

Resumé

PRESIDENT VICTOR C. ALDERSON.

When the Cripple Creek district is viewed from every angle—sentimental, financial, mining, ore dressing, metallurgical, geological, and scientific—it can properly be ranked as the most interesting gold camp in the world. The imaginative writer could take the bare facts in succession from its condition as a cattle range to its place as a producer of millions of dollars annually and weave a fairy story as entrancing as ever kindled a child's imagination. Its story never gets dull. Since the visit of the authors of this Quarterly to the District, in order to secure the latest information, reports have come that lessees on the Mary McKinney have made a shipment of ore running $2,367.50 a ton; that lessees on the Index mine have uncovered a three foot vein that gives assays up to $800.00 a ton; and that the Vindicator has discovered rich ore on its lowest levels; all this in addition to the "underground jewelry shop" discovered on the Cresson which recently made such a sensation.

The problems of the district have been serious. Where water in the mines was in danger of stopping all work a solution was demanded. By the combined efforts of a great engineer—David W. Brunton— and a great executive—A. E. Carlton—backed by the financial resources of the district, the Roosevelt Drainage Tunnel was built, the district unwatered, costs of mining reduced, and the camp given a new term of life.

In the guidance of exploratory work, in understanding of the ore deposits, and in the geological survey of the district the problems were worthy of the careful study of a great geologist—Waldemar Lindgren. In the treatment of the low grade ores the problems have been complex but have been solved by great metallurgists—Thomas B. Crowe and L. A. Blomfield. All in all, Cripple Creek is a great district; it has had great problems, solved by great men. It has, also, been a great producer of millionaires.

To the pessimist who sees only the past the camp will not retain its position. However, to the intelligent optimist, who judges the future by the past, the camp will not only regain its former prestige but surpass it. The great needs of the camp are many but the following are of the greatest importance:

1. Lower cost of supplies and of operation.
2. More skilled miners who will take leases and open new ground.
3. Development work at the low levels by the larger mining companies.

The first of these depends upon general business conditions. The second and third depend upon local interest and faith. To the impartial, conservative observer, it appears that, during the present world-wide period of re-adjustment, Cripple Creek will not only maintain its commanding position but advance to a position of still greater importance and interest.

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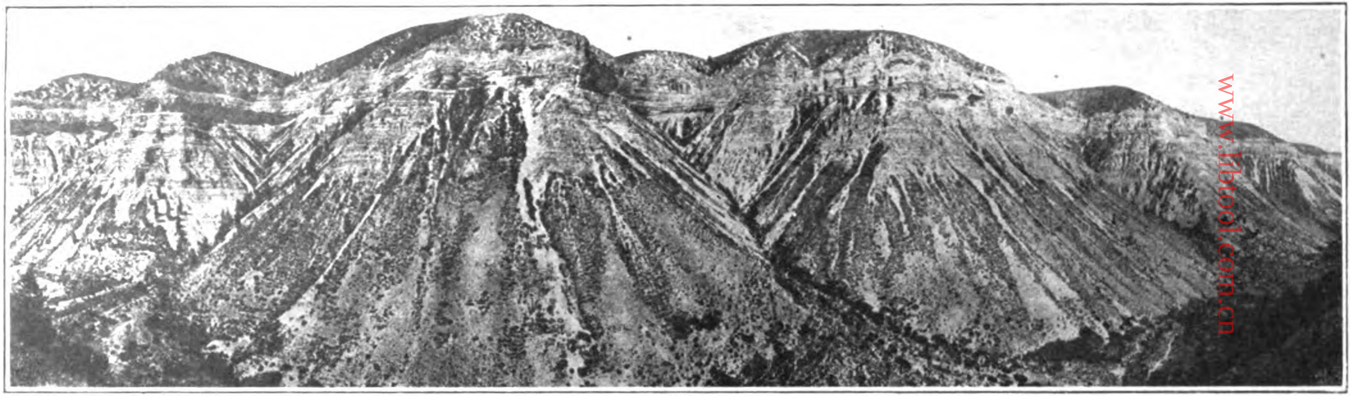
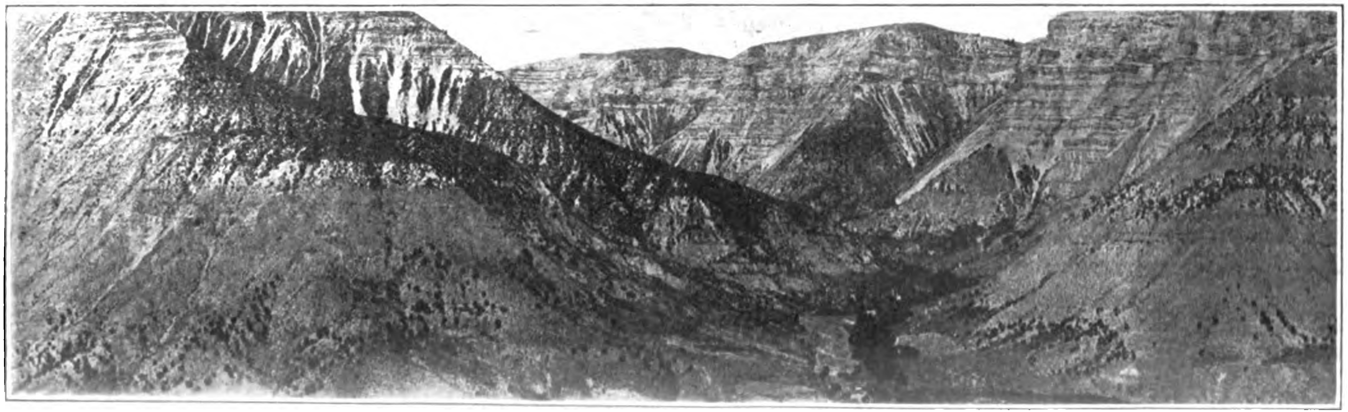


OIL SHALE—Brush Creek, Colorado. Courtesy of J. W. Hess.



QUARTERLY
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The Oil Shale Industry

BY VICTOR C. ALDERSON,
President, Colorado School of Mines.

THE DAWN OF A NEW INDUSTRY Recent years have been filled with stirring and far-reaching events, world wide in their effect, not the least of which has been the birth of a new industry, with a potential supply of raw material that almost defies mathematical computation and staggers the imagination. Can oil wells produce enough petroleum to meet the enormous demand now existing for oil and its products? The answer is doubtful. Will new oil fields be discovered to meet the increased demand in the future? The answer is extremely doubtful. Yet this is the age of oil. Oil we must have. The supply must come from our great deposits of oil shale. If oil is the "king" then oil shale is the "heir apparent."

THE PRESENT CONDITION OF THE PETROLEUM INDUSTRY From 1857 the total of the world production of petroleum was 6,996,674,563 barrels; of this, the United States produced 4,252,644,003 barrels. There are now approximately 250,000 producing oil wells in the United States. The average yield is only four and a half barrels a day. Among the great producers is the Burkburnett pool in Texas that has produced 7,000,000 barrels of oil and the Ranger pool that has produced 12,000,000 barrels. The average output in Wyoming is 40 barrels a day. The low average for the whole country of only four and a half barrels a day is caused by thousands of wells in the older fields that produce less than a quarter of a barrel a day. Of the total number of wells in the United States four fifths do not yield more than a barrel of oil daily.

The United States Bureau of Mines recently made a report to the Secretary of the Treasury on the subject in which it said:

"The United States Geological Survey makes the pessimistic report that our underground reserves are forty per cent exhausted and that we probably are near the peak of domestic production," says the Bureau of Mines report. "The consumption of petroleum is increasing far more rapidly than domestic production. During 1918, 39,000,000 barrels of oil were imported from foreign countries and 27,000,000 barrels were withdrawn from stocks.

"Our future supply of petroleum must be conserved, and it is therefore imperative that the United States make every possible effort to further more efficient conservation of our underground reserves of oil and the more efficient utilization of petroleum and its products, because:

"First—Petroleum has become the fundamental basis of the industrial and military life of the nation in that gasoline has become the motive power for some six million automobiles and trucks, for airplanes, farm tractors, motor boats, etc. Fuel oil has become necessary for our navy, our merchant marine and larger industrial plants. Lubricating oil is essential for machinery of all kinds, and without it not a wheel would turn.

"Second—The potential supplies of crude oil outside of the United States are passing almost entirely into the political and economic control of foreign governments, and the United States is likely to pass the position of dominance into a position of dependence.

"Third—Investigations of the Bureau of Mines, of the Fuel Administration and of other bodies have disclosed that the known oil reserves of the United States are not receiving adequate protection and are being wasted through inefficient methods in production, refining and utilization of the oil."

The report says the Fuel Administration has made an investigation which shows that in 1917 in the exploitation of petroleum and natural gas in the United States the total waste in oil and gas amounted to $2,000,000,000, and continues:

"The need for petroleum reaches every citizen in the United States. There are in service today some 6,000,000 automobiles and trucks using gasoline. The number of automobiles is increasing at the rate of 1,000,000 to 2,000,000 a year. Through pleasure cars, trucks, farm tractors, etc., every family in the United States is virtually interested in gasoline.

"Through lubricating oils every person in the United States has a direct interest. Lubricating oils are one of the three essentials of modern civilization and in equal importance to steel and coal, for without lubricating oils no machinery would be possible.

"The supply of fuel oil is, in the opinion of marine engineers, the strategic point for our merchant marine and in the development of any modern navy.

"For the above reasons it is imperative that the United States take every step possible toward conserving our known reserves of oil. Petroleum and natural gas are not being replaced by nature, and once gone cannot be replaced except from sources involving greater costs."

Many other significant figures could be given but a few will suffice.

	Total number of registered automobiles in the United States	Production of Gasoline
1914............	1,700,000	1,460,037,200 gallons
1918............	6,146,000	3,570,312,963 gallons

Statistics furnished by the United States Geological Survey give the following interesting comparison:

	Amount of Crude Oil in Storage		Amount of Crude Oil Marketed
Dec. 31, 1915....	194,185,000 bbl.	During 1915....	281,104,104 bbl.
Dec. 31, 1916....	179,371,000 bbl.	During 1916....	300,767,158 bbl.
Dec. 31, 1917....	156,168,000 bbl.	During 1917....	335,315,600 bbl.
Dec. 31, 1918....	132,800,000 bbl.	During 1918....	345,896,000 bbl.

Thus, during these four years the amount marketed increased from 281 to 345 million barrels; the reserve supply—that held in storage—decreased from 194 to 132 million barrels. This gives the key to the oil situation. Oil pools are merely reservoirs certain to become exhausted in the course of a few years.

Examining the refining oil we find that from January to September, 1918, the refineries consumed 182,000,000 bbl. During the same period the production was only 170,000,000 bbl. To meet this loss 12,000,000 bbl. had to be drawn from storage, or more than a million barrels a month.

In passing judgment upon the condition of the oil industry as a whole, one must not be blinded by the enormous production of "gushers" nor be made unduly pessimistic over the low average yield of the quarter of a million wells in the United States. A common-sense view seems to be that first, our supply of petroleum from wells is not meeting the country-wide demand and that the limit of production is approaching; second, the supply from wells can be maintained only by the discovery of new extensive pools; thirdly, there is little likelihood that new pools like the Mid-Continental, or California will be discovered because the entire country has already been thoroughly explored; fourthly, that the only great national reservoir that can be absolutely depended upon to supply oil is our deposit of shale. This will be the source of our oil supply for the future. The total world production of oil to date stands at 7 billion barrels of oil with only 6,740,000,000 barrels estimated left in the ground.

NATURE OF OIL SHALE

Oil shale virtually contains no oil as such. It is a consolidated mud or clay deposit from which petroleum is obtained by distillation. In appearance the shale is black, or brownish-black, but on weathered surfaces it is white or gray. It is usually fine-grained, with some lime and occasionally sand. It is tough but, in thin sections, friable. When broken to a fresh surface it may give an odor like petroleum. Thin rich pieces may burn with a sooty flame. E. H. Cunningham-Craig defines it as follows: Oil shale is an argillaceous or shaly deposit from which petroleum may be obtained by distillation but not by trituration or treatment by solvents.

Oil shale must be carefully distinguished from oil sand. In the oil sand the oil is contained in the sand as oil. When the sand is penetrated by a well the oil gushes out or is pumped out. In the oil shale there is no oil as such, but only the uncooked ingredients of oil. When the shale is subjected to destructive distillation, i. e., heated in a closed vessel, or "cooked", shale oil results as a manufactured product.

ORIGIN OF OIL SHALE

Oil shale is one of a long list of natural deposits which result from the deposition of organic matter from plants or animals of a former geologic era—like anthracite, bituminous, and brown coal, peat, petroleum, and asphaltum. Beds of oil shale were laid down in lagoons, or wide expanses of quiet water. They contain a large amount of organic matter—low plant forms of life like algae; also pollen, fish scales, insects, and remains of animal and vegetable life sometimes changed beyond recognition, although 277 species of insects have been recognized.

WORLD-WIDE DISTRIBUTION OF OIL SHALE

Besides the extensive deposit in Colorado, oil shale is found in Utah, Wyoming, Nevada, Montana and California. In Canada it is found in Quebec, New Brunswick, Nova Scotia, and Newfoundland. In Scotland, near Edinburgh and on the Isle of Skye. In France, at Autun and Buxiere les Mines. In South Africa, in the Transvaal, Mozambique, and Natal. Also in New South Wales, New Zealand, Tasmania, Brazil, Italy, Spain, Austria-Hungary, Serbia, and Turkey.

THE OIL SHALE OF SCOTLAND

The oil shale beds of Scotland occur within a small area, twenty miles in diameter, in the counties of West Lothian, Mid Lothian, and Lanarkshire. The center of the district is fourteen miles west of Edinburgh. The shale beds are simply very fine impalpable clay shale, brown to black in color, free from silica, easily cut with a sharp knife, and in form are plane or curly. The beds vary greatly in thickness; it is not uncommon to find a seam pinch out altogether, but another seam, above or below it, increases in thickness and richness as the first deteriorates. Faults, folds, and igneous intrusions are not uncommon. Mining is done entirely through shafts. "Kerogen" is the Scotch term given to the complex organic compounds in the shale which produce petroleum. The richer shales yield from 30 to 40 gallons of oil to the ton of shale. The lower grade shale that yields only from 15 to 18 gallons of oils gives from 60 to 70 pounds of ammonium sulphate. That is, the shale that runs high in oil runs low in ammonium sulphate; the shale that is low in oil is high in ammonium sulphate.

PRESENT VALUE OF THE SCOTCH SHALES

In the earlier days of the industry the shales that were worked produced more crude oil than the shales of today. Notably the Torbanehill material gave from 96 to 130 gallons of crude oil a ton. At the present time the production seldom exceeds 30 gallons a ton, and shale yielding only 15 gallons is successfully treated. The explanation for this lies in the fact that crude oil is not the only product of value that may be obtained. The ammonium sulphate is also valuable. If this is obtained in large quantity, as in the case of shales now being treated, the total result in crude oil, plus ammonium sulphate, may be economically profitable. The following series of products are secured from the Scotch shales:

1. Permanent gases used for fuel under the retorts.
2. Naphtha, gasoline, and motor spirits.
3. Burning or lamp oil.
4. Intermediate oil used for gas-making.
5. Lubricating oil.
6. Solid paraffin.
7. Still grease.
8. Still coke, which contains some oil and is used for gas, smokeless fuel, and carbon for electrical purposes.
9. Liquid fuel used in the refineries.

DESCRIPTION OF THE SCOTCH OIL WORKS

D. R. Steuart in Economic Geology, Vol. 3, 1908, p. 574, describes briefly the equipment as follows: "In a Scotch oil works there are the great benches of shale retorts sometimes more than 60 feet high, with the great stacks of numerous series of 3-inch pipes, 30 or 40 feet high, for air condensers. There is the three-story-high sulphate of ammonia house, with its high column-stills, the acid saturators for the ammonia, vacuum or other evaporator for the sulphate from the recovered sulphuric acid of the refinery, centrifugal driers, storage bins and grinding mills. In the refining departments the stills are small and, on account of the repeated distillations, very numerous; the washers for vitriol and soda are many; there are coolers, refrigerators, filter and hydraulic plate presses for the separation of the heavy oil and solid paraffin; great sweating houses for the paraffin refining; candle works; sulphuric acid plants; acid recovery plant; engineer's, joiner's and plumber's shops—a very large and varied collection of apparatus covering much ground, so that for a comparatively small production there is a very large and expensive plant. A conspicuous feature of oil works is the great hills of spent shale."

As far as our present knowledge extends it is evident that Canada is not so well supplied with oil fields as the United States. For this reason the oil shale industry may make rapid advancement there, since large beds of shale, rich in oil, are known to exist within the Dominion. The Geological Survey and the Bureau of Mines of the Dominion have already given considerable attention, in examinations and reports, to these deposits.

NEW BRUNSWICK SHALES The oil shales of New Brunswick are located in three areas—the Taylorville, Albert mines, and Baltimore. In Taylorville are four beds of shale of good quality; one five feet, one three feet, and two, one foot ten inches thick. In Albert Mines are six beds of the following thickness (the most important in New Brunswick): 6.5 feet; 3.5 feet; 5 feet; 4.5 feet; 6 feet; and one with thin beds of oil shale. In Baltimore are four beds, 4 feet, 5 feet, 7 feet and 6 feet thick, respectively.

NEWFOUNDLAND The oil shales of Newfoundland cover an area of about 750 square miles. The largest deposit lies between the head of White Bay and Deer and Grand Lakes, and varies from 50 to 100 feet in thickness. The dip of the strata is slight and the outcroppings are bold. An analysis of typical shale gave 50 gallons of crude oil and 80 pounds of ammonium sulphate a ton. The Newfoundland shales have great prospective value.

FRANCE Second only to the oil shale industry of Scotland ranks the French, which dates from 1830. After many years of successful operation it suffered from competition with oil wells until the French government in 1890 offered a premium for the production of oil from shale. This bonus, together with the adoption of efficient Scottish methods of treatment, revived the industry. The shales occur at depths from 150 to 300 feet. Five companies are now in operation on the shales of Autun and Buxiere les Mines, where the shales produce 50 gallons of oil a ton.

AUSTRALIA Large outcrops of rich oil shales occur in the gorges of the Blue Mountains, New South Wales. Fossils are found in the lower shale measures. These shales are reported to give 100 gallons of oil and 70 pounds of ammonium sulphate a ton. The government has established a system of bonuses, for the production of oil, which are expected to increase the present annual production from 3,000,000 to more than 20,000,000 gallons. There are two British-Australian companies in the field—the Commonwealth Oil Corporation, capital $6,000,000, operating at Newnes, and the British-Australian Oil Co., capital $1,460,000, operating at Temi in the Liverpool range. From 1865 to 1916, 1,751,367 tons of oil shale have been produced of a total value of $11,606,671.

TRANSVAAL Oil shale is found in two districts—the Ermelo and the Wakkerstroom, fifty miles apart. Although these two deposits may prove to be one continuous bed, yet there is no evidence to that effect at the present time. In each case the shale is associated with a seam of coal. The Ermelo shales have produced from 30 to 34 gallons of crude oil a ton. The Wakkerstroom shale has yielded as much as 90 gallons a ton, but the shale is only 9 inches thick.

BRAZIL Oil shales are exposed at many places on the coast of Brazil. They have been examined by Professor John C. Branner, of Leland Stanford Jr. University, and their composition determined by Sir Boverton Redwood, of London. The richest yielded 44.73 gallons of crude oil and 19.58 gallons of ammoniacal water to the ton. The deposits have not been worked commercially.

The Oil Shales of Colorado

GEOLOGICAL POSITION The oil shales of Colorado belong in the Green River (Eocene) formation. Elsewhere they are found in the Cretaceous, Devonian, and Carboniferous. In recent geologic time this oil shale region of Colorado was an extensive plateau through which the Grand River and its tributaries, Kimball, Conn, and Parachute creeks have cut valleys to a depth of 3,000 or more feet. On either side of the streams are now exposed great beds of shale—even mountains of it.

DEVELOPMENT WORK IN THE OIL SHALES At the present time (October, 1919) we have no exact knowledge of the change or the persistency of oil values with depth, nor the underground difficulties to be met in mining. Up to the present time sampling has been done on weathered outcrops or from shale close to the surface. There is reason to expect that as unaltered shale is reached it will be found to be richer than shale near the surface. Dean E. Winchester reports that one sample taken after the weathered surface was removed gave 32 gallons of oil a ton. A foot and a half was then removed by blasting. A sample then gave 55 gallons a ton. At Elko, Nevada, the shale has been mined for a distance of 200 feet from the outcrop and no decrease has been noticed in the richness of the shale. If these cases are typical we may reasonably expect that deep unchanged oil shale will prove to be richer than shale near the outcrop, and as a result the total content of the oil shale deposits may be much richer than at present estimated.

MINING OIL SHALE The shale beds of Scotland are irregular and lie in synclinal troughs; they pinch out or expand; they have a dip of from 30 to 60 degrees; they are folded or faulted to a great extent and often altered by intrusive volcanic rocks. All mining is through shafts, some of which are very deep. In Colorado, however, the oil shale beds are regular; they are virtually level; the greatest dip noticed is only 10 degrees; only one fault has thus far been noted, and there is little likelihood, to judge from the outcrops and the formation, that many will be found; the level position of the oil shale enables it to be mined by the ordinary methods of room and pillar coal mining. From the standpoint of cheap mining, if comparison is made with Scotland, the advantage is certainly with Colorado.

POSSIBILITIES OF THE SHALE INDUSTRY Inasmuch as the oil shale industry has been in operation in Scotland since 1850—sixty-nine years—and has met and overcome technical, trade, and economic obstacles, it seems a mere matter of common sense for the pioneers of the industry in Colorado first to follow the well known and successful methods of Scotland; to adapt these methods to Colorado conditions, and then to improve them as fast as possible by methods not now known. Besides, the production of crude oil, gas, and ammonium sulphate, other possibilities may open, e. g., the nitrogen may be reclaimed in a form for use in the manufacture of munitions of war; aniline dyes and flotation oils may be obtained; possibly producer gas, a substitute for rubber, and other products may become valuable. The nitrogen content is especially valuable, as each percentage of nitrogen will yield theoretically 93 pounds of ammonium sulphate now worth 7.3 cents a pound. All in all, it should be realized that the oil shale industry presents a long series of interesting technical-chemical problems to be solved by scientifically-trained men. So true is this that the industry can be classed as a combined mining-chemical-manufacturing project.

In some quarters there exists two erroneous ideas, viz., that the distillation of oil from shale is a simple process and that a treatment once devised will apply to all oil shales. To be sure, in a laboratory retort a few pounds of shale can be heated and a small amount of oil produced. So can water be boiled in a tea kettle, but there is as much difference between this puny outfit and the great plants of Scotland as there is between the tea kettle and a great central power plant. Also shales vary to such an extent that each deposit should be tested in a careful, scientific manner, just as large bodies of low grade copper ore are tested and suitable treatment plants erected. As in handling low grade ores, the large profits from oil shale will be made by handling a great tonnage at a low cost to the ton.

DISTRIBUTION OF OIL SHALE DEPOSITS IN COLORADO In northwestern Colorado and northeastern Utah the oil shale deposits underlie an area of approximately 5,500 square miles. In Colorado they occur chiefly in Garfield, Rio Blanco, Mesa, and Moffat counties, and cover 2,500 square miles. The towns of Grand Valley and De Beque, on the line of the Denver & Rio Grande railroad, are the points of entrance.

THE DE BEQUE DISTRICT The exposed shales of the De Beque district lie northeast, north and northwest of the town, on both banks of Roan Creek, its largest tributaries, Conn, Kimball, and Dry Fork creeks, and on all of its smaller tributaries.

THE GRAND VALLEY DISTRICT In the Parachute region of the Grand Valley district is a well defined rich oil shale stratum—twelve to twenty feet thick—that is exposed on both banks of Parachute Creek and all its tributaries almost continuously for a total distance of sixty-nine miles. Many tests show that it will yield an average of at least forty-two gallons of oil to the ton. Assuming that this stratum extends only a mile and a quarter back from the line of exposure—a conservative estimate—the area of this stratum is at least 55,000 acres. This estimate does not include the shale exposed on Battlement Mesa east and southeast of Grand Valley. Using the minimum thickness of twelve feet, allowing 25 per cent of the volume to be left as pillars, and counting only on forty-two gallons to the ton, this deposit would contain 1,012,500,000 barrels of crude oil. A measure of the interest and activity in the oil shale industry can be realized from the fact that since June, 1916, there have been more than 1,500 filings on oil shale land in Garfield County. On December 16, 1916, the United States Government withdrew 45,440 acres of shale land in the Grand Valley district as a source of supply for the use of the United States navy.

LOCATION OF OIL SHALE CLAIMS The statute of 1897 says: "Any person authorized to enter lands under the mining laws of the United States may enter and obtain patent to lands containing petroleum or other mineral oils, and chiefly valuable therefor, under the provisions of the laws relating to placer mineral claims."

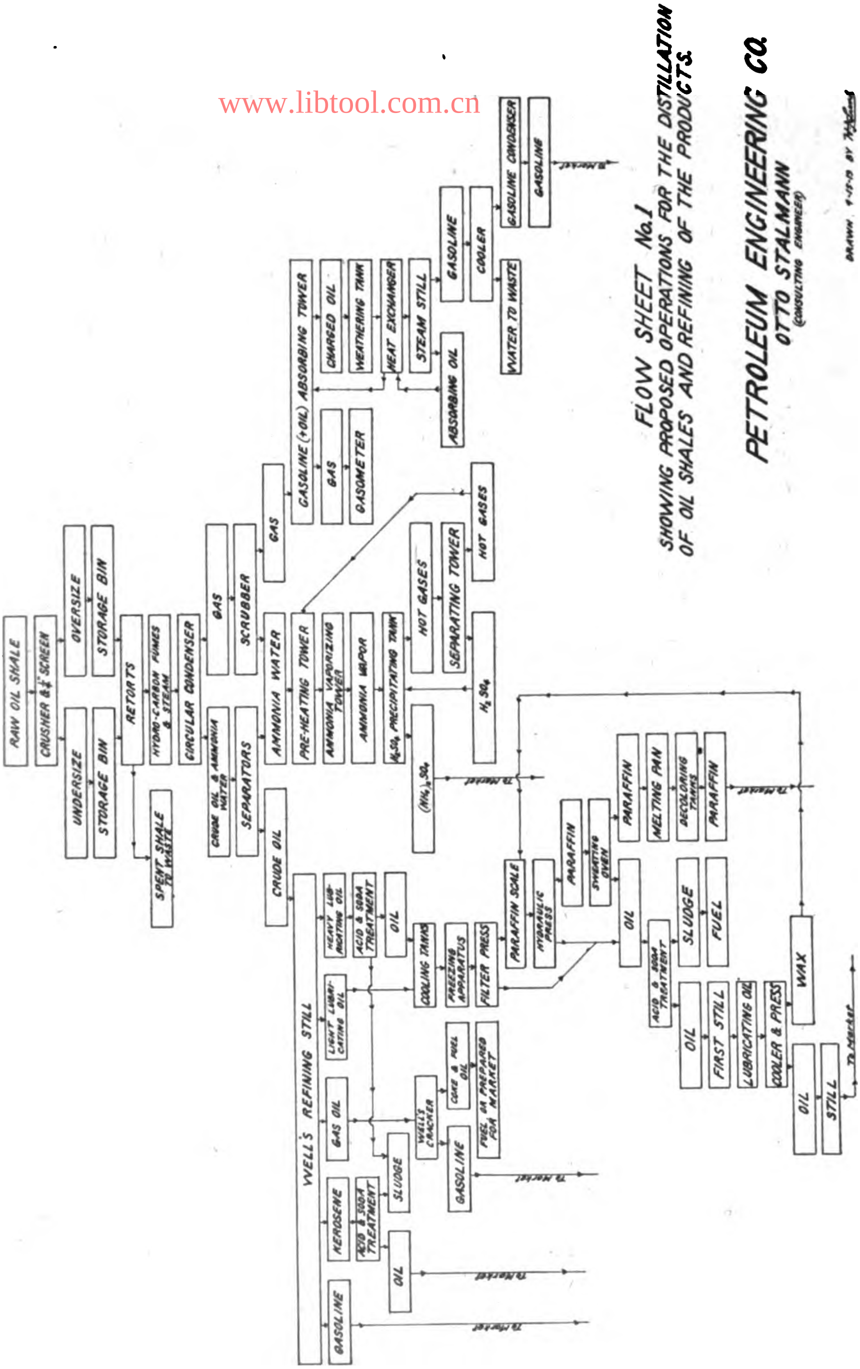
The location of oil lands as placers was general until 1896, when the Secretary of the Interior ruled adversely. Thereupon Congress, in 1897, passed a law re-establishing the former practice. The higher courts as yet have had no opportunity to pass upon the validity of title to oil shale land located under the placer law.

The well known case of Webb vs. The American Asphaltum Co. furnishes the nearest parallel case. In the Circuit Court of Appeals, Eighth District, it was held that asphaltum, when it is in solid form and is found as a vein or lode, should be located as a lode. At the present time no court decision has been rendered which involves specifically the point as to how oil shale lands shall be located; that is, whether as lode or as placer. It would seem, however, that from the peculiar formation of oil shale deposits they should be located as placers. As generally found in Colorado these deposits are virtually horizontal and cannot be said to have apexes within the sense that miners and the Mining Act of 1872 contemplate. Neither can horizontal oil shales, as found in Colorado, be said to be *in place* in the sense that we find deposits of other valuable minerals *in place* when found in lode, vein, or ledge formation. The shale deposits cannot even be said to have a clearly defined hanging wall, such as is contemplated by the statute, since they are not covered by a non-mineral bearing country rock such as the miner is accustomed to find as constituting his overhanging wall, but he finds merely an earthy deposit such as is generally found in the ordinary gold placer.

LEASING OIL SHALE LAND An oil leasing bill of the last congress was killed in the final hours of the session. Another bill is expected to pass the present congress. The general features are likely to be these: the Secreary of the Interior will be given authority to lease an oil shale deposit belonging to the Government and as much of the surface as is needed for operation; leases shall be limited to 5,120 acres and may be indefinite as to length; a royalty of 50 cents an acre must be paid; the Secretary of the Interior may waive the payment of royalty for the first five years; an exchange of land taken under a placer location may be made for leased land to an equal amount; claims valid at time of passage of act may be patented under laws then existent, as an efficient leasing bill will be an encouragement to the industry.

HISTORY OF OIL SHALE The shale oil industry is not new. It has been successfully developed and operated in Scotland for the past fifty years. The first material to be subjected to dry distillation, which furnished the earliest known distillation tar, was described by Boyle in 1661. About this time tar was recovered from the dry distillation of pine in Norway and Sweden. In 1681 a patent was taken out by Becker in England for the recovery of tar and pitch from coal. Becker was also the first to produce coke. The one outstanding achievement in the shale oil indutry is due to James Young. The possibility of extracting oil from bituminous shale had long been known in Scotland, but the small plants which had been erected were of brief existence of little importance. At the suggestion of Lyon Playfair, Young built a refinery for treating petroleum obtained from a spring at Alfreton, in Derbyshire. He produced two kinds of oil, one for lubricating and the other for burning in lamps. Paraffin was also obtained but not utilized to any extent. Within two years the supply began to fail and in 1851 the business ceased. Meanwhile, it had occurred to Young that the oil had been produced by the action of heat upon coal so he attempted to produce an artificial oil by this means. As a result of a long-continued investigation with many varieties of coal he secured a patent in October, 1850, which became the basis of a new industry. "The coals," the patentee says, "which I deem to be best fitted for the purpose are such as are usually called parrot coal, cannel coal, and gas coal, and which are much used in the manufacture of gas for the purpose of illumination." Early in 1850, a material called Boghead coal from Torbane hill was brought to his attention. This he found to be the most promising of any material he had investigated. In 1850, a plant was erected at Bathgate. The salient feature of Young's invention was the distillation of bituminous substances at the lowest possible temperature for the production of volatile compounds. In practice it was found that the best results were obtained at about 800° F.

In the early days of the industry in Scotland, Boghead coal or Torbanehill mineral, as it is sometimes called, was the only material distilled. As the same material was used for the production of illuminating gas, it rose rapidly in price and in 1866 disappeared from the market. Between 1850 and 1860, a number of distilleries and refineries were erected in American towns on the Atlantic coast to treat imported Boghead coal by Young's process. Plants were also erected in Canada to


FLOW SHEET No.1
SHOWING PROPOSED OPERATIONS FOR THE DISTILLATION OF OIL SHALES AND REFINING OF THE PRODUCTS
PETROLEUM ENGINEERING CO.
OTTO STALMANN
(CONSULTING ENGINEER)
RAW OIL SHALE
CRUSHER & SCREEN
OVERSIZE
UNDERSIZE
STORAGE BIN
STORAGE BIN
RETORTS
SPENT SHALE TO WASTE
HYDRO-CARBON FUMES & STEAM
CIRCULAR CONDENSER
GAS
CRUDE OIL & AMMONIA WATER
SCRUBBER
SEPARATORS
GAS
AMMONIA WATER
CRUDE OIL
GASOLINE (+OIL) ABSORBING TOWER
GAS
GASOMETER
CHARGED OIL
WEATHERING TANK
HEAT EXCHANGER
STEAM STILL
ABSORBING OIL
GASOLINE
COOLER
WATER TO WASTE
GASOLINE CONDENSER
GASOLINE
PRE-HEATING TOWER
AMMONIA VAPORIZING TOWER
AMMONIA VAPOR
HOT GASES
SEPARATING TOWER
HOT GASES
H_2SO_4 PRECIPITATING TANK
$(NH_4)_2SO_4$
H_2SO_4
WELL'S REFINING STILL
HEAVY LUBRICATING OIL
ACID & SODA TREATMENT
OIL
LIGHT LUBRICATING OIL
COOLING TANKS
FREEZING APPARATUS
FILTER PRESS
PARAFFIN SCALE
HYDRAULIC PRESS
PARAFFIN
SWEATING OVEN
OIL
PARAFFIN
MELTING PAN
DECOLORING TANKS
PARAFFIN
ACID & SODA TREATMENT
SLUDGE
FUEL
OIL
FIRST STILL
LUBRICATING OIL
COOLER & PRESS
WAX
OIL
STILL
GAS OIL
WELL'S CRACKER
COKE & FUEL OIL
FUEL OR PREPARED FOR MARKET
GASOLINE
SLUDGE
KEROSENE
ACID & SODA TREATMENT
OIL
GASOLINE
TO MARKET

use the Albertite oil shales obtained there. However, the discovery from 1859 onward of abundant supplies of petroleum from wells in the United States forced the dry distillation plants to close. These plants were easily remodeled for the refining of petroleum and were of untold assistance in putting the new American industry on a firm basis. D. R. Steuart says in Shale Oil Industry in Scotland, "James Young may claim to be the father, not only of the Scottish shale oil industry, but also of the great American petroleum industry." When the supply of Boghead coal ceased another material, well adapted for distillation, was found in the bituminous shales found in the Scottish carboniferous formation. In 1859, a seam was experimentally opened at Broxburn and by 1864 several plants were in operation. But although the Boghead coal produced 120 to 130 gallons of oil a ton, the shales yielded only about 35 gallons and at the present time produce even less. In 1850, a plant was erected at Bathgate. In 1861, a second, the Crofthead Oil Works, was in operation. In 1857, when Young's patent expired, thirty-eight new works were established. In 1860 there were six; in 1870, ninety; in 1880, twenty-six; in 1890, fourteen; in 1900, nine. At the present time four companies are refining shale: Young's Paraffin, Light and Mineral Co., Ltd; The Oakbank Oil Co., Ltd; The Broxburn Oil Co., Ltd; and The Pumpherston Oil Co., Ltd. There are three other companies which produce only oil and ammonium sulphate.

GENERAL PRINCIPLES OF MINING SHALE

In mining oil shale, steam shovel methods may be eliminated for the present. Beds of shale amenable to such treatment are far removed from railroads or are on the top of high cliffs. To reach these beds expensive roads would have to be constructed and the first cost of installation would be excessive. In the next place the longwall system of coal mining can be eliminated because under that method the roof is allowed to cave in after mining and this would destroy any beds of shale lying above the one being mined. The room-and-pillar method of coal mining will probably be adopted. In this method of mining, adits are cut into the beds of coal; at intervals cross cuts are made at right angles to the adits, and from these so-called rooms are turned off. Pillars of a size necessary to support the roof are left along the adits, the cross cuts, and the rooms. A large percentage of shale must be left, but this is inconsequential on account of the great extent of the deposits. It goes without saying that to open an oil shale deposit properly, a definite plan of development must be outlined, mechanical ventilation supplied, provision made for rapid and economical haulage, and the numerous appliances provided for handling a very large tonnage in an efficient and economical way. The open cut method may be used in some favorable localities.

VALUE OF OIL SHALE LAND

At the present time virtually all available shale deposits on Government land have been filed upon as "placer". They are generally taken up in "association" claims, i. e., in eight twenty-acre contiguous tracts by eight locators. Each locator has a one-eighth undivided interest in the 160 acres. Annual assessment work to the extent of $100 must be done on the tract to hold the title. The intrinsic value of a particular tract may be much or little. If it is situated far from a railroad, beyond even a wagon road, and without water, it is virtually without present market value. If it is accessible, near to transportation, with an available water supply, with natural benches for retorts and ample dumping ground, and the rich shale beds are thick and easy to get at, then the land may have a present value of from $25.00 to $50.00 an acre and a prospective value in the hundreds of dollars an acre.

THE HEAT VALUE OF GAS PRODUCED

One ton of shale will produce on the average of 2,500 cubic feet of gas of a calorific value of 507 B. t. u. Five hundred and seven by 2,500 gives 1,267,500 B. t. u. as the calorific value of the gas produced from one ton of shale. Colorado coals give an average of about 10,800 B. t. u.; 2,000 by 10,800 gives 21,600,000 B. t. u. to the ton of coal, or approximately 17 times that of the B. t. u. in a ton of shale. In practice coal is only about 60 per cent efficient, but gas is 80 per cent efficient; hence the heat value of the coal is reduced to 13 times the heat value of the gas from a ton of shale. In other words, for each 13 tons of shale mined sufficient gas would be produced to do the work of a ton of coal. Thus, in a 400-ton plant enough gas would be produced daily to be equivalent to more than 30 tons of coal.

AMOUNT OF SHALE AVAILABLE IN COLORADO

To one fond of figuring the following will prove interesting. An acre contains 43,560 square feet. A seam of oil shale 10 feet thick would contain 435,600 cubic feet of shale. Eighteen cubic feet of shale weigh one ton. Hence there are 24,200 tons of shale in one acre of a seam 10 feet thick. In a square mile there are 640 acres and therefore 15,488,000 tons of shale. There are 2,500 square miles of shale in Colorado or 38,720,000,000 tons. Assume that only one-half is available and there remains 19,360,000,000 tons of available shale. This is figured for one ten-foot seam only. A conservative estimate is 30 feet of workable shale or a total of 58,080,000,000 tons of available shale. A fair average production is a barrel of oil to the ton of shale or 58,080,000,000 barrels of oil available. If 100 plants were in operation, each treating 2,000 tons daily, they would have a daily production of 200,000 barrels. To treat this amount of shale would require 290,400 days or 800 years, approximately. These figures apply only to Colorado; they omit shale deposits elsewhere, and are given only to make vivid and emphatic the statement that there are mountains of shale in Colorado.

OIL SHALE ACTIVITY AND DEVELOPMENT

In five states there is activity in the development of the industry; in California, where rich beds are found; at Dillon, Montana, a retorting plant is being constructed. At Elko, Nevada, two plants have been erected; one financed by the Southern Pacific Company and erected under the guidance of the United States Bureau of IMnes, similar to the Pumpherston Plant in Scotland; the other, using the Catlin Process, has completed a successful run and has produced five thousand gallons of shale oil; at Watson, Utah, a plant is under construction to use the Wallace Process.

COLORADO

The Grand Valley Oil and Shale Company, in conjunction with the Consumers Oil and Shale Company, of Chicago and Kansas City, has begun the erection of a 100-ton distillation plant at its property in Sharkey Gulch, six miles from the city of Grand Valley. The property of this company is particularly well placed for successful operation. The allied interests in the Grand Valley district are contemplating the erection of a community refining plant to serve the interests of the shale oil producers. The Colorado Carbon Company has 2,260 acres on Kimball Creek, twenty-seven miles from De Beque. The company work has been mostly of a development nature by means of a 175-foot cut with eleven benches. The company expects to sell their product to the chemical, paint, varnish, and roofing trade. The Oil Shale Mining Company has 960 acres in Dry Creek, twenty miles northwest from De Beque. This company erected the first distillation plant of the Henderson (Scotch) type in the United States. The first demonstration run was made in July, 1917. The company has a

2,000-foot tram and equipment for mining on the ground. The Mount Logan Oil Shale Mining and Refining Company has 1,180 acres on Mount Logan, four miles from De Beque. They have on the ground three twenty-ton retort units with full equipment. The American Shale Refining Company has 12,000 acres on both sides of Conn Creek, twelve miles from De Beque. The company is erecting a 150-ton retort. The cost of this retort was $40,000.00; succeeding retorts will probably cost $15,000.00 each. They will be placed 200 feet above the creek level to give ample dumping ground. The process of distillation and refining has been worked out by the company's chemist and has engaged his time for the past two years. The material for a 3,000-foot tram is now on the ground. The capacity of the tram is 900 tons a day—sufficient to supply shale to six 150-ton retorts. The shale cliffs at the camp rise to a height of 2,500 feet. In these cliffs are the outcropping of five well defined oil strata, but only the two richest will be worked at present. From the camp the outcroppings of the rich shale can be seen at seven different exposures. The first and richest is 200 feet below the summit of the cliff. This seam is sixty feet thick and is expected, from extensive tests made by the company, to yield a minimum of sixty gallons of crude oil to the ton. Both strata are horizontal, lying in a great knob, or outlier, so that their extent can easily be determined. The first stratum, as a whole, is estimated by the company to contain 9,000,000 barrels of crude oil and 9,000 tons of ammonium sulphate; the second has 10,000,000 barrels of crude oil and 10,000 tons of ammonium sulphate. The company has expended to March 1, 1918, $83,101.00 in the development and equipment of its property. The Imperial Oil and Shale Refining Company has 1,200 acres on Brush Creek, 22 miles from De Beque. The company is erecting a 100-ton plant on the property, designed according to plans worked out in a 50-ton experimental plant at York, Pennsylvania. The Colorado Oil Shale and Refining Company is erecting a plant of the Scotch type on its property on Kimball Creek. The Overland Oil and Refining Company is erecting a 50-ton plant on its ground.

Governor Oliver H. Shoup appointed a commission consisting of Commissioner of Mines, Horace F. Lunt; Coal Mine Inspector, James Dalrymple; and Oil Inspector, James Duce, to report on the oil shale industry in Colorado. In their report, they make the following observations on the mining of oil shale:

MINING REGULATIONS

The attention of all shale mine owners in Colorado is called to the fact that, under the existing laws a shale mine, like all mines and quarries, except coal mines, comes under the jurisdiction of the Bureau of Mines. Also a shale retorting plant is a metallurgical plant and is under the same jurisdiction. It is the duty of the Commissioner of Mines to make such rules and regulations as are necessary, in addition to the statutes, to reduce the hazards of mining and metallurgical operations as far as circumstances permit and to safeguard in every possible way the lives and health of the miners and other workers. The mine inspectors are to see that the laws, rules, and regulations are observed and to make such recommendations as may be necessary to carry out the spirit of the law. Any person or corporation starting operations is required by law to notify the Bureau of Mines so that the inspectors may not overlook any operating properties. At this time it appears probable that the first shale mining on a commercial scale will be underground, using the same methods as in mining coal. Consequently the same hazards will be encountered and the same precautions must be observed as in coal mining. Open-cut mining, or quarrying, must be conducted under the same regulations as are observed in other quarries. In underground shale mines there is a possibility that inflammable gas will be encountered. There does not appear to be enough gas to be dangerous in the shale itself. There is, however, a considerable amount of inflammable gas in the underlying strata as shown by numerous gas wells at De Beque and elsewhere. It is quite possible that this gas will find its way into the shale through cracks or minute fissures in the underlying rocks. If, in the course of mining, one of these fissures is tapped, the gas, being under pressure, will escape into the mine, form an explosive mixture with the air, and, if it comes in contact with an open flame or spark, an explosion will result. To guard against this it will be necessary, after shots are fired, to have the mine inspected by a qualified fire boss before the other employees are allowed to enter it.

Another source of danger, and one that is certain to be present, is the dust. Mining operations of any sort are conducive to the formation of large quantities of fine dust which collects on the floors and irregularities of the walls of the workings. Shale dust is highly inflammable and like coal dust, flour dust, or the dust of any other combustible substances, will, under certain conditions, form a dangerously explosive mixture with air. The inflammability of shale dust may be shown by letting a hand full of it trickle through a hot flame. The particles will ignite and give the effect of a miniature Roman candle. This explosive mixture may be ignited by the open flame of a miner's lamp or by the blasts of the explosives used to break down the shale. Coal dust is rendered innocuous by humidity which renders it plastic and prevents its being held in suspension in the mine atmosphere. The necessary moisture is supplied either by the direct use of water, applied with a sprinkler, or by steam. In the latter case, in cold weather, the steam is used to raise the cold air entering the mine to mine temperature by means of radiators, and is then turned into the air to give it the desired humidity. Where it is not practicable to use steam or water, coal dust is mixed with stone or adobe dust so that there is at least 65 per cent of the latter present in the mine dust, under which conditions it will not form explosive mixtures with the air. It seems probable that the latter method will have to be used in shale mining as indications are that shale dust does not easily combine with water. It will require larger quantities of explosive to break the shale than are used in coal mining and the blasting will raise its temperature materially. It is very probable that the heat generated in blasting will be sufficient to cause a slight distillation of the lighter and more dangerous inflammable gases from the hydrocarbons in the shale. To remove such gases, as well as the smoke and gases from the blasting, will require an adequate and reliable supply of air, properly conducted to the working faces. With the above described conditions to be met, it will be necessary in order to secure reasonable safety, to have all blasting done by a properly qualified shot firer after the other employees have left the mine, to use only permissible explosives, to use only electric lamps underground, and to have a mine foreman who holds a first class certificate from the Coal Mining Department. Many of the other coal mining laws are applicable to shale mining and must be observed by the operators of oil shale mines, as well as the general laws relating to all classes of mining. Copies of the Federal and State Mining Laws and of the Colorado Coal Mining Laws may be obtained from the State Bureau of Mines, Denver, for 50 cents and 10 cents respectively. All of the laws and regulations are intended to help the operators in making their properties safe and the Bureau of Mines is always ready and willing to assist operators in any possible way.

The Composition of Oil Shale and Shale Oil

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EXPLANATORY The object of this review is to give a general knowledge of the composition of oil shale and its products, and to show the variation in the composition of the oil shales of Colorado, Utah, Wyoming, and Nevada, in order that it may serve as a basis for comparison in rating the value of any individual sample. Data from all available sources have been investigated and although they show the composition of the oil shale in only about fifty localities in each state, yet they are of considerable value in estimating the composition of the same strata in other localities where the shale has not yet been reached, because the oil in the shale seems fixed and not migratory like petroleum. Differences in laboratory methods of distillation and in the form of apparatus used cause the analyses of oil shales to vary more than any other substance analyzed by the chemist. Until some standard method and type of apparatus is generally adopted by analysts, the results of their analyses must not be interpreted too rigidly. Allowance must also be made for the fact that the plant distillation must necessarily vary from that done with small retorts in the laboratory.

OIL SHALE The following figures are based on the results of one hundred and thirty-two analyses published by the United States Geological Survey, forty-two analyses made in the laboratories of the Colorado School of Mines, and thirty-one analyses from other sources. Fifty-four of the analyses are on Colorado shales, fifty-two on Utah shales, forty-five on Wyoming shales, and fifty-four on Nevada shales.

No. of Analyses	Constituent	Unit	Minimum	Average	Maximum
205	Shale Oil	Gal. per ton	.3	38.0	90.0
205	Shale Oil	Spec. gravity	.832	.890	.950
163	Ammonium Sulphate	lb. per ton	.4	9.4	20.0
64	Gas	Cu. ft. per ton	400.	3800.	5600.
26	Water	Gal. per ton	2.	4.8	8.5
26	Spent Shale	lb. per ton	900.	1200.	1800.
26	Sulphur	Per cent	.25	.80	5.20
16	Heating Value	B. t. u.	1000.	4500.	8000.
6	Carbon	Per cent	.83	22.5	37.2

Shale distillations with steam yield a few more gallons of oil a ton than dry distillations and the specific gravity of the oil is between .03 and .04 greater. Steam distillations also increase the quantity of ammonium sulphate between two and three times the value obtained by the dry distillation. The values given in the table above were obtained by dry distillation. In the laboratory distillations the yield of gas is almost doubled if the retort is surrounded by magnesia insulation and the final temperature is thus increased a few hundred degrees.

SHALE OIL Shale oils vary considerably in color, specific gravity, and viscosity, and in their content of sulphur, asphalt, and paraffin. They invariably contain a larger percentage of unsaturated hydrocarbons than petroleum. This is quite a disadvantage in their utilization for gasoline, but improvement in motors and methods of refining may largely overcome this handicap. Experiments in cracking the heavier distillates from shale oil show that it is possible in this way to increase the yield of gasoline. The following summary is made from data obtained by analysis and distillation of twenty-two different samples of crude shale oil.

	Specific Gravity	Minimum	Aver-age	Maximum
Initial boiling point............		50° C	65° C	80° C
Gasoline, to 150° C............	.750– .850	5%	11.7%	18%
Kerosene, to 300° C............	.820– .900	25%	38%	52%
Heavy oil, residue.............	.900–1.02	30%	45%	63%
Unsaturated hydrocarbons in kerosene....		50%	63%	75%
Unsaturated hydrocarbons in crude shale oil		70%	80%	90%
Asphalt in crude shale oil.....		.35%	2.5%	4.5%
Paraffin in crude shale oil.....		1.00%	5.0%	9.5%
Sulphur in crude shale oil.....		.3%	.75%	1.5%
Nitrogen in crude shale oil....		.75%	1.2%	2.2%

The Production of Shale Oil

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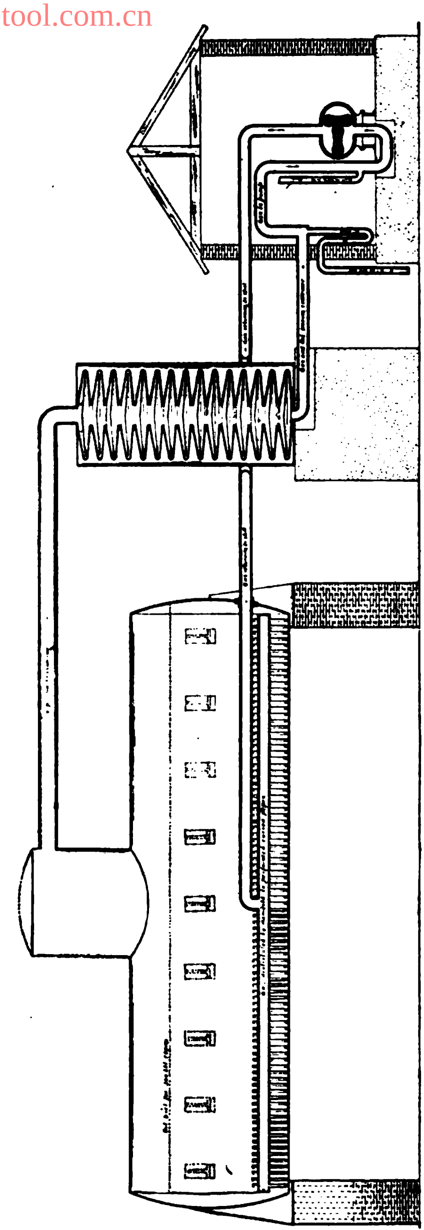
DISTILLATION To obtain an insight into the nature and properties of shale oil, the manner of its production should first be studied. At the outset, it must be remembered that oil shale, the raw material, contains no oil as such, but that the oil is obtained through the dry distillation of the bitumen in the shale. There are here introduced two words that require definition—distillation and bitumen. It is unfortunate that a word like bitumen, used so often, has no precise definition. It is defined in Webster as follows: "Orig., mineral pitch, or asphalt. By extension, any of a number of inflammable mineral substances consisting mainly of hydrocarbons, and including the hard, solid, brittle varieties called asphalt, the semi-solid maltha and mineral tars, the oily petroleum, and even light volatile naphthas." Scheithauer states that the most comprehensive definition of bitumen is, "The substances which furnish tar when subjected to dry distillation." Distillation is a generic term for a class of chemical operations, which are similar in that the substance operated upon is heated in a closed vessel, usually known as the "retort" or "still", and thereby wholly or partially converted into vapor. This vapor is then condensed by the application of cold in another apparatus—condenser—connected with the vessel, and allowed to collect in a third portion of the apparatus, called the "receiver". Distillations may be divided into two classes: first, those which are, and those which are not accompanied by chemical changes. The word "distillation" in a narrower sense, is generally understood to apply to the second class only. The first might be called destructive distillation" if it were not customary to reserve this term for the particular case in which the substance operated on consists of vegetable or animal matter which is being decomposed by the application of heat alone, i. e., without the aid of reagents. An infinite variety of products is invariably formed, which, however, always readily divide into three: first, a non-volatile residue consisting of mineral matter and elementary carbon; second, a part condensible at ordinary temperatures which always readily separates into two distinct layers, viz., (a) an aqueous portion (ammonia liquor) and (b) a semi-fluid, tarry or resinous portion (oil); and (c) a gaseous portion. The ammonia liquor product is the one of all the four products, of which the qualitative composition is most directly dependent upon the nature of the material distilled. In the case of wood it has an acid reaction, from the presence in it of acetic acid. In the case of coal,



Cross Section of a Single Still—Wells Oil Refining Process.

it is alkaline, from ammonia present as a carbonate, sulphide, sulphocyanide, and in other forms. The oil or tar is a complex mixture of carbon compounds, all combustible, but, although all directly derived from a vapor, not by any means all of them volatile. The quantity and quality of the oil naturally depend on the kind of material used, but more on the mode in which the distillation is conducted. Thus, for instance, a coal tar produced at a low temperature contains a considerable percentage of paraffins. If, on the other hand, the distillation is conducted at a high temperature, the paraffins are almost entirely absent, but the proportion of benzols increases considerably.

In the course of his classical investigation on the tar produced in the dry distillation of wood, Reichenbach, in 1830, discovered in it, among other things, a colorless, wax-like solid which he called paraffin because he found it to be endowed with an extraordinary indifference towards all reagents. A few years later he isolated from the same material a liquid oil chemically similar to paraffin, which he called eupion (very fat). For many years both these bodies were known only as chemical curiosities. This was natural enough as far as paraffin was concerned, but it is rather singular that it took so long before it was realized that eupion, or something very much like it, forms the body of petroleum which had been known, ever since the time of Herodotus at least, to well up abundantly from the earth in certain places. Though extensively known it was used only as an external medicinal agent, until James Young conceived the idea of working a comparatively scanty oil spring in Derbyshire, and subsequently found that an oil similar to petroleum is obtained by the dry distillation of cannel coal and similar materials at low temperatures. Generally speaking, a hydrocarbon is the more volatile the less the number of carbon atoms and the greater the number of hydrogen atoms in the molecule. All hydrocarbons are similar in this—they are practically insoluble, in general, in alcohol and ether. They are all combustible and the more readily volatile ones are inflammable.

RETORTS In obtaining oil from bituminous materials, the main object is to prevent the decomposition from proceeding further than is necessary to furnish oil as the principal product and to prevent the oil so formed from decomposition. The most important point is the heating of the retorts. The proper temperature for any given form of retort should be determined. If the temperature be too high, the oil vapors will be decomposed, a greater yield of gas will be obtained, and some of the solid hydrocarbons will be converted into volatile substances rich in aromatic compounds like benzol and its homologues, naphthalene and others. The gases will contain free hydrogen and light hydrocarbons. On the other hand, if the temperature be too low, the bitumen is not decomposed but is carried over with the vapors. In this case, the liquid and solid products are free from aromatic hydrocarbons and consist of hydrocarbons of the fatty series—the higher homologues of methane and ethane—while the gases consist of heavy hydrocarbons, like ethylene and acetylene. The residue is richer in carbon. Next in importance is the manner in which the heat is applied. It is imperative that all of the raw material be exposed to a heat which is uniform or constant at the different stages of the operation. Retorts should be so constructed that the material is heated gently at first and the temperature raised gradually until finally all the bitumen has been decomposed and converted into oil. At the beginning of the industry in Scotland, horizontal retorts were used, but were soon supplanted by the vertical type. In form the horizontal retorts were of oval, or rectangular shape made of cast iron; at one end was a door and at the other a pipe for the removal of vapor to the condenser plant. The material was charged and discharged through the door, so that the operation of the retort was intermittent. To secure a continuously working retort, the vertical type was introduced. These were narrow, oval, or circular cast iron pipes, surrounded by brickwork. They were charged from a hopper at the top and discharged at the bottom through a trough filled with water which acted as a seal. The vapors escaped through the pipe on the side of the retort near the top. These retorts had the advantage over the horizontal retorts of continuous working and a greater yield of oil. Coal fires were used for heating. Their life was, however, short—six to nine months—on account of corrosion. In these early retorts, decomposition was effected at the expense of the paraffin content with the result of an oil low in that substance. To produce an oil which would be rich in paraffin, Young conducted exhaustive experiments which resulted, in the late sixties, in a retort of increased diameter. In this type the retort was jacketed and the vapors were taken off at the bottom. To effect a more economical working and to obtain a lower distillation temperature, Young later began to use the spent shale instead of coal as a source of heat. A retort was devised by which he proved that the spent shale could furnish enough heat for distillation, but it was too delicate for operation by workmen with hundreds of retorts to look after. In 1873, a retort was constructed by N. M. Henderson. A set of these retorts was installed in the Oakbank works in 1874 and did good work for twelve years, when they were replaced by an improved type. They were also used at Broxburn and contributed greatly to the success of the Broxburn Oil Co. The retorts of Young and Henderson, in which shale was burnt, were able to work at a lower distillation temperature and the oil produced was of better quality and richer in paraffin. The working costs were also reduced considerably. Until 1880, the yield of oil was thought to be the most important feature in the process of distillation, and the recovery of ammonia a side issue. At this time Young and Beilby began to investigate the possibility of increasing the yield of ammonia. A retort was constructed with an upper section of cast iron in which the shale was acted upon by a gentle heat for the production of oil, and a lower section of fire brick where the temperature was higher and where steam was introduced. From this retort an excellent oil was produced and the yield of ammonia and gas was increased. The disadvantages were that it required very close attention and its liability to choke if the temperatures became so high as to fuse the charge in the lower portion. To avoid these difficulties, Young constructed a retort known as the Pentland, or Young and Beilby type. Like the earlier Beilby retort this was one of fire brick. There were still occasional interruptions on account of the choking of the discharge passage. This was corrected in an improved retort known as the Henderson. The shape was copied from the Pentland; the diameter was increased; the upper constructed of iron, and the lower of fire brick. The joint between the two was very carefully made. The retort was 27.5 feet high. The temperature in the upper zone was maintained at about 750° F (400° C) and in the lower zone, 1300° F (700° C). The shale was kept in continuous motion by a toothed roller at the bottom of the retort. This prevented caking and the obstruction of the retort. The roller also discharged the spent shale into an iron box from which it was run into cars. The retort was easy to operate and required very little attention. Fresh shale entered the retort in proportion as spent shale was discharged. The yield of ammonia was greater than that from other retorts and the oil was of a good grade.

CONDENSERS The dimensions of the condenser and rate of water flow depend on the temperature of the vapor, on the speed at which the vapor is driven over, on the latent heat of the vapor, and on the specific heat of the distillate. Obviously a condenser under all circumstances is the more efficient the greater its surface and the thinner its body. It is also obvious that the most suitable material for a condenser tube is that which conducts heat best. The vapors are drawn out of the retorts by exhaust fans and led to the condensing plant. The condenser consists of a system of cast iron tubes. In the large plants the diameter of the tubes is two feet to start with and decreases to smaller sizes. In other plants, smaller diameters, usually about four inches, are used. The size depends upon the number of retorts. Air is used as a cooling medium.

SHALE OIL

According to Scheithauer, distillation oils consist of liquid and solid hydrocarbons of the fatty series associated with small quantities of aromatic, acid, and basic (nitrogenous) substances. Oxygen compounds (alcohols and esters), sulphur compounds, and aldehydes have also been detected in the oils. The hydrocarbons are both saturated and unsaturated. Small amounts of napthenes are also present. The oil produced by distillation at a low temperature will not contain many of the aromatic compounds. On the other hand, if the temperature be too high, decomposition of the hydrocarbons is induced and results in the formation of the aromatic compounds, notably benzol. Naphthalene, phenol, and cresols are usually present together with pyridin and quinolin bases. Sulphur compounds, which sometimes give a garlic-like odor to shale oil, are also present. The shale oil produced in Scotland is brownish-red in color, with a dark green fluorescence. Its specific gravity is from 0.860 to 0.900, and in some cases slightly more than the latter figure. The melting point lies between 20° and 30° C. The constituents boil at 80° to 400° C.

AMMONIA LIQUOR

Ammonia liquor, which was formerly regarded as a nuisance, has meant, in many cases, the difference between success and failure in the Scottish treatment plants. Until 1865, the ammonia liquor which forms a large portion of the total distillate, was thrown away. Robert Bell, of Broxburn, is given credit for being the first to treat the water for the production of ammonium sulphate. Of the Scottish shales, those which produced small amounts of oil were generally those which produced the largest yield of ammonium sulphate. From preliminary examination of the shales of Colorado and other western states. the yield of ammonium sulphate from these sources is independent of the yield of oil. In producing ammonium sulphate from the liquor, the procedure is similar to that followed in gas works. The methods and apparatus devised by Beilby and Henderson are the most satisfactory. In the tower still of Beilby, the ammonia is expelled by raising the liquor to the boiling point by means of direct steam. The Henderson still effects the same purpose, but with a smaller amount of steam. The ammonical vapors are then conducted into what is known as the cracker box, which is a vessel containing sulphuric acid. As the absorption is usually not complete in the first box, the vapors are passed over into a second. The acid used in the first box is usually waste, recovered from different steps in the refining of the oil. The second box contains acid of 1.4 specific gravity, which insures complete conversion. The first crystals of ammonium sulphate are large and may be dried by spreading in a suitable room; the smaller crystals are dried by means of centrifugal machines. The salt obtained is pure enough to be used as a fertilizer.

GAS

Gas results from the uncondensed portions of the vapors. Its composition varies with the nature of the material retorted, the design of the retort, the temperature of distillation, and the efficiency and nature of condensers. An idea of its nature may be had from the following analysis, as given in the "Journ. Soc Ind.," 1897, p. 983:

Carbon dioxide	22.08 per cent
Oxygen	1.18 per cent
Heavy Hydrocarbons	1.38 per cent
Carbon Monoxide	9.77 per cent
Methane	3.70 per cent
Hydrogen	55.56 per cent
Nitrogen	6.33 per cent
	100.00 per cent

The high proportion of hydrogen must be attributed to the action of steam upon the carbon of the spent shale. A large proportion of nitrogen indicates leaks of air admitted into the system. To obtain a maximum of heating value, the air admitted should be kept as little as possible. The greater the amount of nitrogen the lower will be the heating value. As the gas produced is used for the partial heating of the retorts, it is necessary to keep its heating value at the maximum point. The hydrocarbon vapors may be largely recovered from the gas by either of two methods: a. Absorption by scrubbing with oils; b. Compression accompanied by cooling.

ECONOMIC CONSIDERATIONS

For the past three years, J. B. Jones, of the Petroleum Engineering Company, Kansas City, Mo. and Tulsa, Oklahoma, has been investigating the deposits of oil shale throughout the United States, to determine if possible the actual conditions of mining and producing oils from shales and whether the industry could be self-supporting and profitable, and could at the present time successfully compete with petroleum oils produced from wells. By request, he contributes the following: To get at the actual facts and to determine as closely as possible the costs of mining, reducing the shales, or producing crude oils, and then into what quantity and quality of manufactured products they can be converted and at what costs, and the value of the resulting products, have been the objects sought in the present tests and investigations. In determining these facts, many elements must be considered, the same as the many different conditions existing in oil fields. The cost of producing crude oil from wells varies in nearly every well and positively so in each individual field, according to its location, transportation facilities, water supply, fuel supply, machine shops, the depth, thickness of sands, saturation or porosity of sands, and many other points which must be considered to determine the cost per barrel of crude oil. It is well, therefore, to consider at the outset, that the location and workability of the shale deposit is of first and vital importance; its accessibility and nearness to transportation and whether it is a proper distance from an open market for oils. The water supply is vital, also the thickness and trend of the shale beds, whether open and exposed for cheap mining or quarrying, or if covered with deep over-burden or dipping steeply beneath the surface so as to increase the cost of operations as mining progresses. Therefore shale oil production becomes primarily a mining industry and a manufacturing one. The most accessible claims are fast increasing in market value, and while some remote claims can still be had as low as five dollars an acre, yet very few desirable locations have sold at less than $25 to $100 an acre, while many choice groups are firmly held at $500 and upwards an acre. When we consider the enormous oil content of these lands and that engineers can sample, measure, and prove up the tonnage, and estimate to a certainty that each acre of the choice lands contains 50,000 barrels and upwards of oil that can be recovered certainly and cheaply, and that each ton of oil shale is of much more value and profit than a ton of coal, and as coal in place in the ground sells at from t to ten cents a ton, then oil shales are certainly worth as much or ı per ton and at a valuation of but one cent per ton or one cent per b· of oil, they are worth $500 an acre, while a fair valuation of but cents a barrel for "oil in place" would make the lands worth $5,00 acre.

THE GREEN RIVER FORMATION The shales in Colorado, Utah and Wyoming found in the middle member of the Green River mation along the Green River, in Wyoming south into Utah and along the White and Gı Rivers and their tributaries in Colorado, and are available along the ver & Rio Grande Railroad through the Grand River valley. T streams have cut through from the Book cliffs and eroded deep val and have left the shales exposed in great open faces lying from 20 1,000 feet above the valley floors, giving the easiest means of mining shales and using gravity to deliver them to the retorts below the mi thus making cheap mining costs. In many places thousands of tons be blasted from the cliff sides or quarried from open cuts, using st shovels and tramways to deliver them to the storage bin or direct to reduction works.

GRAND VALLEY AND DE BEQUE These two points and the valleys tributary the offer the best possible opening for the industr Colorado and owing to the immense and rich at these points it is doubtful if any other points rival them for years. Here are uniform, rich strata from ten up to feet thick of massive, brown curly shale that produce from 40 up to gallons of oil to the ton and hundreds of tests show an average of 5 60 gallons to the ton, while there are from 300 to 1,000 feet of shales g for 20 to 35 gallons to the ton. There are also strata 20 to 40 thick paper shales that mine easier than the massive shales and have an content of 40 to 50 gallons to the ton. This oil is high in gasoline lubricating oils and averages from 15 to 30 per cent gasoline and fr 30 to 60 per cent of lubricating oils according to the method of refin and by cracking processes may produce up to 60 per cent gasoline. contains from 1.5 to 2 per cent of high melting point paraffin wax, wl the asphaltic residue left from refining the oils, of from four to ei gallons to the ton, is similar to the elaterite and gilsonite that is mi in the Uintah basin and is of more value than ordinary asphalt and s at $40 to $60 a ton. It contains much valuable dye stuff and rare che cals. It is used for paints, varnishes, waterproofing, roofings, floorin and as a substitute for rubber in auto tires, belting, and matting. test this district we took many field tests and checked these by tak seven samples as cross cuts on the principal vein of the valley, of ab 1,000 pounds in each sample from which four hundred pounds aver sample was run through the retorts. These samples were taken fr half a mile to three miles apart and safely represent an average of brown, massive shale of Parachute Creek. The average of these sev samples showed a recovery of 67 gallons of oil to the ton. The low sample gave 52 gallons and the highest gave 93 gallons, as a result have estimated to be safe that this district will average 56 gallons to t ton for the massive or curly brown shales and about 30 gallons for t lean or light gray shales, and 45 gallons for the paper shales. The fining record on the Grand Valley oils was exceedingly good and the pr ucts all of very high quality. The paraffin wax has a melting point 135 degrees. The average wax from petroleums has a melting point from 114 to 124 degrees. The higher the melting point the more sale val it has. The Grand Valley lubricating oils are especially fine quali and were 50 per cent of the crude, of 395 flash—475 fire—and with a v cosity of 410 at 100 degrees.

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OIL SHALE—Parachute Creek, City of Grand

refining records show that we produced from Nevada crude shale oil 46 per cent of lubricating and from the Colorado crude shale oil, 50 per : of the crude came through as a high grade mo- 'ds "motor oil" as a trade term, there being such ırket for lubricating oil suitable for internal com- ıs used on automobiles, trucks, tractors, boats, le and stationary gas or gasoline fuel engines, so we use the term "motor oil." From the different l from the crude oil from 30 per cent up to 60 per 'e wish the highest amount possible of gasoline we one of several successful "cracking processes" and nt of gasoline.

st spring, after we had produced and refined suffi- nt shale oil to have a quantity available for com- rcial work, one of our engineers then stationed at : a sample of shale motor oil to the lubricating oil tates government, or purchasing agent of oils for he request that the shale oil be subjected to rigid lubricating and wearing qualities. This official nent departments were too crowded to accept any sted our engineer to submit the oils to the Depart- ngineering, Experimental Engineering Laboratory, stating that it was fully equipped for such tests.

n submitted to the Ohio State University labora- tests a shale oil lubricating distillate just as it 'ithout any treatment or finishing and representing le shale oil and showing a low viscosity, being 133 . This was tested by the University in competition o.'s gas engine cylinder oil, made from petroleum sity of 374 at 70 degrees. Record as follows:

s make of gas engine cylinder oil used in test

:y, Baume	24.4
....	405.
....	485.
sity at 70..................	374.
....	No. 6

/alley, Colorado. Courtesy of J. W. Hess.

Shale oil used in test showed:

Gravity, Baume ....
Flash ....
Fire ....
Viscosity at 70..................
Color ....

This oil was used on a 12-hour continuous r
shows the following salient features:

1. The engine ran for one hour using the petrole
12 hours using the shale oil, in each case the
were 275 and the explosions per minute were
2. **The engine ran cooler using shale oil.**
It required 50 pounds less jacket water per ho
using shale oil.
400 pounds of jacket water, using shale oil, k
jacket water from vaporizer at 185, while it to
to keep it at 211 using petroleum (Standard Oi
3. **Engine carried a heavier load using shale oil.**
Net brake load using shale oil was 40 lbs.
Net brake load using petroleum oil was 38.2 lb
4. **Developed more horse power.**
Brake horse power using shale oil, 6.28.
Brake horse power using petroleum oil, 6.
5. **Mean effective pressure on piston.**
Was less using shale oil, showing less friction
Mean effective pressure shale oil, 37.80.
Mean effective pressure petroleum oil, 49.
6. **Mechanical efficiency was better.**
Mechanical efficiency shale oil, 54.5.
Mechanical efficiency petroleum oil, 52.4.
7. **Engine friction was less.**
Engine friction using shale oil, 4.87.
Engine friction using petroleum oil, 5.45.
8. **Fuel used** (to perform better service) **was redu**
using shale oil.

Fuel used was kerosene; per indicated horse
sumed 0.5 pounds using the shale oil, while it co
using petroleum.

Per brake horse power, per hour, consumed but 0.9 pounds using shale and required 1.25 pounds of fuel oil using petroleum, per brake horse wer, per hour.

IMMARY ON IBRICATION The results of these tests prove the superior lubricating qualities of shale oils, when properly produced and finished. We have found from many tests at improper temperatures in the retorts and high temperatures in the lining will ruin the wonderful natural excellence of the shale oils, so oper methods and process in reduction and refining are an absolute ime requisite of success and for the successful production of superior oducts. American oil refiners lead the world in results and efficiency do American mining engineers and there are no problems in the oil ale industry that cannot be successfully answered when under the managment of trained and competent men.

JBRICATING LS IE KEY TO JCCESS Motor oils or lubricating oils are worth in carload lots all the way from 25 up to 60 cents a gallon. The average wholesale price for motor oil in the United States is from 30 to 45 cents a gallon. One barrel, 42 gallons, of Colorado shale oil can produce 21 galis of motor oil, and if the shale makes but one barrel of oil to the ton, e motor oil is worth at 35 cents a gallon, $7.35 from each ton, and as costs from the mine to the consumer will not exceed $4.00 a ton, a ofit of $3.35 a ton would result from the motor oil alone, leaving the soline worth $1.89, ammonium sulphate 80 cents and other products orth 99 cents, a total of $7.03 a ton net profit. Many of the good shales Colorado and Nevada will exceed one barrel of oil to the ton. A 500n plant should make net profits of $3,500 a day, or $100,000 a month, d this is a very safe and conservative estimate, which under proper anagement and process should surely be accomplished.

IVESTMENT ALUE AND ICOME If a company were going into production of crude petroleum in the Mid-Continent fields and were to purchase outright their oil production today, it would require, to secure a production of 500 barrels of ude oil daily, with reasonable territory in reserve, an investment of not ss than ONE MILLION DOLLARS to secure this production. After ying this production it will constantly settle or grow less and at the id of one year be considerably less than now unless you re-invest a rge amount in constant and new drilling—at least fifty per cent of inme must be set aside for operating, drilling and maintaining producon, leaving but fifty per cent of income for dividends or surplus. Bedes, in this case the company will not own or operate a refinery and as to take the price paid by the pipe lines for crude oil.

If you invest a like amount in the shale oil industry, you may now equire your lands with sufficient supply for 100 years or more of raw aterial for the production of 500 barrels and upwards daily of crude oil nd also build, equip, operate and own a complete reduction works and efinery and thereby obtain the wholesale market value of refined oils or an almost permanent industry, with a capacity and output of 500 barels or more daily. The value of the refined products is from three to our times the value of crude oil. The complete cost for building and quipping a shale plant will run from $1,000 to $2,000 per ton of shale andled accordingly as it is equipped and the complete or incomplete nishing work done on the oils and by-products. A skimming or crackig plant can be built to make good returns, but it is advisable to build complete works, equipped for paraffin wax, lubricating oils and ammoium sulphate, for this will more than double the profits.

OIL CONTENT PER ACRE—OIL SANDS SHALE LANDS The Bureau of Mines of the U. S. Geological Survey has estimated, and the best history proves that the oil sands of the petroleum producing areas of the United States have a record of producing an average of 3,000 to 5,000 barrels to the acre, while the same authorities and the Colorado state authorities estimate the Colorado shales will produce upwards of fifty thousand barrels of crude oils to the acre.

An oil shale stratum of twenty feet thick will contain about 43,000 tons to the acre, thus if only one barrel is produced to the ton it will produce eight times as much as an acre of oil sand; but the Colorado beds contain parallel strata one above the other, of five to seven veins of workable thickness of from seven to fifty feet thick that will run forty gallons and more and from 300 to 500 feet of solid lean shales (richer than Scotch shales), that will run thirty gallons to the ton, making a possibility of recovering several times forty thousand barrels to the acre.

A COMPLETE SHALE OIL REDUCTION PLANT Works would consist of:

1. Mining camp, site, and equipment. Bunk houses, cook house, blacksmith and machine shop.
2. Shale cutting machines, steam, electric or compressed air driven drills. Powder house. Tramway for conveying ore to plants. Tools and complete mining equipment. In some cases, steam shovels.
3. Rock crushers, to roughly break the shale in chunks one to twelve inches. Fines are eliminated and left as waste in Scotch mines. Ore or storage bins located above the retorts and to supply the crushed shale by gravity to retorts.
4. Ovens and retorts, built in benches, usually four ovens to a bench, called a unit. Plant site should be selected to provide room for building additional units as business expands. Retorts connected to proper condensing system to condense the vapors and oils. Also with a compression or absorption plant to recover gasoline from the gases. Scrubbers to remove by-products from gas.
5. Refining:
   - (a) Stills for straight run refining; stills for re-running and finishing; stills for cracking gas oil into synthetic gasoline or motor spirit.
   - (b) Storage tanks for crude; run down tanks for various fractions and products; storage for refined products.
   - (c) Pipe lines from retorts to refinery and from refinery to railroad.
   - (d) Agitators and agitator house for acid and soda treatment of oils, and washers to remove same from oil.
   - (e) Clay burning house, for purifying and renewing the "Kieselguhr" or diatomaceous earth used in the stills and filters.
   - (f) Pumping plant for pipe lines, and water supply for retorts and refinery, using a large amount of water for condensing and cooling.
   - (g) Wax plant, coolers, refrigerators, hydraulic and filter presses to separate the paraffin wax from the heavy distillate; sweating houses for paraffin wax refining.
   - (h) Loading racks at railroads, barreling, packing and shipping house, carpenters, tool, and repair shop.
   - (i) Electric light plant for mines, retorts and refinery; also power plant for mining and pumping.
6. Ammonium sulphate plant. In Scotland, "A three-story high ammonium sulphate house, with column-stills, acid saturators for the ammonia, vacuum evaporator, centrifugal driers, storing bins and grinding mills, sulphuric acid making plant; acid recovery plant."
7. Conveyor belts to carry off spent shales to dump below reduction works.

The following contribution to the subject is made, by request, by Otto Stalmann, a consulting engineer, of Salt Lake City. Mr. Stalmann was the consulting engineer for a well known prominent firm of Glasgow, Scotland, for many years, during which time he directed their mining and oil shale interests in all parts of the world. His experience has given him a first hand and intimate knowledge of the oil shale industry in Scotland. In Salt Lake City he has made extensive tests on shale from Colorado, Utah, Nevada, Wyoming, California, and Montana, in lots from five to six hundred pounds each.

INTRODUCTION It is a well known fact that for many years the exploitation of the oil shale beds in Scotland has furnished most successful and profitable results. But on that account it is not to be assumed that the apparatus used in Scotland and the method of treatment in use there must result equally satisfactorily when treating oil shale originating in the western states of the United States, as the character of these shales, as far as they have come under the writer's observation, is different from that exhibited by the Scotch shales. As the metallurgist cannot employ one general method of treatment for all copper ores for instance, but must find out and adopt the most suitable method of treatment to the particular physical and chemical character of the ore, so must the treatment of oil shale be adapted to its particular physical and chemical character. The difference in the character of the Scotch shales, as compared with that of American shales is to be found in the fact that, whereas in the Scotch shales the silica contents are very low, if present at all, and the alumina contents correspondingly high, in the Western shales silica predominates and the alumina contents are correspondingly low, to judge from the results of tests made on a considerable variety of Western oil shale. It has also been found that, generally, the Scotch shales contain considerably more nitrogen than the large variety of Western American shales, which have been tested by the writer. Whereas in the American shales the quantity of oil that may be produced from them is generally large enough to be depended upon for satisfactory commercial results, considering the sulphate of ammonium product, a welcome by-product only, in most oil shale plants in Scotland the latter product is of paramount importance, to make, together with the oil product, the operations of the plants remunerative. Some oil shale plants in Scotland would even be unremunerative, if they had to depend on the yield of oil from the shale alone, the sulphate of ammonium product being their main dependence for commercial success. It is obvious, therefore, that the Scotch plants are designed, having the production of sulphate of ammonium in view as much as, and in some cases more than, oil. As these products are formed under different conditions of temperature, the apparatus and the method of treatment required must be adapted to these different conditions in order to obtain the best possible economical results. In Scotch plants, therefore, the construction of the distillation apparatus, having a different object in view and working under different conditions, is different from the retort that is best suited to the character of American shales. But even for the various Western American shales modifications in the construction of the retort are required for the different characters of shales, their behavior not being always the same when subjected to heat and superheated steam, although a preliminary examination in the laboratory may not always suggest this.

RETORTS It has been the object of the Petroleum Engineering Company, whose engineers have thoroughly studied apparatus and methods of treatment as employed abroad, and who have for a long time experimented with many varieties of oil shale in a retort of nearly commercial size, holding a charge of about 500 pounds, to construct a retort which is easily adapted by simple modifications to the successful and profitable treatment of all the Western oil shales which have come under their observation and the results obtained have fully justified their expectations. The retort, as now constructed, is cast of a particular mixture of iron, which has been found to be least affected by the consequences of changing temperatures in the retort oven and which secures the absence of blow holes and other deleterious defects as much as this is possible. The retort has the shape of a frustrum of a cone, 1 foot 6 inches inside measurement at the top or charging end and 2 feet 3 inches at the bottom or discharge end, and 18 feet long. The casting is 1.5 inches thick. A tuyere box encircles the lower part of the conical cylinder to provide for the admission of super heated steam to the charges in the retort. The top of the retort connects with a charging hopper, where the charge is stored and at the same time preheated. At the bottom of the retort an automatic discharging arrangement is installed, consisting essentially of a revolving disk, whereby a regulated continuous discharge of the spent shale and a continuous movement downward of the charge in the retort is secured. Connected with and operated by this automatic discharge apparatus is an arrangement, whereby the charge in the retort may be loosened, if it should "clinker" occasionally, and, if necessary, it may be operated continuously to agitate the charge, preventing it from sintering. The arrangement is such that the top of the charge in the retort is always automatically maintained at the same level at some distance below the gas exit pipe near the top or charging end of the retort to avoid the possibility of carrying over any fine solid material with the gas and steam. Charging hopper, retort, and automatic discharge are so connected that they are hermetically closed and an arrangement of air tight gates is provided, whereby charging and discharging of the retorts takes place without any interruption of the operation and without the possibility of air entering the retort or steam or gas escaping from it, except through the discharge provided for the latter near the top of the retort, whence they are conducted to the condenser. Four of these retorts are assembled in one oven and as many ovens as necessary to satisfy the desired capacity of a plant are built into one bench. The number of retorts required for a certain daily capacity, depends on the time required for the complete distillation of a given oil shale. This may vary, according to the writer's experience, from four to eight hours, but some shales have been treated in the above mentioned plant, which require a much longer time. Shales from Parachute Valley, Colorado, and some from Utah and Nevada, require about four hours for their complete distillation. A plant of four ovens, or sixteen retorts, would, therefore, treat about 150 tons a day. For practical purposes, however, it would be safe to depend with such a plant on a daily capacity of 100 tons. The retorts are charged by a conveyor which transports the oil shale from the storage bin to the charging hopper. The shale, before it reaches the storage bins, is broken by a set of "spike rolls", similar to those employed for breaking coal. Experience in Scotch plants, confirmed by extensive experiments in the small plant mentioned above, has shown that more satisfactory results are obtained in the distillation of oil shale, if the fine material, say less than 0.25 inch in size, be screened from the bulk of the broken shale and the two screened products be treated separately.

In Scotland the fine material is not sent to the distillation plants for treatment as a rule, but is used in the mines for "filling" purposes. The separate treatment of the screened products is aimed at in the plants designed by the engineers of the Petroleum Engineering Company. The shale is broken by the spike rolls to pass a 6-inch screen, hence comparatively small amounts of material less than 0.25 inch in size are obtained from the crushing of most shales. The spent shale, discharged by the above mentioned automatic discharge arrangement, drops into a storage bin situated below the retorts and is thence transported by conveyors to the waste dump. The steam entering the retorts through the tuyeres near their discharge end is taken at low pressure from the boilers, in the above mentioned plant, at a pressure of 1.5 pounds per square inch, and is super heated during its passage through a series of coiled pipes built in the interior of each oven, before entering the retorts at a temperature of from 600° to 1000° F., the most suitable temperature depending on the character of the shale to be treated. The heat required for the operation is supplied by firing the retorts with the gas produced from the distillation of the shales. Suitable baffles, built in the interior of the ovens, conduct the products of combustion gradually from the bottom of the retorts to the top of the oven, where they escape into the chimney. The products of the retorts are hydrocarbon gas, steam with ammonia, and spent shale. The latter is free from oil-producing matter, if the operation has been properly conducted, and goes to the waste dump. The former products leave the retort together by a branch pipe near their top, through which they enter the main gas conduit, common to the gaseous products of all the retorts in the unit, and are conducted to the condenser.

CONDENSING PLANT The usual method in Scotland of the condensation of the gaseous products issuing from the retorts is accomplished by passing them through a long and extensive series of pipes exposed to the atmosphere, whose temperature is depended upon to cool and consequently condense the vapors. The quality and uniformity of the condensed product, the distillate, depending on a uniformly maintained temperature, it is evident that, on account of the constantly changing temperature of the atmosphere, it is impossible to maintain the uniform temperature required for the production of distillates of good and uniform quality. It is a well known fact that the speed of the condensation is not only dependent on the degree of temperature, but on contact of the vapors with a cooling surface. In a steady flow of the vapors through the series of pipes as ordinarily employed, the circumferential part of the vapor column only will be in contact with the cooling surface of the pipes, a thorough mixing of the vapors during their passage through the pipes, to bring each portion of the vapors in contact with the cooling surface of the pipes, being incidental and partial, if it takes place at all. Again, a well known fact is that the forceful impinging of the vapors against the cooling surfaces facilitates and expedites the process of condensation to a considerable degree. In the condensation plants as now ordinarily employed, neither the thorough mixing of the particles of vapor, nor the great advantage obtained by forceful friction and impinging of the vapors against the cooling surfaces, has been made use of. To obviate the disadvantages of the condensing apparatus as now ordinarily employed for the condensation of the vapors issuing from the shale retorts, the writer has constructed a simple and comparatively inexpensive condensing arrangement, which, in a modified form has been successfully used by him on a commercial scale in the condensation of metal fumes. This apparatus secures in an effective, simple, and economical manner the three cardinal principles of effective condensation and consequently of hydrocarbon vapor condensation, i. e.:

1. Uniform temperature of the cooling surfaces.
2. Thorough mixing of the particles of vapor.
3. Forceful friction caused by the impinging of the vapors to be condensed against the cooling surfaces. (U. S. Patent No. 225058.)

This condensing apparatus consists of an exterior tank, constructed of steel plate, ten feet in diameter and ten feet high for a plant having a capacity of 100 tons of shale per 24 hours. Concentrically arranged in this tank and resting at its bottom, is a series of five circular, so-called, water jackets at a radial distance of three inches from each other. In this manner these water jackets form six circular spaces, three inches wide and ten feet high each, their respective circular lengths increasing as their distance from the center of the tank increases. The water jackets are provided with suitable openings for the passage of the gas from one space to the next, these openings being alternately at the top or at the bottom of the jackets. Baffles extending vertically along the whole height of the tank are inserted into each space between the jackets near the proper side of the opening to force the passage of the gas continuously in one certain direction. The main gas conduit, carrying the gases from the bench of retorts to the condenser, enters the latter through the bottom of the tank and extends to some distance from the interior top of the tank, which is formed of concrete. The gas flows over the top of the main gas conduit and travels, assisted by a fan mentioned below, spirally around the open circular space formed by the outside of the vertical main gas conduit and the inner wall of the water jacket nearest the center of the tank, until it passes through the above mentioned opening at the top of the water jacket into the next circular space formed by the outside wall of the above mentioned jacket and the inside wall of the next jacket, the second from the center of the tank. A baffle, placed vertically near the proper side of the opening on top of the first jacket forces the gas to travel in the same spiral circular direction as it did in the first space, until it reaches an opening in the second jacket provided near its bottom. The gas passing through this opening enters the third space formed by the outer wall of the second jacket and the inner wall of the third jacket, being guided in the same direction as before by a baffle placed vertically near the opening in the second jacket. The third jacket has an opening at the top, the fourth at the bottom and the fifth again at the top, baffles being properly placed in each case to force the passage of the gases in a spirally circular manner until the permanent gases finally leave the tank near its bottom. The cooling medium, air or water, enters the water jacket nearest to the circumference of the tank at the point where the permanent gas leaves the tank and is forced to travel in a direction opposite to that taken by the gas by baffles or a suitable position of the inlet and outlet pipes. The cooling medium leaving the first water jacket, enters the second jacket at the point where the gas enters the space between the two jackets nearest the circumference of the tank, and continues to travel in a similar spirally circular manner towards the center of the tank through all the water jackets. In this manner, gas and cooling medium traveling in opposite directions, it is evident that proportionately, as the velocity and the temperature of the gas decreases, the speed and temperature of the cooling medium increases and hence the hydrocarbons of highest boiling point will be condensed in the space between the jackets nearest the center of the tank, where the temperatures of the cooling medium is highest and successively gases of lower boiling point are condensed as they reach on their way towards the circumference of the tank, the spaces between the jackets which contain a cooling medium of gradually decreasing temperature. It is obvious that this apparatus can be, and in some cases should be, so arranged that the cooling medium is either air or some liquid, or partially air and partially liquid. The products of the condenser are gas, crude oil, and ammonia water, the latter two leaving the condenser together from spouts at the bottom of the tank leading into the spaces between the water jackets. In this manner six classes of oil will issue from the condenser, the classes being distinguished by their different boiling points and specific gravity. Each of these classes of oil, together with the ammonia water, is transported by short pipe lines to individual separators where the ammonia water is separated from the crude oil. The separators are circular tanks, each four feet in diameter and six feet high. A vertical partition, reaching from the top of the tank to within about six inches from the bottom, separates the tank into two unequal compartments, the smaller compartment representing about one-tenth of the larger one. Crude oil and ammonia water from the condenser enter together through the cover on top of the larger compartment of the separator, where they segregate according to their specific gravity, the water passing under the bottom of the vertical partition into the smaller compartment of the separator. The oil, collecting on top of the water leaves the separator through a spout near its upper rim leading into a pipe line, whereby it is conducted to its respective storage tanks supplying the refinery. Six storage tanks for crude oil are, therefore, required for the crude oil product of the condenser. The ammonia water issues through a spout near the top of the tank from the smaller compartment of the separator, to be transported by a pipe line to the storage tank for ammonia water for treatment in the sulphate of ammonium plant. The permanent gas is withdrawn from the condenser by an exhaust fan, which, being in immediate connection with the closed circuit formed by it, condenser, and retorts, facilitates the passage of the gases from the retorts through the main gas conduit to the condenser and forces them to a scrubber, where any ammonia, still retained in the gas, is extracted.

AMMONIA SCRUBBER PLANT

The scrubber consists of a vertical pipe 24 inches in diameter and 30 feet high. With exception of the upper and lower parts, four feet long each, the pipe is filled with diamond-shaped wooden baffles, placed in alternate layers at a small distance apart from each other, in such a manner, that each baffle in a layer covers a corresponding opening in the succeeding upper and lower layers of baffles. The permanent gas from the condenser enters the pipe column near its bottom and, ascending through the layers of baffles, meets a descending spray of water, which absorbs any ammonia that may be still left in the permanent gas. The resulting ammonia water, which may be re-used for this purpose, leaves the pipe column near its bottom by a pipe line, which transports it to the storage tank for ammonia water for treatment in the sulphate of ammonium precipitating plant. The gas, after ascending over the baffles in the pipe column, leaves the latter at its top by a pipe line which conducts it to the bottom of a similar pipe column, also filled with baffles as described.

GASOLINE ABSORPTION PLANT

The gas, in its ascent over the baffles, meets a spray of oil entering at the top of the pipe column and descending over the baffles towards the bottom of the column pipe. The oil used for this purpose is specifically heavier than gasoline and absorbs any of the latter that may be present in the gas. It has been found that from two to four gallons of gasoline may thus be extracted from the gas per thousand cubic feet of the latter, or from four to eight gallons per ton of such western oil shales as have come under the writer's observation. The final permanent gas, deprived of its gasoline, leaves the pipe column at its top and is conducted to the gas reservoir, to be eventually made use of as fuel. It may be stated here that most western oil shales tested furnish an excess of gas over that required for treating them in the retorts. The oil charged with the gasoline absorbed from the gas is then treated in a plant the modus operandi of which has been adopted from a plant described in a bulletin of the U. S. Geological Survey, who have made large tests with this plant on a commercial scale for the extraction of gasoline from natural gas. This plant, according to the statement of the Geological Survey, has given very satisfactory results and, since it is simple and economical as far as installation and operation are concerned, it has been adopted here. This plant, adapted to the needs of an oil shale plant of one hundred tons daily capacity, operates as follows: The oil, charged with the gasoline absorbed from the gas, is first conducted to a horizontal so-called weathering tank—an ordinary plate steel cylinder, one foot six inches in diameter and twelve feet long. This tank has a relief valve at its upper circumference, through which the lighter parts of the gasoline escape as vapors, which may be conducted to the gas reservoir. From this tank the oil is conducted to a heat exchanger, where it is preheated by the hot oil returning from the still, mentioned below, to the absorbing tower for re-use. From this heat exchanger the preheated oil, charged with the gasoline absorbed from the gas, is conducted to a still operated by live steam. Here the gasoline is expelled from the oil, the vapors being conducted to a cooler box, where the water is separated from the gasoline, the latter going to a condenser, the condensate being ready for the market after teatment, eventually, if the quality of the condenser product requires it. The hot oil remaining in the still, after having been freed from the gasoline, is conducted through the above mentioned heat exchanger, where it travels through pipes in the opposite direction to the cold oil charged with gasoline, passing to the still, preheating the latter liquid. After having transferred the greater part of its heat to the oil passing to the still, it is conducted through water-cooled coils to the absorption tower for re-use.

SULPHATE OF AMMONIUM PLANT

The ammonia water coming from the separators, which segregated it from the oil, together eventually with the ammonia water coming from the scrubber, is conducted to a column apparatus, where the ammonia gas is evaporated. This column apparatus is constructed of ten sections of cast iron, twenty-four inches in diameter, twenty-eight feet high. The sections are provided with flanges at their ends and bolted together to form a vertical column of the size stated. Within this column there are seventeen shelves, at equal distances apart, cast in one piece with the sections. Three nozzles tapering from 2.5 inch in diameter to 1.5 inch and 4 inches long, are cast with the shelves. Extending upwards and over the shelves a hood or bell is fastened at a distance of about one-half inch above the orifice of the nozzles. The bottom of this bell is cut out zig-zag shape to a height of two inches in such a manner that the lower part of the mantle of the bell represents about one half metal and one half opening. A two-inch nipple extends from a point three inches above each shelf to a point about three inches below the shelf. At the seventh section from the top connections are made with a tank containing milk of lime. The ammonia water, after passing through a heat exchanger, enters the column at the top and remains on the uppermost shelf to a depth of three inches, when it overflows into the two-inch nipple, which drops it onto the second shelf on which it also remains to a depth of three inches, when it passes to the third shelf by overflowing into the two-inch nipple which transports it to the fourth shelf and so forth over all seventeen shelves, until it passes to the bottom of the column, where it issues as waste, after having been deprived of its ammonia. At the seventh shelf from the top a connection is made with the milk of lime storage tank, from which such an amount of milk of lime flows into the seventh section from the top as has been previously determined by an analysis as necessary. Steam enters the column at the bottom and ascends through the tapering nozzles, being diverted by the top of the bell towards the bottom, where it enters the ammonia water, through the zig-zag shaped openings at the bottom of the bell, heating the water and driving off the ammonia gas. From the lower section the steam ascends to the next upper section through the tapering nozzle, operating in the same manner as described from shelf to shelf, until the remainder finally issues, together with the volatilized ammonia, from the top of the column into a standard steam separator, where it is separated from the ammonia gas, which, by means of a pipe line, is conducted directly to the pecipitating tank.

NOTE: The free ammonia is volatilized only in the upper six sections, while from the combined ammonia (ammonium chloride, ammonium carbonate, etc.), which is practically always present in the ammonia water, the ammonia must be set free by combining its impurities with lime. Ammonium chloride for instance, treated with milk of lime, furnishes calcium chloride, water and ammonia, according to the equation:

$$2(NH_4)Cl + CaO = CaCl_2 + H_2O + 2\,NH_3$$

In a similar manner ammonium carbonate furnishes, in combination with lime, calcium carbonate, water, and ammonia, according to the equation:

$$(NH_4)_2CO_3 + CaO = CaCO_3 + (NH_3)_2 + H_2O$$

The precipitating tank contains dilute sulphuric acid into which the ammonia gas is conducted, combining with the sulphuric acid to form sulphate of ammonium, according to the equation:

$$H_2SO_4 + 2(NH_4HO) = (NH_4)_2SO_4 + 2H_2O$$

The precipitating tank is built of wood and lined with lead. It has one sloping side, along which the crystals of sulphate of ammonium are removed to a draining floor or they are freed from moisture by a centrifugal machine. The sulphate of ammonium product is then dried and ready for the market. The reaction between the ammonia vapors and the sulphuric acid generates a large amount of heat, which generates steam, carrying some ammonia and fine particles of sulphate of ammonium along. For this reason, and also for the protection of the workmen, the reaction takes place under a bell, the top of which ends in a pipe which is connected with a trap, separating the particles of sulphate of ammonium from the steam, which then enters the heat exchanger, mentioned above, to preheat the original ammonia water before it enters the column apparatus. The economic products of the distillation plant are therefore: crude oil, gas, gasoline, and sulphate of ammonium. The latter two are ready for the market, the gas is made use of in the plant as fuel, while the crude oil is stored for treatment in the refinery.

The cost of a plant as outlined above is from $65,000 to $100,000, according to local conditions.

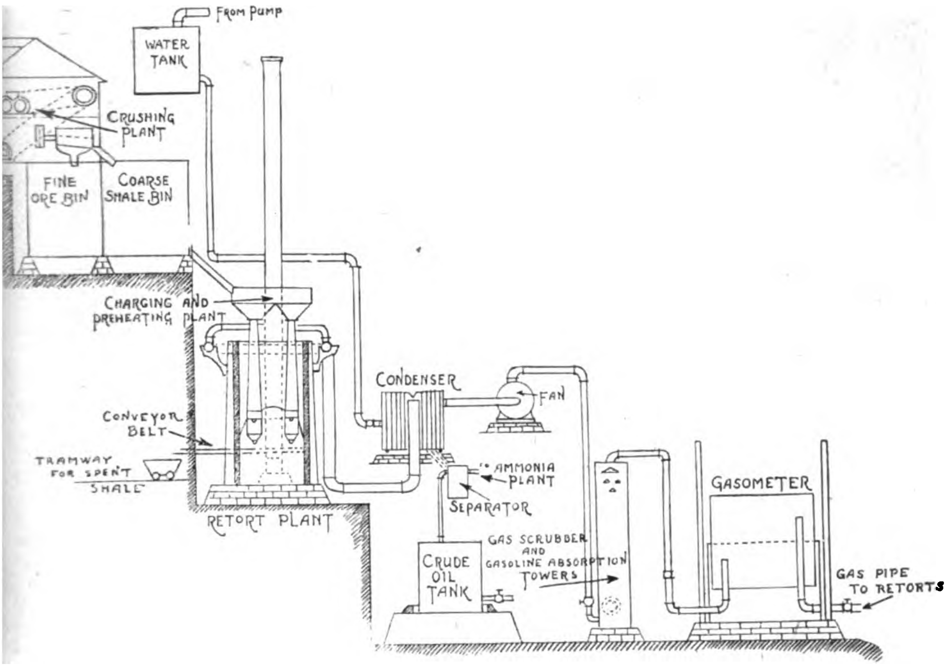
The cost of a 300 tons daily capacity plant for distillation and a Wells system refining plant for 400 barrels of crude oil is from $450,000 to $500,000, according to local conditions.

Inasmuch as the Wells Oil Refining Process Company has done much experimental work in refining crude shale oil, Willet C. Wells, president of the company, has, by request, contributed the following:

MINERAL OILS Mineral oils being tenaceously blended substances of wide range of volatility and density, and so sensitive to the action of heat required to evaporate them, that their evaporization, aided by the lavish use of steam, produces gas, that is not condensable at normal temperatures, and carbon (coke) residue. This gas and carbon is separated smoke of the overheated material, resulting in greatly diminished quantity and quality of valuable products, and necessitating wasteful and expensive means to prepare them for use.

THE WELLS PROCESS The Wells Process passes a neutral permanent gas in myriad fine streams through a body of heated volatile liquid; the gas, previously heated, or heated in contact with the liquid, seeks to saturate itself with vapors with avidity proportionate with its temperature; the surface of each bubble of gas being free surface at which vapors can form within the body of the liquid below its boiling point, and where the absorptive properties of the heated gas, and the vapor tension of the heated oil, coact to rapidly evolve all of the volatile portion of the liquid in vapor at temperatures insufficient to change the constitution of any portion thereof; in fact, the solid bitumi-

nous residue of evaporated petroleum or shale oil can be completely dissolved in the distillates therefrom and reproduce the original oil without the loss of one-fourth of one per cent. By passing the thus vapor-loaded gas through a largo body of filtering material in the dome of the still, globules of unvaporized spray, carried by the steam of bubbling liquids, are eliminated. The filtering material, being heated by the vapor-laden gas passing through, is of lower temperature than the temperature of the vapors that heat it, consequently some of the less volatile portions of the vapors are condensed in the filtering material and absorbed and retained therein until re-evapoated therefrom by the progressively rising temperature of the filtering material, thus securing much closer separa-



Cross Section of a Single Unit—Stalmann Oil Shale Reduction Plant.

tion of the more volatile from the less volatile portions thereof, resulting in greatly increased quantity of gasoline of a given gravity and end point, more homogeneous commercial products in general, much better formation of wax crystals, and complete separation of the bituminous residue from the distillates. The gas, after its load of vapor is condensed therefrom, repeats its performance in continuous cycle. Thus, by the application of the simplest laws of nature, oils are divided into commercial fractions, so perfect in their inherent constitution, that they will reproduce their original state by blending. A large portion of the distillates of petroleum or shale oils produced by the Wells Process have, as measured by a viscosimeter, greater viscosity than castor oil. By our improvement in wax presses, the wax is readily expressed from these viscid oils.

SHALE OIL PRODUCTS The writer has twice visited the shale oil refineries in Scotland. We have had several barrels of crude Scotch shale oil shipped to Columbus, and have investigated other foreign shales, such as New Brunswick, Cuban, and others. We obtain from one sample of Grand Valley, Colorado, crude shale oil of 23.3 Be. gravity:

19% Gasoline, 460 End Point.
12% Gas Oil.
60% Lubricating Oil. 395—Flash. 475—Fire. 410 Vis. at 100.
5% Asphaltic residue.
2% Wax.
2% Loss.

The lubricating oil produced by the Wells process from these shale oils require no chemical treatment to fit them for the market. They are superior to petroleum lubricants in adhesiveness and endurance; in immunity to the action of acids, and freedom from oxidization in heated contact with air; and the paraffin wax thus produced is harder and of much higher melting point than the paraffin wax from petroleum. The residue of petroleum or shale oils, produced by other processes, is carbon (coke). The residue of the same oils produced by the Wells Process, of whatever dryness, is pitch, wholly soluble in the distillates therefrom. The residue of shale oil is superior to asphalt or coal tar pitch in toughness and has a greater range of temperature between its melting point and brittleness. We also have a highly efficient automatically controlled continuous process of converting the maximum percentage of the low priced oils, between gasoline and lubricating oils, into gasoline, without pressure or possibility of burning to the still bottom.

The following information is contributed, by request, by Joseph Bellis of Grand Valley, on the oil shales of Parachute Creek. Mr. Bellis has given close attention to the matter for several years and is unusually well informed on the general and practical phases of the oil shale industry:

PRESENT CONDITION OF THE INDUSTRY IN PARACHUTE CREEK, GRAND VALLEY

During the past year many new methods and inventions have been presented for the proper treatment of our mammoth bodies of oil shale, but the results show that the methods used in the Scotch oil shale industry are the most efficient, practical, and reliable when slightly modified to suit conditions of our shales. This young industry is afflicted with many new and varied "processes" presented and vouched for by half-baked scientists and promoters. Two plants are planned and probably will be installed in Parachute Creek-Grand Valley field before next summer (1920). These plants will prove that there is an inexhaustible supply of very high-grade oil in our western Colorado oil shales; that it can be economically and uniformly distilled into crude oil; that this crude oil is superior in quality to any crude oil produced from oil wells; that, after being fractionated, more than fifty per cent in volume of this crude oil will produce a high-grade lubricating oil, and that without further refining this large volume of lubricant, which refiners refer to as "lubricant stock," will uniformly show a viscosity test of better than 400 at 100° Fahr. This lubricant stock will excel all other known lubricants for internal combustion engines, because of its, tenacious adhesion to heated moving polished metal surfaces, its high fire test, its freedom from oxidation in contact with heated air, and its consequent long lasting and superior endurance. The gasoline will also be a high-grade product. The paraffin wax is more resistant to heat, to the extent of about fifteen degrees, than the best paraffin wax produced from well petroleum. The asphaltic residue at the tail end of the refinery, or fractionation plant, makes an ideal rubber filler, since it is a very unusual and exceptional quality of asphalt susceptible to being blended and affiliated in large percentages with vegetable rubber in the manufacture of long life automobile tires and other high-grade rubber goods. Crude shale oil sold in the open market is likely to command a price of $5.00

a barrel just as soon as its many superior qualities and products are commercially established—a condition which is not far distant. It can be produced for less than $2.00 a barrel with a 200 ton per day retort plant. Such a plant, including an ammonium sulphate and gasoline absorption equipment complete, can be installed for one hundred thousand dollars, at the present high prices. All estimates are made on shale of a minimum richness of one barrel (42 gallons) of crude oil per ton of 2,000 pounds of shale. These retorts, or reduction plants, can be advantageously installed in units of a capacity of 100 tons per 24 hours. A complete Wells refinery will be installed, including the cold storage wax plant, which, when complete, will not exceed $350,000 in cost, with a capacity for handling 400 barrels of crude shale oil in 24 hours, as soon as the two projected retort plants are erected. By "complete refinery" is meant a plant that makes the products from crude oil in approximately the following percentages:

Gasoline	25 per cent	
Lubricating oil	60 per cent	
Paraffin Wax	2 per cent	
Kerosene or fuel oil......	3 per cent	Not including the products of the gasoline absorption plant.
Asphaltic residue	7 per cent	
Loss	3 per cent	

In addition to these products, there will be the ammonium sulphate ranging from 20 to 30 pounds to the ton of shale, and about 2,500 cubic feet of gas, from which can be extracted from two to three gallons of gasoline per 1,000 cubic feet of gas, with sufficient high-grade hydrogen gas left over for all fuel requirements in operating the retort and refinery plants. These products and average percentages in gallons and pounds per barrel and probable wholesale prices are as follows:

Main Products:			
Gasoline, 25%—10 gallons at 18c............	$1.80		
5 gallons reclaimed from gas at 18c..........	.90		
		$2.70	
Lubricating oil, 60%—25 gallons at 30c....		7.50	
			$10.20
Other Products:			
Paraffin wax (145 M.P.), 6 pounds at 15c...........		$ .90	
Asphaltic residue—(rubber filler), 20 lb. at 5c......		1.00	
Ammonium sulphate—20 lbs. at 4c..................		.80	
			$ 2.70
			$12 90

Crude shale oil can be fractionated or refined into these products at $1.00 a barrel or less, in a plant of a minimum capacity of 400 barrels per 24 hours. These are the commercial products that will be produced from the shales. At some time in the future, many by-products, such as analine dyes and other commercial commodities may develop, but they have not as yet arrived on the scene of action except in laboratory tests. Under certain conditions, without refining, a very fine flotation oil can be obtained from the shale, but the possible market demand for it in volume is too limited and restricted to be regarded as of great commercial importance at this time. There are no gold, silver, tin, or platinum values in any of our shales in paying quantities. This has been checked and rechecked. There is no warrant or justification for this claim being made, and no excuse for anyone being misled or imposed upon. In retorting or distilling these shales, there are a few well-known and established facts that should be kept in mind, to-wit: the shale should not be crushed, but fed into the retorts as "run-of-mine", except that pieces larger than about five-inch cubes must be broken to about this maximum size and with the further exception that the "fines" less than quarter inch mesh in size, will be screened off. These "fines" will be a negligible quantity—about a half of one per cent. Besides the added expense for fine crushing, it would necessitate agitation mechanism in some form. It is doubtful if agitation machinery can be devised for durable work in varying temperatures of from 400 to 1,000 degrees of heat. A very good mining machine was presented for mining the shales, but it cut them up into average cubes of half inch and smaller, hence it could not be adopted. After many very careful tests and substantiation by Scottish practice for half a century, it seems to be an established fact that the material must be loaded into the retort "run-of-mine". Also, that wet steam must be supplied near the bottom of a vertical retort, under about two pounds pressure, and continuously let off at the top of the retort under proper pressure gauge, as the vapors and gases form in the retort from the indirect action of a maximum of 1,000 degrees Fahr. of heat upon the shale. These vapors are condensed into crude oil and ammonia water and the gas treated in the absorption plant. If desired to carry the crude oil by pipe line any great distance, the hot oil and ammonia water together can be run probably 15 miles in a buried pipe with proper fall and the separation between the oil and water made at the point of delivery. The average Parachute shales can be retorted by this method in less than five hours with an extraction of 98 per cent or more of volatile matter. The consumption of water needed in distillation is about 40 gallons to the ton of shale, but a large percentage of this can be reclaimed if the crude oil and ammonia water separation is made at the retort. The owner of any oil shale property can use, for domestic or manufacturing purposes, water that is developed by sinking a well on the property. A stream may have been adjudicated for irrigation, but a well can be sunk at any point beyond its banks and water pumped from it for domestic or manufacturing purposes. The shale oils must be refined at low heats, not to exceed 1,000 degrees Fahr., so as to preserve the high qualities and consequent large quantity of the lubricating oil. High-grade lubricants are in demand, and, with the truck and tractor age just being ushered in, this demand will increase. Hence the best money-making element in our shale will be the large lubricating content that will probably bring not less than 40 cents a gallon f. o. b. cars railroad, without further refining, but can be sold at a handsome profit by the shale oil refinery for as low a price as fifteen cents per gallon, if such an unusual and improbable market conditions develop.

The successful distillation of crude oil from Colorado shales and the refining thereof into commercial marketable products is now a proven fact. Approximately 200 samples, weighing between 500 and 600 pounds each, have been run in a small commercial retorting plant. The crude oil produced therefrom was collected and fractionated and then the lubricant cut of 60 per cent subjected to severe tests under actual working conditions. I am fully convinced that the industry has passed the experimental stage and this present year will see the beginning of the most permanent, extensive, and lucrative manufacturing industry that has ever been developed in this state. The great money-making element in Colorado shales is the large percentage of high-grade lubricating oil that can be cheaply produced. More than fifty per cent in quantity of the crude shale oil can be fractionated into first class lubricants for internal combustion engines.

PROCESSES Although at the present time no plants are producing shale oil on a regular commercial basis, yet a number of different types of retorts have been designed for the production of shale oil. Several of these retorts have been built of the same size as the proposed commercial units; others have been made of a size which is not designed as commercial retort but only for the purpose of demonstration. Some of these retorts appear to have merit, but others seem to be doomed to failure because they fail in correct mechanical design and do not follow the fundamental principles of destructive distillation. The majority are designed for the purpose of producing a crude oil from shale to be sent to a refinery, but others have been designed with the purpose of effecting distillation and refining in one operation. To one not personally interested in any particular method of retorting, it would appear that the retort with the best chance for success would be one patterned after the Scottish retorts, modified to suit our local conditions. It is not to be understood that the present Scotch retort is perfect, but it is one of known capabilities under the conditions existing in the Scotch shale industry. Before any retort is adopted, it should be thoroughly tried out. A shale plant, to be successful, involves a large expenditure, and any mistake made in the design of its most important part, the retort, may be disastrous.

Some of the processes which have been advanced and the companies interested in them are given in the following list:

1. Crane Process—Crane Shale Corporation, Elko, Nevada.
2. Erickson Process—Rainbow Petroleum Products Co., Salt Lake City, Utah.
3. J. B. Jenson Eduction Process—C. B. Stewart, 806 McIntyre Bldg., Salt Lake City, Utah.
4. Pearse Process—Arthur L. Pearse and Co., 50 East 42nd St., New York City, N. Y.
5. Pumpherston or "Scotch" Process—Glasgow, Scotland.
6. Scott Process—Detroit Testing Laboratory, 674 Woodward Ave., Detroit, Mich.
7. Stalmann Process—Otto Stalmann, 521 Atlas Block, Salt Lake City, Utah; or Petroleum Engineering Co., 420 Dwight Bldg., Kansas City, Mo.
8. Wallace Process—George W. Wallace, Consulting Engineer, East St. Louis, Mo.
9. Wingett Process—American Shale Refining Co., First National Bank Bldg., Denver, Colo.
10. Chew Process—National Shale Oil Co., 1530 Welton St., Denver, Colo.
11. Galloupe Process—J. H. Galloupe, 1101 19th St., Denver, Colo.
12. Simpson Process—Louis Simpson, 172 O'Connor St., Ottawa, Can.
13. Prichard Process—Dr. Thomas W. Prichard, 52 East 41st St., New York, N. Y.
14. Bishop Process—James A. Bishop, 1526 N. LaSalle St., Chicago, Ill.
15. Brouder Process—Clark, Long & Co., 50 E. 42nd St., New York, N. Y.
16. Catlin Process—R. M. Catlin, Franklin Furnace, New Jersey.
17. Del Monte Process—C. A. Prevost, 814 Southern Bldg., Washington, D. C.

ESTIMATED COST OF DISTILLATION AND REFINING PLANTS

The cost of a distillation plant with all accessories of a capacity of 100 tons of shale a day is estimated at from $65,000 to $100,000, according to local conditions. If proper plans were made in advance for enlargement additional units could be erected at about one-half the cost of the original unit. The cost of a Wells Refining plant with a daily capacity of 400 barrels, to include a sulphate of ammonium and gasoline absorption plant, would cost from $300,000 to $350,000, according to local conditions.

ESTIMATED COST OF MINING AND RETORTING The following estimate of the cost of producing crude shale oil without refining is based on a plant of 400 tons daily capacity.

	Cost per ton:
Mining	$1.25
Breaking or coarse crushing	.10
Retorting	.35
Loading and shipping	.05
Amortization, interest, and overhead expenses	.10
	$1.85

These costs for mining and retorting are estimated on the basis of 42 gallons to the ton of shale, but there are several available, workable strata in the Parachute Valley that will produce from 50 to 100 per cent more. Consequently, in practice, these costs per barrel of crude oil produced may be considerably reduced.

ESTIMATED COST OF MINING, RETORTING AND REFINING The following estimate of the mining, retorting, and refining is also based upon oil shale producing a barrel of shale oil (42 gallons) to the ton of shale in a plant treating 400 tons a day.

	Cost per ton:
Mining	$1.25
Breaking or coarse crushing	.10
Retorting	.35
Refining by the Wells Process	.42
Piping, loading, and shipping	.10
Amortization of plant equipment	.05
Interest on investment	.05
Overhead expenses	.25
	$2.57

Opinions

Van H. Manning, Director United States Bureau of Mines, Bureau of Mines Yearbook, 1917. "The question is being asked daily what this country is going to do when our petroleum resources are exhausted. We have as yet untouched our great reserves of shale that contain oil. These shales are found in many parts of the United States, and tremendous reserves are known in Colorado, Utah, and Wyoming. Some of our shales are much richer than the Scotch shales, and are conservatively estimated to contain many times the amount of oil that has been or will have been produced from all the porous formations in this country.

"To obtain the oil from oil shale it is necessary to heat the shale in great retorts. The oil is the result of destructive distillation and is driven off in the form of vapor and is later condensed by cooling. As stated above, this process has never been used in this country because of the lack of necessity, for our oil reserves are great, and it would not be commercially economical to invest money in retorts for distilling oil from shale that would have to compete with the crude oil obtained by other methods. But this condition will not last forever. In fact, it is thought that it will be only a very short time until the oil shale industry will be one of magnitude."

"Investigation of Oil Shales," Seventh Annual Report of the Bureau of Mines, Van H. Manning, Director, to the Secretary of the Interior, for the Fiscal Year Ended June 30, 1917.

"During the year the Bureau of Mines has been particularly interested in the vast deposits of oil shales in Colorado and Utah that have been disclosed by the field investigations of the Geological Survey. Because of the threatened shortage of petroleum from oil fields in the future, these shales are considered to be the principal reserve in this country for the future supply of gasoline and other petroleum products. Consequently, much attention has been given to preliminary investigations of the richness of the shales, and a detailed study is being made of the best methods of obtaining oil from the shales, the character of the shale oils and the proportions of the various oil products and byproducts obtainable by different methods of distillation. The investigations made lead to the belief that it is now commercially feasible to work selected deposits of shale in competition with oil from oil wells, and that these oil shale reserves can be considered of immediate importance to the oil industry. Several commercial plants for mining and treating the shale have been planned and the Bureau of Mines will closely follow the developments. It is believed these investigations have already demonstrated a reserve of oil adequate for all future needs of the Navy."

Franklin K. Lane, Secretary of the Interior.

Mr. Lane said, in reply to a Senate resolution regarding gasoline, and referring to the shale beds of the country: "The development of this enormous reserve simply awaits the time when the price of gasoline or the demand for other distillation products warrants the utilization of this substitute source. This may happen in the future. At all events these shales are likely to be drawn upon long before the exhaustion of the petroleum fields."

Walter Clark Teagle, President Standard Oil Company of New Jersey.

"The total number of wells completed in the United States in the first eleven months of this year (1917) was 21,302. Of the completed wells the total number that produced oil was 15,205. There was an increase in total production from all wells this year over last. The total production of petroleum in all parts of the country in the first ten months was about 272,000,000 barrels. The production for the eleven months is accordingly almost equal to the total yield for the twelve months of 1916, but that has not been sufficient to meet the demands of the refineries, for about 16,000,000 barrels have been taken from stock so far this year to supply the refiners. The stock of crude, accordingly, has decreased both in 1916 and in the present year. The total stock of crude on January 1, 1916, was 198,000,000 barrels, including storage of crude held in private tank farms and leases. On November 1, 1917, it was approximately something over 158,000,000 barrels, or less than one-half a year's yield of crude.

George Otis Smith, Director, U. S. Geological Survey, in a Letter to Congressman E. T. Taylor, September 8, 1917.

"It is true that the Government, and particularly the Geological Survey, has spent considerable time and money in the last few years in a study of the oil shale deposits. As a result of the field examinations made from 1913 to 1916, it has been clearly demonstrated that the latent potentiality of the oil shale of this region as a source of petroleum is enormous. It is also known that there is locked up in these shales a vast amount of nitrogen which can be recovered as a by-product in the refining of the shale and used in the manufacture of fertilizers and explosives."

Extract from Letter from George Otis Smith, Director, United States Geological Survey, December 19, 1918.

"The day that some company undertaking the production of oil through the distillation of oil shales in this country proves, through actual practice, that oil may be produced successfully and continuously on a commercial scale at its plant, a new page will be turned in the industrial history of the United States. The significance of the first genuine production at a profit is hardly likely to be over-estimated. Such a demonstration will tend to limit maximum petroleum prices in competing areas and to reassure the American Republic as to its oil supplies.

"These circumstances justify the interest displayed by the public as well as by the companies that are honestly undertaking the task of designing and constructing plants while the industry is yet in its experimental and, therefore, uncertain stages. As soon as the oil is produced successfully on a commercial scale, the industry is destined to expand rapidly, unless interfered with by the discovery of an important oil field between the Rockies and the Sierra-Nevada-Cascade Range barrier. Its normal expansion, however, will probably not be so rapid as to affect petroleum prices especially.

"Although the conditions of shale mining in northwestern Colorado and northeastern Utah are in general widely different from those in Scotland and France and to a certain exent from those in Australia, and though the composition of the Green River oil shales undoubtedly differs somewhat from the Old World deposits, much should be gained by the utilization of the experience and methods of those who have long been engaged in the industry with financial success. In the attack on the technological questions of oil extraction, the United States Bureau of Mines is extending constructive cooperation as well as cordial interest.

"Notwithstanding the work done over sixty years ago in the distillation of shales and coal, the proposition of producing oil on a large scale by shale distillation is in fact essentially new in this country. The problem is bound to attract more attention as the demand for petroleum continues to gain on the supply from wells in the United States.

"The generously encouraging attitude of the Federal Government and of the states toward the establishment of new industries, and especially toward the development of mineral deposits, makes possible the perpetration of numerous frauds under guise of oil shale promotion. It is the duty of officers like yourself, who are on the ground and who are in a position to gather knowledge enabling you to discriminate between the fraudulent promoter, on the one hand, and the honest experimenter and developer, on the other, to expose the frauds and put in motion the machinery which, under state and Federal laws is, in many cases at least, sufficient to put an end to such business. On the other hand, it is as important that honest, well-organized companies, with promising plans and methods, should be helped by all wise and legitimate means."

"The Investigation with Mapping of the Deposits of Oil Shale in the West," Thirty-Ninth Annual Report of the Director of the United States Geological Survey, George Otis Smith, Director, to the Secretary of the Interior, for the Fiscal Year Ended June 30, 1918.

"The investigation, with mapping, of the oil shale in the West, begun by the Geological Survey in 1913, largely as a measure of preparedness, has yielded a volume of information as to the distribution, richness, character, composition, and possibilities of these shales which is now proving invaluable in the foundation of a new industry that is sooner or later to be of very great economic importance to the country. The many experimental plants now in operation or under construction for producing oil from these shales for commercial use should soon demonstrate whether, as was expected, the moment has already arrived when the production of shale oil will not only regulate the price of gasoline, but will assure an almost unlimited supply of that essential fuel. Conservative estimates of the quantity of crude oil that may be recovered from beds of shale three feet or more in thickness and capable of yielding twenty-five gallons or more of oil to the ton of shale (some beds will yield as high as seventy gallons) indicate that the shales of northwestern Colorado and northeastern Utah alone can produce over ten times as much oil as has been recovered from oil wells in the United States since the first commercial oil well was drilled in Pennsylvania in 1859. What the full possibilities of these shales may be in the way of by-products other than gasoline remains to be seen. It is not impossible that new products or preparations yet to be discovered in the experimental laboratory may be of signal importance to the country and may radically affect the commercial success of the industry. The tests already made indicate that the shales will furnish material for dyes, fertilizers, rubber substitutes, paving materials, drugs and lubricants."

"Development of Oil Shales"—"Petroleum, a Resource Interpretation," by Chester G. Gilbert and Joseph E. Pogue, Smithsonian Institution, United States National Museum, Bulletin 102, Part 6, 1918.

"Granted the utmost in the development and use of the remaining supply of petroleum, economic pressure from oil shortage will still be not far distant. Attention turns, therefore, to sources of supply other than the porous rocks of oil fields thus far exclusively exploited in this country. It is of great significance, therefore, that within the past five years geological explorations on the part of the United States Geological Survey have definitely established the existence of vast areas of black shale in Utah, Colorado and Wyoming, much of it capable of yielding upon distillation around fifty gallons of oil, 3,000 cubic feet of gas, and seventeen pounds of ammonium sulphate—the whole constituting an oil reserve aggregating many times the original supply of petroleum."

"The Oil Shale Areas," Dorsey Hager, "The Search for New Oil Fields in the United States," Engineering and Mining Journal, New York City, January 5, 1919.

"These shale areas will be developed in time on as safe and sane a basis as our coal mines of today. When that time arrives, the remains of oil prospecting will have fled and the whole complexion of oil production will change. It will, literally, be oil mining with steam shovels in open pits and glory holes; and, later, tunnels and adits. There will be no lack of oil products for several generations to come, but the true oil fields of today will probably disappear within another generation and be replaced by oil mines."

"Billions of Barrels of Oil Locked up in Rocks," by Guy Elliott Mitchell, of the United States Geological Survey, in the National Geographic Magazine for February, 1918.

"Is the United States facing a gasoline famine? Shall we be required to forego automobiling except to meet the stern necessities of war and of utilitarian traffic? Are our petroleum fields showing signs of exhaustion?

"The output of petroleum has not yet begun to diminish; statistics show that it is still increasing; yet the downward trend of production from the present oil fields is plainly in sight.

"The war has made a sudden and enormously increasing demand on the oil fields of America, and though the industry has never been so feverishly active as it is now and the output never so large, the truth is that the demand has not been entirely met. And during the next year and as long as the war lasts the demand will be ever increasing, ever more pressing.

"Many of the host of larger vessels that we are now building will be equipped with oil-burning furnaces, and the vast swarm of airplanes that we are building, as well as the thousands of war automobiles and trucks that we are turning out, will consume an enormous quantity of gasoline. Yet no great new oil regions comparable with the mid-continent or California fields are being discovered, and it is questionable whether any will be, for our oil geologists have pretty thoroughly combed the accessible oil areas. What then, is the answer?

"It is just at this juncture that we have made a discovery that has disclosed what is undoubtedly one of our greatest mineral resources—one that should supply the needs of the war, and that for generations to come will enable the United States to maintain its supremacy over the rest of the world as a producer of crude oil and gasoline and incidentally of ammonia as a highly valuable by-product. We have discovered that we possess mountain ranges of rock that will yield billions of barrels of oil.

"For many years travelers going west through the Grand River Valley of Colorado and into the great Uintah Basin of eastern Utah have looked from the windows of their Pullman cars on the far-stretching miles and miles of the Book Cliff Mountains, little realizing that in these and adjoining mountains, plainly exposed to view, lay the greatest oil reservoir in the country—the oil shales of Colorado, Utah, Wyoming and Nevada.

"These shales, it is true, were known to yield oil. Campers and hunters in building fires against pieces of the rock had been surprised to find that they ignited and burned, and investigation showed that they contained oil. This fact was looked upon, however, as only another of the natural curiosities of the great West and little or no attention was paid to it because of the seemingly inexhaustible pools of crude petroleum found elsewhere under great areas.

"In connection with its investigations of the undeveloped mineral resources of the country the United States Geological Survey has recently made special studies and tests of these oil rocks and has brought to light two important facts: First, that our Western shales are phenomenally rich in oil, and, second, that in foreign countries, particularly Scotland, much inferior shales are today successfully mined and worked as a source of oil and other commercial products. The industry in Scotland is seventy years old and is still in a highly flourishing condition."

"A Vast Reserve of Oil," by Robert G. Skerrett, in "Munsey," February, 1919.

"Moses performed a miracle, in the eyes of the children of Israel, when he tapped the rocks of Kadesh for water. But our scientists, to the automotive world, have achieved a far greater wonder, for they have discovered where we can draw an almost boundless measure of oil from stone.

"Strange as it may seem, this hitherto untouched source of supply is not hidden far beneath our feet, but rises high above our heads in towering mountain formations. In the past, we have drilled into the bowels of the earth to tap rich subterranean stores of petroleum. These hidden reservoirs are not inexhaustible; indeed, many authorities declare that our great and steadily increasing rate of consumption threatens to exceed the available supply within a comparatively few years. When that happens, kerosene and gasoline may become dearer but we shall not have to do without them. We can push confidently into the hillsides, knowing that we shall strike oil—not in the form of an oleaginous gusher or flood, but in the shape of a solid substance, susceptible, when suitably treated, of giving an abundance of liquid fuel, motor spirit, and a variety of valuable by-products. The United States is fortunate in possessing far-flung strata of oil shales which bulk all the way from outcropping ledges to the dignity of veritable mountains."

Oil Consumption Exceeds Production—Petroleum, January, 1918 "California crude stock is the lowest in years. Reduction of crude-oil stocks in California to slightly less than 34,000,000 barrels, the smallest in more than six and one-half years, emphasizes the strength of the oil situation on the Pacific Coast. Several million barrels are regarded as unavailable for use, so actual surplus is smaller than appears. Consumption of crude oil by Pacific Coast refineries has been exceeding production at rate of about 1,000,000 barrels a month the last year or so. In twenty-two months California stocks of oil in storage and above ground have been depleted by over 23,000,000 barrels."

Dean E. Winchester, U. S. Geological Survey, Bulletin 641-F, Page 141. "In Colorado alone there is sufficient shale, in beds that are three feet or more thick and capable of yielding more oil than the average shale now mined in Scotland, to yield about 20,000,000,000 barrels of crude oil, from which 2,000,000,000 barrels of gasoline may be extracted by ordinary methods of refining, and in Utah there is probably an equal amount of shale just as rich. The same shale in Colorado, in addition to the oil, should produce, with but little added cost, about 300,000,000 tons of ammonium sulphate, a compound especially valuable as a fertilizer. The industry requires a large equipment of retorts, condensers, and oil refineries, as well as of mining machinery, so that it cannot be profitably handled on a small scale."

Professor Charles Baskerville, College of the City of New York, Engineering and Mining Journal, July 24, 1909, P. 150. "The development of the Scotch shale oil industry has been carried out with skill and energy, and it is to be regretted that the industry has not met with the entire commercial success it well deserves. Ever since 1850, it has only been by skilful management and the constant and intelligent application of science to the improvement of processes and to the utilization of waste products that the oil manufacturers of Scotland have been able to hold their own. The success of the companies now in operation, however, is shown by the following list of dividends paid annually: 1904-1907, Young's, 6 per cent; Oakbank, 15 per cent; Broxburn, 15 per cent; Pumpherston, 20, 30 and 50 per cent; Dalmeny, 10 and 25 per cent, and in 1906-1907, nil."

SIGNIFICANT FEATURES Oil shale land is primarily acquired from the government under the Federal mining laws governing placer mining claims. At the present time, however, all shale land advantageously situated has been filed on and is owned by individuals or corporations.

Oil shale itself varies greatly in different localities and in different strata in the same locality.

The oil shale industry is a comprehensive one and embraces features of mining, shale reduction, mechanical engineering, oil refining, applied chemistry, and the business involved in marketing the products.

Little manual labor is required as automatic machinery does the bulk of the work.

Variation in the estimated cost of producing crude shale oil is caused by the exclusion or inclusion, in the estimate, of the by-products in the retorting, like ammonium sulphate. Another cause of difference is the high or low estimate of the amount of shale oil that can be extracted from each ton of shale. Inasmuch as there is known to exist in the De Beque-Parachute district a large commercial supply of shale that will produce a barrel of crude oil—42 gallons—to the ton of shale and such shale deposits have the economic advantages of altitude, nearness to water, accessibility, and proximity to transportation, one is on a safe, conservative basis to estimate a barrel of oil to a ton of shale. The amount of shale of this grade now available will last for many years.

The early success of the industry will depend upon the cost of production and marketability of its main products—not upon its by-products—no matter how fascinating these by-products may now appear.

Black powder is more efficient in mining shale than dynamite.

Some shales contain sulphur and hence produce an inferior grade of oil, but the Colorado shales are free from sulphur and produce a high grade of crude oil easily amenable to refining.

Gasoline from Colorado oil shale does not become dark, off color, or otherwise deteriorated by standing. Samples refined by the Wells process are known to have kept their color for more than a year.

Crude shale oil is a manufactured oil and consequently can be kept virtually free from impurities. Tests thus far made indicate that the great majority of shale oils produced, and all those made from Colorado shale, when made under proper conditions, are of a quality greatly superior to the oil produced from wells. The quality of oils produced from wells varies considerably. Impurities that prove injurious to the quality of the oil are present, to a greater or less extent, in almost all well oils. The majority of shales do not contain impurities to such a degree as to affect the quality of the oil produced. Kerogen, the oil producing matter, and hydrogen (present in the natural state of the shale and added in the process of distillation), are, as a rule, the only constituents which form the oil. These constituents make a virtually perfect oil.

The oil produced from 4.44 tons of shale (42 gallons to the ton) is equivalent to the heat effect of one ton of coal of 11,000 calorific value.

The heat value of 2.41 tons of oil shale (42 gallons of oil to the ton) is equivalent to the heat value of one ton of coal of 11,000 calorific value.

Colorado massive shale will average 18 cubic feet to the ton; when broken, 30 cubic feet in volume to the ton.

A ton of shale (42 gallons) will produce 2,500 cubic feet of gas. A 400-ton plant would therefore produce daily 800,000 cubic feet of gas. Ninety-four pounds of coal are equivalent to 1,000 cubic feet of gas. Consequently the 800,000 cubic feet of gas produced daily by a 400-ton distillation plant would be equivalent to 75,200 pounds of coal, or 37.6 tons.

The minimum capacity of a distillation or retorting plant to include crushing, retorting, gasoline absorption, and ammonium sulphate units, should be 100 tons daily, provided the distillation required not more than six hours, or at least four charges made daily. The cost of such a plant would be approximately $100,000. Additional 100-ton units could be installed for $50,000 each. These estimates are made for retorts which have a capacity of 1.5 tons to the charge. From five to six charges can be made daily, resulting in a daily capacity of from 7.5 to 9 tons a day. A bank of 16 retorts would have a theoretical capacity of from 120 to 144 tons a day. However, in order to allow for accidents and delays a bank of 16 retorts is roughly assumed to be of 100 tons daily capacity. A 100-ton plant should be regarded as only a starter. Four hundred tons should be regarded as a minimum size for continuous commercial operation.

The minimum size for a refinery, to include a paraffin wax plant, should be 400 barrels daily, and would cost approximately $350,000. This also should be regarded as only a starter. A refinery of 1,000 barrels daily capacity should be regarded as the minimum daily capacity for continuous commercial operations. One refinery in the De Beque-Parachute district would fill the needs of several distillation plants.

At Tulsa, Oklahoma, the cost of refining is 38 cents a barrel in the Cosden & Company plant of 40,000 barrels daily capacity. In a two months' test run by the Wells process at this plant the cost was 27 cents a barrel.

A plot of ground 200 by 300 feet is sufficient for a distillation plant of 400 tons daily capacity.

Only about 60 per cent of the gas produced would be needed to supply power for the distillation and refinery plants. The remainder, 40 per cent, would be available for other purposes.

Kerogen—the oil producing ingredient in oil shale—contains plenty of carbon but little hydrogen. The introduction of steam in the distillation process supplies the hydrogen necessary. On most shales. tests with and without steam have shown a greater production of oil with the use of steam than without it, and a greatly superior quality of crude oil.

Ore is crushed, but shale should be broken. This is accomplished in Scotland by the use of spiked rolls. Spikes 2.5 inches at the base and 3 inches long are arranged spirally in rolls and are removable. In Scotland all shale smaller than one inch is left in the mine. Colorado shale breaks well.

Sticking of shale in the retort, in some cases, causes serious trouble. Tests show that if the temperature is kept below 850° sticking does not occur in Colorado shales, but they do stick if the temperature goes above that point. Samples of Nevada and Utah shales have been tried that do not stick up to 1,200°. Mixtures of Nevada and Colorado shale seemingly do not stick. In Parachute Creek the black, rich streak sticks at 850°, but if mixed with poorer shale (35 to 40 gallons to the ton) in the proportion of 100 pounds of the poorer to 400 pounds of the richer the product does not stick below 1,000°. However, sticking is prevented by the introduction of steam, provided the steam is injected early enough in the process.

Crude petroleum from wells varies widely in different fields. Crude shale oil is virtually a manufactured article. It may be spoiled, in the manufacture, for refining into valuable products. Also, good shale oil may be subjected to an inefficient method of refining and become commercially unprofitable.

In Scotland two men working together produce 8 tons (2,240 lbs.) a day at a cost of 5 shillings, or $1.25 a ton. Reduced to a ton of 2,000 lbs. this would be $1.11 a ton. The Scotch miner works on a seam only, 6 or 7 feet thick, hundreds of feet below the surface under unfavorable conditions. If the Scotch miner, under unfavorable conditions, can mine four tons of shale, certainly the American miner in our shale beds so easily worked can produce twice that amount. It is certain, then, that our estimate of $1.25 a ton for mining is large enough and in practice will surely be reduced.

The quantity and quality of oil that can be produced is variable, according to the skill and intelligence of the operator, the method used, the type of retort, the rate of heating, the amount of heat applied, the introduction of steam and many other details. In short, oil produced from shale may or may not show good results, from no fault of the shale. Good shale, subjected to poor methods, may give oil that fails to yield to refining. Hence follows conflicting opinions as to the character of the shale oil produced and the results from refining. Retorting shale and refining oil are not "fool proof" processes.

A frequent distinction is made between American and Scottish shale, as if there were only two varieties—one American and one Scotch. It should be clearly understood that there is a great variety of American shales—as great a difference between them as between any one and the Scotch shale. Hence even varieties of American shale may require different forms of treatment.

In Colorado alone the available oil from shale is conservatively estimated at 58,080,000,000 barrels. To produce this would require the work of 100 plants each producing 2,000 barrels daily for 800 years.

Summary

1. The oil shale industry has reached its greatest development in Scotland, where it was established in 1850. Next in importance comes France and then New South Wales.

2. In Scotland the technical and chemical problems of the industry have been carefully solved and, on the whole, the industry has been commercially profitable.

3. The Scotch shale beds are comparatively thin, irregular, steeply inclined, deep, and expensive to work.

4. The oil content of the Scotch shales is now much less than formerly and the shale could not be worked profitably if it were not for the ammonium sulphate produced as a by-product.

5. The increased demand for petroleum, the exhaustion of producing wells in the near future, and the enhanced price will result in competitive shale oil, produced from an inexhaustible supply of shale by cheap mining, efficient retorting and distillation.

6. The oil shale industry is not, in ordinary parlance, "a poor man's game". The technical and chemical problems are numerous and require a high grade of scientific ability for their solution.

7. A plant of 400 tons daily capacity is as small as can be operated permanently and successfully, as the profits will depend chiefly on the large tonnage handled. In this respect the oil shale industry bears the same relation to oil that Utah Copper and the other copper porphyries bear to copper.

8. An investment of $500,000 is as small as can be safely counted upon to make a single project successful.

9. Labor is cheaper in Scotland than in the United States; the Scotch shale produces more ammonium sulphate than the Colorado shale. These are the only factors favorable to the Scotch shale; all other elements that enter are distinctly in favor of Colorado shale.

10. The favorable features in the oil shale industry in Colorado are:

a. The enormous extent of the deposits.

b. The great thickness both of the medium and high grade shale.

c. The horizontal position of the strata and their height above the level of the creeks—a combination that affords cheap mining.

d. Adequate water supply for the condensing and cooling systems of both the distilling and refining plants.

e. Accessibility and nearness to railroads and markets.

f. The great richness of the shale.

These features combine to make the oil shale deposits of Colorado the most valuable deposit of their kind in the world.

In the minds of those men who are best informed on the technical and business phases of the oil shale industry, it has passed the experimental stage and "has arrived".