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Electrometallurgical Resources of The North Platte River Basin, Wyoming

DIETZ

The Wyoming Geological Survey

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Electrometallurgical Resources Of The North Platte River Basin, Wyoming

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The
Electrometallurgical Resources
of the
North Platte River Basin,
Wyoming

A Preliminary Industrial Survey of the Sundry Minerals, Chemicals and Power Producers of Southeastern Wyoming

By

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Contents

List of Illustrations

Prefatory Statement

January 11, 1932, Senator Kendrick introduced a bill in Congress for the construction of the Casper-Alcova division of the North Platte River irrigation project. The recent measure calls for the reclamation of 66,000 acres of land situated in the vicinity of Casper as well as such incidental power development that the Secretary of the Interior may find necessary and feasible to generate by the operation of the several component members of the proposed irrigation system.

Until quite recently the United States Reclamation Service has almost entirely relied upon the sale of irrigation rights for financing their projects constructed in Wyoming and in other states. As the main reservoir unit of the Casper-Alcova proposal involves the completion of a dam in the Seminoe Canyon capable of producing 50,000 horsepower of hydro energy, leading sponsors of the project have long maintained that both power sales and irrigable land sales will yield equally important sources of income for assuring an early repayment of the entire construction investment.

Preliminary reports completed by the engineers of the United States Reclamation Service indicate that all of the hydro energy developed by the Casper-Alcova project will be absorbed during the next 10-year period by normal expansions in the power market that already exists in Wyoming and in the adjoining states of Colorado and Nebraska. On the other hand certain technologists are of the opinion that the available output will find its most profitable market wholly within Wyoming. According to their calculations the proposed volume of thermal energy could not begin to reduce the huge dowry of ferro-alloy ores and complemental chemicals that have long remained unexploited in the Wyoming sector of the North Platte basin.

A sum totaling over $300,000,000 has so far been expended in building sundry power works on three far famed river courses of America. The colossal capital outlays of the past were not at all times preceded by economic surveys of the scope already completed for the pending hydro proposals. Every year auxiliary power projects thus far constructed at two points on the Wyoming stream channel have unfailingly poured large profits into the Federal Treasury. Last year the North Platte irrigation project yielded nearly one-half of all power profits collected from the 20 plants that were operated on various western rivers by the United States Reclamation Service. Other indirect revenues have resulted from Federal development of hydroelectric power. Last year minor operations on the North Platte enabled one of the more progressive municipalities of this state to conduct its government on a tax-free basis.

Rivers that justify investigation for power expenditures are few and far between in the United States. For development of power resources no stream offers the complete possibilities of the North Platte River. Along its precipitously descending Wyoming gradient, geologic forces unwittingly excavated the deep rock-ribbed canyon gorges so essential for the construction of high dam barriers at the minimum cost. Other dynamical and chemical agencies did not remain idle in the distant past. Conveniently awaiting development near the unusual structural sites are great deposits of uncommon ores. So far the national steel industry has scoured all continents for similar minerals to manufacture the newer and stronger metals commonly designated as ferro-alloys.

Heretofore many alleged rare ores have been hauled from far-away desert, jungle and mountain-top for domestic reduction at Niagara Falls. To both mine and refine such minerals in a single valley would add a new chapter to American electrometallurgical practice. Nevertheless, until such steps are taken in Wyoming or elsewhere, this nation will continue to rely on foreign raw material for the manufacture of its several grades of steel capable of passing present-day military specifications.

All automobile and airplane concerns introduce larger volumes of imported alloy material into their annually improved vehicular models. Such trends of progress in the transportation field cause technologists to display increasing interest in the strategically located ore potentials of the remarkable Wyoming basin. In time the direct reduction of these ores by known electrothermal methods may become imperative if American leadership in the constantly advancing steel industry is to remain unchallenged.

The present outline is not offered as a geological or technical work. It is designed to afford the student, the consumer, the investor and the producer a commercially convenient compilation of the mineral resources most feasible for hydroelectrical development in southeastern Wyoming. Its general form is along the lines of a companion guidebook published four years ago in which the chemical deposits of the southwest quarter of the state were mainly stressed.

In the meanwhile some of the preceding materials have been put in the crucible. Costly research investigations of previously correlated resources are now drawing considerable attention. Enthusiastic workers frequently report their findings in leading chemical journals. Writings now based on actual experimentation in the laboratory and in the pilot plant already exceed the volume of publicity originally circulated by the State of Wyoming.

By this date the commercial possibilities of vast mineral reserves long ignored in southeastern Wyoming warrant consideration. In the following pages the industrial potentialities of a broad diversification of natural resources are correlated for the first time. The longer expositions relate to mineral products that enter markets still free of over-production evils within the American industrial realm.

In times of deepest depression only the exceptional mineral deposit is worthy of attention in Wyoming or elsewhere. The ensuing appraisals cover reserves that carry far higher values than those previously pointed out for another quarter of the state.

C. S. DIETZ.

Cheyenne, Wyoming
December 31, 1932.

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CHAPTER I

TITANIUM

Introductory

To the electrometallurgist the North Platte River basin of Wyoming extends a wide variety of opportunities.

For immediate development the huge dike of gangue-free, titaniferous ore situated near the railway station of Iron Mountain offers the strongest attractions. In a titanium circular published two years ago the United States Bureau of Mines recognized the Iron Mountain reserve as one of two American locations that warranted development at that time. Since then other factors have served to stimulate interest in the Wyoming mineral deposit.

Successful reduction of the titanium ore is dependent on low-cost electric power. Last winter a bill was introduced in Congress for the construction of a large hydroelectrical powerworks at a favorable site within the valley in which the titanium deposit is situated. The new measure attracted wide attention and it immediately became distinguished by the volume of support it received from important bureau chiefs and departmental heads of the Federal Government. At this point it is mentioned that no electrometallurgical industry of magnitude will be established in the Wyoming valley until private or public capital constructs the leading power site of the state.

Another timely inducement for exploiting the Iron Mountain ore body has been the proven ability of the titanium industry to run countercurrent to the severe business depression that has generally paralyzed other industries since the fall of 1929. In the past two years far wider markets have been opened for new titanium products. The magnitude of these recent expansions receives further discussion in this report.

In addition to titanium the Iron Mountain deposit is known to carry appreciable amounts of chromium, manganese and vanadium, three ferro-alloy metals for which the American steel industry relies on foreign ores for its main sources of supply. The chromium, manganese and vanadium contents are all too low for the Iron Mountain deposit to singly serve as an ore. Nevertheless, the combined value of the latter metals reaches a figure sufficiently high to classify the big dike as an increasingly important reserve of ferro-alloy minerals. At the present time the unusually high titanium and iron contents form the major values in the remarkable deposit. Important secondary values will also be recovered from the ferro-alloy minerals as soon as operations are started at Iron Mountain.

Other measurements place the Iron Mountain deposit in a more attractive light. The Wyoming ore body is of sufficient visible dimensions to contain 100,000 tons of vanadium metal. In actual tonnage this content is not exceeded by any potential vanadium reserve so far recognized in the United States.

To awaken interest in local metallurgical problems this paper points out a number of procedures for recovering all of the ferro-alloy metals contained in the titanium mountain with the aid of native Wyoming resources, exclusively. No textbook has yet appeared in this specialized field, and few of the suggestions offered herein could be supported by personal experimentation. Should subsequent operations in laboratory or pilot plant yield results not anticipated, such contrary findings need not prove totally discouraging. In fact the variety of raw chemicals and energizers present in the Wyoming valley is quite amazing. As soon as some of the local forces are liberated in the proper ratios, the highly refractory ore at Iron Mountain is bound to yield appreciable recoveries of several metals for which serious shortages have long been known to exist in this country.

CHAPTER II

PRIOR REPORTS—LOCATION

Prior Reports

The huge dike of solid, heavy, powder-black mineral that forms the main Iron Mountain deposit could not escape the notice of the first explorers in Wyoming. Long ago it was the scene of repeated mining stampedes and, since 1853 several geologists and scientists have published reports on this most spectacular mineral occurrence in the state.

Citations in this outline are only made to the last two reports filed on the Iron Mountain deposit. The best descriptions of the local geology are in United States Bureau of Mines Bulletin No. 64, entitled "The Titaniferous Iron Ores of the United States." This bulletin was published in 1913 under the authorship of Dr. Joseph T. Singewald, Jr., former member of the Government and Maryland Geological Surveys, and at present professor of geology at Johns Hopkins University.

The sole economic object of the Singewald investigation was to consider the value of domestic titanomagnetites as prospective reserves of iron ores. At that time American ironmasters looked upon titanium as a deleterant, and all of the Singewald metallurgical tests were made with the object of preventing the entry of an unmanageable nuisance into the blast furnace. Today titanium ores are esteemed more highly. In the open market they bring several times the price of ordinary iron ores.

Regardless of intervening technological advancements, the long out-of-print Singewald report is still a highly important geological document. For comparative purposes it still serves as the best directory extant on domestic titanium deposits. In it the Wyoming titanium deposit is listed as the largest known in the United States.

In the following year of 1914, Charles W. Comstock prepared an exclusive metallurgical report on the Iron Mountain titanium deposits. Among other things his valued report even then recommended that private capital construct the Seminoe Canyon power project for the sole object of reducing the Wyoming titanium ore to alloy forms by using both the Rossi electric furnace and the Goldschmidt aluminothermic patented processes.

Comstock disclosed that sufficient power could be generated at the exceptionally favorable Seminoe dam site to manufacture 125,000 tons of ferrotitanium annually. No such market has so far developed for titanium products. To stimulate sales Comstock recommended that a wider demand be created for the alloy by a well conducted advertising campaign. Regardless of the merits of new products, their introduction is generally a disheartening and costly procedure. The hesitancy of capital to enter such doubly speculative ventures is never surprising.

Since the date of the Comstock report, the ingenuity of inventors both here and abroad has opened far wider markets for newly developed titanium products. These recent outlets have caused American capital to open titanium mines and refining plants in foreign nations. The foreign activities may suffer a noticeable curtailment as soon as the essential hydroenergy of the North Platte River basin is available for the direct reduction of the domestic Wyoming ore.

Location

The main deposit of titanium ore is situated in Albany County at a point nine miles west of Iron Mountain station on the Colorado and Southern Railroad. From the base of the exposed ore body to the railroad, the descent approximates

300 feet. The deposit is cut by Chugwater Creek and along its uniform gradient a railroad extension could be built at the lowest cost.

From Cheyenne the titanium deposits lie 45 miles to the northwest. From Wheatland their distance is slightly less in a southwesterly direction. Other highly mineralized areas occur nearer to Wheatland. In the hills west of town are minerals that enter into titanium industrial products. Other important ores and raw materials that are used in electric furnace metallurgy are now being mined and quarried near Wheatland.

In the development of basic industrial potentialities Wheatland has advanced more rapidly than Cheyenne. Wheatland is already a terminal point for a power line leading from a Government hydroelectric plant, and a pipeline connected to the larger natural gas fields of Wyoming also terminates in the city. A proposed extension of the pipeline would pass the titanium properties within a distance of five miles.

Processes suggested in this paper for the reduction of the highly refractory ore are mainly dependent on the availability of large quantities of low-cost electricity and natural gas. These modern forms of basic energy are the two types most desired in the industrial world. Not everywhere is it possible to tap either one or both of those sources of primary power at an attractive cost within the immediate proximity of an important ore deposit.

Natrona County Royalties

Lines 8 to 18, inclusive, on page 2 of the pending Kendrick Bill read as follows:

> The remainder of the construction cost of said Casper-Alcova division shall be financed as follows: The entire revenue derived from royalties on oil developed in Natrona County, Wyoming, which, under existing law, is required to be covered into the reclamation fund, shall be applied to the payment of that portion of the construction cost not allocated to the irrigation district on account of the irrigable lands of said division, and that portion of said construction cost not paid from power profits, as provided in Section 3 hereof.

The specified mineral royalties are of ample magnitude for paying the entire cost of the power unit of the Casper-Alcova project.

It is hard to say too much in favor of the proposed financial arrangement. Settled production in the Natrona County oil fields has proven to be unusually strong and steady. Nevertheless, current production levels cannot continue indefinitely. In course of time the oil content of the great producing horizons that form the Natrona County pools will be expended. Before it is too late steps should be taken to transform those huge supplies of energy into a more enduring form of power.

Hydraulic power is a form of Sun power and will continue in existence long after the oil fields of Natrona County are exhausted. Oil accumulations are the result of past radiant energy but the huge Solar Engine causes water and wind forces to go on forever. In the doubly favored North Platte basin past stores of energy are being rapidly drawn upon, but one form of power will continue uniform and constant as long as the present regional contour remains intact.

Much of the power potential of the North Platte basin is capable of immediate development. Present plans call for uniform production over the whole period of the year. Continuous water power applied 24 hours per day yields three times the energy of fuel engine power at eight hours per day. For stabilizing taxable values in the Oil Capitol of Wyoming huge supplies of temporary energy should be converted into more lasting forms of wealth.

The development of Natrona County resources is inseparately connected with that of its water power. For attracting the industrial grouping symbolized by its name as well as other industries generally free of overcapacitation burdens, a firm power supply foundation must first be laid.

CHAPTER XVII

SEMINOE CANYON POWER SITE

Government Report—Map—National Power Costs—Secondary Power—Other Firm Power Sites—Power Profits—Current Criticism—Seminoe Dam Substitutes.

Government Report

The engineers of the U. S. Reclamation Service recently filed a report on the Seminoe Canyon Power Site. The first publication of their report appears below:

> Preliminary Report
>
> *North Platte River Power Investigations*
>
> September 1, 1931
>
> **Need for Additional Storage**
>
> The irrigation shortage of the current year on the North Platte project located on North Platte River in Wyoming and Nebraska, has conclusively demonstrated the need for more storage to enable increase in irrigated areas, such as contemplated for the Casper-Alcova and Saratoga projects.
>
> The Seminoe is the most favorably located reservoir site to enable irrigation expansion in Wyoming, and from incomplete studies of the data available, a capacity of 910,000 acre feet has been selected for the basis of a preliminary report. Some modification of such capacity may finally prove advisable but such modification will not materially alter costs nor unfavorably affect the conclusions presented as to financial feasibility.
>
> This adopted reservoir capacity is from present data considered adequate to offset the increased demand on North Platte River that might result from the construction of the Casper-Alcova irrigation project.
>
> **Seminoe Reservoir Site**
>
> The damsite is located in the Granite Canyon carved by the North Platte River between Seminoe Mountains and Bennett Mountain about 33 miles northeast of Rawlins,

Wyoming. A capacity of 910,000 acre feet can be obtained by a dam raising the low water level of the river 185 feet to elevation 6350. The reservoir area is uninhabited and uncultivated, being largely of desert character and used mainly for grazing purposes. The damsite lies in a narrow gorge, one abutment being of granite entirely exposed and the other partially so. The bed of the river has been explored with diamond drill and found to have a cover of 25-30 feet of sand, gravel and boulders. While not easily accessible, the damsite presents no unusual difficulties for the gravity type of concrete dam proposed, the cost of which is estimated at $3,750,000. Pathfinder reservoir, the high water line of which is but a few miles below the Seminoe damsite, with a capacity of 1,070,000 acre feet, must be operated so as to meet immediate irrigation demands. Its storage is ordinarily withdrawn from July 1 to September 30 of each year. Seminoe reservoir can be operated for power purposes with its outflow redistributed by Pathfinder reservoir to fit irrigation needs. Both reservoirs would fill in years of large runoff and be depleted in periods of scant stream flow, their full capacity, excepting only dead storage set aside for power head, being available to meet irrigation needs.

Sixty thousand acre feet of the Seminoe reservoir capacity would be set aside to maintain a minimum power head of 93 feet. The remaining 850,000 acre feet would regulate the stream to produce a uniform output of 18,100 K. W. Variation in power load in the more immediate markets would make it necessary to install a power plant with a capacity of 38,400 K. W. in order to properly market the average output of 18,100 K. W.

Cost of Power

Preliminary estimates of the cost of construction of the Seminoe dam and power plant and transmission lines to markets at Casper, Green River and Cheyenne are summarized as follows:

Seminoe dam	$3,750,000
Power plant	2,280,000
Transmission lines 360 miles at $6,500	2,340,000
Investigations, roads and right-of-way	130,000
Total cost	$8,500,000

(COURTESY UNITED STATES RECLAMATION SERVICE)

Seminoe Power Site

Assuming a similar financing scheme as adopted for the Boulder Canyon project on the Colorado River, the annual costs of the complete development would be as follows:

Fixed Charges	
Repayment 4.655% of $8,500,000 =	$395,675
Depreciation on power plant 1.25% of $2,280,000 =	28,500
Depreciation on transmission lines 1.9% of $2,340,000 =	44,460
	$468,635
Operating Charges	
O & M power plant at $1 per K. W. capacity =	$38,400
O & M transmission lines at $100 per mile =	36,000
Sub-total	$74,400
General Expense 2%	10,865
Total annual cost	$553,900

Average cost per Kw-hr. delivered assuming 12% line losses and 150,000,000 Kw-hrs. per year generated = 4.2 mills.

Alternate Scheme

The Green River-Rock Springs territory is almost wholly supported by the coal mining industry which is at present in a marked stage of depression. For this reason it may not prove attractive to extend a line from Rawlins and the following estimate covers this situation, but in lieu thereof adds a line from Tie Siding, Wyoming, to Fort Collins, Colorado, to connect with the Colorado system of the Public Service Company of Colorado:

Seminoe dam	$3,750,000
Power plant	2,280,000
Transmission lines, 290 miles at $6,500	1,885,000
Investigations, roads and right-of-way	130,000
Total cost	$8,045,000

Annual Fixed Charges	
Repayment 4.655% of $8,045,000 =	$374,495
Depreciation on power plant 1.25% of $2,280,000 =	28,500
Depreciation on transmission lines 1.9% of $1,885,000 =	35,815
Sub-total	$438,810

Annual Operating Charges	
O & M power plant at $1 per K. W. capacity =	$38,400
O & M transmission lines at $100 per mile =	29,000
Sub-total	$67,400
General Expense 2%	10,120
Total cost	$516,330

Average cost per kilowatt hour delivered (150,000,000 Kw. hrs. delivered for year) = 3.9 mills.

If sale of power is made at the switch board and transmission lines financed by the users similar to the arrangement at Boulder Canyon, the estimated total cost becomes $6,160,000 and the annual cost as follows:

Fixed Charges	
Repayment 4.655% of $6,160,000	$286,750
Depreciation on power plant	28,500
Sub-total	$315,250
Operating Charges	
O & M power plant	$38,400
General expense 2%	7,070
Total cost	$360,720

Cost per kilowatt hour generated (150,000,000 Kw-hrs. output per annum) = 2.4 mills.

POWER MARKET

The power market prospective for the Seminoe power development divides itself into two classes: (1) the present load of existing power systems in the territory and ordinary increases thereof, including short line extensions into adjacent areas, and (2) load which might become available due to the development of mineral or other natural resources within reasonable distance of the power site.

The market available from existing power systems within probable economic transmission distance of the Seminoe site would require the construction of three transmission lines in different directions and are referred to here as the North Platte River valley territory, the Rawlins-Rock Springs territory and the Laramie-Cheyenne-Colorado territory.

The North Platte River valley territory consists of the territories served by the system of the Mountain States Power Company from Casper to Guernsey, Wyoming, the North Platte Project power system from Guernsey, Wyoming, to Scottsbluff, Nebraska, and the system of the Western Public Service Company in western Nebraska. At the present time the Mountain States Power Company secures the bulk of its power from the North Platte Project system but the rapidly growing load in this territory has already nearly reached the capacity of the plants on the project and additional capacity must be provided in the near future.

Based on information available in this office regarding the growth of load on the North Platte Project system and on information furnished by the Mountain States Power Company and the Western Public Service Company the following tabulation shows the present and anticipated loads in this territory:

	Millions of kw-hr.				Kilowatt Peak			
Year	1930	1935	1940	1945	1930	1935	1940	1945
Mt. States Power Co.	13.8	19.0	27.0	39.0	3000	4200	5400	6900
No. Platte Project	10.2	14.5	21.0	29.5	2700	3500	4500	5800
W. Pub. Serv. Co.	17.9	26.0	37.0	54.0	5500	8200	12000	18000
Subtotal	41.9	59.5	85.0	122.5	11200	15900	21900	30700
Available from No. Platte Proj. Plants	28.0	32.0	32.0	32.0	6000	6000	6000	6000
Additional from other sources	13.9	27.5	53.0	90.5	5200	9900	15900	24700

As the anticipated growth of the Western Public Service Company will shortly be sufficient to absorb all the power available from the present North Platte project power plants it is believed that the territory on the project and that of the Mountain States Power Company can be considered as tributary to the Seminoe development.

Casper can be reached by a transmission line about 58 miles long where an interconnection can be made with an existing line which now connects with the North Platte project system. This connection would probably serve the territory until 1937 or 1938 when either the voltage would have to be raised on the Casper-Guernsey line or additional transmission facilities provided.

The Rawlins-Rock Springs territory is divided into two parts with Rawlins and Parco on the east end and Green River, Rock Springs and adjacent coal mining camps on the west end.

The territory on the east end can be reached with about 33 miles of transmission line and available information from the present generating agencies shows the following load conditions:

	Millions of kw-hr.				Kilowatt Peak			
Year	1930	1935	1940	1945	1930	1935	1940	1945
Rawlins	1.6	1.9	2.3	2.7	590	700	830	980
Parco	2.4	2.9	3.4	4.0	500	590	690	810
Total	4.0	4.8	5.7	6.7	1090	1290	1520	1790

By extending the Rawlins line an additional 120 miles the Rock Springs-Green River territory can be served and from data gathered in connection with the investigation for the Fleming Gorge development on the Green River the following load conditions apply:

	Millions of kw-hr.				Kilowatt Peak			
Year	1930	1935	1940	1945	1930	1935	1940	1945
Rock Springs	31.0	40.5	52.9	68.5	10000	12800	16300	21000
Green River	1.7	2.5	3.5	5.0	450	570	720	940
Total	32.7	43.0	56.4	73.5	10450	13370	17020	21940

The Laramie-Cheyenne territory in Wyoming can be served by a transmission line about 150 miles long and about 50 miles additional would effect a tie with the existing system of the Public Service Company of Colorado at Fort Collins, Colorado, which would give a direct connection to the Denver, Colorado, district.

The probable load conditions of the Wyoming section of this territory as estimated by the operating power companies is as follows:

	Millions of kw-hr.				Kilowatt Peak			
Year	1930	1935	1940	1945	1930	1935	1940	1945
Hanna	2.4	2.9	3.4	4.0	1100	1200	1300	1400
Laramie	9.8	14.5	21.4	31.8	3500	5200	7600	11300
Cheyenne	11.2	15.0	17.9	20.8	3000	4280	5110	5930
Total	23.4	32.4	42.7	56.6	7600	10680	14010	18630

As the Colorado territory of the Public Service Company of Colorado is at present well supplied with hydroplants and a modern, efficient steam plant, it is believed that only a small part of the present load plus the future growth in load can be in any way assumed as prospective market for Seminoe power. From information secured from this company the following is estimated as forming the potential market:

Year	Millions of kw-hr.	Kilowatt Peak
1930	30	10,000
1935	130	37,000
1940	250	69,000
1945	425	130,000

In general there would appear to be no serious obstacle in securing the existing loads in the Wyoming territories mentioned. All the power generated, except on the North Platte project, is by means of small and comparatively inefficient steam plants. This is evidenced by the fact that the Mountain States Power Company has in Casper probably the most efficient steam plant in the State and still is willing to pay from 6 to 7 mills per kilowatt-hour for power at Guernsey and transmit it over 100 miles to Casper for use there.

The Colorado territory, however, on account of the long transmission distance and competition of a large, highly efficient steam plant near the load center, does not offer as bright a prospect, especially for firm power. It may, though, offer an excellent outlet for dump power until such time as this power can be absorbed in Wyoming territory on a firm power basis.

The Seminoe development as contemplated in the present plans would have an installed capacity of approximately 45,000 kv-a. and could produce an average annual output of about 150,000,000 kilowatt-hours. The present and anticipated loads of the market previously mentioned are summarized as follows:

	Millions of kw-hr.				Kilowatt Peak			
Year	1930	1935	1940	1945	1930	1935	1940	1945
Wyoming	74.0	107.7	158.1	227.3	24340	35240	48450	67060
Colorado	30.0	130.0	250.0	425.0	10000	37000	69000	130000
Total	104.0	237.7	408.1	652.3	34340	72240	117450	197060

If the Wyoming load only of the above tabulation can be secured it seems possible that there would be sufficient to load the Seminoe plant to two-thirds of its capacity by the time it could be built (1935) and to absorb its entire output by 1940.

In addition to the above-mentioned loads, which are quite probable and depend only on continued growth of present load at a somewhat less rate than has been experienced in the past, there exist many potential possibilities especially in the mining and refining of minerals. A publication of the Wyoming Geological Survey entitled: "The Developed and Undeveloped Mineral Resources of Wyoming," printed in 1929 as Bulletin XXI, goes into considerable detail in discussing these possibilities. The prospects which are reported in this publication as offering the most promising prospects are briefly listed as follows:

Titaniferous iron ore near Iron Mountain
Hematite iron ore near Seminoe Mountains
Chrome iron ore near Casper Mountain
Mineral fertilizers from Wamsutter to west
Magnesium salts near Medicine Bow
Copper near Tie Siding and Encampment
Platinum near Centennial
Manganese near head of Sheep Creek

In an address given by State Geologist John G. Marzel before the Casper Chamber of Commerce in 1929 he especially stressed the value of the titaniferous ores at Iron Mountain and the chrome iron deposits at Casper Mountain. The successful reduction of both these ores is reported as depending on the heat of the electric arc and would require large quantities of power.

In a report dated March, 1927, by the U. S. Forest Service, the potential possibilities for a paper mill at Laramie, Wyoming, were discussed. An annual yield of 1,289,000 railroad ties, 15,200,000 board feet of saw logs and 68,440 cords of pulpwood without depletion of the timber stand was reported as possible. A potential market for 50,000 tons per annum of newsprint was stated to be available in the adjacent mountain states territory. A pulp mill to supply this amount of newsprint would be a very considerable user of power.

In past reports on possible market for this development mention has been made of the electrification of the Union Pacific Railroad. Present information indicates that, due to the very marked increase in power, speed and efficiency of present-day steam locomotives and to the present and prospective amount of traffic, it is not probable that this will be accomplished for a number of years to come.

A considerable potential market may also exist in the electrification of oil fields which are now developed or may be discovered in the future. Even in the Salt Creek field, which is now supplied by a large modern steam plant, the use of gas for fuel is being objected to due to its contended higher value for removing oil from the wells by the repressuring system. The necessity of pumping condensing water through a very long pipe line is also a serious factor in the cost of operation of this plant.

Summary and Conclusions

The Seminoe reservoir, if built to a capacity of 910,000 acre feet, will provide the needed water supply for the Casper-Alcova project and incidentally permit an annual power output of 150,000,000 K. W. H. with production costs, including repayment of reservoir and power facilities in 50 years with 4% interest, as follows:

	Construction Cost	Necessary Selling Price of Power to Repay Cost with Interest at 4%
Dam and power plant—no transmission lines	$6,160,000	2.4 mills per K.W.H.
Dam, power plant, and transmission lines to Casper, Rawlins, Cheyenne and Colorado	$8,045,000	3.9 mills per K.W.H.
Dam, power plant, and transmission lines to Casper, Rock Springs and Cheyenne	$8,500,000	4.2 mills per K.W.H.

Nearby Wyoming power markets are supplied from steam plants with production costs such that Seminoe power should be readily salable at prices at least as high as the amounts indicated to be required to repay construction costs with interest. Normal growth in existing power uses would consume the entire output by 1940.

The utilization of power in new chemical and metallurgical industries also offers some possibilities.

Map

The report of the Reclamation Service is accompanied by a large map insert that shows the high dams, hydroelectric plants, coal and gas-fired steam power plants, substations, Government and public utility transmission lines already completed in the North Platte basin. The Seminoe power site and the three transmission lines proposed therefrom also appear on the map.

Inquiries in regard to the unpublished map should be addressed to the Denver office of the U. S. Reclamation Service. No map has yet been projected that shows all of the mineral, fuel and chemical deposits in the North Platte basin. None of those locations appear on the preceding map. To plot all of the ore deposits, chemical beds, oil, gas and coal fields merely intersected by the North Platte channel would badly mess up any map not printed in several color tones.

National Power Costs

The preceding report does not record the costs of generating power at other points. At this time a number of taxpayers in Wyoming desire figures on comparative costs. A request for a cost list was accordingly addressed to the General Electric Company. The letter was referred to their Consulting Chemical Engineer, C. L. Mantell, Ph.D., Pratt Institute, Brooklyn. As Dr. Mantell had recently completed an international power-cost survey he kindly supplied the following table on current charges at nine major points in this country.

Power Costs at Electrochemical Centers

Locality	Type of Plant	Power Cost Mills per kw.-hr.
Alabama	Steam	3.8-6
Anniston, Ala.	Steam	5
California	Steam	3.8-6
Great Falls, Mont.	Hydro	3 -4
Kanawha Valley, W. Va.	Steam and hydro	4 -8
Massena, N. Y.	Hydro	3.8
Niagara Falls, N. Y.	Hydro	3 up
St. Louis	Steam	4 -5
Tennessee	Steam	3.8-6

A broader list of typical power costs appears in Mantell's Industrial Electrochemistry published in 1931 by the McGraw-Hill Company, New York. Therein, the rates for this country as well as for hydro points in Canada, Norway, France, Switzerland and other European nations are arranged in comparative form.

The Mantell tables quote no domestic power cost as low as the 2.4 mill rate calculated for sales at the switchboard in the Goverment report. That comparison is made because a number of important ore and alkali deposits are known to occur within a 10 mile radius of the Seminoe power site. The higher 3.9-4.2 mill rates are delivery costs over systems that include the construction of several hundred miles of transmission lines to proposed terminals in Wyoming as well as in Colorado.

It must be noted that the rates quoted by the Government are selling costs. Those figures allow for interest, amortization, depreciation, overhead and all other charges incidental to the operation of a big hydro project in a profitable business-like way. By this time the engineers of the Reclamation Service have accumulated considerable experience in operating power projects within the highly remunerative Wyoming field.

Hereinbefore, conclusions have been filed to the effect that it would require the output of two projects of the Seminoe size just to develop the ore and chemical deposits known to occur in or near the City of Casper. The mapped length of the transmission line from the Seminoe site to Casper is only 58 miles. Should no additional lines be constructed firm power would be sold in Casper at 2.7 mills per kw.-hr. No power cost listed in the Mantell tables is as low as the Casper figure. At those major electrochemical centers the cost of power ranges from 10 to 200 per cent higher than the price calculated for Casper.

As repeatedly stressed the electrochemical industries must have cheap power. In recent years a few large electrochemical and electrometal concerns have been searching the country for power at the very lowest prices obtainable. As stated before such sites are absolutely essential for the treatment and reduction of high-priced foreign ores and chemicals.

It is little wonder that the electrochemist is constantly on the lookout for low cost kw.-hr. In time he may not only seek the rock-bottom rate but also be forced to look for a basin in which a wide variety of metals, alloys and chemicals can be produced without utilizing foreign ores, minerals, salts and fluxes for his fundamental electrolytes and furnace charges. The discovery of a fully self-sustaining hydro basin in Wyoming or in any other state would add a brand new chapter to American electrochemical practice.

Engineering economists from Wyoming as well as from one neighboring state advise us that hydro development must always remain subservient to the needs of another industry in the North Platte valley. Profitable development of the Wyoming basin must logically rest on its inherent ability to turn out finished products on a highly competitive basis, or say, at cost levels that cannot be duplicated elsewhere. Natural endowments generally play an important role in the growth and evolution of any community.

The cost of producing one electrical unit of energy in the North Platte basin has already been calculated. Figures are also available on the cost of irrigating one acre of land in the same basin. As yet no adherent of the subserviency hypothesis has taken the trouble to publish a book on comparative irrigation costs in Wyoming or elsewhere.

Secondary Power

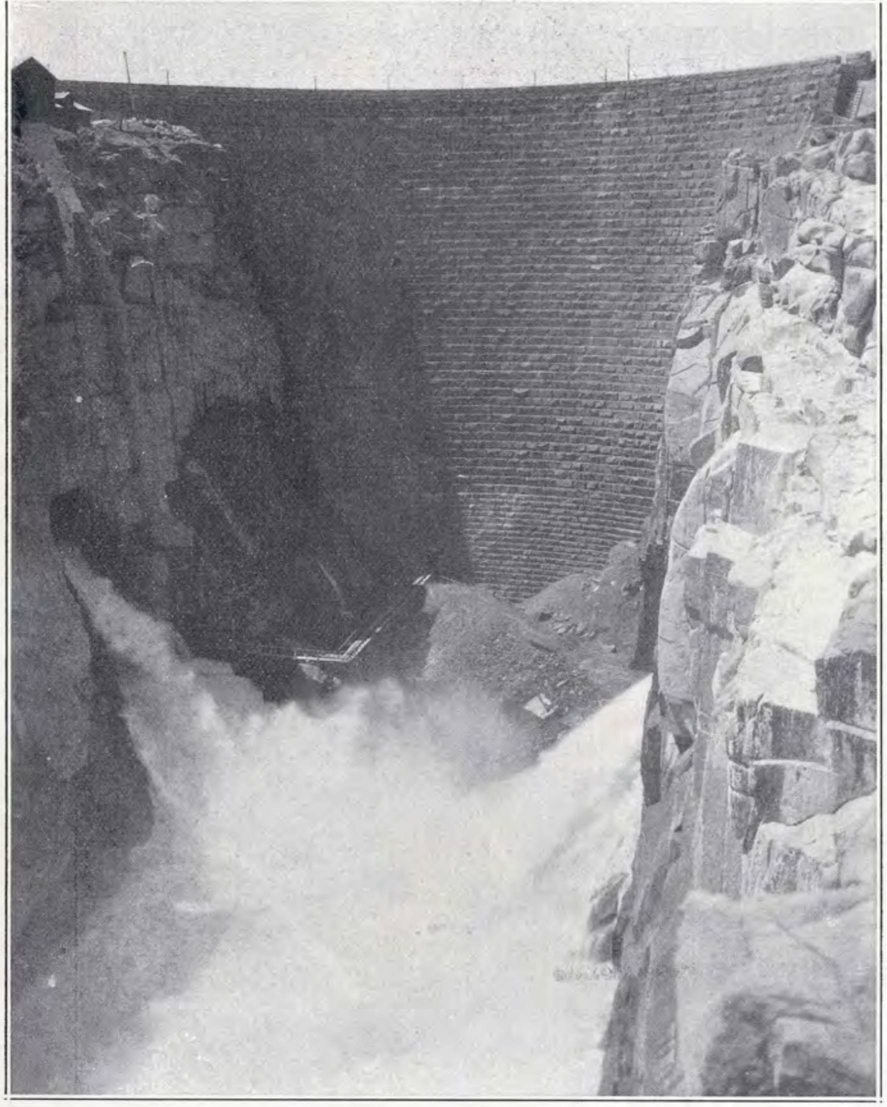
The dump power potential of the North Platte channel is not discussed at length in the preceding report. Two dams below the Seminoe site could be utilized for raising the power output of the North Platte 400 per cent throughout the irrigation season. The water supply would be released from huge storage reservoirs and the production of extra power would be regulated at a uniform rate during several months of the irrigation period.

On page 225 is a photograph of the Pathfinder storage dam constructed some 20 years ago to a height of 218 feet. This dam is 38 miles southwest of Casper. One-half of its head should be utilized for seasonal power development. In that lower down gorge the discharge of the North Platte is considerably greater than in the Seminoe Canyon. The 16-foot higher head would also permit greater power output at the constructed dam during the irrigation season. As soon as the Seminoe system is completed, cost of power development and transmission from the Pathfinder dam would merely involve the construction of a power plant.

On the following page is a photograph of the diversion dam proposed for the Casper-Alcova irrigation project. The line drawn on the photograph shows the designed height of the dam. That elevation is 169 feet above the low water elevation of the river. When completed the diversion dam will be 5 feet higher than Niagara Falls. Water will go over the top of the dam every day of the year and all of the head will be available for power development. The diversion dam will also be on the route of the proposed transmission line to Casper. Most of the seasonal power of the North Platte will likely be developed at the Alcova site which lies but 28 miles southwest of Casper.

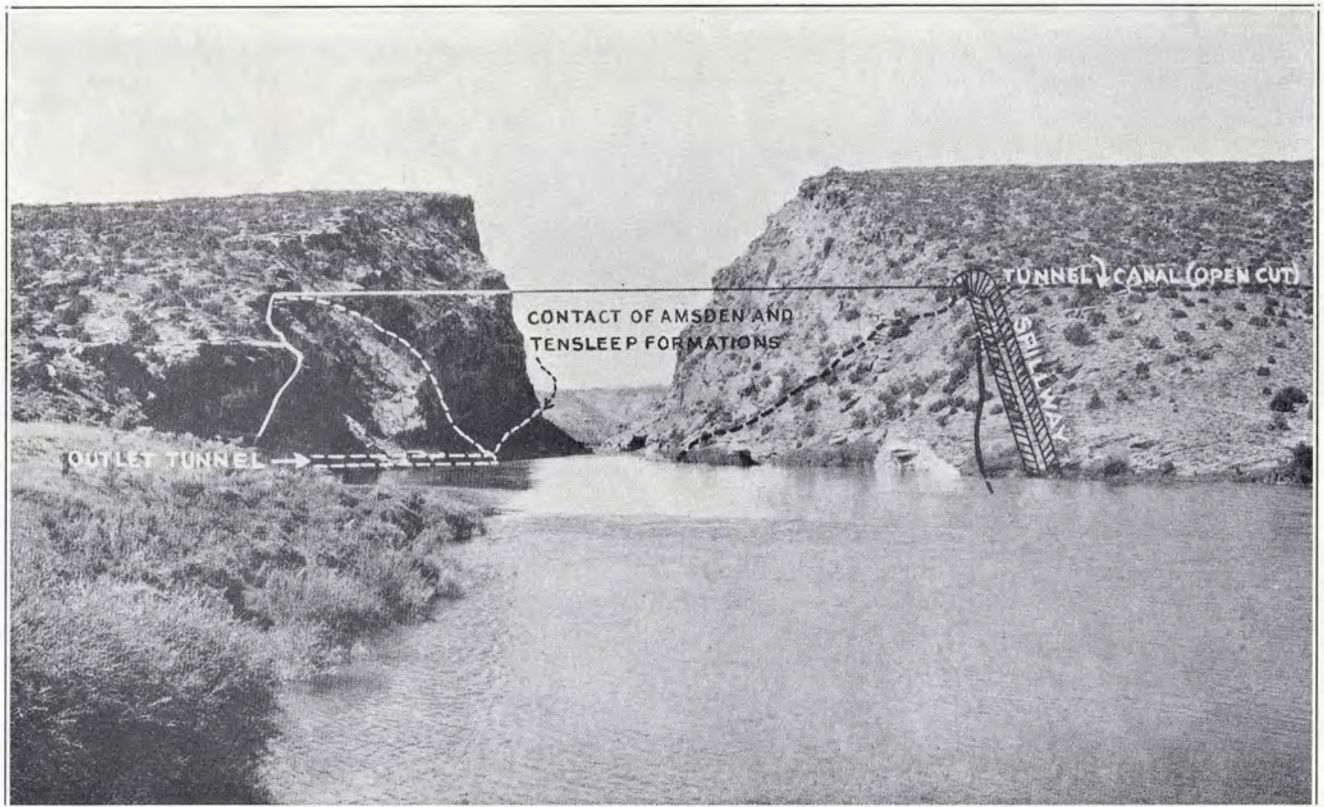
Irrigation operations on the precipitous channel of the North Platte are exceedingly favorable for the development of low-cost dump power as an incidental by-product. Large volumes of such highly stabilized energy should be utilized for seasonal mining and milling operations as well as for the reduction of the more refractory types of ores known to occur in Natrona and other counties. Furthermore, such secondary energy could be profitably exploited in Wyoming at one-third of the record low figure hereinbefore quoted for firm power.

The North Platte and Niagara rivers differ in one respect. Between the lakes Erie and Ontario levels the total fall of the Niagara river is only 326 feet. Between the Colorado and Nebraska boundaries, the North Platte river drops 3,900 feet



(COURTESY UNITED STATES RECLAMATION SERVICE)

Pathfinder Dam Near Casper



(COURTESY UNITED STATES RECLAMATION SERVICE)

Site for Casper-Alcova Diversion Dam

in Wyoming. All but 1,100 feet of that mountainous obliquity is in the channel that lies above the City of Casper.

In the scenic Wonderland of Wyoming the North Platte has carved out three or more canyons far deeper and longer than the single gorge so far eroded away in the youthful Niagara channel. At previously photographed sites a number of barriers equally as high as Niagara could be constructed for low-cost power production. On page 149 the possibilities of reusing the rapidly descending flow of the North Platte several times for localized mineral development is pointed out.

Other Firm Power Sites

While this manuscript was in preparation it was necessary to call on Mr. E. B. Debler, Chief Hydraulic Engineer for the U. S. Reclamation Service. On one occasion he mentioned that the Seminoe Canyon provided two power sites. Both locations were described as of equal merit for the development of identical volumes of power. In a private report prepared by the U. S. Geological Survey those locations are called Damsites, No. 1 and No. 2. The intervening distance is about 10 miles and due to the sharply ascending gradient the waters impounded by the lower dam would not extend to the higher site. Final selection of the Seminoe power site may yet require some exceptionally close figuring as to the respective costs per kw.-hr. generated.

In the opinion of the writer it is safe for private capital to develop all of the firm power resources of the North Platte river that could be profitably sold at or below the rates now charged in the Niagara district. In the Seminoe Canyon power construction would relieve the Government from building one of the regulation service dams proposed for the main Casper-Alcova irrigation system. Obviously, construction of that beneficial order should never be financed without first sounding out the cooperative attitude of the U. S. Reclamation Service.

Power Profits

Some taxpayers in Wyoming and elsewhere continue to look upon power development on the North Platte river wholly in the light of a hopeless subsidy. Few half-informed critics profess any knowledge as to the unexampled profit margins—per horse power generated — that the Government has annually collected from projects so far completed on the severely condemned Wyoming channel. In this defensive publication financial reports of recent date must likewise be exhibited. In the May, 1932 issue of "The Reclamation Era" power development history on the North Platte river is summarized as follows:

> ### *Lingle and Guernsey Plants*
>
> There are two hydro electric power plants on the North Platte project. The smaller of these, known as the Lingle power plant, located on the Fort Laramie Canal, was originally built to furnish cheap power for the operation of electric excavators engaged on the construction of the Fort Laramie Canal. The plant was placed in service on May 1, 1919, and on December 4, 1919, service was begun to the town of Torrington, Wyo. As the main transmission lines were extended eastward, additional towns contracted for power and the Government is now supplying power to 9 towns, 4 companies, and 2 irrigation districts. The original Lingle power plant contained two generating units having a combined installed capacity of 750 kilovolt amperes. In 1925 the plant was rebuilt and two additional units were added, making the total installed capacity 1,750 kilovolt amperes. The turbines operate under a head of 107 feet.
>
> The Guernsey power plant, located at the Guernsey Dam on the North Platte River, was placed in operation on July 26, 1927. It contains two generating units operating under heads varying from 70 to 90 feet, and the total installed capacity is 6,000 kilovolt amperes. Net power revenues on the North Platte project now average well over $200,000 per year. Since the Lingle plant was first placed in service in 1919 to the end of 1931 the net revenues from sale of power over and above the amounts required to provide for operation and maintenance, have

amounted to over $1,000,000. The net revenues, after setting aside suitable amounts to cover the estimated depreciation of the power system, are credited to the irrigation districts on the North Platte project and applied on their annual construction payments.

The following clipping records the comparative profits that were earned on all successful Government hydro projects during the year 1932:

Power Sales Finance U. S. Projects

Western Electrical Plants Aid Federal Reclamation Work

Government Bureau Makes Annual Report Showing Profits Earned Thru Irrigation Work; Finance Program Studied

(By Charles O. Gridley, Denver Post Staff Correspondent)

Washington, D. C., Dec. 3.—Expansion of federal reclamation in the future may be financed chiefly thru the income from one of its by-products—the development of hydroelectric power—which is already yielding a net revenue of $400,000 annually from twenty plants on eleven projects in western states.

From the manufacture of cheap power for pumping purposes, plants on several projects have progressed to the development of all electricity used by settlers, with a substantial surplus for commercial sale.

The annual report of the bureau of reclamation, issued Saturday, lists among the profitable power plants of federal reclamation projects those on the North Platte project in Nebraska, which earned a net revenue of $177,850 during the last fiscal year; the Boise and Minidoka projects in Idaho, which earned $89,940 and $112,631, respectively; the Shoshone project in Wyoming, with earnings of $31,425, and the Yuma project in Arizona, with $56,231.

Revenue Is Larger Than Payments

On the last of those projects, the revenue is larger than contract payments required from irrigators, with the result that the lands of the valley division will receive a credit of $1 per acre this year.

> The prosperity of the power plants confronts the federal reclamation bureau with the need of a fixed policy regarding the application of this income, which threatens to provoke a controversy with settlers in several instances.
>
> The bureau maintains that since the hydroelectric installations have been paid for by the government, the profits should be applied first to the repayment of plant construction cost, next to repayment of the construction cost of the dam or other structure which makes the power development possible, and third to the reclamation fund to be used for building additional reclamation works.

In the Washington dispatch the North Platte project is accredited to Nebraska. Most all of its irrigable acreage is in Nebraska but the first citation indicates that all power works thus far constructed on the system are in Wyoming. The same remarks will likely apply to future power works. Hereinbefore, the vertical drop in the Wyoming channel was recorded at 3,900 feet. That declivity may prove sufficiently steep to rank the North Platte river as the No. 1 profit-payer of the Government for many years yet to come.

In recent years the Government has entered more and more lines of business. Apparently, not all of the newer ventures are on the right side of the ledger at the end of the year. In Wyoming, however, the Government is known to operate two forms of industrial enterprises on an extremely profitable basis per dollar invested. During periods of pronounced distress some members of the laity are of the opinion that the Government should confine most of its expansion activities to undertakings that have a chance to pay out a profit especially in the never-failing Wyoming field.

Current Criticism

For some inexplicable reason most all of the criticism so far hurled against the Seminoe power proposals comes from professional engineers, hydraulic and otherwise. In the December 2, 1932 issue of the Cheyenne Tribune an outside engineer is accredited as having made the following assertion in the Capitol building during a stated session of a debating club:

> "It is no fault of Colorado, he added, that the North Platte in Wyoming flows through deep canons and cannot be reached."

The preceding statement was made by the bitterest critic that has so far appeared against the Seminoe proposals. He can see no merit in that power-site regardless of the extremely rare type of topography he described for the immediate locale. Elsewhere, groundwork of the preceding portrayal has been pronounced as of fundamental importance for power generation at the rock-bottom cost per kw.-hr. produced.

Apparently some technically trained critics are unaware of the truly prodigious forces that combined terrestrial and celestial influences expend in the construction of a first-class hydrosite. Hereinbefore, the Niagara and the North Platte rivers have suffered comparison from several angles. Recessional measurements not necessary to outline herein seem to quite accurately establish the birth date of the Niagara gorge at only 10,000 years ago. On the other hand the North Platte required a considerably longer interval to carve out its more scenic rock-ribbed canyons. In this locality the terrestrial isostatic equilibrium was disturbed in a pronounced manner approximately 75 million years ago. Since then Old Sol has unceasingly continued to transport sizable volumes of aqueous vapor from distant oceans to the uplifted terrain of Wyoming. In 1932 the weight of the condensed vapor that passed the gaging station at Casper was calibrated in round numbers at slightly more than 1¾ billion tons. That weight does not have to drop very far before perceptible energy is created. In Natrona County a number of folks are of the opinion that at least 3 or 4 per cent of a 3,900-foot plunge of aqua pura should be harnessed for all time, preferably, in the Seminoe Canyon.

During the past few months the Seminoe power proposals have served as a target for much misdirected disapprobation. In a publication of the present scope all aspersions of an engineering origin are dismissed as hopeless hokum.

Apparently the Seminoe project is immune from legal attacks. Classical decisions handed down by the higher Courts on riparian rights along the North Platte channel may continue to uphold its provisional water titles as instrumentalities eminently just and equitable to all concerned.

Another group of critics point out the unfairness of utilizing any portion of the irrigation funds contributed by Wyoming for the construction of irrigation projects in Wyoming. Many of the preceding objections are answered in the following letter of the Secretary of the Interior:

Department of the Interior,
Washington, February 29, 1932.

Hon. John Thomas,
Chairman Committee on Irrigation and
Reclamation, United States Senate.

My Dear Mr. Chairman:

In response to your request of January 19 for report on S. 2842, a bill to authorize construction of the Casper-Alcova division, North Platte project, Nebraska-Wyoming, I transmit herewith a memorandum on the subject that has been submitted by the commissioner of reclamation. After review of the proposed measure I agree with the commissioner.

I do not consider the proposal to apply the royalties from Natrona County, Wyo., directly to the Casper-Alcova project as startling as it may first appear. The reclamation fund has been built up over a period of years, one of its contributions being 52½ per cent of all royalties received by the Government. The total amount paid into the reclamation fund from this source as of June 30, 1931, stands at $40,384,803.34, of which $30,328,528.34 has been contributed by the State of Wyoming, which amount has largely been contributed by Natrona County wherein the Casper-Alcova project is situated. The proposal to apply future oil royalties to the Casper-Alcova project for a temporary period I believe to be an equitable adjustment

> of the unusual contribution of Wyoming to this fund. The development of this project will in the end contribute toward the perpetuation of the reclamation fund in that revenues from the proposed power plant will eventually become perpetual increments when the fund can no longer look to oil royalties as a source of income.
>
> The matter has been submitted to the Director of the Bureau of the Budget, who advises that there is no objection to this legislation subject to the specific understanding that the expeditures for this project from the reclamation fund can be regulated so as not to further impair the future solvency of that fund within the meaning of requiring advances to that fund from the general Treasury.
>
> Very truly yours,
> Ray Lyman Wilbur.

A number of private individuals have also been known to question the merits of the Seminoe power-site. Unofficial criticism of an unorganized order is not subject to review in this tome.

Seminoe Dam Substitutes

Various contrivances have already been devised for something just as good as the Seminoe Dam. In castle-building the previously quoted engineer recently jumped to the head of the class. In this commentary only two of his latest improvisations are touched upon.

Instead of damming water in the deep rock canyons that * * * "the North Platte in Wyoming flows through" * * * the cited engineer has discovered impoundage sites somewhere * * * "near the Nebraska state-line." By building two reservoirs in that locality he estimates that * * * "they together would hold about 400,000 acre feet for emergency use." In other words those two basins together would be nearly half as good as the single Seminoe reservoir for which the Government engineers have already designed an unfailing impoundage capacity of 910,000 acre feet for continuous release throughout the year.

Until more definite information is on hand, the two substitute reservoirs may safely be regarded as common mud ponds of highly speculative value for storage and absolutely impossible for the production of power revenue. Instead of being built in a leak-proof container of solid rock the recommended reservoirs will more likely occupy shallow sand basins on wind-swept plains, whereat more than half of their calculated storages will annually vanish in the form of evaporation. Such engineering grotesqueries simply do not belong in the future picture of industrial Wyoming.

In the last sentence of the cited Washington dispatch the Reclamation Service strongly stresses the necessity of utilizing power profits * * * "for building additional reclamation works." Apparently, the irrigation industry is no longer able to stand on its own feet. In the chemical and mineral depository of Wyoming, the erection of power dams should always precede the construction of the more costly irrigation units of a generalized river improvement program. Under one operating project, the Government would have to step up its annual water charges around $50 an acre before the irrigationist would pay the profit parity exacted from the power customer.

Profitable operations of any description generally reflect indirect benefits upon the surrounding community. In Torrington, Wyo., the cost of local government has been financed exclusively by the resale of power purchased from a Federal hydro project. What this country mostly needs is more tax-free municipalities. In Wyoming, only one type of engineering structure has fulfilled expectations in that direction.

The sizable volumes of energy that terrestrial and extrinsic agencies consume in constructing a feasible hydrosite, free of charge, has already been outlined. Should the present generation decide to duplicate the scale of rock carving thus far completed in Wyoming, provision should first be made for the erection of a flock of dynamite factories. Nevertheless, proposals have recently been heard in Colorado for transporting one-half the flow of the North Platte from the western to the eastern slope of one of the loftier mountains on the Great Divide.

A few years ago a puny railroad bore was at last driven through the Colorado Rockies by the expenditure of capital on a shockingly extravagant scale. Many years may pass before another tunnel nostrum is successfully launched in this general territory at the expense of the taxpayers.

A transmontane diversion of the mighty Platte is really an engineering proposal of the first water.

Chapters
18 to 21
Not Completed

Chemical composition of some of the larger Wyoming alkali deposits—Continued.

Name of alkali deposit or lake	Sample as received											Calculated as dry salts						Analyst†	Remarks
	Laboratory No.*	Water	Insoluble	Sodium sulphate	Sodium chloride	Sodium carbonate	Calcium sulphate	Magnesium sulphate	Magnesium chloride	Sodium borate	Sodium bicarbonate	Sodium sulphate	Sodium chloride	Sodium carbonate	Calcium sulphate	Magnesium sulphate	Sodium bicarbonate		
Carbon County																			
Bull Spring or Bothwell	158	46.99	4.15	44.92	1.32			2 62				91.94	2.69			5.37		S.	Sampled at surface.
Do.	159	42.99	1.79	55.05	.17			Tr.				99.68	.32					S.	Sampled at 1 foot depth.
Do.	160	17.08	10.71	69.16	.84			2.21				95.78	1.16			3.06		S.	Sampled at 2 feet depth.
Do.	157	34.11																S.	Selected crystals.
Dillon	168	35.18	8.57	38.22	3.75		13.27	1.01				88.92	2.35			8.73		S.	Surface deposit.
Natrona County.																			
Morgan:																			
Top crust		6.93	0.43	84.86	1.55	6.23						91.60	1.68	6.72				A.	Sampled by D. H. Attfield in February, 1891. (See Jour. Soc. Chem. Ind., January, 1895.)
New deposit		53.89	.41	43.93	.77	1.00						96.14	1.68	2.18				A.	
Old deposit		40.70	25.40	32.28	.45	1.17						95.24	1.33	3.43				A.	
Independence Group:																			
New York	149	53.02	.33	36.80	3.81	6.04						78.86	8.20	12.94				S.	Surface sample.
Do.	150	36.66	39.05	17.87	2.94	4.48						70.66	11.62	17.72				S.	Sample from 4 inches depth.
Do.	151	47.58	9.67	40.86	.77	1.12						95.58	1.80	2.62				S.	Sample from 4 to 12 inches depth.
Wilmington	152	51.99	9.14	21.42	2.90	14.55						55.14	7.47	37.42				S.	Deposits along shore of lake.
Do.	153	55.10	.74	42.34	.28	1.54						95.80	.60	3.60				S.	Deposits from bottom of lake.
Do.	154											24.40	17.71	57.89				S.	Lake water; specific gravity 1.104.
Wilkesbarre			9.23									39.04	1.83	59.00				R.	Dried sample.
Omaha	79	36.67	.97	25.88	4.83	26.83					4.82	41.51	7.74	43.02			7.73	S.	Surface sample.
Do.	78	45.21	.71	6.85	.05	47.18						12.67	.09	87.24				S.	Salt from surface to 10 inches depth.
Do.	77	49.97	19.04	2.94	1.50	26.55						9.49	4.84	85.67				S.	Salt from 10 to 14 inches depth.
Do.	76	53.17	18.29	4.66	1.16	17.31					5.41	16.36	4.05	60.62			18.97	S.	Salt from 14 to 17 inches depth.
Do.	148	39.46	30.30	11.25	.95	18.04						37.20	3.14	59.66				S.	Salt from 2 feet depth.
Berthaton	80	51.21	7.01	15.61	2.63	21.00					2.54	37.36	6.30	50.26			6.08	S.	Surface sample.
Do.	81	53.87	3.06	14.75	2.66	59.55						34.27	6.16	59.57				S.	From large lake and from best product of deposit.
Do.	84											20.44	13.84	65.72				S.	Solution from upper lake.
Gill		1.61		94.50	.54			2.52										R.	Undetermined and loss 0.83.

*Numbers used by E. E. Slosson in Bull. Wyoming Exper. Sta. No. 49. †S., E. E. Slosson; P., H. Pemberton and G. P. Tucker; A., D. H. Attfield; R., L. D. Ricketts.

Map

The Schultz report contains a map that shows the location of the 12 most important alkali deposits in Wyoming. They include the salt deposits in Crook and Lincoln Counties, the magnesium sulphate lakes in Carbon County and the sodium sulphate and sodium carbonate deposits in Albany, Carbon and Natrona Counties. Unfortunately, the U. S. Geological Survey no longer retains possession of the preceding map plate.

An informative publication on the interlocking resources of southeastern Wyoming would require more than a map of its chemical deposits. By this time a map of the leading hydrosites and developments as well as the Government and private transmission lines would be equally desirable. To complete the picture other maps should show the major deposits of common and rare ores that are susceptible of reduction in the electric furnace if certain alkalis are utilized for the fluxing and separatory agents. Another map should be made of the oil, gas and coal fields. Such a chart would necessarily delineate a thousand miles or more of the oil, gas, naptha and gasoline pipelines that also serve for the basic nervework of an industrial valley in the making. A complete atlas would include a plat of the leading railways, highways and arterial airways already established in the valley. Manifestly, the assemblage of such cartographic exhibits would more than double the cost of the present handbook.

Schultz stated that all soda lakes of commercial importance are in Albany, Carbon and Natrona Counties. Aside from Laramie, they are the three most populous counties in southeastern Wyoming. These counties appear on the adjoining pictorial map recently published by the Casper Chamber of Commerce. None of the salt beds are plotted on the present map insert. Nevertheless, several locations from the nearest town or city are listed on the preceding tables. At this time

PICTORIAL MAP OF WYOMING

(Courtesy Casper Chamber of Commerce)

the producing lakes either adjoin or are located near the rights-of-way of leading railway lines.

The listed analyses account for three different types of lake beds in Wyoming. The deposits of sodium sulphate are more abundant than the sodium carbonate and magnesium sulphate beds. As import figures show that serious shortages of sodium sulphate are rapidly developing in this country, the ensuing descriptions are mainly devoted to the latter alkali.

Future Reports

It is often heard that an up-to-date geological report would stimulate development of the variegated salt resources that are found, here and there, in this State. Such effort would call for unnecessary duplication. Over 30 years ago a report was completed by the late Professor Knight of the University of Wyoming. All of the facts amassed in the preceding tabulations were copied from data originally assembled by two painstaking professors of the University. Their labors may have been completed at a premature date, but so far their highly informative compilations have weathered the test of time. Higher analyses have since been published for the magnesium sulphate beds, but their inclusion in the present digest would unnecessarily complicate debatable issues of minor moment.

Interest in the industrial potentialities of the Wyoming alkalis will likely remain dormant until they are collectively examined by a technologist personally acquainted with the revolutionary changes that have taken place in the chemical industry within the past four or five years. In neighboring states soda lakes have recently been leased on Government lands. Elsewhere, state and federal treasuries have displayed some concern in regard to the new source of royalty receipts.

In Wyoming soda lakes are known to occur on the Public Domain and to a lesser extent on the millions of acres still owned by the state itself. No chemical lake beds are purer or lie as close to the national markets than those of Wyoming. Should a perceptible decline occur in the oil royalty receipts it might pay to conduct an inquiry as to the public revenue potential of the salt beds in this state. Obviously, an industrial translation of all facts massed in the preceding compilations would be a time consuming affair. For accelerated results such a job should be delegated to a name that carries weight in the salt world.

An investigation of the preceding scope might prove too costly. In time the expenditure may be entirely obviated. As soon as the Kendrick $8,000,000 hydro system is built, investigations of varying degrees of complexity would necessarily be financed by chemical concerns. The story has already been told of the interest that embryonic industries displayed as soon as plans were announced for harnessing another power channel. No chemical deposits of any description are intersected by the route of that river. In the Wyoming basin a wide diversification of high power chemicals appear on the open terrain.

Salt

A few of the alkalis listed in the preceding tabulations contain small amounts of common salt. In Wyoming no halide beds appear on the surface and no underground deposits of commercial importance are officially recognized in the quarter of the state covered by the present compendium.

In the preceding citation Schultz mentioned that * * * "extensive beds of salt of great purity occur in Crook County." From Casper those beds are almost as distant as the present sources of supply for the big industries at Niagara Falls. In Wyoming that distance (125 miles) is too far to go for any raw material.

Economically speaking, common salt does not belong to the group of alkalis reviewed in this chapter. This country will never experience a shortage of the preceding ubiquity. Excessive supplies of raw materials generally develop pronounced overproduction evils during periods of prolonged depression. Moreover, the present book contract excludes specific descriptions of resources utilized by industries not yet freed of excessive overcapacitation or underconsumption problems. Such discussions would be highly unseasonable and in no way descriptive of municipal backgrounds that present a wide range of selectivity for industrial pursuits. At Casper electrochemical operations should supplement and not conflict with industries long established elsewhere.

National Review

Improved technology particularly in the Niagara Falls area, has brought about radical changes in the basic chemical industry during the five-year period last past. Unfortunately, new processes have eliminated the old reliable sources of supply for sodium sulphate in this country. The serious after-effects of salt cake (sodium sulphate) curtailment is disclosed in the December, 1932 issue of Chemical and Metallurgical Engineering. Extracts from their review follow:

> ### *Changes in Acid Manufacture Cut Down Salt Cake (Sodium Sulphate) Supply*
>
> Census figures for 1931 report a material falling off in domestic production of hydrochloric and nitric acids in comparison with the totals produced in 1929. In each case, the smaller output reflects the position of the different consuming industries. On the same authority production of salt cake in 1931 was 121,366 tons compared with 206,612 tons in 1929 and niter cake totals were 34,908 tons and 111,522 tons for 1931 and 1929 respectively.
>
> The fact that the salt cake supply for the two-year period declined to a greater degree than hydrochloric acid supply calls attention to the effects which followed the

change in process for manufacturing the acid. This is exemplified still more strikingly in the case of nitric acid and niter cake. Production of nitric acid in 1931 was less than 19 per cent below that reported for 1929. In contrast, production of niter cake for the same interval was reduced close to 69 per cent. In fact the statistics for niter cake bear out the report that, with one exception, nitric acid manufacturers are employing the ammonia-oxidation process.

The curtailment of salt cake production as a byproduct of hydrochloric acid manufacture gave some stimulus to the development of natural deposits in recent years. Production of sodium sulphates from natural deposits in 1931 were reported at 32,510 tons compared with 32,630 tons in 1930. These totals include glaubers salt as well as salt cake.

Production

Production of natural sodium sulphate in the United States in recent years was as follows:

	Short Tons	Value
1931	32,510	$198,132
1930	32,630	203,348
1929	7,540	41,199
1928	6,580	42,485

Imports of salt cake (sodium sulphate) increased very appreciably in recent years with import data as follows:

	Lb.	Value
1931	151,061,330	$860,738
1930	173,329,114	892,154
1929	125,181,318	549,736
1928	37,239,231	164,551
1927	16,207,970	76,222

The largest production of natural salt cake in 1931 was from the deposit owned by the Sodium Products Corp., leased and operated by the Arizona Chemical Co. The plant is located at Camp Verde, Ariz. The Rhodes Alkali & Chemical Corp. also produced a small quantity from deposits near Mina, Nev.

Recent reports from Monahans, Texas, state that the sodium impregnated waters of Soda Lake, situated 14 miles south of here, are to be commercialized on an extensive scale by the Ozark Chemical Co. of Tulsa, Okla., which has let the contract for the construction of a plant to cost $350,000 for the extraction of sodium sulphate from the

> lake. The company has been making tests and experiments during the last several months to determine the best method of handling the water. It was found that the sodium sulphate can be precipitated in practically its pure state by the freezing process.
>
> **New Production Planned**
>
> Further efforts to increase domestic production of natural salt cake are found in an announcement of last month to the effect that the Salt Lake Sodium Products Co. is preparing to erect a refining plant for the production of sulphate of soda and its derivatives from raw material obtained from the southeast shore of Great Salt Lake, near Saltair, Utah. The company is operating under a sublease from the Great Salt Lake Chemical Co. of Salt Lake City.
>
> **Imports**
>
> Imports of salt cake have cut so deeply into the domestic trade that over a year ago a request for an anti-dumping order was requested by producers in this country. The application was strongly opposed by Kraft paper, textile and glass interests and it was decided that a decision of dumping was not justified.
>
> The hearings, however, which developed as a result of the dumping charge brought out considerable information about the domestic salt cake industry and among other things revealed that domestic output of natural cake could not compete in price with the imported material.
>
> German exports of sulphate of soda and niter cake in the first half of this year totaled 47,558 metric tons. Shipments to the chief markets were in metric tons, as follows: United States, 16,789; Belgium, 7,702; Sweden, 6,772; Finland, 3,183; the Netherlands, 2,111; Panama, 1,359; Czecho-Slovakia, 1,848; and Italy, 1,300.

Many different kinds of industries are in the United States. Only a few of them were able to stage a 400 per cent increase in both output and importation of the basic raw material during the four-year period of profound economic transition defined as 1928-1931, inclusive. The sodium sulphate industry belongs to the preceding category. At the present time over 80% of the sodium sulphate consumed in this country is the foreign salt. It is interesting to note that imports of the duty-free salt reached their highest known historic levels during the depths of the current depression. That economic anomaly is not surprising. Existing ideas on domestic shortages of sodium sulphate deposits may be laid to well meaning conservationists who have long been proclaiming Stone Age doctrines in regard to the apparent barrenness of industrial opportunities in southeastern Wyoming.

The previously inserted review accounts for a number of new sodium sulphate developments especially in states that are contiguous to Wyoming. Our lake beds lie nearest to the national markets and there is good reason to believe that sodium sulphate of the purity generally shipped by our neighbors could be produced at a lower cost in Wyoming. However, a nation-wide review accredits no new salt developments or expansions for this state.

Some states have accumulated considerable knowledge on the technological possibilities of their more unusual mineral deposits. While more mineral royalties have been collected from Wyoming than from all remaining states, nevertheless, only an insignificant portion of the preceding receipts have been ploughed back into the mineral industry. In Wyoming such revenues are generally distributed to outlets that have little or nothing to do with the mineral industry.

Foreign countries mainly supply the domestic requirements of the several types of resources selected for review in the preceding chapters. For raising the self-sufficiency factor of this country no state offers the diversified opportunities of Wyoming. In times of ugly depression some dependence should be placed on research work, heretofore the seed and germ of all economic life. Perhaps, one state may soon develop ways and means for placing a few hundred of the unemployed millions on the payrolls of new-type industries. Progress in that direction would measurably fortify the financial structure of the nation in several respects.

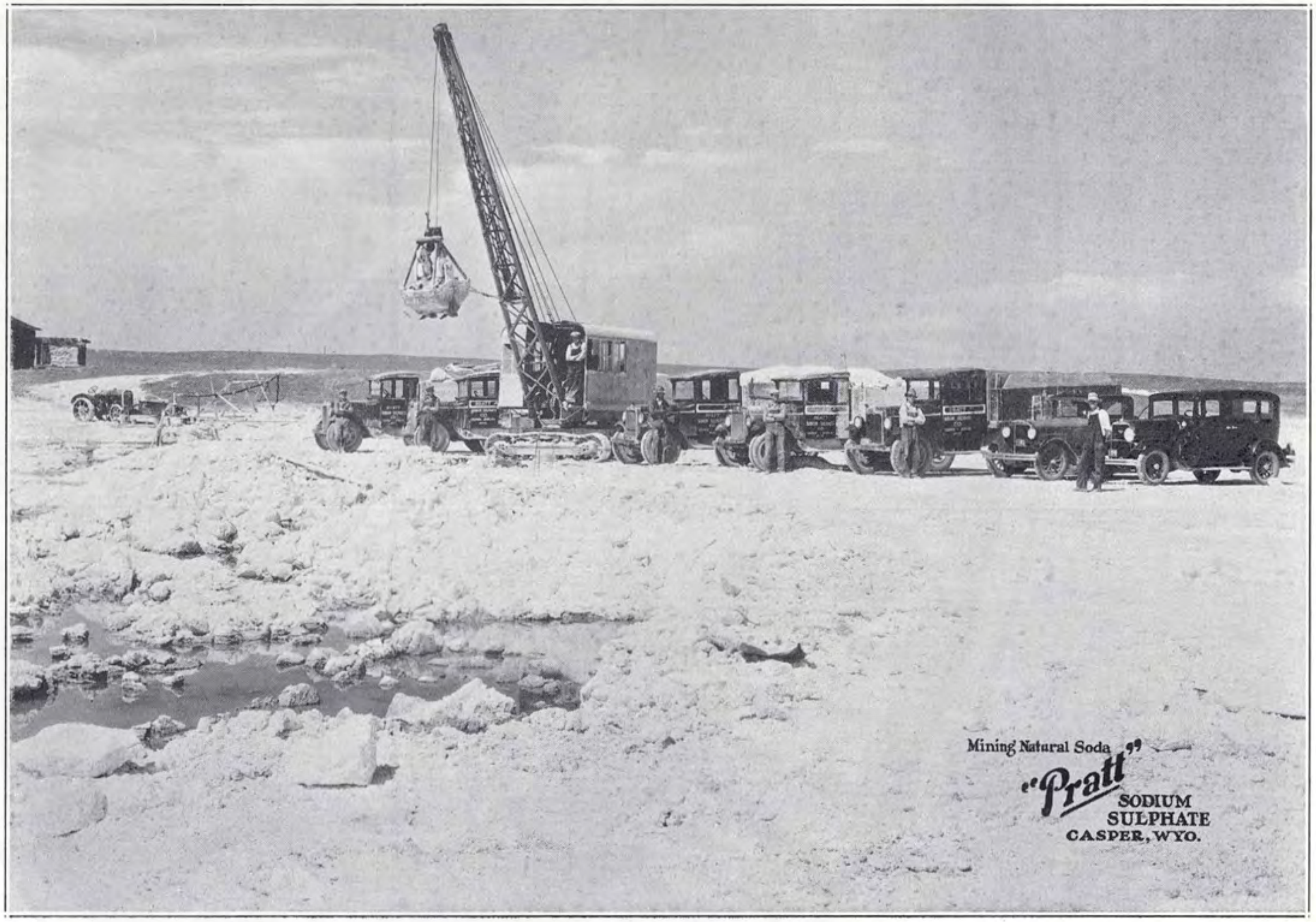
Wyoming Sodium Sulphate Production

During the past 14-year period the Gill Soda Company of Cheyenne and its lessees produced slightly over 50,000 tons of sodium sulphate from natural lake deposits situated in the vicinity of Casper. No figures were examined on the production of the Iowa Soda Products Company. The latter concern has been shipping sodium sulphate for three years from the large Bull Lake deposit situated 28 miles north of Rawlins. Their output to date is estimated at 10,000 tons.

In recent years the Pratt Sodium Sulphate Company, a leasing unit of the Gill Soda Company, has been the leading salt producer in the state. Most of its output is from Gill Lake which is located eight miles northeast of Casper. A view of the deposit showing the 10-foot thickness of the top-seam as well as the shovel and rolling stock equipment of the leasing company appears on an adjoining page.

The Pratt Company also produces considerable sodium sulphate from a private lake located about 4 miles east of Casper. The latter lake lies about ½ mile north of the loading racks on the Chicago & Northwestern and the Chicago, Burlington & Quincy railroads. In that vicinity those main granger roads respectively traverse the south and north shore lines of the North Platte River. Past operations accredit the lake with an annual inflow of 1,000 tons in soluble sodium sulphate. Its magnitude, however, was far too small to receive a listing under the preceding tabulations.

The principal warehouse of the company is located on the small lake. In view of the rail, water and suburban facilities mentioned, Mr. Pratt claims that the best location in the state for a metallurgical operation capable of consuming 15,000 tons



(Courtesy Casper Chamber of Commerce)

of sulphate annually would be next door to his warehouse. The preceding figure represents the present output capacity of the Pratt organization.

At this time the big warehouse is filled to the rafters with snow-white sodium sulphate. Before it is emptied Mr. Pratt is impersuasibly convinced that drastic anti-dumping legislation will have to be passed in order to curtail the mounting imports of the manufactured salt that have been entering this country, duty-free, in recent years.

For several years, the Columbian Hog and Cattle Powder Company has been shipping sodium sulphate from a dry-lake bed that adjoins Sodium, a railway station in Natrona County. The deposit is located 30 miles northwest of Casper. It is also one of the properties of the Gill Soda Company. The deposit at Sodium is likewise unlisted in the preceding compilations. However, in Bulletin No. 717, of the U. S. Geological Survey, the quantity of sodium sulphate available for shipment at that point is estimated at 250,000 tons.

So far the pioneer salt producers have confined their development activities to deposits that lie within a reasonable distance of the leading railway systems. It is beyond the aim of the present publication to file a tonnage estimate on the commercial salt reserves of the North Platte basin not recognized in the preceding tabulations. At this stage of industrial development the compilation of such figures would be a trifle premature.

Utilization

So far as known all of the sodium sulphate production of Wyoming is utilized in the preparation of medicated stock foods. Veterinarians frequently prescribe the salt as a hydragogue purgative for cattle, horses and sheep. Manifestly, the preceding market has its limitations, and during periods of depression the purchasing power of the trade is subject to considerable contraction.

In neighboring states of the arid West the production of sodium sulphate has greatly increased during the past 4-year period. The Wyoming producers have the bigger and better deposits. Moreover, the more alert producers still retain the mechanism and technic of industry essential for high-class productive efficiency. But before appreciable expansions can be expected in this state it would be well to prepare advertising copy of an aggressive character, and also pay some attention to the development of a superior sales organization. Obviously, the more chary producers will be unable to avoid such missionary expenditures until sizable electrothermal reduction works are erected on or near their respective lake-bed holdings.

Modern monographs and treatises of the standard recently published by the American Chemical Society and the Canadian Department of Mines list too many sodium sulphate uses to copy in the present booklet. A general survey of the situation indicates that many new uses will originate for the salt directly within the North Platte hydro basin. For that reason the preceding correlations merely considered the serviceability of sodium sulphate as a connecting link for the organization of a completely integrated chemical industry in Wyoming. Elsewhere, the salt seems to be increasingly esteemed as a base for making higher cost sodium compounds, as an electrolyte for dilute acid manufacture, as a conductor in plating solutions, and also as a fluxing and separatory agent in the electrothermal reduction of the highly intractable type of ferro-alloy ores generally found in Wyoming. Before further remarks are filed on its applicability within the specialized Wyoming field the underlying technical principles of several suggested processes should be fully corroborated by laboratory experimentation on sundry raw material assemblages.

Sodium Carbonate

So far no attempts have been made to exploit the sodium carbonate lakes in Natrona County. For descriptions of their varying magnitudes and degrees of purity the reader should consult the several listings recorded in the prior compilations.

Construction of large hydro-works in Natrona County should stimulate considerable interest in regard to the economic value of natural deposits of the second most important chemical manufactured in the United States. Deposits of comparatively pure sodium carbonates are seldom reported this side of Africa. In Wyoming, however, such deposits may rightfully be listed as one of the fundamental affiliates for a modernized, fully self-sustaining, dual chemical and metallurgical hydro-basin.

Most schoolboys possess a passing knowledge in regard to the general uses of sodium carbonate. In Wyoming the raw lake crudes could qualify as first-class fluxing agents for the electrothermal reduction of the tremendous deposits of variegated rare ores known to occur, here and there, within its leading hydro-basin.

Magnesium Sulphate

In the Chromium Chapter mention is made of the magnesium sulphate lake situated in the vicinity of Medicine Bow. Since writing the preceding chapter Mr. Paul Peterson, manager of a local mud mine has supplied a photograph of the lake. The view takes in a central section of a 94-acre deposit of common drug store epsom salts. The Peterson photograph showing a huge warehouse on the right quarter of the distant shore-line is submitted below.

Magnesium Sulphate Lake, near Medicine Bow

The foregoing lake is situated in a region in which extensive beds of bentonite are known to occur. Bentonite is the colloidal clay that is now being mined by Mr. Peterson and associates. The highest priced bentonites only appear in Wyoming. A Canadian analysis consulted for this publication indicates that the chemical mud colloids of the Peterson properties are entirely free of ubiquitous soda. Apparently, that freedom is of primary importance for the formation of a deposit of epsom salts on the open and exposed terrain. On the other hand the cited analysis shows the local bentonite to carry 3.24%, MgO; 0.75%, SO_3; and 1.35%, K_2O. Those magnesia and sulphuric anhydride percentages are not excelled in any of the widely separated bentonite beds of the United States that are listed in the 1931 circular of the Canadian Department of Mines. Containing alkali material more or less acted upon by the highly charged gypsiferous waters of the locality, a few foreign geologists are now claiming that bentonite is the original source material for a purified type of alkali deposit only known to occur extensively in the North Platte hydro basin.

Within a reasonable distance of the photographed lake, exhaustless beds of bentonite are found. Waters percolating through the soluble surface beds of solid gypsum, which extend for miles in the same locality in thicknesses up to 60 feet, doubtlessly exercise a vigorous solvent or displacement action on the unusually high alkali content of the ultra-microscopic colloidal muds. If the fundamental chemistry of the preceding theory can be sustained by a simple experiment in a beaker glass it will be necessary to revise estimates filed years ago on the tonnage reserves of Wyoming alkali deposits. Annual increment reports reaching this desk strongly indicate that the lake beds of Wyoming do not belong to the common groups of finite mineral deposits that cannot be replenished at an economic rate when once worked out.

In a geological sense observable formative processes are different in Wyoming. In the vast laboratory and natural powerhouse that comprises the southeast quarter of the state, visiting engineers are forced to make allowances for the increments annually received in local crystallization and precipitation basins. At places the Wyoming background is sufficiently diversified to justify such calculations.

Schultz mentioned that the annual storages of the Wyoming alkalis are increasing regardless of the huge volumes carried away by wind transport. His original description of the wind action on the prodigious quantities of alkali stored away in the highly pulverulent, supersaturated soils of the Red Desert is extremely interesting. In reality that bizarre and captivating area could well serve as a natural physical laboratory for charting the dynamical variables constantly at play within a given volume of the atmospheric envelope. Swirling currents laden with smoky, tell-tale colloids offer measurable evidence as to the magnitudes and frequencies of circulatory forces that are undetectable in less favored environments. As many as six vacuum pockets or embroynic cyclones have been noted to be in action at one time from a sun-baked observation point free of perceptible wind movement.

In the broader sense artificially constructed wind-tunnels no longer reveal everything about the medium in which aircraft navigates. For the establishment of fundamental aerodynamical knowledge, a 4,000-square mile area in Wyoming encompasses a much wider vista for observation and calibration. Cinema producers are already aware of the unusually high photographic value of magnesium sulphate. In the more massive crystallized form that salt makes the best of all motion-picture snows. Obviously, maximum optical contrasts are only registerable in the crystal clear atmosphere that characterizes the Red Desert country when not unduly roiled by countercurrent wind blasts.

Utilization

Chemical manufacturing processes and European imports are believed to supply all of the magnesium sulphate consumed in this country. Apparently the Dow Chemical Company of Midland, Michigan is the largest domestic producer. By their patented process deep brines and bitterns are converted into magnesium sulphate by the aid of sulphur dioxide and oxygen.

At the present time most of the magnesium sulphate output is consumed in the medicine, mineral waters, leather, cotton goods, rayon, silk, dyeing, explosives, matches, fertilizers, fireproofing, paper and cosmetic industries. In Wyoming the surficial deposits of the salt should provide groundwork of sufficient solidity for the erection of a vertical alkali trust. Additional uses will be found for magnesium sulphate as soon as a complete correlation is published on the technological resources of the North Platte depository. A number of products could be manufactured on a non-competitive basis as soon as the raw chemicals and rare ores in the local storehouse are accoupled in the correct ratios. Hereinbefore, metallic magnesium has been suggested for the reduction of the chrome deposits that occur in the City of Casper.

The most prosperous division of the magnesium industry is the manufacture of light alloys. Statistics are not yet available for the 1932 output. The heaviest known increase occurred last year. In 1931 the magnesium alloy production of this country was 5 times the amount of the preceding year. Magnesium is 40 per cent lighter than aluminum and its alloys find increasing outlets in the aircraft industry. The Dow Chemical Company now manufactures six magnesium alloys. The one with maximum corrosion resistance contains 98.5 per cent magnesium. Their strongest alloys consist of 90 per cent and more of magnesium combined with aluminum, manganese, copper and other metals. Elektron, made by the German chemical trust, is the most widely known magnesium alloy imported into this country.

Only a few industries discovered a 500 per cent market outlet increase awaiting their finished product in the statistical year last past. The production of metallic magnesium was one of those industries. Such industries justify a study of fundamental economic metamorphoses. After completing a dispassionate analysis and appraisal of available resources, the magnesium industry is likewise pronounced sufficiently modern and promising for entry within the fully self-sustaining North Platte hydrobasin.

In accordance with the latest methods of unit cost procedure only two factors need be considered in selecting a site for a reduction works. In simplest words a cheap supply of magnesium salt must be openly intersected by a transmission line capable of delivering huge volumes of electric power at an exceedingly low cost. Surface beds of magnesium solubles of the dimensions shown on a preceding view are extremely rare in the United States or in any other geographic subdivision of similar magnitude. Incidentally, the transmission line of the U. S. Reclamation Service to Laramie and Colorado points is mapped but four miles south of the big magnesium lake. The selling price for the firm power along that route is estimated at a figure considerably below the costs now charged at domestic electrochemical centers.

Drawing cards of the preceding sequence are not of frequent occurrence. In only one respect has Wyoming failed to develop the optimum locational setup desired by the modern and rapidly expanding metallic magnesium industry.

Lithium

Lepidolite was found in the Marion pegmatites of Copper Mountain at the time the beryllium discovery was announced four years ago. Mention of the local geology appears on page 117. On Copper Mountain lithium and beryllium minerals occur in separate dikes of an unmapped extrusive system.

Several specimens weighing 125 pounds and more of solid crystallized mineral were inspected by the State Geologist. Flame tests of the mineral indicated a strong lithium content but lack of spectroscopic equipment prevented examination for caesium and rubidium. The latter metals invariably appear in the mineral. As a matter of fact lepidolite carries more rubidium than any other known mineral.

Caesium is the most electropositive of all the elements. Before the radio and television industries appeared, no useful applications were generally recognized for either caesium or rubidium. At this writing, salts of those metals serve as the electric eye and part of the brainwork of mechanical robots. In the chemical industry such automatons are gainfully employed in operating valves, producing mixes, or turning heat on or off when the color, density or other property of certain processes reach predetermined values.

Lepidolite is the most valuable of the lithium ores. In the raw form it is used in making special glasses. Practically all of the lepidolite mined in California is shipped to the glass-making districts in West Virginia. Simple thermic treatments conducted in the laboratories of the State Geologist were sufficient to convert the lilac colored mineral of Copper Mountain into a milky, iridescent, opaline glaze. Obviously, such products are different than the ordinary run of glassware. The lepidolite quality is demanded by the more fastidious trade. The glass industry buys the largest quantities of lepidolite. Broad patents, however, cover the use of the mineral for that purpose.

Some time ago considerable quantities of lithium salts were consumed in the form of mineral waters. For many years lithia waters were drunk as a cure for rheumatism, the gout and other chronic ailments. When highly advertised springs were discovered to be remote from known deposits of lithium minerals in the earth's crust, the demand for lithia waters rapidly declined.

The light alloy field will likely provide the most uses for lithium—the lightest of all known metals and elemental solids. Alloys of lithium and beryllium that float on water have already been made. In Germany lithium is used for hardening both lead and aluminum. When lithium is substituted for magnesium in the duralumin types, an alloy of extreme hardness is produced.

Lithium is prepared by the electrolysis of the fused chloride. The methods of treating lepidolite for the production of the electrolyte are not described in textbooks. Doubtlessly such procedures are more or less secret and changed from time to time as the cost of chemicals and other factors vary. In Wyoming the extraction of lithium salts would involve no mysterious process. The analytical chemist uses sodium carbonate for the decomposition of lepidolite. On page 118, the nearness of the light-metal ore deposits to natural sodium carbonate lakes is pointed out. In Wyoming, practical extraction of several metals from their ores would merely demand a gradual step-by-step development of laboratory technique into operations of engineering feasibilities and magnitudes.

The minerals from which lithium may be extracted occur in only a few regions in the United States. In Wyoming, however, ores of the lightest metals known occur on adjoining mining claims owned by the Marion interests.

At times complaints are heard in regard to the high cost of light weight alloys. The prices of such products will likely remain extremely high until their manufacture is attempted in a hydro basin that can offer everything in the way of raw materials. In several respects the North Platte basin affords a natural site for the manufacture of all sorts of light metal alloys and many alloy steel products too.

CHAPTER XVI

MINERAL FERTILIZERS

Phosphates — Electric Smelting — Governmental Ownership — Potash Investigations — Alumina — Ammonia — Other Papers — Foreign Interest — Natrona County Royalties.

Phosphates

Deposits of phosphorous, potassium and nitrogen containing minerals are also found in Wyoming. The foregoing elements form the grand triumvirate of mineral foods consumed by plant life.

Nearly all of the preceding deposits occur in southwestern Wyoming. However, the phosphate beds more recently discovered in the Lander area doubtlessly extend to points within the North Platte basin. No other deposits of fertilizing minerals in or near the North Platte watershed warrant development at this time.

The preceding resources are fully described in Bulletin No. 764 of the U. S. Geological Survey entitled, "Phosphate Deposits in the Wind River Mountains near Lander, Wyoming." On page 24, the following description is filed on a bed situated 8 miles south of Lander, an important railway terminal in this state.

> "Exposures in Sec. 25 probably represent the upper bed at its best in the Wind River Mountains. . . . It ranges from 3½ feet to six feet in thickness and is thickest in the southeast part of the township in Sec. 25, where it is also the richest, carrying 49.2 per cent of tricalcium phosphate compared with only 43.2 per cent in Sec. 5."

The preceding passage describes a phosphate bed considerably narrower and of far lower tenor than those mined at Cokeville in southwestern Wyoming. At the present time the

Lander beds have no value but deposits of that grade seem to be adapted for electrothermal treatment. Before the unpayable rock at Lander is converted into salable commodities folks in that locality should take note of the power development program now pending on the North Platte river.

Hereinbefore, a few views were inserted of the Basic Industries in the Niagara Falls district. Among those illustrated is a plant of a phosphorous concern. No phosphate deposits occur in the Niagara valley and the nearest mining operations for the rock are conducted at points in Tennessee.

Three factors should be considered in selecting a site for a volatilization plant. A discovery of a workable phosphate bed at a point where hydro energy could be developed at half the cost generally charged at electrochemical centers may seem important. In the wilds of Siberia such a discovery may have but little meaning. In Wyoming, however, the largest river is now widely known as the American Nile.

No valley in the United States produces more sugar beets than the tonnages annually harvested from the irrigated flats and benches of the North Platte. Unfortunately, fabulous yields of beets and other crops have appreciably diminished the phosphate content in those fertile soils. As mentioned in Chapter XI, the preceding deficiency is corrected by shipping phosphate solubles into this state. To retransform the North Platte valley into a completely self-sustaining agricultural unit it will be necessary to construct a phosphate plant in the immediate locality.

During periods of economic distress local markets generally govern new industrial construction. Already, the leading beet sugar company of this country has accurately gauged the annual market requirements of the North Platte basin for soluble phosphates.

Electric Smelting

The authority most frequently cited in regard to the electric smelting of phosphate rock is Wm. H. Waggamann, Scientist in Fertilizer Investigations for the U. S. Bureau of Soils. His monograph recently published by the American Chemical Society considers the commercial possibilities of phosphate rock of the Lander type for thermic treatment. The following passages are selected from pages 80 and 222, as having bearing in the Lander locality.

> Probably an even more promising means of developing the western phosphates is the more general adoption of the pyrolytic or volatilization method of producing phosphoric acid. This process which may be carried on either in an electric or fuel fired furnace has the advantage of producing directly from medium or low grade rock relatively pure phosphoric acid of a high concentration. Since cheap coal is available in the western phosphate regions and there is every reason to expect further development of hydro-electric power, the pyrolytic process offers attractive possibilitis.

Electric Smelting of Mine-Run Phosphates

> But there is another important factor having a direct bearing on the cost of the unit of P_2O_5 manufactured by the furnace process which was not taken into consideration during these earlier experiments. This is the great saving which can be effected by employing low-grade and run-of-mine phosphates which are either unfit for treatment with sulfuric acid because of the inherent nature of the rock itself, or must be treated by some mechanical means to separate the phosphate from the impurities with which it is associated. With these facts in mind, the senior author undertook a number of experiments with the smaller electric furnace at Arlington Experimental Farm, Va., and while these tests were not conducted over any long period of time, they show that impure phosphates which can be readily and cheaply mined may be advantageously smelted in the electric furnace and the final

> product not only obtained more cheaply but a great conservation of our phosphate resources effected.

The extraction of phosphorous from phosphate rock by the application of electrical energy has been practiced for many years. The most successful operator in the domestic field is the Federal Phosphorous Company. At the close of 1929, the output of their plant at Anniston, Alabama exceeded 30,000,000 pounds of pure phosphoric acid.

The largest plants for volatilizing phosphates have been built in Europe. Two years ago the engineers of the Federal company completed a plant in the French Pyrenees for the Societe des Phosphates Tunisiens twice the size of the Anniston works. African rock is utilized for the operation of the new plant. The best phosphates of Tunis appear to carry 60% in phosphate of lime. Rock of the slightly lower Lander grade is also exported from African points. For rock carrying 70 to 72 per cent in lime phosphate it would be well to rely upon the larger beds in southwestern Wyoming.

Governmental Ownership

Most all of the mineral fertilizers, raw chemicals, fuel deposits, etc. occurring in Wyoming are now owned in perpetuity by the Federal Government.

For pouring heavy revenues into the public treasuries, a phosphate plant offers a wider margin than bringing additional acres under the plow in Wyoming or elsewhere. The two leading beet producing states form the exterior boundaries of southeastern Wyoming. No phosphate deposits are found in those adjoining states. Private research has lately demonstrated a surprising deficiency of phosphatic mineral in the more heavily irrigated soils of those states. By this date the Wyoming treasury should be exacting mineral royalties from phosphate sales and shipments to nearby states.

So far only two general methods have been perfected for extracting phosphate from suitable rock deposits. Hereinbefore, they have been called the acid and electric processes. Southeastern Wyoming has no sulphur deposits suitable for acid manufacture.

To prevent the entry of electrothermal works into this state a number of engineers circulate propaganda to the effect that power development must forever remain subservient to the long range needs of another industry. Such far-seeing visions are vociferously upheld regardless of the fact that no moratorium or less tenuous form of subsidy has ever been granted under a power project thus far constructed by the Federal Government in Wyoming. No one can cite an instance in which the irrigation industry was molested by a power completion on the highly profitable North Platte channel. Aside from legalizing a permanent title to all of the water that still remains in the North Platte, the type of expansions covered by this publication will not disturb the Wyoming irrigation industry in any particular. On the other hand the local plants are in no way related to the huge power project erected at Muscle Shoals during the war excitement.

As a taxpaying unit the beet growers of Wyoming are entitled to certain privileges. In order to conduct their business operations in a free and unmolested manner, they should be permitted to purchase their plant food requirements at a reasonable price. Several years ago the Federal Government decided to retain ownership in perpetuity to divers types of mineral deposits concentrated within the Wyoming depository. Apparently, such ownership involved certain responsibilities, implied or otherwise. Among other moral obligations the new form of retainership should not exempt the holder from ignoring prospective royalty receipts and revenues of other sorts as soon as localized markets originate for mineral products peculiar to the Wyoming protectorate.

On certain occasions the public as well as the private owner should display an equal degree of perspicuity. As stated before, only one type of project merits consideration on the Wyoming tenure. In times of mounting deficits, public river improvement programs may well be limited to projects that can pay out the original investment cost solely from the mineral and chemical royalties collectible from operations on the tributary Public Domain. Such projects do not belong to the non-revenue style of river improvements that were seemingly designed for no more worthy motive than to obtain 15 per cent or more of the traffic formerly controlled by taxpaying railway groups.

For stimulating mineral development no stream can surpass the North Platte river. Current contracts with the oil and iron mining industries have made that channel the most profitable power course thus far developed by the U. S. Reclamation Service. As yet no attempt has been made to develop the full power potential of the North Platte. When that task is completed present profits may look like a drop of water in the proverbial bucket.

At this writing much unnecessary fuss is being made in regard to "Buy American" and "Buy Uncle Sam" campaigns. Such slogans have nothing to do with the type of proprietorship generally prevailing in Wyoming. For example, take sodium sulphate—the most common surficial type of chemical deposit in the North Platte basin. A quotation in the preceding chapter disclosed that imports of the foreign salt into this country increased 1,000 per cent during the past 5-year period of accelerated unemployment decline. In Wyoming 99 per cent of the total tonnage of the salt is probably held in perpetuity by Uncle Sam. For conversion into higher cost, salable compounds no native owner of salt deposits is in a position to invest $8,000,000 in an overlapping hydroelectric system on a river channel commonly referred to as a Federal irrigation course.

Bigger imports of the Wyoming type salt may be expected. In times of increasing shortages one form of trusteeship finds it cheaper to buy the foreign salt rather than to exploit its free supplies of native raw material. Discussions like this lead to nowhere. The annals of history record many orations on the concomitant evils of absentee landlordism and disinterested aloftness as practiced in Wyomnig and elsewhere.

Local proponents of the ''Nothing-in-Wyoming'' schism have probably done more harm than the slogan-makers in retarding normal industrial expansion in this state. Many years will pass before the baneful effects of some recently expounded hypotheses are fully forgotten. To prevent future recurrences, schoolboys of the present period should receive more light as to the basic import of multifold types of resources assembled within their several quarters of the state.

Potash Investigations

An Iowa tourist recently handed the following clipping to this writer:

> Out in Wyoming there are mountains of lava bearing approximately 12 per cent potash in this silicate combination. Not very far away from the potash deposits are vast phosphate beds, and still in the same vicinity are deposits of low-grade coal. This haul is too long to justify bringing either the coal or the phosphate across the plains to Eastern markets, and nobody has heretofore known how to use the potash. But Turrentine and Royster, of the United States Department of Agriculture, have found out that a blast furnace, operated on this cheap Wyoming coal, could be utilized to bring about a reaction between the silicate of potash and the phosphate of lime.
>
> The proper proportion of the two ores is loaded along with the coal into the blast furnace. When a temperature

> of up around 2,000 degrees is reached and everything in the blast furnace is at fusing heat, the potash leaves the silica combination and joins up with the phosphorous, which has similarly left its combination with lime. The silica and the lime then get together to make a clinker, while the potassium phosphate which is formed becomes volatile at this high temperature and goes as a fume up the smoke stack. Before it reaches the outer air and is lost, however, an ingenious device known as an electric precipitator throws it down in solid form.
>
> Tentative figures put out on a basis of small experimental operation of the process point in fact to costs so low as to be more or less revolutionary. These experimenters get a cost of only eighteen dollars a ton for pure potash. It will be remembered that we are now paying around forty dollars a ton for 50 per cent potash from abroad. If we can produce the same stuff for nine dollars, or even double this amount, not only would we cease to draw on a foreign supply, but potash use in this country would tilt sharply upward.

The preceding passages were taken from the October, 1931 issue of the Country Gentleman, a staid agricultural monthly published by the owners of the Saturday Evening Post. The clipping refers to the research investigations now being conducted under the authority of the Winter bill. Since that Act passed Congress in 1929 the sum of $200,000 has been available for ascertaining the commercial possibilities of potash deposits situated in southwestern Wyoming.

The pending investigations were entrusted to the Bureau of Chemistry and Soils and to the Bureau of Mines. Both groups of Federal workers continue to display increasing enthusiasm in regard to their labors in the Wyoming field. Recently announced findings indicate that the door is at last open to manufacture not one but every type of mineral fertilizer in the complete Wyoming depository. Heretofore, the bulk of the potash and nitrates consumed in this country came from Germany and Chile. At the present time the Bureau of Chemistry aims to produce those materials and other fertilizers in Wyoming at costs that will permit sales in the highly competitive markets of the world. Publicity circulated two years ago by the Department of Agriculture stated that the Winter Act type of experimentation is designed to cut down the farmers annual fertilizer bill $60,000,000. In the meanwhile sharp declines in agricultural commodities have seriously constricted the market for mineral plant foods.

In preparing this advance inventory for a new quarter of Wyoming it was necessary to ignore the division of the mineral industry that has long led all Wyoming industries in regard to valuation output. The present listings are largely descriptory of raw materials utilized by industrial groupings still able to maintain satisfactory price structures for their newer lines of finished products. This chapter is included for the reason that no corporation has thus far started to manufacture phosphate solubles in this state.

Strange to relate only the plant food minerals of this state have been subjected to original technological investigation. During the present financial stringency few taxpayers are in favor of spending some stated percentage of the oil royalty receipts with the aim of ascertaining the intrinsic merits of sundry sorts of mineral deposits not yet exploited on a big scale in this country. Some Wyoming types deserve to be pushed forward for no more worthy object than to cut down national import figures that may continue to increase as long as this unprecedented period of economic paralysis prevails. In certain deposits lie the source of much future wealth and mutative stability. Give the research man continuity of support and the over-all results might be successful. As yet not many taxpayers are aware of the preliminary publicity that Wyoming fell heir to the first time that a few dollars of the royalty millions were expended on actual research investigation.

Recently, a number of publications have appeared on the present research investigation. In November the Bureau of Mines published a report entitled "Economics of Potash Recovery From Wyomingite and Alunite." That 78-page report, among other things, now serves as a complete directory of the chemical deposits in southwestern Wyoming. Before action should be urged on the Casper hydro-project an equally authoritative compilation should be available on the more colorful resources appearing in southeastern Wyoming.

The original purpose of the Winter Act was to ascertain the potash value of the lavas located in the vicinity of Rock Springs. Current investigations are of a broader scope. Present experimentation is conducted with the view of manufacturing concentrated products that will contain all elements of the grand trinity consumed by plant life. No other locality can supply every type of raw material that is requisite for the operation of a completely integrated fertilizer industry. In past addresses the State Geologist frequently stressed the futility of seeking optimum locational figures for several types of industries outside of the Wyoming boundaries.

Alumina

The August 1932 issue of Industrial and Engineering Chemistry contained a paper jointly prepared by three scientists of the Fixed Nitrogen Division of the Bureau of Soils entitled "Potash and Alumina From Wyomingite." The basic principles of the process are outlined in the following foreword:

> Treatment of Wyomingite rock with nitric acid and oxides of nitrogen extracts 70 per cent of its metallic constituents as nitrate salts. Upon evaporation and heating to 850° C., these nitrates decompose, yielding nitric acid and oxides of nitrogen together with metallic oxides and potassium aluminate. The nitrogen content of these salts is thus regenerated through the gas phase, while

> potassium aluminate, being the only watersoluble constituent in the residue, is leached out by cold water. A recovery of potash and alumina from wyomingite is thus effected from which a concentrated fertilizer (potassium nitrate) and high-grade alumina can be obtained.

Striking photographs of the rock fields in the vicinity of Superior appear in the cited magazine. For the further guidance of the reader the results of the experimental findings are plotted in the form of extraction and absorption graphs. The article, however, only covers laboratory experimentation. For engineering scale investigations, the authors concluded as follows:

> . . . the wide spread between costs of raw material and current prices of the finished products and the varied and cheap fuels available in Wyoming are attractive considerations.

The new experimental technique was designed for the object of extracting an added value from the Wyoming rock. Chemically prepared alumina is far more valuable than any ore of the metal. Before aluminum is obtained by electrolysis, it is necessary to extract the purified oxide from the ore by costly chemical processes. Considerable quantities of aluminum ore as well as the reduced metal are annually imported into this country. Should a commercial process be perfected for utilizing the Wyoming rock an adequate supply of raw material would be assured for many years to come. In Bulletin No. 512 of the U. S. Geological Survey, the alumina content in the Wyoming lava flows is recorded at 197,300,000 tons. The potash is recorded at the same figure. Average analyses since published by the Bureau of Chemistry and Soils would raise those totals more than 10 per cent.

Little light can be added in this paper in regard to the international ramifications involved in the production of aluminum. Subsidiary companies of an American cartel may own vast deposits of bauxite ores in some steaming tropical jungle. Some of that raw ore may later be consigned to hydro and reduction subsidiaries operating at interior points in Quebec. Finally, appreciable quantities of the metal reach the fabricating plants of the parent concern that are located in this country. Recently, Mr. A. Real Miner, mining economist on the Denver Post staff, editorialized on the political angle of the preceding circumambulations as follows:

> *Americans Develop Aluminum Mine But Britons Manufacture Output*
>
> Just one example of this control will suffice. When the Aluminum Company of America leased the extensive bauxite deposits in British Guiana, it was stipulated in the contract that this bauxite should be processed and the metal aluminum manufactured in a British dominion, hence the enormous power development and metallurgical plant on the Saguenay river in the Lake St. John basin in Canada, fostered by a United States company.

The extraction of aluminum from the vast rock fields of southwest Wyoming is yet an unsolved problem. However, in the past year or two both the Italian Government and the U. S. Bureau of Chemistry have made pronounced progress in that direction.

Apparently, the investigators working under the far-seeing Winter Research Act are inordinately zealous of extracting the last cent of value from the Wyoming potash rock. Against them, witness the bitter-enders fighting to the last ditch to prevent the entry of the basic hydro industry into this state. Obviously, the time has arrived for inculcating new-type, British concepts into the minds of schoolboys in regard to the economic significance of the combined powerhouse and storehouse of minerals and chemicals that literally lies under one roof in Wyoming.

A cursory review recently concluded of the research problems now engaging the attention of quasi public institutions, both here and abroad, indicates that two types of workers are busy within the geologic sphere. One domestic school is earnestly endeavoring to formulate ways and means for transforming the U. S. A. into a self-contained economic unit worthy of the name. In creating new knowledge an equally worthy group of savants appear to be more interested in permanizing their names in the Latinized form to one or more of the millions of insect species that suffered complete extinction by cataclysms that likely occured in the pre-biblical past. At this time a number of workingmen seem to show more concern about the first set of problems. Their interest, however, may involve nothing more material than the price of the next meal ticket.

Ammonia

In the Industrial and Engineering Chemistry article the government investigators mention that nitric oxide produced by ammonia oxidation was utilized for attacking the wyomingite. Today, most ammonia is made from air and water. In the new works at Trail, British Columbia, nitrogen from the air is made in a Claude liquid-air rectifying plant capable of producing 1,340,000 cu. ft. of 99.9% nitrogen daily. The hydrogen is obtained by the electrolysis of water by utilizing Trail's other great natural resource—cheap water power. Later the two elements are combined into ammonia by the new Italian process.

In California the chemical subsidiary of the Shell Union Oil Company utilizes natural gas for hydrogen manufacture. From that raw material both hydrogen and carbon black are produced by a cyclic thermal decomposition. In Wyoming the potash lavas touch the giant Baxter Basin gas field which is the largest and cheapest gas producing reservoir so far discovered in the Rocky Mountain petroliferous province. Largely for that reason the government investigators are of the opinion that the manufacture of 100 per cent plant foods like potassium nitrate and ammonium phosphate are feasible at local contact points.

The manufacture of synthetic ammonia is mainly an energy consuming process. Various forms of the latter commodity are manifest in southwestern Wyoming. The leucite necks and knobs pierced the heart of a 20,000- sq. mi. coal field. Before reaching the surface those titanic volcanic flows were forced through a long series of thick coal seams. Those white-hot extrusions may have disturbed a few million tons of good subbituminous coal suspected of containing a high potash content in the ash. Such damages, however, may be disregarded. Geologists figure that over ½ trillion tons of coal still remain intact in the southwestern Wyoming field. Nevertheless, catastrophes of the preceding category are deemed indispensible in providing Class ''A'' groundwork for erecting a powerhouse—chemical works superstructure on a single site.

By this writing no synthetic ammonia plants have been constructed nearer Wyoming than Midland, Michigan and Pittsburg, California. A bulletin published 4 years ago reviewed the hydro, gas, coal, potash and phosphate resources of the Green River basin. The publication averred that the Green River locality provided the low-cost site for the manufacture of ammonia and other related products.

Other Papers

During the past two year period the writer noted about half-dozen articles on the raw chemical resources of southwestern Wyoming in the cited magazine which is the industrial organ of the American Chemical Society. Some communities would probably sense a constructive value in unsolicited publicity of the preceding scope. As a matter of fact papers of a complimentary tone were noted on the Wyoming locality in uncited journals during the two year period last past. By this time the official report of the Bureau of Chemistry is anxiously awaited in many quarters.

Foreign Interest

Interest in the industrial possibilities of Wyoming is no longer confined to points on the Potomac. Discussions on those resources are also heard on the Seine. A recent correspondent summarizes the foreign viewpoint as follows:

———— Paris, June 1, 1932.

Mr. C. S. Dietz,
Deputy State Geologist,
Wyoming Geological Survey,
Cheyenne (Wyoming) U. S. A.
Dear Sir:

Our associates "Cie pour le traitement des Minerais ——— ———" have been studying at their factory in ———, for a number of years, the various problems indicated by the corporate name.

They have been successful in obtaining interesting and conclusive results which undoubtedly are of particular interest to your State in view of the important deposits of leucite and phosphate.

Our processes are quite new and simple, they forego the utilization * * * * * of the phosphorus as this is the case with the American processes in order to heat the raw material before charging it into the furnace, or according to the German processes in order to manufacture hydrogen.

Our process enables us to manufacture, under particularly economic conditions, phosphoric acid. monocalcium phosphate and potassium phosphate which can be utilized as raw materials for the manufacturing of all kinds of phosphates used industrially. The products obtained with our process have the advantage of being very cheap and free of arsenic which otherwise is added by the sulfuric acid when following the regular chemical processes.

* * * * * * * * * * *

> Furthermore our process permits, by the manufacturing of double superphosphate with the high contents of from — to —% of P_2O_5 the easy and economic extraction of the potassium that is contained in feldspar and leucite of which your State has abounding deposits.
>
> The directors of this Corporation are the founders of the Franco Wyoming Oil Company which had an active share in the initial exploitation of the Salt Creek Oil Fields. This may explain to you why they always followed with much interest the industrial development of your State and that they also know your remarkable essay "The Developed and Undeveloped Mineral Resources of Wyoming" which was published in 1929, which publication also mentions the particular value of Leucite Hills as potassium deposits.
>
> On the other hand, the State of Wyoming seems to also possess very interesting deposits of phosphate. Therefore, our processes could be used to utilize this natural wealth and to start a new era of prosperity for your State.
>
> We are quite anxious of making a complete economical survey of the underlying conditions and would therefore be very much obliged to you if you sent us two copies of your forementioned publication of 1929. Kindly find enclosed a check in the amount of \$2.
>
> In event that in the meantime new publications relating to the phosphate and leucite deposits in the State of Wyoming, as well as to the exploitation of the water power in your State have been edited, we would also greatly appreciate if you sent us the same and let us know at the same time the amount which we might owe you for these publications.
>
> Trusting to hear from you in due time, we remain,
>
> Very truly yours,
>
> ———————

The omitted passages mainly refer to process modifications that should not be published at this time. The deleted factory site is located in one of the countries that pioneered in hydroelectrical development.

The plant engineer that wrote the foregoing letter desires advance information on available water power development in Wyoming. For the operation of plants of his style, Wyoming has nothing to offer in the way of unsold hydro-capacity. Before such a commodity will appear on the local industrial market, much loose talk on the current Subserviency Notion will have to be squelched. So far no State Department or booster organization or local technological society has advanced any reason for placing hydro energy on the Wyoming industrial market. That statement is made regardless of the ridiculously low figure that such a highly modern commodity could be developed in precipitous rock-ribbed canyons long ago excavated on the Wyoming terrain. If types of mineral and chemical resources peculiar to Wyoming are to be exploited it will be necessary to make provision for the requisite form of energy first of all.

In time much of the preliminary groundwork will likely be financed by outside interests. Plenty of precedents are citable for such maneuvers in the Wyoming theatre. The quoted writer advises that his present associates were the chief parties of financial interest in the organization of the Franco Wyoming Oil Company. That concern was a pioneer operator in the Salt Creek pool. That American oil field is unique in one respect. Unlike all others, early explorations in the giant pool were mainly financed by French, Dutch and Belgium capital. Before those interests invested in the prospective oil structure, far-seeing businessmen of this state had to hire a number of foreign geologists who entertained conjectures not then universally accepted by the oil industry. The ruthless energy and inspiring resolution that still active businessmen exercised in bringing the oil industry to their native state is already forgotten. Nevertheless, genetical theories once expounded and expanded within the spacious outdoor laboratory of petroleum research that is in Natrona County now appear as basic principles in textbooks studied by schoolboys.

Other savings result from the use of tungsten. The manufacture of a popular V-8 car seems to call for far more machine work than formerly put into its ancestor, the venerable Model T. In man-hours the labor is actually less. As frequently heard, one man with one lathe and tungsten hi-speed steel tools can do as much work as five men with five machines and carbon-steel tools. Widia, a harder tungsten alloy recently produced in Germany, now selling at $450 per pound, will likely cause further revolution in machine shop technique. Tools will have to be redesigned for operating at far higher speeds than hitherto developed. For accelerating the tempo of civilization, too much tungsten cannot be produced. At this time reported discoveries of the metal in Wyoming or at points a few miles beyond its boundaries attract considerable attention.

Molybdenum

For some reason yet unsolved one of the really great ferro-alloy deposits was left out of the basin now drained by the headwaters of the Platte. About four or five miles west of its topmost boundary a company is now mining 85% of all of the molybdenum produced in the world.

One mile east of Climax, Colorado, at the 12,000 foot elevation on the Continental divide, is located a molybdenite deposit that far exceeds in size any other source of the ore now known. Current mining operations at that point were described in the November 18, 1932 issue of the Denver Post, as follows:

Mining Company Will Increase Its Payroll and Add to Output

Returning Prosperity Leads Molybdenum Firm to Boost Its Expenditures

News with a real prosperity savor trickled into Denver from Climax, Colo., Friday.

The Climax Molybdenum company, the world's principal producer of Molybdenum, is preparing to speed up its production and increase its output from 60,000 pounds to 100,000 pounds a month.

At the same time it was said if orders continue to increase at the present rate the company will soon expand its operations to produce 200,000 pounds a month.

Manager Arranges for Expansion

H. L. Brown, manager of the Denver office of the company, was at the mine at Climax Friday arranging for the renewed activity, according to word received from Leadville nearby.

Since molybdenum is used principally for hardening steel, the increase in orders is looked upon as a forerunner of a marked upturn in steel tonnages.

A good share of the new orders received by the Climax company are said to have come from European steel mills.

While it could not be verified, one report reaching Denver said the Krupp steel mills in Germany had ordered eleven carloads of molybdenum, mills in England were said to be getting nine carloads and an order from France and another from Belgium were said to amount to seven carloads each.

The Climax company, it is said, found several months ago that it had such a large supply of molybdenum on hand that it could keep well ahead of its orders by cutting production to 60,000 pounds a month.

Orders Make Expansion Necessary

However, the recent orders have indicated that the supply would be quickly depleted unless the rate of output were nearly doubled.

> The Climax company for several years has had a policy of keeping a supply of about 3 million pounds of molybdenum on hand to take care of unexpected orders.
>
> It possesses the world's only known large supply of the important steel alloy. Max Schott, formerly a Denver representative of the American Metal company, founded the Climax company in 1917.
>
> Last year the entire production of the company was less than 800,000 pounds. That amount was produced in the first five months of 1932.

The story of the Climax properties did not start until 1917. At that time British munitions experts began a worldwide search for deposits of molybdenum ore. They wanted the metal to harden the steel which was to go into armor plate for battleships and other engines of war. At a recent railroad hearing in Denver letters and radiograms were produced from Government officials to point out that molybdenum is the only steel alloy of which the United States has a sufficient quantity to be self-supporting in wartime. The military market, however, is not the only outlet for the metal. As late as 1923 only 22,667 pounds of molybdenum was produced in the United States. By 1929 its production had ballooned to 3,904,648 pounds. That was 95% of all the molybdenum produced in the world in that year. Thanks to the pioneer spirit displayed at Climax, Colorado, this country finally succeeded in producing one of the dozen ferro-alloys in sufficient volume to meet its own industrial requirements.

A Neglected Investigation

It necessitated a cataclysm as furious as the World War to open a molybdenum mine in Colorado. The same convulsion might have been utilized for ascertaining the merits of a vanadium property in Wyoming. As a matter of fact the molybdenum in one pound of Climax ore is of no higher value than the vanadium in one pound of Iron Mountain ore. Moreover, 15 years of exploratory and mining operations at Climax have failed to reveal an ore reserve larger than the tonnage total hereinbefore calculated as visible to the eye at Iron Mountain. Only one value is contained in the Colorado ore. The appraisal tabulated in the preceding chapter indicates that vanadium is but one of the minor values in the giant dike at Iron Mountain.

The extraction of the vanadium from the Iron Mountain rock is here entered as a problem yet to be solved. On the other hand considerable labor was required in formulating practical procedures at Climax, Colorado. Six years had to follow the Great War before that mine could reach the stage of a successful producer. That was a lot of time to expend on rather speculative mining, milling and metallurgical deviations from established procedures. However, some of our neighbors claim that the preceding expenditures were justified, at least in the light of subsequent events. At the present time the largest metal mining operation in Colorado, a far famed mining state, is conducted on the Climax molybdenum property. But in times of deep depression the atmosphere around a ferro-alloy property should be a trifle clearer than the fogginess that envelops the mining camp merely producing one or more of the metals typical of cultural periods now past.

Analytical Discrepancies

A preceding chapter had to be devoted to the economic importance of always having on hand up-to-date analyses, especially for those mineral deposits that form the bolder type of relief on the southeastern Wyoming terrain. During the Great War the hue and cry for more vanadium was no less vociferous than that heard for more molybdenum. But no citizen of Wyoming will blame prospectors for passing up Iron Mountain in 1918. With the information on file the Wyoming dike could only be looked upon as a huge deposit of extremely intractable iron ore. The analysis of the Government made a half century earlier showed no vanadium in that uniform mineralization. If a modern analysis had been available the War Minerals Board would have doubtlessly financed a thorough investigation of the Wyoming property. By this time either the Board or its duly subsidized agents might have devised ways and means for releasing vanadium or some more conspicuous value from its long imprisonment at Iron Mountain.

More recent analyses consulted in the preparation of this commentary account for a total contained value of \$150.23 in each ton of the Iron Mountain rock. Hereinbefore, all but \$6.37 of the preceding figure is tabulated in the form of "rare" ferro-alloy metals.

The problem of extracting a part or all of the sum total value at Iron Mountain may look quite inviting. But no present-day disciple of defeatism or patterer of the "nothing-in-Wyoming doctrine" is going to tackle such a formidable task. On the other hand a persistent research worker may find the undertaking equally as engaging as evolving original methods for extracting molybdenite within the amphitheatre that overlooks the high headwaters of the Platte.

CHAPTER XIV

IRON ORES

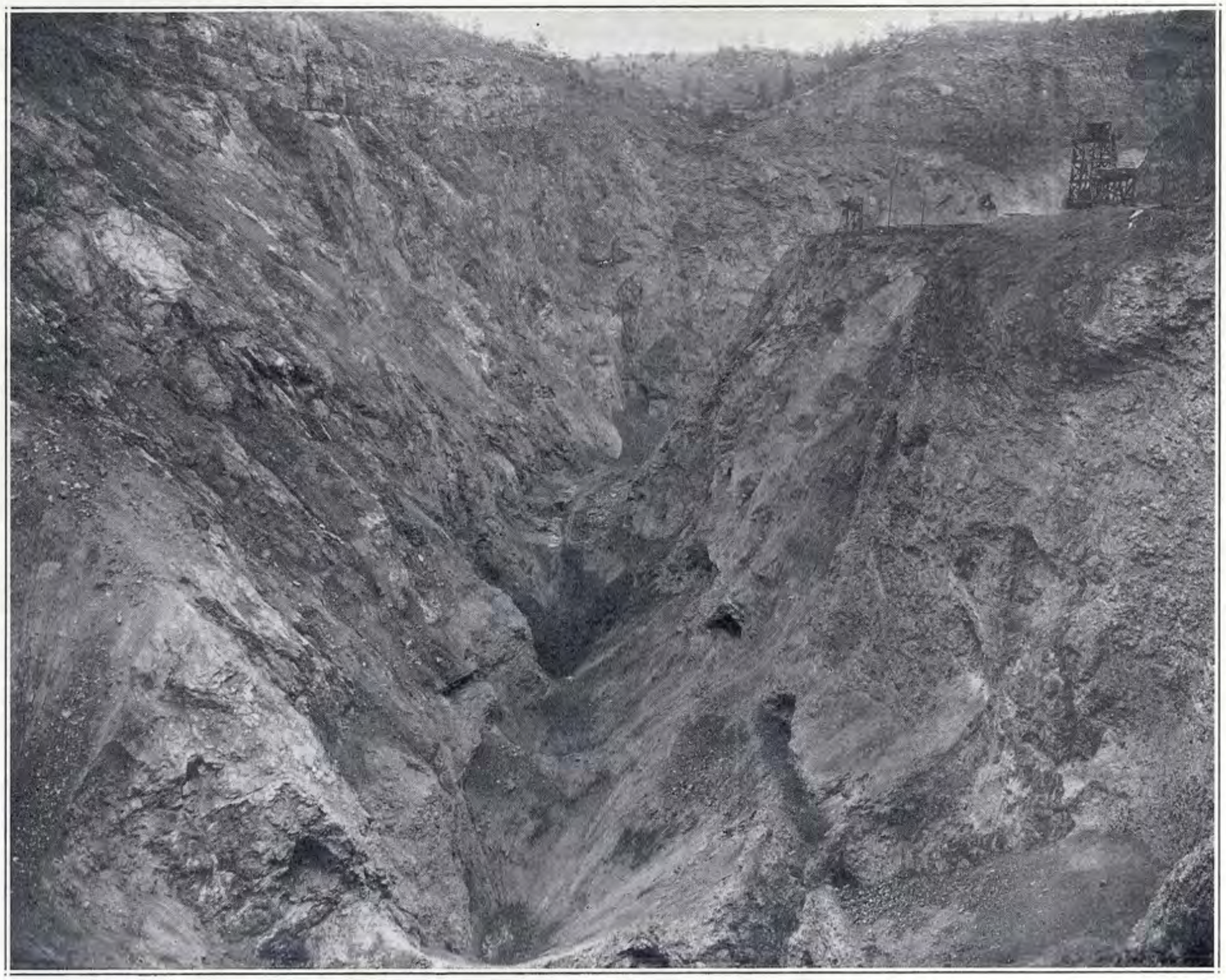
Introductory Remarks—Sunrise Mine—Newly Discovered Reserves — Alloy Iron Ores — Electric Steels — Electrolytic Iron—Political Attitude.

Introductory Remarks

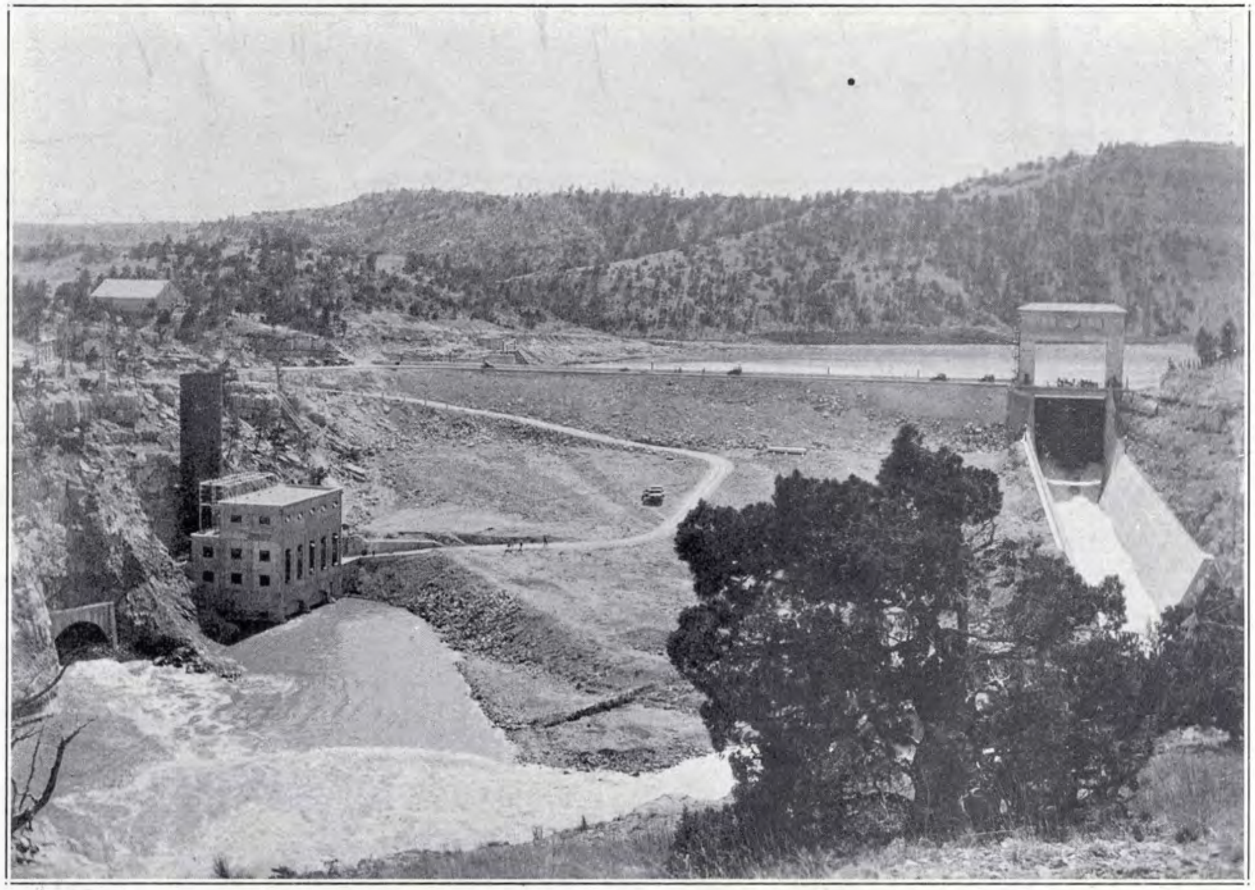
In one of his popular lectures the late great Edwin E. Slosson, one-time dean of the chemical department at the University of Wyoming, stated that only 55 tons of steel were produced by the electric furnace during 1908 in the United States. By 1929, the year of peak production, this figure had risen to 951,431 tons. The manufacture of the preceding product consumes tremendous volumes of electrothermal energy. Continued expansions in that field may cause the steel industry to seek a sizable deposit of iron ore directly within a valley in which increasing quantities of hydro-power are thrown on the market at extremely attractive rates. At this time such a novelty may not be found outside of Wyoming.

On the opposite page is a photograph of the Sunrise Mine, often referred to as the deepest open-pit iron mine in the world. This mine is situated five miles northeast of Guernsey. Five years ago the U. S. Reclamation Service erected a dam at Guernsey across the North Platte river. Since then, current for operating the big mine is sent over the transmission line that was constructed by the Government. The power rate has proven extremely profitable to both contractual parties.

A photograph of the 105-foot high dam recently constructed at Guernsey appears on an adjoining page. The view from downstream shows the spillway, power house and outlet tunnel of the structure.



Sunrise Iron Mine, Sunrise, Wyoming



(Courtesy U. S. Reclamation Service)

Guernsey Dam and Power Plant

Transmission losses over 5-mile long power lines are comparatively insignificant. For low-cost power delivery the North Platte river offers advantages that should not be expected from a stream of the average type. In southeastern Wyoming its cascading waters have excavated deep canyons throughout many miles of granite and other hard rock formations. At the Pathfinder site the Reclamation Service completed a storage dam 218 feet high 20 years ago. Their current report on the proposed power dam at the Seminoe site forms a subsequent chapter in this publication.

The rapidly descending flow of the North Platte could be reused for low-cost power development at a number of other equally advantageous sites. Important deposits of ores and beds of raw chemicals are also known to occur within the immediate vicinities of the latter points. Before the entire power potential of the North Platte is finally hooked-up by an interconnected transmission system a number of hydro-works of the Guernsey type should be constructed, here and there, to expedite localized mineral development. At this inopportune time manufacturers should of course confine their expansion plans to such mineral and chemical products that are still imported into this country in large quantities.

Sunrise Mine

The Sunrise mine is the ore-producing unit of the Colorado Fuel and Iron Company. Over 13,000,000 tons of ore have been shipped from this mine to the Pueblo furnaces of the company. In 1927 the Sunrise mine ranked 19th in point of production in the United States. In years of good business only three or four iron mines outside of the Lake Superior district exceed its output. In the Hartville Folio of the U. S. Geological Survey, the ore shipped from the Sunrise hematite mine is described as . . . "of high grade, averaging about 62 per cent of metallic iron, with about 2½ per cent of silica and practically no phosphorus or sulphur. The maximum iron content is about 66 per cent and the lowest silica about 1 per cent.''

For maps and further descriptions of the premier iron-ore producing region of the western half of the United States the reader should consult the quoted geological folio as well as Bulletin No. 315, likewise published by the Federal Survey. The U. S. Mineral Resources of the Bureau of Mines generally record the annual productions of the Sunrise property during the past 33-year period.

Newly Discovered Reserves

In the last annual report of the Colorado Fuel & Iron Company mention is made of the tremendous new deposits of iron ore that were discovered at Sunrise, Wyoming, during the year of 1931.

The preceding discovery was made by means of a geophysical survey which among other things involved an interpretation of the resistivity differentials calibrated for several stratum contrasts of the locality. These studies were in progress over a year before the presence of the hidden ore body was confirmed by diamond drill tests. Descriptions of the local survey appeared in the last two annual reports of the Wyoming State Geologist that were published in the Casper Tribune-Herald. Extracts from his last report follow:

> From the standpoint of pure and applied science it is gratifying to report the discovery of an immense ore reserve —the first time that modern ''doodle-bug'' instruments were utilized to search for metallic minerals in this state. . . . Using diamond drills at the point of discovery miners penetrated 300 to 400 feet into a bed of ore of higher quality than any thus far worked in the Sunrise area. For many years past the Sunrise ores have carried a far higher metallic content than the constantly declining tenor of those mined in the bigger producing regions of the nation. Had the discovery been announced in any year other than 1931 it doubtlessly would have been hailed far and wide.

The latest reserve is of sufficient dimensions to meet the ore requirements of the Rocky Mountain market for many years to come.

In some quarters much is still heard about all of the gold, silver and copper in Wyoming being discovered during those periods when the state was largely under the dominion of the Indian and the buffalo. At times accidental discoveries of such metals do occur. In 1915 a deposit of copper was encountered while carrying on regular iron-ore mining operations in the big pit at Sunrise. According to Government reports 6,000,000 pounds of copper and several thousand ounces of silver were recovered from the Sunrise iron mine during the ensuing four year period. The ore carried from 14 to 16 per cent in metallic copper. That degree of richness has not been surpassed by the price-wrecking discoveries of the red metal that have been made more recently in Africa, Canada, Chile and in other far-flung parts of the globe.

Geologically, the Hartville uplift in which the Sunrise iron mine is situated may be considered a pocket edition of the Black Hills uplift in which is located the largest gold mine in the United States. If pits are dug deep enough either one or both of those frontal outposts for the main chain of the Rocky Mountains may be expected to display the rare and the unusual in regard to mineral associations. Apparently, periodic surveys of both of those uplifts are justified as long as the art of doodle-bug prospecting tends to mature along the lines of an exact mathematical science.

Alloy Iron Ores

In ordinary steel centers pig iron from the high-grade Sunrise ore would be looked upon as extremely desirable material for introduction into the electric furnace. Within the diversified depository of the North Platte another ore may be found to possess a more suitable composition for electrometallurgical treatment. Visible reserves of the latter deposit greatly exceed the tonnage volumes hereinbefore accredited for the hematites that are so remarkably free of deleterious substances.

In Chapter VI the contained alloy metals in the Iron Mountain ore are held to be of the right ratios for the manufacture of an electric-furnace steel recently patented abroad, that is, if the overwhelmingly high titanium content is first removed therefrom.

A number of native Wyoming reagents are believed to possess sufficient potency to isolate the firmly united titanic oxide radical from the Iron Mountain mineral. Elsewhere sodium sulphate seems to prove acceptable for that work. Hereinbefore, Wyoming natural gas of double calorific power is thought to have value for making the desired separation. Should that cheapest gaseous fuel in the nation prove to be too weak for the task, industrial hydrogen may be utilized as a final resort. In major hydro-centers large volumes of that overpowering reducing agent are made by the electrolysis of water. In Wyoming its manufacture may be more economical by cracking natural gas into its component elements. Already the important municipalities in the North Platte basin are connected by natural gas pipelines.

Roughly speaking, the metallurgical problem at Iron Mountain may be divided into two parts. The first step calls for the isolation of the $90 titanium value carried by each ton of the uniform mineralization. Prior investigators have invariably classified the preceding value as a worthless nuisance. Future research workers ought to hold the metal in higher esteem. A successful separation may simply call for a political, economic and geographic comprehension but slightly broader than the observational latitudes covered by past investigators.

Electric Steels

Once impoverished of its titanium content the gangue-free ore of Iron Mountain should be utilized for the manufacture of high-grade alloy steels. The best steels are made in the electric furnace. Many scientists are of the opinion that a good alloy cannot be made without introducing materials from Peru, Russia and Central Africa into the furnace charge. Steps should soon be taken to upset that idea. Once freed of titanium the Iron Mountain ore would contain commonly imported ingredients in the proper proportions for the manufacture of a first-class alloy steel.

Electrolytic Iron

The Iron Mountain ore is likewise suitable for the manufacture of an extremely pure electrolytic iron. In order to point out the higher values overlooked by past investigators the iron content in the big dike was unduly derided in the preceding chapters. As stated previously, extraction of the predominating values by a sodium sulphate fusion would form excessive quantities of ferrous sulphate in the waste liquors. In France and elsewhere ferrous sulphate serves as the electrolyte for making ''Swedish'' iron of a 99.97% degree of purity. No purer iron can be made by any method. For the manufacture of superior alloy steels wholly from Wyoming raw materials, iron of the preceding purity should be used. The electrolysis of the waste liquor may yield an important credit for a titanium operation in the specialized Wyoming field. If dump power is utilized for the electrolysis of an otherwise nuisance solution, pure iron should be produced at a figure considerably below prevailing costs.

Political Attitude

Local boosters occasionally criticize steel companies for not building furnaces and mills in this state. They point to the large iron ore deposits and also stress the fact that no state approaches Wyoming in known coal reserves. At the present time the entire coke production of the state is limited to the output of the several oil refineries. Lacking suitable coals, many years may pass before lowly pig iron is produced in this state by the older methods of carbon smelting.

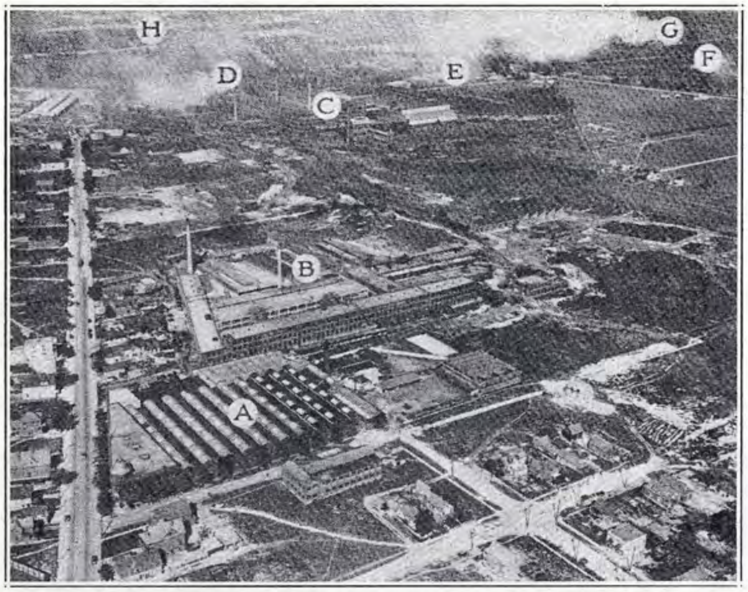
In lieu of investigating procedures for producing purer iron and stronger steels in self-contained basins of Wyoming, a few dogmatizers are now preaching highly retrogressive doctrines in regard to pending improvements on the channel that generates most of the power profits for the U. S. Reclamation Service. As they put it, power development should forever remain subservient to the whimsicalities of another industry more or less subsidized along the banks of major river courses in the western United States. Seemingly, some citizens of Wyoming do not yet know that the industry they most loudly champion has long been relying on the power profits and mineral royalties collected from the extremely fertile North Platte basin for the bulk of its national subsidy receipts.

It is not again necessary to dwell upon the interlocking topographic and geologic potentialities of a basin in which strictly modern metallic products can be manufactured without the employment of distantly transported foreign ores and fluxes for the essential furnace charges. In the Prefatory Statement rivers that justify expenditures for power development were held to be few and far between in the United States. The most notable exception is the Niagara River. The plants near Niagara Falls together form the largest water-power development in the world. To obviate costly and time consuming inquiries authority to reprint three of the industrial views that appear on pages 320 and 321 of the second volume of "Niagara Power" by Edward Dean Adams, views are hereat inserted.

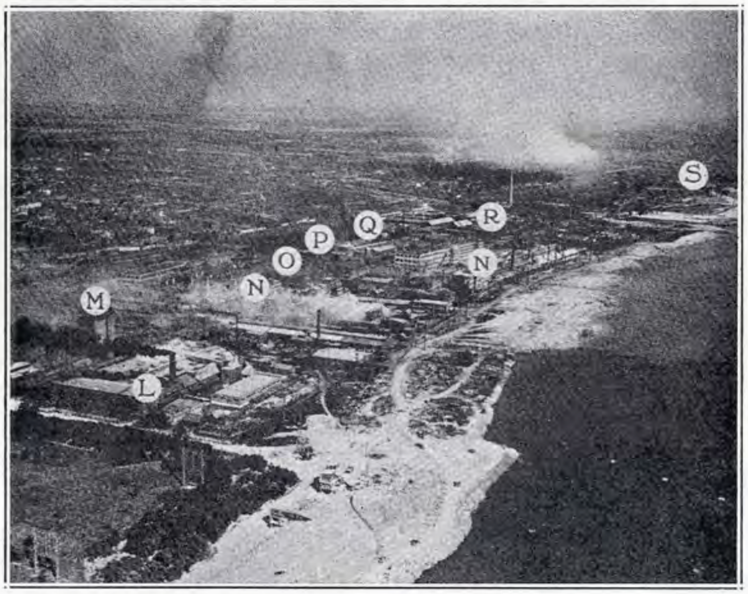
Line
Omitted

In time a majority of the basic industries appearing on the selected photographs may consider the merits of the North Platte area as a prospective location for branch plants. No general

NIAGARA'S BASIC INDUSTRIES



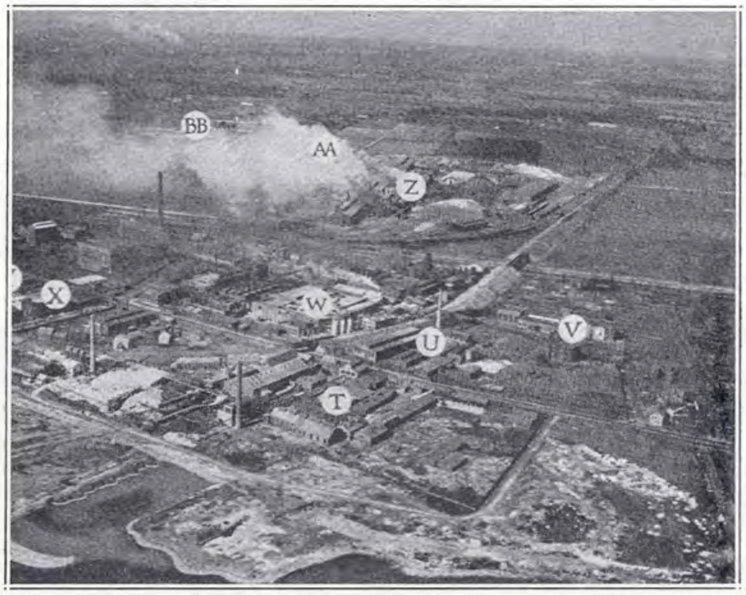
A	American Sales Book Company	E	General Abrasive Company
B	United States Light & Heat Corp.	F	Republic Carbon Company, Inc.
C	National Carbon Company, Inc.	G	United States Ferro Alloys Corporation
D	Pittsburgh Metallurgical Company	H	Titanium Alloy Manufacturing Co.



(COURTESY NIAGARA FALLS POWER COMPANY)

L	Certainteed Products Corporation	P	Mathieson Alkali Works, Incorporated
M	Acheson Graphite Company	Q	Niagara Electro Chemical Company
N	Carborundum Company	R	Norton Company
O	American Magnesium Corporation	S	Ramapo-Ajax Corporation

NIAGARA'S BASIC INDUSTRIES



(COURTESY NIAGARA FALLS POWER COMPANY)

T	Oldbury Electro Chemical Company	X	Electro Bleaching Gas Company
U	Phosphorus Compound Company	Y	Niagara Alkali Company
V	Niagara Ammonia Company, Inc.	Z	Union Carbide Company
W	Hooker Electro Chemical Company	AA	Isco Chemical Company
		BB	Kimberly-Clark Company

exodus may be expected in that direction until all of the power resources of the Wyoming river are fully developed.

Only one similarity can be pointed out for the North Platte and Niagara rivers. Engineering experts of the U. S. Reclamation Service have calculated the cost of firm power development on the North Platte at a figure slightly below the current rate at Niagara.

For the operation of the several plants illustrated, many types of raw materials from widely separated sources of supply are required. The Niagara valley is known to contain large supplies of limestone and sand, but other basic materials must be sought outside of its boundaries. The North Platte valley is different. Within its confines are tremendous deposits of the ores, chemicals, salines, alkalis, fuels, fluxes, as well as the more ubiquitous raw materials that frequently enter the larger electric furnaces. In regard to both low and high-cost finished products the firmly established Niagara location is superior to Casper for reaching the national markets.

Other economic limitations and attitudinal comparables, likewise, justify consideration. For instance, the question of making power development subservient to farming or any other form of industry is not a general topic for discussion among debating societies now thriving unmolestedly in an international basin duly accredited with a possible hydro-potential of 6,000,000 horsepower. In this vicinity, however, a number of taxpayers ofttimes stress the economic necessity of utilizing the last drop of water remaining in the North Platte solely for the object of placing tremendous additional acreages under the plow. Equally opinionative folks, however, hold to the view that a sufficient number of farms are already in Wyoming and elsewhere for the general good of the country. Local expansion in the agricultural industry may not prove expedient until wider market outlets are established directly within Wyoming. It would be more logical for such an achievement to follow rather than to precede increased industrial development in this state. At this time it may prove more profitable to consider ways and means for reproducing the sky-line perspective of going electrochemical centers upon preliminary sections of the waterfront at Casper.

Varieties of industrial products far too numerous to list in this booklet could be produced at the minimum cost in the North Platte basin. Development of natural resources peculiar to that area is mainly dependent on low-cost power. For stimulating wide interest in local industrial opportunities private or public capital should construct the power unit of the proposed irrigation system first of all.

(COURTESY CASPER CHAMBER OF COMMERCE)

Pathfinder Gorge and Dam

A quotation in a prior chapter described the interest that certain embryonic industries displayed as soon as plans were announced for harnessing Niagara Falls. Equally wide interest should be manifest as soon as plans are announced for subduing the more precipitous channel of the North Platte. In no catchment area is concentrated a wider and a more overlapping assortment of the basic materials commonly consumed and reduced at the larger hydro centers.

CHAPTER XV

SALINE AND ALKALINE DEPOSITS

Introductory — Geology — Government Report — Origin — Distribution—Alkali Lake Tabulation—Tabulation of Analyses—Map—Future Reports—Salt—National Review—U. S. Sulphate Supplies Cut Down—New Production Planned —Imports—Wyoming Sulphate Production—Utilization—Sodium Carbonate — Magnesium Sulphate — Utilization—Lithium.

Introductory

Several of the larger plants shown on the Niagara Falls views are engaged in the electrolysis of common salt. The raw material comes from underground deposits that are located in the stream basins of central New York. Chlorine, caustic, hydrochloric acid and metallic sodium are some of the products derived from salt. The chlorine gas of the Niagara district is put into steel cylinders and shipped over the world for the purification of the drinking water supplies of most villages and cities. Its use has virtually eliminated typhoid fever epidemics in the United States.

In the hydro basin of Wyoming several types of salts are available for electrolysis. In the latter valley it is not necessary to search for salts at profound and uncertain depths. All recognized deposits appear on the surface for measurement and whatever further observation that may be deemed desirable. On the open terrain estimates of available material can be made with a degree of accuracy that eliminates the element of speculation common to the ordinary mining venture.

Geology

Several reports have been published on the alkali resources of this state. The one that contains the greatest amount of conveniently arranged tabulated information was written by Alfred R. Schultz. It was published in Bulletin No. 430 of the U. S. Geological Survey. This bulletin is no longer available for public distribution.

Basic information of academic and economic value appears in the Schultz report. Liberal quotations sustain the general theory of the late Professor Knight now accepted for the origin of alkali lakes. The main findings of the Schultz report are reprinted below:

Deposits of Sodium Salts in Wyoming

By Alfred R. Schultz

Introduction

Wyoming is noted for its salt, sulphur, iron, alkaline earth, mud, and hot springs, which are scattered all over the state. In addition to the deposits formed from these mineral springs there occur in Wyoming extensive deposits of soluble salts of sodium and magnesium—sodium sulphate, sodium carbonate, and magnesium sulphate—for the most part in small drainage areas or basins which have no outlet. Many of these depressions are locally called "lakes," as they form the lowest parts of the basins and during the spring and early summer months are covered with shallow waters. During wet seasons some of these "lakes" contain water throughout the year. A few of the soda lakes, as the Wilkesbarre and Wilmington lakes, never become dry and form no solid deposits, the soda being entirely in solution. The soda basins or "alkali lakes" are more or less irregular and the deposit of salt in the different parts of the basin of varying thickness. The salt beds are usually very thin along the edge of the basin and thicken toward the center. In some localities these alkali deposits have been utilized, but for the most part no effort has been made to develop them for commercial purposes. A few of the mineral springs in Wyoming have been developed for their medicinal value and have attained considerable commercial success.

In the Yellowstone Valley salt springs are numerous, but thus far no effort has been made to utilize the brine in the manufacture of salt. Extensive beds of salt of great purity occur in Crook County west of the Black Hills and in western Uinta County along the Salt River Mountains. Salt springs and deposits are known to be present in Bannock County, Idaho, and western Uinta County, Wyo., along the state line. In both of these localities salt has been produced for many years. The salt-producing area in Uinta County, Wyo., lies south of Star Valley, on the route from Smoot, in upper Star Valley, to Thomas Fork. The salt developments are located on Salt Creek, in the SW 1/4 sec. 26, T. 29 N., R. 119 W., about 8 miles northeast of Green's ranch or the head of Thomas Fork. The brine springs in this part of Wyoming are similar to the workable springs along the Idaho-Wyoming border described by C. L. Breger in the preceding paper in this bulletin. It is highly probable that in this vicinity rock salt will be found beneath the surface similar to the rock-salt deposits discovered in 1902 on lower Crow Creek, a tributary to Salt River in eastern Idaho.

No attempt will be made in this paper to describe all the various salt deposits, mineral springs, and alkali flats in Wyoming or to give their distribution. A few of the largest and most important soda deposits and lakes will be briefly described, and a short discussion of the sodium-carbonate developments at Green River will be presented.

ALKALI DEPOSITS

Lakes and Ponds

In various places in Wyoming there are thick deposits of high grade soda in the beds of dry lakes or ponds, ranging from those a few feet in diameter to some that cover several hundred acres and lying at various elevations above the sea. Most of these alkali deposits seem to have a common origin, and they occur in all parts of the state. Alkali deposits are found here and there and alkali crusts form in abundance about all depressions, ponds, or "dry lakes" in geologic formations above those of Paleozoic age. They are most abundant in the Triassic beds, but occur in all the geologic formations from the Paleozoic down to the soils of the present time. The Mesozoic and Cenozoic formations contain many times as much alkali as the Paleozoic and lower rocks.

In some localities the amount of alkali stored in clays and shales is enormous. In the midst of the Red Desert there are clay beds of a dull-red color which have a rather pulverulent surface during dry weather. Only a few inches below the surface in many of these beds the alkali amounts to 30 or 40 per cent of the mass. When there is a slight rainfall the clay forms a protective covering and none of the alkali escapes. During periods of heavy rain, which rarely occur, the water often finds its way through this clay mantle and, following the alkali surface, carries away all the salts that will pass into solution. At such times the water draining from these places and entering the soil is nearly saturated with salts. In many of these small basins the alkali is left unprotected on the surface, where it is deposited on the evaporation of the water that brings it into the depression either by drawing it up from below through capillary attraction or by carrying it in from the surrounding country on the surface or through underground seepage.

In the fall, when the surface becomes a powdery mass, the winds carry away the soda in huge clouds of dust. The air is so filled with the desiccated salts that anyone at a distance of 4 or 5 miles from these beds and unacquainted with the conditions would pronounce the dense white clouds the result of some great conflagration. Often in the fall, when the wind is blowing from 40 to 60 miles an hour, anyone standing on the slope of the mountains can see a cloud of alkali dust rising to a height of 50 to 100 feet from every dry alkali pond and extending for some distance beyond its borders. In this way the annual supply of alkali washed into these depressions is to a certain extent reduced, but this reduction is not equal to the storage and in consequence the deposits are increasing in volume. There are numerous alkali flats in the region of the Red Desert similar to the flats east of the Boars Tusk, in T. 23 N., R. 104 W., and north and east of Black Rock, in T. 22 N., R. 101 W. Some of these are large, others small, but the history is much the same for all. Most of these flats are too small to be taken into consideration in this preliminary paper.

Origin

The large size of some of these salt deposits and their number and areal distribution have given rise to considerable speculation as to the source of the soda and magnesium compounds in the "soda lakes." It is believed by some that the salt is brought in by the water draining into the lakes from the surrounding country and is held in solution until the water evaporates, the crystallized material being deposited in beds ranging in thickness from a few inches near the borders of the lake to several feet near the center. Others believe that the soda is brought from other sources through the agency of springs. Both of these theories are tenable and to account for all the conditions and the observed facts regarding the deposits in the various lakes both theories are required.

It was formerly believed that much if not all of the alkali in the arid West was formed through the decomposition of granitic rock by the oxidation of the feldspars, but it is now known that none or at best very little of the alkali so abundant in Wyoming has originated through the direct decomposition of the granites in the vicinity of the granitic masses.

During the late eighties it was argued that the alkali found in extensive deposits or dry lakes in Wyoming was derived largely from springs in the immediate vicinity of some of these lakes. This theory is set forth by Rickett's [a] in the following manner:

> It was at first generally supposed that the soda arose simply by the evaporation of surface waters that had drained through the soil into the lakes and in this way dissolved the sodium salts. For many reasons this supposition was doubted, and it is now proved to be incorrect. While it is true that the soda deposits occur in basins with no visible outlet, there are also a great number of such basins with lakes or ponds in them which contain only alkali waters, or, when dry, but a thin crust of the alkalis or alkaline earths. The true soda deposits, on the other hand, though the basins in which they occur are not of abnormal area, always contain exceedingly large quantities of the salts peculiar to them, and these are pure and are not, as a rule, a mixture of sodium, magnesium, and calcium salts, which would be present if they were the result of the evaporation of surface waters. Mr. Arthur L. Stone, of Laramie City, has found that the Union Pacific Lakes near Laramie are fed by springs whose waters are highly charged with sodium sulphate. Finally, at Rock Creek there are in one and the same basin some lakes containing pure sulphate of magnesium, others which contain with the latter also large quantities of sulphate of sodium, and still others which contain no deposits whatever. For these reasons it seems very certain that all of the large deposits of soda in Wyoming arise from the evaporation of the waters of springs which feed the lakes and which are highly charged with soda.

In a later report [b] Ricketts makes the following statement:

> There can be no question but that these deposits all arise through evaporation of the water of mineral springs which feed into lakes and have no way of escaping.

That Ricketts as well as others was led astray in making his deductions on the origin of the Wyoming soda deposits

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[a] Ricketts, L. D., Ann. Rept. Territorial Geologist Wyoming, 1887, p. 46.

[b] Ricketts, L. D., Ann. Rept. Territorial Geologist Wyoming, 1888-1889, p. 67.

was in part due to the assumption that the salts were pure and not, as a rule, a mixture of sodium, magnesium, and calcium salts. That the salts in these "lake deposits" are seldom pure is clearly set forth by Knight:[b]

> The salts stored in the basins, either in solution or as a solid, compare in chemical constitution with the salts found in the soils and as efflorescent crusts. To be sure, the sulphate of lime is quite insoluble and in consequence is very rapidly precipitated when concentrated in depressions. The difference in the salts found in the same basin but in different depressions is very interesting but is accounted for in several ways. In the first place, there is no deposit of pure Epsom salt or magnesium sulphate, for it always contains some Glauber salt or sodium sulphate, unless one selects pure crystals for analysis. The relations between these deposits with varying composition should be considered in discussing their origin. The deposit rich in Epsom salt occupies the lowest point in the basin. Magnesium sulphate is more soluble than sodium sulphate at ordinary temperature, and in the case of a heavy rain when the soda has been deposited in the small depressions above the large ones, the freshet would carry away the magnesium sulphate to the lowest depressions, where it is found. The magnesium sulphate, being much more soluble, would also tend to store the Epsom salts in the lowest depression on account of the percolation of the water, rich in these salts, to the lower level.

Knight is the chief advocate in recent years of the theory that the Wyoming soda lakes are formed by the soda brought in by the water from the country draining into the lakes. More than any other one man he has carefully studied the Wyoming alkali deposits and proved that they were formed by accumulating salts that remained after the evaporation of the water in the small basins and "dry lakes." This theory can best be set forth by quoting at length from Knight's report as follows:[c]

> While it is possible that considerable alkali is being brought to the surface with spring water, the amount is insignificant as compared with the supply that is constantly being derived from the soils and other formations.
>
> In looking into the "spring" theory careful observations were made at nearly all of deposits of note in the state. In no instance were springs found on a level with or above the deposit or water line. In five instances deposits were found without any appearance of moisture, and in digging into the mass no water was found. In other places the deposits were underlaid with a saturated solution of sodium sulphate and other salts, while in other localities the soda is always in solution. In

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[b] Knight, W. C., and Slosson, E. E., Alkali lakes and deposits: Bull. Wyoming Exper. Sta. No. 49, 1901, pp. 84-85.

[c] Idem, pp. 85-88.

the latter instance I believe that there are springs that feed the lakes; but whether or not the waters are rich in sodium or other salts has not been determined. There are many instances where the water came up and filled an opening made when blocks of the salt were being removed, and following this the opening was immediately filled with crystallized salts. This was in all probability due to the water below the deposit and the superincumbent weight was sufficient to force it to the surface. In one instance of this kind when the cube of soda was taken out for the world's fair the bed of salt was pierced several times with an inch bar, and through this opening the water came in at the rate of 450 gallons per hour. This solution had a gravity of 31° Baumé, and an analysis made for sulphur trioxide proved it to contain 19 per cent SO_3, corresponding to 76 per cent of Glauber salts or 57 per cent of Epsom salts. Both these salts were present. While the springs play some part in the accumulation of the soda deposits, they must be considered of minor importance as compared with other factors.

From personal observations it is my opinion that the alkalies have been derived from the soils and the strata which surround the deposit or drain into them. In localities where there are vast beds of shale and clay with undrained depressions we always find alkali being stored. There is no exception to this statement so far as I am aware. In hundreds of places there are slight depressions at the present time, where there is an accumulation of salts going on; but no one has pretended to measure the amount that accumulates annually.

* * * * * *

In summing up the evidence relating to the origin of the so-called alkali salts of Wyoming I have arrived at the following conclusion: Primarily the alkali has been produced by the decomposition of the various rocks containing these elements. These salts appear to have been formed extensively during the Mesozoic and Cenozoic eras, but in place of being stored in deposits were carried down with the sediments. Later through the mountain-making agencies these formations were brought to the surface and through the influences of decomposition and erosion have been converted into soil. The salts have remained in the soils so formed, since there has not been sufficient water to leach them out. The decomposition of the rocks is still in progress, and from this source and the storage already accumulated in the soils the deposits of alkali have been formed and are being increased.

There are hundreds of places in Wyoming where sodium salts are being accumulated; but as a rule they do not form beds of much consequence. Upon the Laramie plains alone there are no less than one hundred slight depressions containing more or less alkali. In the majority of cases the alkali is found in the fall of the year in a thin crust upon the bottom of small ponds which have recently dried up. The deposits which are to be discussed under the above heading are those where there has been a considerable storage of alkali and where it forms masses of sodium sulphate and associated salts to a thickness of 1 or more feet.

Since the alkali deposits look very much alike and have been deposited under similar conditions a general discussion of the beds will not be out of place at this point. In many instances the name alkali lake has been applied to the soda deposits, since in the early spring and often into late summer the deposits are covered with water. The water accumulates through the melting snows and rain and is often a foot or two in depth; but beneath this one can find a solid bed of crystallized alkali. Later in the season these so-called lakes are deposits of snow-white alkali, which when seen from a distance resembles a snow-covered basin.

The deposits vary in size from a few to 100 acres, and in thickness from a few inches to 10 or possibly 15 feet. The salts are always found resting upon a muddy bed, which is usually very soft, and without difficulty one can force a pole to 5 or 6 feet below the hardened deposit. The mud varies in color from almost black to bluish, and contains many crystals of sodium sulphate. When it is removed from the bed it has a strong odor of sulphureted hydrogen, and often one is conscious of an odor resembling that rising from dissolving sodium hyposulphite. This mud always contains quite a percentage of salts found in the deposits.

For many years it was supposed that all of the alkali deposits were of crystalline purity, and for commercial purposes they could be quarried, dried, and made ready for the market. Upon making a careful section of several deposits it was found that none of the beds were pure; but were alternating layers of salts, sand, and mud. The thickness of the sodium sulphate bands depends upon the rapidity with which the salts were washed into the depression. It appears that at the close of each season, or during the fall, all of the water was evaporated and upon the alkali deposit the winter's wind carried the usual amount of sand. On the following spring the melting snow and rains carried into the depression not only the salts, but also muddy water which settled to the bottom and made a stratum of mud or muddy deposit. In some instances the accumulations of alkali of one or more previous seasons might have been dissolved, and all of the sand and mud concentrated at the bottom of the deposit or stratum. It is a rule that the deposits are mixtures of the various salts arranged in bands of varying thicknesses and alternating with other bands containing large percentages of sand or mud.

Distribution

Soda lakes of considerable size and importance are located in Albany, Carbon, Natrona, Sweetwater, Fremont, and Johnson counties. (See fig. 49.) Many of the lakes are small and of little or no economic importance. Others are large in areal extent but contain very thin beds and so far as investigation has progressed seem to be of no commercial value.

Of the counties above mentioned Albany, Carbon, and Natrona contain the most numerous soda lakes. The lakes outside of these counties, as well as many of those within these counties, have no commercial value at the present time. Some of the more important lakes are briefly described in the accompanying table, which gives the geologic horizon, location, and approximate area of the basin, the thickness of the salt beds where known, and such additional information as bears directly on the deposits themselves.

Chemical Composition

The alkali deposits in the "soda lakes" may be divided into two classes—(1) those that contain considerable quantities of carbonates and consist chiefly of sodium carbonate, sodium sulphate, and sodium chloride, and (2) those that contain very little carbonate and consist chiefly of sodium sulphate, sodium chloride, and magnesium sulphate. Traces of other salts, as potassium, lithium, iron, aluminum, manganese, borates, nitrates, sulphites, and phosphates, are associated with these principal salts in many of the deposits. Regarding the salts of the "soda lakes," E. E. Slosson makes the following statement: [a]

> The salts found in the soda lakes are the same as those which occur in the soil of the surrounding region and form alkali crusts as they are drawn up from below with the water and left on the surface as this evaporates. Of these salts the most abundant in Wyoming is sodium sulphate. This exists in two forms—with water of crystallization and without. The former has the chemical symbol $Na_2SO_4.10H_2O$, and is called mirabilite in mineralogy and Glauber's salt in medicine. The pure crystals contain 55.91 per cent of water and 44.09 per cent of the dry sulphate. It forms large, transparent crystals, which, when exposed to the air, lose all their water of crystallization and fall into a fine white powder (Na_2SO_4), known as thenardite.
>
> Magnesium sulphate ($MgSO_4.7H_2O$), epsomite, or Epsom salts, is found as long, needle-shaped crystals or short, thick crystals about a quarter of an inch thick, and contains 51.2 per cent water of crystallization, which it loses in part when exposed to dry air.
>
> Sodium carbonate ($Na_2CO_3.10H_2O$), sal soda, or natron, contains 62.9 per cent water of crystallization when fully hydrated, but will lose from a half to nine-tenths of it to dry air.
>
> Sodium chloride ($NaCl$), common salt, or halite, contains no water of crystallization.

The chemical composition of some of the Wyoming alkali deposits is shown in the following table, compiled from the report of Knight and Slosson, already cited:

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[a] Knight, W. C., and Slosson, E. E., Alkali lakes and deposits: Bull. Wyoming Exper. Sta. No. 49, 1901, p. 106.

Statements regarding some of the larger alkali deposits in Wyoming.

Location.	Name of alkali deposit or lake.	Number of deposits or lakes.	Area covered.	Thickness or depth.	Age of underlying rocks.	Remarks.
			Acres.	Feet.		
Albany County.						
22 miles southwest of Laramie: secs. 15, 21, 22, T. 13 N., R. 75 W.	Downey	3	100	0-10	Triassic	North Lake, the lowest of the three, has a good quality of soda. Middle Lake, the second lowest, has a good quality of soda. South Lake is soft and miry and contains no hard beds of soda.
13 miles southwest of Laramie	Union Pacific	4	60	0-40	Cretaceous (Benton)	Big Lake, Track Lake, Red Lake. Besides four large lakes that vary from 4 to 40 acres, there are near by scores of depressions containing small quantities of alkaline water or salts.
12 miles northwest of old Rock Creek station, Union Pacific Railroad.	Rock Creek group	Numerous.	Several hundred.		Triassic	Numerous small depressions contain alkali; the largest covers about 90 acres. The lower parts of these depressions contain more magnesium sulphate; the higher parts contain sodium sulphate. There are about 26 small lakes or ponds, many of which are of no importance on account of small size or thin deposits.
	Brooklyn	1	90	0- 1		
	Philadelphia	1	40	4- 7		
	Chicago	Group.	1-10	0- 6		
Carbon County.						
3 miles northeast of Browns Canyon.	Rankin	Numerous.	Several		Cretaceous	These deposits are usually under water.
7 miles northeast of Rawlins	Dillon				do.	
30 miles northwest of Rawlins, sec. 23 and 26, T. 25 N., R. 89 W.	Bothwell deposits or Bull Spring Lake.	1	30	0-20	Tertiary	Part of Red Desert. There are several smaller alkali deposits to the west and south that drain into this one. Red Desert has numerous small alkali lakes.
Natrona County.						
7 miles below Split Rock Postoffice, south of Sweetwater River; T. 28 N., R. 88 W.	Morgan	1	100	0-15+	do.	This lake lies in a long, narrow depression south of Sweetwater River in the southwest corner of Natrona County. The thickest part of the alkali deposit occupies about 6 acres.
Sweetwater Valley, near Independence Rock.	Independence group	Many.				The alkali deposits occur in two pronounced old river channels north of the present Sweetwater River. The channels are about 3 miles apart and are separated by a marked divide. The lakes in Series I, or the Dupont Lakes, occupy the southern channel, and those in Series II, or the Berthaton Lakes, the northern channel. The Dupont claims comprise also many lesser lakes of little importance.
	Series I (Dupont claims):					
Sec. 12, T. 29 N., R. 87 W.	New York and Philadelphia		110	0-20	do.	Two claims on one lake.
Secs. 23, 10, and 11, T. 29 N., R. 86 W.	Wilmington		160	0-40+		Lake containing water throughout the year.
	Wilkesbarre		50			Do.
	Omaha		4	0- 8		Large percentage of sodium carbonate and bicarbonate. Used by the Mormons for raising bread.
	Series II (Berthaton claims).	2	640 80			All lie in an old channel of Sweetwater River about 3 to 4 miles in length.
8 miles northeast of Casper; sec. 26, T. 35 N., R. 78 W.	Gill	4		20+	Cretaceous	Soda pits have been sunk to a depth of 12 to 20 feet, but the entire thickness of the soda has not been determined.

Chemical composition of some of the larger Wyoming alkali deposits.

Name of alkali deposit or lake	Laboratory No.*	Sample as received										Calculated as dry salts						Analyst†	Remarks
		Water	Insoluble	Sodium sulphate	Sodium chloride	Sodium carbonate	Calcium sulphate	Magnesium sulphate	Magnesium chloride	Sodium borate	Sodium bicarbonate	Sodium sulphate	Sodium chloride	Sodium carbonate	Calcium sulphate	Magnesium sulphate	Sodium bicarbonate		
Albany County																			
Downey	162	44.41	0.11	28.24	0.28			26.96				50.90	0.50			48.60		S.	Crystallized salt in middle of northern Downey Lake.
Do.	178	55.43	2.24	39.17	.12		0.80	2.24				92.54	.28		1.89	5 29		S.	Clear crystal mixed with mud and water 6 feet below surface.
Do.	163	74.60		6.93	1.16			17.31				25.61	5.28			70.11		S.	Solution above sample No. 162.
Do.	176	72.79	.13	12.77	.86	0.05		13.40				47.18	3.17	0.18		49.47		S.	Solution in the blast hole from which No. 178 was taken.
Do.	173	75.89	.02	11.50	.45	.06		12.08				47.74	1.86	.24		50.16		S.	Solution from southern Downey Lake.
Do.	175	49.29	.51	19.67	.50			30.03				39.18	1.00			59.82		S.	Crystallized salt from ditch in southern Downey Lake.
Do.	182	55.94	.10	41.02	.12			1.82				95.46	.28			4.26		S.	Pure crystal at north end of northern Downey Lake.
Union Pacific (Big Lake, Track Lake, Red Lake)	172	55.55	.09	42.75	.70			.91				96.37	1.58			2.05		S.	Marketable dried soda.
Do.	A	46.87	13.86	34.85	1.16		1.45	.97				94.23	3.14			2.63		P.	Average sample from lakes.
Do.				44.90			1.75	.60	6.43	1.46								P.	Specific gravity 1.0487.
Do.				75.63			1.46	.70	3.00	1.21								P.	Specific gravity 1.0725.
Do.				93.07			2.01	1.43	4.16	.75								P.	Specific gravity 1.0887.
Rock Creek Group (Brooklyn, Philadelphia, Chicago, and others)	88	44.50	.65	12.13	.38			42.34				22.13	.69			77.18		S.	From surface of largest lake.
Do.	89	48.03	.08	24.49	.24			27.16				47.19	.46			52.35		S.	From depression in a small lake.
Do.	90	51.08	1.13	10.22	.46			37.11				21.41	.95			77.64		S.	From large deposit about 1 mile north of No. 88.
Do.	91	49.66	.58	40.52	.42			8.82				81.43	.84			17.73		S.	From deposit immediately north of No. 90.
Do.	92	27.71	64.96	1.20	.66			5.47				16.33	9.06			74.61		S.	From mud beneath No. 89.

*Numbers used by E. E. Slosson in Bull. Wyoming Exper. Sta. No. 49. †S., E. E. Slosson; P., H. Pemberton and G. P. Tucker; A., D. H. Attfield; R., L. D. Ricketts.

> ### *Sodium Sulphate*
>
> Sodium sulphate, at one time an almost unsalable by-product, has become during the last few years, a commodity which is commanding some of the major attention of the chemical industry. It forms one of the raw materials for some of the important and rapidly growing industries of the United States. These include the manufacture of rayon, textiles, glass, ceramics, heavy chemicals and sulphate pulp and paper, the pulp and paper industry being the largest consumer.
>
> The rise of the synthetic ammonia industry has rapidly brought about a decrease in the manufacture of nitric acid from sodium nitrate and sulphuric acid, thus curtailing the chief source of niter cake, which has been used as a substitute for salt cake and also as a raw material for its manufacture. (Its principal use is in the smelting of copper and nickel.) Changes in the manufacture of hydrochloric acid, produced from salt and sulphuric acid, have decreased the by-product supply of salt cake. Much hydrochloric acid is now made directly from hydrogen and chlorine which are by-products from the electrolytic caustic-soda industry.
>
> Enormous deposits of sodium sulphate are available in the United States and Canada. Due to the increased demand for this chemical and the diminishing production from by-product sources, these deposits have commanded much attention. Hindering the development of such deposits are the low cost of imported salt cake and the high transportation costs of finished material from the deposits to the markets.
>
> United States.—The largest producer of natural salt cake in the United States during 1931, was from the deposit owned by the Sodium Products Corp., leased and operated by the Arizona Chemical Co. The plant is located at Camp Verde in Yavapai County, Ariz. The Rhodes Alkali & Chemical Corp. also produced a small quantity from deposits near Mina, Nev. Glauber's salt was produced by the Gill Soda Co. and by W. E. Pratt at Casper, Wyo., by the Iowa Soda Products Co. at Rawlins, Wyo., (that produced by the latter company being shipped to Council Bluffs, Iowa, for refining) and by the American Sodium Co., Wabuska, Nev.

Aside from mentioning the distance of the crude lake salts from present markets, no explanation is recorded for the limited exploitation of the salt beds of Wyoming and of the far more remote states. Such mere locational figures of speech should soon be silenced. Until plant engineers ascertain the magnitude and diversity of resources that lie contiguous to the big salt beds in Wyoming, further periods of instability will likely rule within the highly volatile and yet embryonic chemical industry. To lead those salts of mountainous volume to Mahomet would be a mistake. A far less expenditure in muscular effort would be required in event the local salines are simply utilized for the manufacture of concentrated products on the spot.

A number of products have already been mentioned that could be made by properly mixing the different salines and ore-types of Wyoming. As an example, take the ferro-alloy group of metals. In time the Wyoming finished product might be shipped even as far as those otherwise little known geographic obscurities from whence come the raw ore supplies commonly imported into this country. In the crude form sodium sulphate will never travel that far. To date a 600-mile radius has sharply defined the trade territory of the pioneer salt producer in Wyoming.

Metallurgical Processes

Existing textbooks do not devote an undue amount of space on the outstanding efficiencies of sodium sulphate as a reagent for modernized metallurgical operations.

As a tried-out separatory agent no salt possesses a wider range of serviceability than sodium sulphate. In matte work it frequently eradicates a contaminating metal in the convenient form of a compound alkali soluble. In the reduction of certain ore complexes mattes of different specific gravities are also formed. When a furnace effluent of that type readily fractures along a sharply defined plane, further separations are possible by gravitational or mechanical methods that are too simple to touch upon herein. After reviewing much fragmentary literature of varied origin the remaining remarks of this chapter are presented solely for the critical perusal of the present school of Wyoming metallurgists.

Nickel

Long ago it was found necessary to employ a sodium sulphate fusion to isolate the first ferro-alloy metal from its ore. The basic principles of the process are quite similar to the fusion described in Chapter VI for the recovery of titanium dioxide.

Nickel is the oldest and still most common ferro-alloy metal. Aside from the prehistoric, celestially blended ferro-alloys occasionally sent as meteoric irons, it seems that no nickeliferous material was encountered until 200 years ago. This fall a Believe-It-Or-Not cartoon stated that one of the U. S. coins was named after the Devil. Authority for that statement was probably obtained from a widely read advertising brochure recently republished by the International Nickel Co., Ltd. An explanatory passage follows:

> *Nickel Named After "Old Nick"*
>
> In the transition from fable to fact, nickel picked up its name at a time when men thought it was sent by the Devil and not by Heaven. In the early part of the eighteenth century fresh lodes of ore were laid open in Saxony where from times immemorial, silver and copper mines had been worked. This new ore was so glittering and full of promise as to cause the greatest excitement, but after innumerable trials and endless labor, all that could be obtained from the ore was not metal but a worthless slag. In disgust the superstitious miners named the ore Kupfernickel (copper-nickel) after "Old Nick" and his mischievous gnomes who were charged with plaguing the miners and bewitching the ore.

For 150 years after the old German miners first coined a name for the new element, metallurgists continued to look upon nickel as a hopeless metal. In 1893, however, a Yankee shoemaker discovered that the associated copper in Connecticut ore was soluble in an alkali sulphide. His basic patent is now called the Orford Process. In a short time that process became the backbone of the nickel industry.

The world's greatest concentration of nickel ore is in the famous Sudbury basin of Ontario. From that area the British-controlled company normally supplies 90 per cent of the nickel consumed by the world. After being mined the ore is subjected to a sodium sulphate fusion in order to make the nickel-copper separation. The process is described in a Canadian treatise, as follows:

> ### *Nickel Refining*
>
> In refining nickel matte by the Orford process sodium sulphate is employed in the form of nitre cake.
>
> The process consists in fusing the matte containing the sulphides of iron, copper and nickel with sodium sulphide or with sodium sulphate and coal (which mixture produces sodium sulphide on fusion) in a cupola furnace and tapping into pots. The greater part of the nickel sulphide and small percentages of the iron and copper form a matte which sinks to the bottom of the pot and can be readily separated.
>
> The process is being continually improved upon but it is the basis of the process employed by the International Nickel Co. at their refinery at Port Colborne, Ont.
>
> The following quotation from the patent specifications of the U. S. patent No. 802012 granted to Ambrose Monell, gives the outline of the process insofar as it deals with sodium sulphate:
>
> > Instead of smelting the compound matte, as heretofore, in a cupola-furnace and running the product continuously into moulds, I so smelt the matte that when melted it will remain in a molten state subject to the high temperature of a furnace for a considerable period of time, during which I find that the copper and iron sulphides will be thoroughly dissolved by the sodium sulphide, and in one melting a good separation can be effected, and by two such treatments results are obtained equal or superior to the results of the four or five meltings which have been employed heretofore. For this purpose I employ as the smelting-furnace an open-hearth reverberating furnace lined with magnesite brick, as I find that silica-lined furnaces

> are quickly destroyed by fluxing with the sodium sulphide. Into such furnaces I introduce a charge of nickel-copper-iron matte, either solid or molten together with coke and sodium sulphate, the latter being preferably present in the proportion of sixty per cent of the weight of the matte, and the coke in the proportion of fifteen per cent of the matte. The sulphate is preferably added in the form of commercial nitre-cake. Where, for example, a fifty-ton charge of matte is treated containing, say, forty-five per cent of nickel sulphide and thirty-five per cent of copper sulphide, it is melted in the furnace and retained subject to the heat for some time—say, four to five hours after fusion has occurred—during which time it is preferably ''poled''—that is to say, treated by immersing beneath its surface poles of green wood, which evolve hydrocarbon gases and vapors, and thus aid in the reduction of the sulphate and produce an agitation of the material, which facilitates and renders more thorough the solution of the sulphides to be removed. Nearly complete solution of the copper and iron sulphides in the sodium sulphide reduced from the nitre-cake is thus effected, and the molten charge may be tapped from the furnace and allowed to separate in moulds.
>
> The possibility of utilizing the sodium sulphate of western Canada for this purpose depends entirely on the price of the material as compared with nitre-cake.

As in the previously described titanium process the worthless iron is removed in the form of a compound matte soluble.

The author suggests the possibilities of utilizing the sodium sulphates of western Canada for nickel refining. Apparently, those salt beds do not approach the nickel smelteries nearer than 1,500 miles. For Wyoming practice no greater distance than the width of a single county should separate its big ferro-alloy ore deposits from the requisite beds of reducing salts. In Wyoming, one-half the expanse of a continent is too far to go for the essential ingredients of any furnace charge.

Salt experts have long recognized the preceding bulletin, ''Sodium Sulphates of Western Canada,'' by L. H. Cole, Department of Mines, Ottawa, Can., as the best general treatise extant on sodium sulphate. It is a far bulkier volume than similar publications put out by the several bureaus of this country. Western Canada contains the largest known sulphate beds of the world. At one place those vast deposits are properly described as of the Wyoming type of lake salts. In view of that neighborly cognizance producers of sodium sulphate in this state should purchase copies of the Canadian publication. It will also serve as a convenient reference work on sodium sulphate technology.

Other Siderophiles

In recent years the International Nickel Co. ranked second only to Russia in the production of platinum metals. As should be anticipated the sodium sulphate process throws down those precious metals with the nickel. Not necessary to touch upon complicated geologic affinities here, but it is interesting to note that in his September, 1932 address before the Electrochemical Society, Dr. Mantell mentioned nickel refining slimes as the sources for rhodium and palladium. The same material was also listed as a leading source of platinum. Last year the Canadian company collected 91,643 ounces of platinum group metals. At this time the eyes of all interested in platinum are turned towards Canada. For recovering the precious metal from primary rock material as a low-cost by-product, no metallurgical procedure is as important as the basic sodium sulphate fusion.

In Canada the nickel ores occur in a deep-seated norite core rock. Some recent discoveries of platinum in Africa are connected with a lower norite zone. In Wyoming, the several ferroalloy deposits likewise offer the most favorable geology for the deposition of the platinum metals. In this vicinity a commercial discovery could be welcomed by a localized process that would isolate those metals from the most refractory of gangue materials. Mere discovery of platinum in the primary source rocks is not sufficient to guarantee successful mining operations. In some of the newer platinumiferous areas, recovery procedures will likely remain in the light of chemical impossibilities until suitable beds of sodium sulphate are also brought to light.

Radium

Reference has already been made to the $33,000 shipment of radium ore despatched from Lusk in 1919. Within the few months that operations were unmolested by extrinsic influences, no satisfactory system could be improvised for separating all of the earthy big-pay uranium mineral from the gangue rock. Nevertheless, at or about the same time, similar radium ores were being successfully fused with three times their weight of sodium sulphate in Australia. The end reactions of the fusion left the radium in suspension with the lead and barium sulphates.

Subsequent discoveries of sensationally rich ores in equatorial Africa put a sudden end to the radium industry as then organized in Australia, United States and elsewhere. Within the past two years a find of equal richness has been announced from the frozen tundra of arctic Canada. Some time may elapse before this country will again produce 95 per cent of the radium supply of the world. Should the metal regain its price level of yesteryear, bigger profits would loom in the offing for former operators at Lusk. For higher recoveries, the Lusk ores should be fused with the cheap lake salts that likewise appear in quantity within the southeastern Wyoming depository.

Beryllium

Some four years ago when an assistant of the late Hans Goldschmidt, long known to the world as the inventor of the various thermit processes, reported a high temperature method for producing beryllium, W. L. (Bill) Marion and his Lander associates announced an important discovery of beryl on Copper Mountain in Fremont County. At that point the mineral appears within the white feldspar segregations of a huge pegmatite dike. Before the date of the synchronized announcements, large crystals of beryl were frequently encountered in the big sheet muscovite dikes of the Hartville uplift, a highly mineralized district in Platte and Goshen Counties. The latter crystals, however, contain less beryllium oxide than the recently discovered ores of Copper Mountain.

The first step for the commercialization of the Wyoming deposits should involve an ore dressing that will extract the beryllium content in the form of the purified oxide. For that object the mineral should be fused at a high temperature with four times its weight of crude salts from the carbonate lakes, in lieu of the sulphate forms recommended for all preceding ore beneficiations. Lake beds containing up to 87%, Na_2CO_3, are located 45 miles due south of Copper Mountain. A soda fusion would first isolate both the beryllium and aluminum in the form of oxides. For the separation of those closely allied oxides, acid sodium carbonate should be utilized as the native precipitating agent. As previously stated, one of the local lake beds contains 18.97%, $NaHCO_3$. The extraction of course, consumes considerable muriatic acid, a common commodity not yet made from the abundant raw materials of Wyoming.

Since the commercial process was first announced from the research laboratories of the Siemens-Konzern, improved technology has reduced the price of the metal from $225 to $75 per pound. From time to time confusing reports appear in technical journals about new German processes for the production of cheaper beryllium. A serious drawback against the wider application of the metal has been the exorbitant prices asked for the best ore grades that must contain at least 95% of inert matter. But as soon as the miners will condescend to ship chemical concentrates containing 10 times the beryllium content of the native mineral, further drastic reductions may be expected for the price of the finished metal product. For preparing the purified oxide in Wyoming, the ore and requisite separatory salines occur in adjoining counties.

In beryllium technology, the Germans appear to be several years in advance of the rest of the world. So far the demands for beryllium products have been mainly supplied by their pioneer Siemens & Halske works. As soon as extensive markets develop in this country, the metal should be reduced at a Wyoming hydro-site by using the Stock admixture of beryllium oxyfluoride and sodium and barium fluorides for the electrolyte.

Beryllium has the lowest specific gravity of all metals that have inherent merits for utilization within the alluring light alloy field. A few years ago the element was supposed to be possessed of many hyperphysical powers. So far beryllium has revealed one secret of possible serviceability within the coming domain of applied atomistics. This year Professor Bothe reported the production of cosmic rays artificially by the transmutation of beryllium and helium into carbon with a release of energy greater than that put into the apparently approximated equational process. To settle fundamental arguments long raging in those branches of geology and astronomy that appertain to the birth and evolution of the several components of the local Galactic Universe, basic beryllium experimentation may further surrender excessively penetrating scintillation in respect to formative processes observable for embryonic matter.

For some time to come the heavy metal alloying field will probably offer the widest range of practical uses for beryllium. Several alloys of this type have already been produced which possess extraordinary strength, hardness and remarkable fatigue resistance. The only one so far quoted in domestic trade journals is a solution of beryllium in copper. At times much is heard about the miraculously tempered weapons that were fabricated during the Copper Age. Perhaps the technique for manufacturing the ornaments and implements of that cultural period was not as involved as present-day procedures.

Vanadium

The processes of the preceding chapter only outlined the initial reactions of sodium sulphate on the Wyoming type of vanadium ore. Therein, no explanation appeared on the energetic solvent action that the waste liquors from a fusion would exercise on other vanadium minerals. At this time domestic mining operations for vanadium are chiefly conducted in two states that adjoin Wyoming.

For 140 years or more the primary product of all sodium sulphate reductions of the LeBlanc order has been sodium sulphide. More recently a progressive metallurgical unit purchased a patent for utilizing the solvent action of the latter alkali on vanadium ore. The printed abstract of the Bureau of Mines follows:

PAUL, IRA M. (to Metal & Thermit Corporation). Treating vanadium ores. U. S. Patent 1696923, January 1, 1929, Chem. and Ind. (London), vol. 48, March 15, 1929, p. 215.

"The ore is heated with crystals of sodium sulphide until the latter melt in their water of crystallization and the mixture finally dries to a solid mass. Extraction of this mass with water yields a solution containing the vanadium."

Other sodium sulphate patents for dissolving vanadiferous material were examined. Lack of space precludes their listing in this prospectus.

Other By-product Utilizations

At ordinary smeltery and chemical sites, ways and means must be devised to get rid of the great volumes of slags, slimes and sludges commonly produced. In the bigger metropolitan centers the disposition of such wastes frequently drives hardworking plant engineers to the point of distraction. On the other hand some processes are known to consume vast amounts of energy in the form of costly manufactured chemicals. For carrying on the larger operations it is often the custom to select a site known beforehand to be remote from important beds of raw chemicals. In such barren localities the ingenuity of technical staffs are severely taxed in solving basic reclamation problems appertaining to the regeneration and revitalization of high-price chemical forces, already expended.

About 20% of the furnace charge suggested for the Iron Mountain fusion would be virtually gangue-free ore. As indicated by the equations in Chapter VI, the chief product of the fusion would be a soluble matte of sodium and iron. The soluble action of both of those sulphides on nearby manganese ores has already been pointed out. As stated, the alkali member also exercises a vigorous solvent action on the contained vanadium mineral. In its original or easily oxidizable forms mercury and silver minerals as well as the ores of other metals not known to occur in considerable quantities in Wyoming are readily dissolved. Elsewhere the said sulphide is used as a solvent for gold in the hydrometallurgy of gold ores. It also serves as a sulphidizing agent for treating oxidized lead and copper ores preparatory to flotation. Moreover, both of the preceding sulphides readily oxidize to the sulphate state. Two recent textbooks propose ferrous sulphate as a cheap electrolyte for the manufacture of purified iron, seamless tubings and special steels. If big-scale alloy operations are started at Iron Mountain, excessive quantities of ferrous sulphate would oxidize from the waste solutions.

Sodium sulphide always sells for more than twice the price of sodium sulphate. Aside from the glass industry the more versatile sulphide compound enters into all of the industries quoted for sodium sulphate in the introductory section of this chapter. The iron sulphide and sulphates of the tank waste obtainable in the reduction of the alloy ore are also utilized in different ways in the paper, dyeing, textile, leather, and fertilizer industries. A paper company recently completed an investigation of the timber resources in this locality.

Present-day industries of Wyoming could only consume an insignificant fraction of the waste liquors that would be produced from an alkali fusion of alloy ores. For many years Wyoming has ranked either first or second among the big wool growing states. In some years our flockmasters would like to buy a good sheep dip at a reasonable figure. The base of the dips that generally come into the state is sodium sulphide.

Alkali Redundancies

Until the alkali lakes of sodium carbonate in Wyoming are exhausted, it would hardly be necessary to convert the waste saline matte into soda ash, white caustic and like cornerstones of the chemical industry. At this premature date a discussion of such conversion procedures would call for further prolixity.

In point of value or volume soda ash is the second most important manufactured chemical. A liberal supply of that great alkali has long remained unexploited in the lake beds of Wyoming. To complete the other end of the picture, some local process must be improvised for the manufacture of sulphuric acid—the largest product of the giant chemical industry.

Sulphuric Acid

The conversion of all waste slags from a sulphate fusion into salable commodities would demand production technique developed to a high degree of efficiency. For abating a possible public nuisance as well as for avoiding the non-essential separations previously detailed, all of the soluble matte admixture should be burned for the spot manufacture of sulphuric acid. At this stage of industrial development Wyoming can provide a local market for all of the acid that could be made from otherwise thoroughly useless furnace effluents.

Oil Refining

Normally the fertilizers and petroleum refining industries consume half of the sulphuric acid made in this country. For each of the 12 years last past, petroleum refining has led all Wyoming industries in regard to product valuation. More than 75% of the crude oil output of the state is refined in the Casper district. Long ago a sulphuric acid plant would have been built in that leading industrial city of the state had acceptable raw materials been procurable for its operation.

New Phosphate Market

A new and wider market for sulphuric acid has recently been created in this state. Three years ago chemists of the Great Western Sugar Company first demonstrated the general phosphate deficiency of Rocky Mountain soils. Since then the growers have learned to expect an extra beet yield ranging from \$15.00 to \$30.00 from each acre that they treat with a \$3.00 application of ordinary soluble phosphates.

Unsurpassable climate long ago sharply delimited the national beet industry to Wyoming and to each one of the 6 states that forms its boundaries. At the present time Colorado and Nebraska lead all states in beet production. Those two states form the exterior boundaries of the quarter of Wyoming covered by this pamphlet. Unfortunately, the two leading beet producing states are short of the ingredients essential for the manufacture of soluble phosphates. As soon as alloy ore is chemically fused at Casper the waste effluents of the furnace should be converted into sulphuric acid for direct comminglement with the exhaustless high-grade phosphate rock deposits that occur near Lander, Cokeville and at other points in this state.

The sulphuric acid and fertilizer industries are generally complemental enterprizes. As a rule the selection of the mixing-plant site calls for some degree of geographic judgment. A heart location may, however, require further investigation of the economic groundwork. To minimize distribution costs and to shut off distant competition it is also important to seek a fresh and fertile marketing field for the location of a going chemical works. During the past 3 years of unprecedented price declines the highly artificial, so-called, beet industry remained the most profitable form of agricultural endeavor in Wyoming. The success of this crop is mainly due to the life-giving waters supplied by our streams and to the remarkably high volume of radiant energy received from the Sun. To equalize threatened tariff reductions much will be dependent on the ability of the Wyoming grower to purchase the essential phosphate food for his beets at half price.

As stated before, among the easily procurable products of a local alloy ore fusion would be sulfides, sulphates as well as thiosulphates. The soluble sodium and iron matte could also yield sulphurous acid. According to patent literature all of the preceding forms of sulphur, when applied separately or collectively, possess some value for breaking down refractory phosphate mineral. However, while this manuscript was in preparation no extended tests were attempted for the object of ascertaining the respective attacking potentials of such prospective materials on Wyoming rock containing up to 72% in tri-calcium phosphate.

As elsewhere, the King of Chemicals will likely remain the most effectual agent for decomposing common phosphate rock.

An Integrated Chemical Industry

The State of Wyoming annually attracts many types of excursionists. Future gad-abouts may include one or more graduates of the present depression period. To some carefree vagabond the Wyoming panorama may unfold in a manner quite remindful of the well-stocked laboratory bench recently left behind. Furthermore, if the yet unfossilized mind of the visitor is able to penetrate beyond the obscuring mists and terrifying circumscriptions of the lecture room, a fresher and better rounded portrayal than existing executions would be delineated on latent industrial opportunities peculiar to this locality.

While ambling through the Wyoming field of particulars, many combinations of unusual minerals and powerful native reagents could be weighed for spot conversion into finished products possessing varying degrees of intrinsic merit. In endeavoring to formulate the fundamental unified process capable of breaking down different forms of still dormant indocilities, sodium sulphate might be selected as the base reagent for key operations on the Wyoming terrain. If that lowly saline can be forged into the magic link some of the chemical lakes that dot the present perspective would command valuations considerably in excess of their current appraisals.

CHAPTER XII

TABULATION OF VALUES

Quantity and Value of Metallic Products in Ton of Iron Mountain Ore — Extraction Costs — New Research Methods Needed—Raw Materials Requirements of Hydro-Projects — Economic Value of New Steel Products.

So far no complete appraisal has appeared on the total value contained in the huge dike of uniform mineralization at Iron Mountain. In the following tabulation the quantity of each salable product in one ton of the ore is evaluated at current quotations.

Quantity and Value of Metallic Products in Ton of Iron Mountain Ore

Ore Analysis	Finished Product	Pounds Per Ton	Value Per Lb.	Value Per Ton
TiO_2 =23.49%	Titanic Oxide	469.8	$0.20	$ 93.96
Cr_2O_3 = 2.45%	Chromium	33.3	.80	26.64
Mn_2O_3= 1.53%	Manganese	21.4	.40	8.56
V_2O_5 = *.384%	Vanadium	4.2	3.50	14.70
Fe =45.49%	Pig Iron	910.0	.007	6.37
Totals		1438.7 lbs.		$150.23

*Average Analysis by Union Pacific Railroad. Remaining Analyses from Bulletin 64, U. S. Bureau of Mines.

Outside of Wyoming, visible quantities of unexploited ore grossing $150.00 or better to the ton in contained values is believed to be quite limited. Careful siftings of publications put out by other states failed to locate any like claim.

A calculation on the ore reserve at Iron Mountain appears in Chapter III. A simple multiplication accounts for a potential valuation that dwarfs the sums received by two financial kings for the vast ore beds in Minnesota and a sundry array of other properties at the time the steel trust was incorporated. In the meanwhile a good share of those proceeds have been expended in the dissemination of erudition in Wyoming as well as in other states and nations.

In a more prosperous era some statesman uttered the prophetic remark: "What this country needs is a good nickel cigar." By this date its need for a billion dollar deposit of alloy ores would seem to be more important. A discovery of that magnitude in Wyoming or elsewhere might stop the long established custom of relying on every clime for the several ore-types listed in the preceding tabulation.

Extraction Costs

The foregoing tabulation should be accompanied by a second chart which would record the cost of producing one pound of each of the commodities previously listed. No tabulation like that will be filed at this time. Considerable experimentation within the locality should be performed before an itemized cost sheet is published.

The major value at Iron Mountain is titanic oxide. In Chapter VI an old process is suggested for extracting that pigment wholly by the use of Wyoming raw materials. The most costly item consumed by the decomposition is sodium sulphate. Its cost is previously recorded at $15 for each ton of ore or concentrate fused in Wyoming. Apparently much of the expended fluxing agent would revert to its original form for reuse.

The chromium, manganese and vanadium values are tabulated in the form of elementary products. Recently, Dr. C. L. Mantell published figures on the amount of electrical energy consumed in the production of one pound of each of the foregoing metals. Authority to reprint his basic charts was not requested for this publication of the state. This writer's computations show that power consumption would be a minor economic factor in the production of alloys from raw materials and forces that are all native to Wyoming. People interested in power consumptions should purchase copies of Mantell's Electrochemistry, recently published by McGraw-Hill Co., N. Y. Many calibrations are tabulated in the preceding volume.

Several recent publications seem to veer in a common direction. At this writing it can safely be concluded that low-cost production of expensive pigment materials and steel alloying metals is only possible in areas known to contain hydro-works in juxtaposition to tremendous tonnages of base ores, chemical fluxes, reducing agents and other less important complementals.

New Research Methods Needed

Various investigators have already completed studies of the Iron Mountain complex. The more costly and time consuming inquisitions appear to have been actuated by a common motive. Strangely enough it was to devise a feasible method for extracting the iron value from Iron Mountain. In the preceding tabulation, that long sought value, viz., $6.37, is consigned to the cellar position. It will likely remain there until common pig iron is once more produced at a profit somewhere on the globe.

A citizen of Wyoming would commit a grave mistake by filing a protest against the type of research work most frequently attempted at Iron Mountain. Give the original investigator a free hand for isolating his iron profit and as soon as he succeeds in eliminating that non-essential, plenty of pay mineral will remain for the actual owners of the ore-body. As soon as a process is perfected for the removal of the entire iron contaminant, the remaining 30 per cent of the original complex would have a ton value of $500.00 either for the manufacture of new paints or for the fabrication of the far harder, tougher, stronger, purer, rustless steels that are much in demand at this time.

A profusion of precedents is citable for financing costly research investigations on rocks suspected of carrying $6 or less in recoverable values. In this general territory private as well as public agencies have recently expended many thousands of dollars in endeavoring to extract oil from shale carrying from 15 cents to $1.50 to the ton in petroliferous matter. Such experimental efforts are doomed to failure regardless of the degree of sincerity or keenness of heart that scientists may put into their labors.

To be ready for the Casper-Alcova hydro-project certain separatory tests should have been performed on the Iron Mountain ore several years ago. In the earlier chapters, new mechanical, magnetic, physical, thermic and chemical procedures are described as having merit elsewhere. To ascertain their respective applicabilities within the Wyoming sphere, much work remains to be done.

During the past two-year period, Natrona County has been loudly calling for the construction of a small hydro-works. Such a preliminary plant would serve as a starter for the development of the more timely resources situated within its tributary trading territory. Unfortunately, most research reports consulted in the preparation of the present appraisal had to be dismissed as hopeless anachronisms. At this belated date the greatest of all mineral royalty paying counties is entitled to a new deal. To entrust its brilliant future to the guesser, the routineer, the narrow specialist, the merchant of the obvious, the retailer of ancient formulas or to the traditionally staled academician might retard the wheels of progress too much. To weigh the outstanding opportunities of that favored area may occupy the time of sundry technologists for several years to come. Such experts may not display undue interest in local industrial opportunities until a definite program of action is under way for the development of the hydro-resources of the largest river basin in the state.

Raw Materials Requirements of Hydro-Projects

All hydro-construction should be preceded by a sound survey of the local revenue potential. Take for example the North Platte River. Engineers of the U. S. Reclamation Service have estimated the total cost of the power plant, dam, and transmission line network recently proposed for that stream at $8,045,000. Hereinbefore, the values contained in a single ore deposit of the local basin are conservatively tabulated at more than 100 times the cost of the proposed hydro-system. A differential of that magnitude may be pronounced reasonably wide for the amortization of a power plant to be built in Wyoming or elsewhere.

At the present time a number of river improvement programs are under way in the United States as well as in an adjoining Dominion. Some of them call for capital outlays from 10 to 100 times as much as the cost previously cited for the Wyoming works. What type of resources are native to those major river improvement basins? Urgent appeals addressed to departmental heads of the several states brought no definite information as to the quality, quantity, suitability, reliability and permanency of raw materials that are available for non-competitive chemical and electrothermal development within the improvement districts aforesaid. In some respects it may safely be inferred that the North Platte basin is in a class by itself.

In view of the preceding findings the general practice of expending colossal sums on river development had to be disapproved in the Prefatory Statement of this report. Tragic failures of the past offer ample evidence on the futility of constructing costly hydro-projects in regions barren of unusual assemblages of the raw materials consumed by present-day electrochemical practice.

Already high officials of neighboring states are reasonably well informed as to the character and magnitude of interlocking resources still awaiting development within the North Platte basin. Some of those dignitaries utter no alarm against the construction of the irrigation unit of the Casper-Alcova project. On the other hand, unyielding hostility is openly avowed against the completion of the far less costly but, nevertheless, vital power member of the system. Such fears are in no way surprising.

A review of much reclamation history indicates that not half of the acreage of the larger projects is occupied by bona fide settlers. Should many years pass before all of the Casper acreage is successfully cultivated much of the North Platte river flow might be deemed logical spoils for fomenting a war of words between the several states traversed by its channel.

In recent years, Federal Reclamation projects in Wyoming and elsewhere have more than ever depended on the growing power market to provide the big end of their profitable revenues. In these days such receipts are welcomed for wiping out the deficits incurred from ordinary irrigation operations. Lucrative development of more than one mineral deposit in the Wyoming basin could readily consume twice the power output that would be generated at the Seminoe site. Should any large portion of the headwaters of the Platte be diverted into a separate watershed of a foreign state, the power potential of the Wyoming channel would of course suffer proportional contraction.

The North Platte river traverses three states. The Wyoming inflow is equal to the combined production of the two remaining states. Already, more than half of the Wyoming contributory flow is irrecoverably deeded for the irrigation of lands in Nebraska. To protect the remaining life-giving waters from further diversion, division or distribution, private capital should build the Seminoe Canyon hydro-project now.

As soon as water would go over the top of the dam, a legal title based on the fundamental doctrine of prior usage would automatically issue to the State of Wyoming for all of the flow remaining in the North Platte river. Such an expenditure might be justified even if it did no more than put perpetual debating societies and river conferences that lead to nowhere completely out of business.

Economic Value of New Steel Products

New uses for iron and steel caused several historic panics to end unexpectedly.

One hundred years ago, England was in the midst of depression following the Napoleonic wars which had ended at Waterloo in 1815. Her economists could figure no escape from the mounting debts, debased currency and unemployment problems at that time. Their calculations were a waste of time. Soon thereafter the steam engine was introduced in factories, mines and on the railways. The new contrivance opened incalculable fields for far more productive employment. For creating the wealth necessary to wipe out the petty debts inherited from past wars, steam power proved to be a more effective agent than muscular power.

The recent Age of Steel really did not start until Bessemer perfected his cheap manufacturing process about 1860. A great English invention again elevated the living standards at a time when the general populace had abandoned all hope for future improvement in transportation, in industry, in commerce and in agriculture. By that date steam operated factories in which men and children slaved from 12 to 15 hours daily were already glutting markets with far more goods than a semi-educated world of still inconceivable frugalities could possibly consume. Calculating economists were again terrified; but none of them had any concept of what was in store for a world criss-crossed with Bessemer rails 50 years later.

The Bessemer steels with their tensile ratings of 60,000 pounds per square inch have already outlived their period of usefulness. At the present time it is impossible to make a steel strong enough to satisfy the specifications of the aviation engineer. Before radical advancement will eventuate in the new transportation field an alloy steel with a 500,000 pound tensile rating, now known in the laboratory, must be produced within the price-range of the American workingman, heretofore the King of all consumers.

Already certain alloy divisions of the steel industry show unexpected signs of improvement. New trends in salesmanship are likewise observable within the basic industry which has so long served as the business barometer of the nation. In a recent issue of a weekly smartchart, three progressive companies carried full page ads as to the respective merits of their latest lines of ferro-alloy products. Extracts from an October announcement appear below:

> THE MIDNIGHT OIL **IS** BURNING . . . in the laboratories of hundreds of manufacturers. They are getting ready to offer you the metal that stays forever bright —in any one of a thousand forms you want . . . kitchen utensils, industrial pipe, jewelry, laundry machinery, milk cans, ships' hardware, automobile accessories. Almost everything possible is now, or soon will be, offered in *———— Metal.
>
> WE'RE BUSY. YOU'RE LUCKY. 2,627 manufacturers who never did business with us before have placed orders for *———— Metal this year. Add these to the hundreds of manufacturers already using this metal and

---

*Trade Name Deleted.

> you'll see what a bright future is in store for you. Easy to clean as glass, everlastingly rustless, strong, economical, permanently beautiful.

Recent issues of trade journals corroborate certain statements appearing in the foregoing advertisement. Two headlines from a leading chemical review follow:

> (1) Alloys Progress Bright Spot in Business Gloom.
> (2) Hard Times Fail to Depress Electrochemical Activities.

Not every community has the proper background to gain entrance into the promising ferro-alloy industrial field. No area in the United States has the unique concentration of essential alloy ores and chemicals that still repose undisturbed within the Wyoming sector of the North Platte basin. To excite the interest of the electrochemical world some of the more progressive communities occasionally construct a big hydro-works. The following historic passage is extracted from Adams voluminous monograph on Niagara Falls:

> The story of the development of these industries at Niagara Falls reads like a fairy tale. While the possibilities of many of the present electrochemical processes were recognized years ago, their commercial development necessarily was dependent on the production of abundant and cheap electricity. No sooner were our plans for harnessing Niagara Falls made known than men interested in the embryonic industries made inquiries concerning electrical power and shortly thereafter established factories at the falls.

The ores and chemicals reduced at Niagara are hauled from points far beyond the boundaries of the Niagara River valley. Nevertheless, Adams stated elsewhere . . . "the value of the products dependent upon Niagara power is reckoned in billions of dollars annually."

To create additional wealth it would be well to seek a billion dollar deposit of alloy ores directly within a valley capable of generating hydro-power at a lower cost than the contract rate prevailing at Niagara Falls. At this time such a set-up should not be sought outside of the Wyoming sector of the North Platte valley.

CHAPTER XIII

ALLOY ORE RESOURCES OF ADJACENT STATES

National Review—Geographical Factors—Tungsten—Molybdenum—A Neglected Investigation—Analytical Discrepancies

National Review

For 20 years or more leading technical magazines have been calling attention to the serious shortage of ferro-alloy ores in this country. The most lucid exposition on the present situation was printed in a recent issue of the Wyoming State Tribune. Extracts therefrom follow:

> *Science Is Making Marvelous Metals*
>
> Wonderful Possibilities Brought Out by Production of Alloys
>
> From an address by John A. Mathews, vice president, Crucible Steel Company of America, at Columbia University, January, 1931.
>
> I have called the Twentieth Century the Age of Alloys because they have assumed such wide importance within the last 30 years. They have been known for 100 years, but their use was not great until science caught up with the art of mixing metals and taught us how to develop their latent possibilities in many ways. It long has been known that meteors usually are iron alloyed with nickel and cobalt, and Michael Faraday experimented with synthetic alloys more than a century ago, but the mere making of them was not enough; we had to know about their constitution and treatment "to fit them for use." This second phase of metallurgy is practiced broadly by the steel mill metallurgist.
>
> The plain carbon steels, while still constituting the bulk of steel mill production, are not sufficient to meet all needs of industry, hence there are now made some three to four million tons annually of steel to which is intentionally added one or more of the following metals: silicon, manganese, nickel, chromium, copper, tungsten,

molybdenum, vanadium or cobalt. Occasionally still rarer metals are added. The effects of these additions are many; they may improve the strength and toughness, the magnetic or electrical properties, the corrosion resistance, etc. All of these effects have been discovered by study and research, to the great advantage of industry and the public. In the automobile we desire maximum strength and toughness of metal parts coupled with light weight. In airplanes this is still more desirable. When the metallurgist can make one pound of steel go where two went before he is promoting real conservation of national resources.

We are fond of boasting to our European visitors about our wonderful mineral resources, which give us iron, copper, coal, oil, lead and zinc. We are sadly deficient in most of the metals that make up alloy steels. Of all the elements previously mentioned we have an adequate supply of but two—silicon and molybdenum. We import most of our manganese, tungsten and vanadium and all of our nickel, cobalt and chromium. From a strategic and military point of view this is a serious situation, and the War Department is much concerned over it. Here is an opportunity for mining men to locate new and adequate sources and the metallurgist to develop substitute alloys for those that might not be available in wartime. During the great war tungsten mounted to $10 or more a pound, and all that could be had was required for making high-speed steel.

High-speed steel is an American achievement which revolutionized machine-tool operations about the year 1900. Prior to that time most turning, drilling, punching and tapping operations were done with plain carbon steel tools of from 0.90 to 1.30 per cent carbon. Such tools are decidedly limited in operating speeds. High-speed steels permitted the tripling of speeds on lathes, drill presses and shaping tools. It became apparent that the machine tools of the day were not powerful enough to utilize to the full the possibilities of the cutting tools. All machine shop equipment had to be remodeled and strengthened, and in 1904 my experiments with vanadium—at that time a chemical curiosity — produced a further doubling or tripling of the efficiency of the high-speed steel of 1900.

Just consider what this steel contains and where it comes from. The iron is of domestic origin, the manganese comes from Brazil or Russia, the tungsten from inland China, the chromium from Central Africa, the vanadium

> from Peru and the cobalt from Australia or Canada. Imagine the difficulties of assembling those raw materials in wartime. Here is a major problem for the metallurgist to make us independent of foreign sources in the making of high-speed steel. Not over 8,000 to 10,000 tons of this key alloy is made per annum, but all modern manufacturing is predicated upon its use.

During the past 15-year period prospectors have brought to this writer a number of minerals that were identified as ores of tungsten, molybdenum, cerium and other lesser known metals that enter into the ferro-alloy industry. Some of these minerals were reported as coming from various points in southeastern Wyoming. No detailed descriptions will appear on these recent discoveries for their validities have not yet been confirmed by visits in the field.

Geographical Factors

Geographic factors may largely decide the location of the future alloy steel capital of the United States. The widest variety and greatest tonnages of ferro-alloy ores in this country appear to be concentrated in the Wyoming sector of the North Platte basin. For furnishing the steel base the largest iron mine west of the Mississippi is also located in the same community. Five of the six states that surround Wyoming also contain alloy ore deposits of varying degrees of merit. Descriptions of some of those neighboring resources have already been filed.

This chapter is mainly devoted to alloying metals not yet known to occur in quantity in Wyoming. Deposits of two additional metals, however, occupy exceptionally favorable positions for reaching a central mixing site in this state that can supply the widest varieties of ores, chemicals, fuels and fluxes at the lowest net cost resultant. At the present time the City of Casper could easily fulfill the preceding requirement. But as stated before the dominating factor in the location of an electrometallurgical plant is power supply. To round out the locational configuration steps must be taken to place appreciable volumes of hydro-power on the Casper market at even more attractive rates than those securable in long established electrochemical centers.

Tungsten

Some samples received a few years ago from the scheelite claims situated south of Glenrock showed good tests for tungsten in the laboratory of the State Geologist. Those claims belong to Charles Wells. He describes the mineralization as a triangular apex in an igneous complex. The triangle is said to be 200 feet long and 150 feet wide at the base.

The highest tungsten tests were obtained from rather badly weathered basic rock containing pyroxene, lime and a degree of epidotization suggestive of a contact-metamorphic deposit. Carnotite was present in some of the samples that yielded negative tests for tungsten. That mineral association is unusual. An assay quoted in Chapter X accounts for a 3% vanadium content in the ore. Apparently, for ascertaining the value of the property a systematic assay map should be made of much irregular mineralization. Analyses of tungsten, vanadium and uranium minerals are extremely costly. Elsewhere, progressive communities frequently finance analytical charges to help out the prospector who now and then selects a camping site within the local environs.

Only one other occurrence of tungsten is recognized in southeastern Wyoming. In U. S. Geological Survey publications a stringer of wolframite is recorded as occurring — "in Albany County, in a copper mine near Holmes."

In recent years the states of Colorado and South Dakota have frequently been accredited as ranking second and fourth, respectively, in tungsten production. The Colorado output is mostly from the famous Wolf Tongue ferberite (iron tungstate) mine situated in the Boulder Canyon at a point about 85 miles southwest of Cheyenne. In South Dakota wolframite is an associated mineral in the gold ores. Most of the production is from or near the great "glory hole" of the Homestake Mining Company. That largest gold mine of the United States lies in the South Dakota sector of the Black Hills about 14 miles east of the Wyoming boundary.

Tungsten is one of the key metals of present-day civilization. Mention has already been made of the manner in which it suddenly sky-rocketed to fifth place among the list of indispensable metals. It has the highest melting point of all metallic elements. Its recorded tensile strength of 590,000 pounds per square inch ranks tungsten as the strongest material known to the world. It also forms the hardest alloys ever known. Hess of the Bureau of Mines recently published the following remarks on the economic value of an elementary substance endowed with the preceding range of superlatives:

> No other metal produced in such small quantity has the industrial importance and has such an influence on the people at large as tungsten. Its use in incandescent lamps in place of the carbon filament which it superseded saves large quantities of electricity. To have produced the artificial light in the United States in 1927 by lamps having carbon filaments would have necessitated an added expenditure of two billions of dollars. * * * For all of these (illuminating) uses not more than a hundred tons of concentrates carrying 60 per cent WO_3, valued at $60,000 to $65,000 is used per year.

Elsewhere, Dr. Zay Jeffries, consulting metallurgist for several corporations, recently stated that tungsten costs $1.00 per pound. Apparently, that price is not too dear. He further mentioned that when tungsten is used to replace carbon in electric lamp filaments we could afford to pay $330,000 a pound for the metal and still obtain our light at the same cost.

As completed, no one can attack the Federal report on the grounds of impartiality. Not mentioning any locality and also being entirely unbiased in regard to the outcome of any particular process, it would seem that the valued research studies of the Bureau could have been conducted at a laboratory site in Washington, in Casper, or elsewhere with an equal degree of enthusiasm.

For a comparative ratal of the potentials of the average chrome locality, the recent report of the Bureau will henceforth serve as a high-speed reference work. But in the industrial sense, Casper is not an average locality. By itself it can ably serve as the National proving ground for trying out the industrial feasibility of not one but all of the multifold laboratory processes recently tabulated in the Government publication. At Casper, the applicability of all preceding processes as well as the applicability of yet untested, potentially stronger processes must be ascertained in the near future.

Originally it was intended to pad this manuscript with copious extracts from the report of the Bureau. But becoming convinced that certain natural lake admixtures would serve as far more efficient fusion agents than the purified chemicals used in the Federal experiments, the foregoing idea was soon dismissed. Manifestly, that would be a procedure glaringly unfair for appraising true values of multitudinous resources that were long ago crowded within the Natrona County storehouse. In lieu of following the original plan, more research work entirely within the Natrona County laboratory is accordingly prescribed by this digest.

One of the simpler processes sighted in the Bureau's report is here christened "The All-Casper Process." Therein, it is described as follows:

> ### *Roasting Chromic Oxide with Sodium Sulphate and Lime*
>
> Several tests in which chromite ore or Cr_2O_3 was heated with sodium sulphate alone indicate that there is no reaction at the usual roasting temperatures. A combination of sodium sulphate and lime, however, is more effective in promoting oxidation of chrome than is lime alone. This improvement is due to the fact that sodium chromate is more stable than calcium chromate. The sodium chromate may be formed by either or both of the following mechanisms:
>
> A $4CaO+2Cr_2O_3+3(O_2)=4CaCrO_4$ (11)
> $CaCrO_4+Na_2SO_4=CaSO_4+Na_2CrO_4$ (12)
> B $CaO+Na_2SO_4=CaSO_4+Na_2O$ (13)
> $4Na_2O+2Cr_2O_3+3(O_2)=4Na_2CrO_4$ (14)
>
> * * * * *
>
> Data on reactions (11) and (14) have been presented. Precipitated calcium chromate is changed to a green calcine when ignited at red heat. If it is heated with sodium sulphate, the melt is yellow and the chromate dissolves much more readily than calcium chromate, proving that reaction (12) took place during the heating. In roasts containing only a small excess of sodium sulphate, the calcine has a green color, which is mostly destroyed by a hot-water leach, indicating that reaction (12), when not completed during the roast on account of insufficient molecular contacts, may be completed during the dissolution. The data of Table 5 indicate that under ideal conditions the conversion to sodium chromate would be almost, if not entirely, complete.

For ore of the Casper grade, 43% Cr_2O_3, the Bureau's tabulation records a 92% extraction for a 16-hour sulphate roast at 900°C.

The cited equations only account for chromite, sodium sulphate and lime in the furnace charge. As previously pointed out, considerable quantities of both chromite and limestone occupy contiguous positions in the City Park as well as on lands adjoining therewith. To obtain the remaining sodium sulphate, it would be necessary to travel three miles east of town to the Pratt Lake at which point the 11-foot wide, top seam of almost pure sodium sulphate is now being worked.

For some chrome operations the use of lump ore instead of grinding fines is preferred. In the designated "All-Casper" process the ore and all of the reagents were ground to 130 mesh fineness. At Casper the mineral would leave the concentration mills in the specified degree of fineness. In this narration, the requisite pulverization costs have already been charged to mining operations.

Apparently both coal and low-power gas fired furnaces were tried in the Federal tests. At Casper, soft coal, pure petroleum coke, double-power natural gas and fuel oil have long been available on a highly competitive basis for all sorts of firing operations. To complete the picture, it is anticipated that sizable volumes of exceedingly low-cost electrothermal energy will likewise be available at the latter point in the near future. There is no occasion to look for a similar site in the combination heat line. Surprising as it may seem, no place like that is yet plotted on geographical maps.

On another page in the research report, big advantages were noted when a lime-magnesia mixture was substituted for a common lime flux. To obtain the higher conversion figures recorded, local practice would demand the blasting down of the Alpine crags and precipices of dolomite that at present form much of the scenery in the backyard of Casper. Only at the City of Casper focal point do all of the raw chemicals, ore, fuels, and fluxes unite into the composite industrial mosaic that must be sought for making chromates at hitherto unchallenged, rock-bottom costs of production.

Elsewhere in the research report of the Bureau the following statement is averred:

> In the present work, parallel tests using equivalent weights of soda ash and sodium sulphate show that *under proper roasting conditions* there is but a small difference in the conversions obtained by the two reagents. With cheap source of sulphate (either crude lake salts, by-product, or regenerated from the leach liquor) the saving in cost of chemicals might more than compensate for slightly lower recoveries.

As explained before, chemical consumption costs might at the outset be completely disregarded when aiming for maximum chromate conversions from Natrona County ore. Only in that favored area it would never be necessary to purchase either one of the prescribed salts in the costly manufactured form. Publications of the U. S. Geological Survey account for a wide dissimilitude of lakes in Natrona County. Their recorded analyses show one type of lake bed to carry as high as 87.24%, in soda ash; and other beds to consist of 96.14%, sodium sulphate. Today both types of the preceding salts could be hauled into Casper over oiled pavements and thereat mixed and blended in proportions duly calculated beforehand to yield the maximum chromate extractions from the ore body occurring in the city.

Incidentally, a Government analysis discloses one of the Natrona County lakes to contain 18.97% sodium bicarbonate. None of the 153 tests tabulated in the Bureau's report account for a try-out of that chemical for chromate conversions. As a stimulator for cutting down roasting times and temperatures as well as overhead in general, fundamental chemical theories strongly indicate that a partial admixture of the acid compound would prove to be a far more efficient fusion agent than either of the pure salt forms used in the Government tests.

For reasons already pointed out the research labors of the Bureau are hereat pronounced, decidedly incomplete.

For ascertaining the maximum technological possibilities within an especially seasonable and alluring field of endeavor, all bureaucratic research investigations now under way should be forthwith transferred to a duly qualified site within Natrona County.

Superficial previews of other research investigations conducted by divers Federal Bureaus during the last few years also seem to establish outstanding superiorities of several Wyoming localities for the manufacture of new-type industrial products. Such reports, however, were mainly prepared to arouse interest amidst technological circles. Obviously, critical analyses of their findings from a local vantage point would unduly prolong the length of the present disapprobation.

Private Chrome Investigations

For obtaining a more practical slant on matters appertaining to the chromium industry, it sometimes pays to read the reports filed by consulting engineers on the commercial possibilities of the better known ore deposits. As a rule their findings can be expected to contain more color and savor than that ordinarily appearing in the voluminous writings of academicians.

Already some of the more progressive communities of the West have financed private examinations of chrome deposits situated within their tributary trading zones. The only state, adjoining Wyoming, that has chromium deposits is Montana. In that state officially recognized ore occurs within six miles of the Wyoming boundary.

In both states the ore is the result of magmatic processes of concentration. In other respects analogous geology has already been pointed out for both localities. Categorically speaking, the remaining chrome deposits of the United States simply do not belong to the Casper-Montana grouping. At the outset it should also be assumed that comparable geologic factors frequently offer like problems in the development of the so-called new types of ore deposits.

Last winter a distinguished Turko-American engineer completed an investigation of the low-grade chrome deposits situated near Red Lodge, Montana. His major findings were published in the newspapers and in view of their seasonable character, two of his despatches follow below:

Millions of Tons of Chrome Ore Found Near the Surface in Montana

> (Denver—Nov. 14, 1931)
>
> The American people are too easy going to develop their own mineral resources and are paying unnecessary tribute to foreign producers.
>
> That is the opinion of A. A. Hassan of New York, well known as an expert geologist, metallurgist and consulting engineer. He was born in Constantinople, Turkey, and was educated in Vienna, Cracow and Leopold (the old time Lemberg). His private mineralogical laboratories are among the foremost.
>
> "I have been in Montana for months investigating the chrome ores," Hassan said at the Brown Palace Hotel Friday. "The entire United States produces only 200 tons of chrome ore annually and imports 200,000 tons, mostly from Rhodesia and the Transvaal. In Montana, near Red Lodge, I find millions of tons of lower grade chromite in veins close to the surface 60 feet wide, and have brought many samples to Denver for tests.
>
> "The African ores run from 48 to 54 per cent in chromium oxide, with iron oxide, which is difficult to eliminate. At Niagara Falls, N. Y., is a company which converts it into ferrochrome for the steel trade. This sells for $17 a ton. The freight from Montana to Niagara Falls, or Pittsburgh, Pennsylvania is $15 a ton and therefore our Montana chromium ores must be refined on the spot. Nearby we have ample natural gas and electric power and a government highway from Red Lodge to Cook City passes through the chrome properties.
>
> "My objective is to devise methods of refining these ores into a pure grade of chromium for the steel trade."—(Denver Post)

Power Project Awaits Action of Congress—Chromite Mill Will Be Constructed If Montana Dam Is Built

Red Lodge, Mont., Dec. 26.—Industry and agriculture in a large part of Yellowstone, Big Horn and Carbon Counties are looking to this session of Congress for financing to develop a power and irrigation project in the Big Horn Canon.

Engineers for whom Dr. A. A. Hassan, geologist and mining engineer, recently examined chromite ore deposits in the Beartooth Mountains, near here, have been quoted as looking on the mineral area as susceptible of profitable development.

The plan contemplates a mining and concentrating plant in Rock Creek Canon, a chemical conversion plant near Red Lodge and possibly a steel alloy plant near Billings. Need for 100,000 horsepower would be met by construction of the Big Horn Dam, which also would store water for a considerable area of agricultural land.

The transportation problem is met by the Red Lodge-Cooke City Park approach road, now under construction.

Hassan said the $10,000,000 necessary to finance the chromite project is ''waiting'' until preliminary problems are solved, including the evolution of a satisfactory formula for concentration and flotation.—(Denver Post)

As at Casper, it is doubtful if a chrome operation will start in Montana until provision is made for a sizable hydroelectric plant. The Montana proposals logically call for a power works twice the size of the one proposed at the Seminoe site. Moreover, backwater from a high dam constructed on the Montana sector of the Big Horn Canyon would naturally overflow considerable scenery in this state. Not all of the huge impoundment basins thus far completed in Wyoming have proved to be consummate blessings within the esthetic sense of the word.

For other reasons the people of Wyoming should strongly pull for the location of a $10,000,000 chromium industry at a boundary point in an adjoining state. First of all, one of the primary units is a chemical plant. As soon as it is built a local market outlet would at last originate for the huge beds of widely diversified salts still undeveloped in Natrona County, Wyoming. As yet, geological literature recognizes no like depositions of essential chemicals within the confines of Montana.

The report of the engineer likewise makes logical provision for a steel plant. For making rustless chrome steels a nearby deposit of high-grade iron ore would be a complemental asset of basic value for large-scale operations. For the past 30-year period, almost all of the iron ore mined west of the Lake Superior fields came from a single mine located in the Wyoming basin of the North Platte River. Moreover, the establishment of an alloy steelworks anywhere within the Rocky Mountain province would soon bring into the limelight the even larger deposit of alloy ore situated at Iron Mountain.

It is interesting to note that it would cost $15 per ton to ship a $17 chrome concentrate from Montana to the nearest reduction works. To completely paint-out so calamitous a demarcation from an otherwise brilliant chromolithograph, immediate steps will have to be taken for the construction of a sizable hydro-works somewhere in the West. At this writing it is hard to guess if the Big Horn or the North Platte will be selected as providing the more discriminating site for the primary low-cost power plant. In the final analysis the relative merits of the two rival streams for intensified power development may possibly be decided by statesmanship. In the past two-year period no congressional delegation has worked harder for urgent and pressing hydro-development than the delegation from Wyoming.

The grade and magnitude of the Montana ore deposits have already been established by a private field examination that extended over a period of several months. It may take an equally long interval to delimit the boundaries and to ascertain the varying values disseminated throughout the wider dike buried at Casper. Heretofore American deposits of chromite have generally been considered as of little consequence. But to upset that idea in Montana, the services of an outside engineer were recently recruited. Until lately his native land, the former Ottoman Empire, was accredited as containing the largest known chrome deposits.

Already Federal engineering experts unconditionally approve the North Platte River for low-cost power development. To translate their findings into something of economic significance, other reports should unmistakably demonstrate the existence of potential local markets capable of consuming the last kilowatt of energy that may ever be generated from the precipitant gradient of the North Platte River. As a natural depository of the rarer ores and raw chemicals generally imported into this country, no valley is sufficiently diversified to stand comparison with the Wyoming basin of the North Platte River.

Before preparing this correlated outline, a number of important bureau chiefs were interviewed as to their personal knowledge of the multifold natural resources present in the southeastern Wyoming depository. Some heads of statistical departments appeared to entertain the idea that nothing within the entire state could possibly prove of interest to either the old or the new schools of industrialists. Other chiefs interrogated were firmly convinced that everything in Wyoming was long ago discovered and that already some of its leading mineral resources are rapidly being exploited to a state of exhaustion. Beforehand, it was inconceivable that the more outstanding potentials of Natrona County, in particular, could be dismissed with such surprising degrees of jocularity.

Suffice to state that not all of the pessimistic prognostications of apostles of doom found their way into the present manuscript. Consider for example the imposing congregations of localized raw materials and technical indispensables previously grouped, here and there, in the single county of the United States from which national and state treasuries have recently exacted a contribution of over $40,000,000 directly in the form of mineral royalties. In an inventory of this scope, justice demands that a more open-minded degree of receptivity be taken towards those modern types of raw materials and basic energizers that are of proven utility for the new ideas, new inventions, new processes, new products that so ably serve to distinguish the present-day age of ease and luxury from all of its predecessors.

As said before, the main theme of this paper is centered around the Casper-Alcova hydroproject. Its format is rather flexible. If there is nothing in Wyoming, it is possible that all of the power output of the proposed project could be conveniently transported and marketed at a point directly across the state boundary. At this particular moment a discovery of a workable deposit of several million tons of the new rustless steel ore, in Montana or elsewhere, would be a factor of revolutionary industrial importance for the United States. If Wyoming is only called upon to furnish the power to reduce such a highly refractory ore, all will agree that her further sacrifices towards augmenting the wealth and strength of these United States would serve as another example of placing national loyalty on a pedestal far above the more circumscribed, more selfish preachments often advanced by dogmatists schooled in the fundamental doctrine of state rights.

In a more bulky tome, a diversity of precedents could be pointed out on the never failing readiness of Wyoming to share and divide a princely heritage of natural resources among her less fortunate sister states.

Recent Chrome Discoveries

Discoveries announced within the past two-year period would indicate a wider distribution of chromite over Wyoming than generally recognized heretofore.

During the present fall prospectors reported new occurrences of chromite at two points on Casper Mountain not covered by this review. For some time certain super-educated persons have made it a business to belittle the accumulated findings of the faithful prospectors who have labored for many years on top of the promising Casper Mountain area. Their present exploratory activities, however, appear to be of a constructive order.

For several years the Casper prospectors have been trying to add light on mooted points not fully clarified in the report published 20 years ago by the U. S. Geological Survey. In the previous quotation taken therefrom, mention is made of the buried syncline suspected of connecting the two widely separated chrome areas so far recognized on the mountain. In traversing the deeply eroded creek canyons that intervene the two outcrops, the prospectors may have found low-level exposures sufficient to trace the extension of a continuous belt of chromite for a distance of over 20 miles on Casper Mountain.

A wide difference in dimensional magnitudes likewise exists between the fine grained spherulites disseminated throughout the David Crockett dike and the huge slabs of solid mineral present in the Deer Creek mine. Nevertheless, it is possible that both extreme phases of segregational phenomena originated from a common, deep-seated magma. In support of this theory the single analysis made a month ago of the Crockett concentrate is of interest. That return showed a chromic oxide content of 42.77%. For purposes of comparison the two assays published years ago by the Federal Survey disclosed equally gangue-free ore from the distant Deer Creek mine to carry 42.36% and 44.81%, respectively, in chromic oxide.

Later tests concluded in the private laboratories of the writer likewise provided supplemental evidence for establishing common physical characteristics and identical molecular arrangement for both of the widely separated ore types. In the massive form neither type is visibly attracted by the magnet but when finely ground, a strong six-inch magnet is just sufficient to collect the last particle from each of the highly pulverized ore masses. Ordinary chrome ore is not endowed with the degree of magnetism so measured.

Should Casper prospectors succeed in locating a continuous belt of workable chrome mineral larger than any deposit so far recognized in the United States, another argument would be available for the immediate construction of the Seminoe Canyon project. At this opportune time, Casper chemists should carefully scrutinize all black sand concentrates that prospectors commonly collect from the stream channels which debouch from both sides of the mountain between the chrome outcrops on Gold and Deer Creeks. Such examinations may yield preliminary data of critical importance to Casper geological firms duly qualified to interpret the varying potentials registerable by concealed chrome deposits on latest type geophysical appliances.

At the present time only agricultural and irrigation divisions of the Federal Government are lending active bureaucratic support towards the early construction of the Casper-Alcova project. To consider the project solely as an instrumentality for putting more land under cultivation is unfair. At this occasion it would be more seasonable to weigh the wider power possibilities of the project. From the mineral sense several bureaus in Washington have long countenanced a multiformity of movements primarily designed to make the United States the best-equipped country in the world. For drawing the attention of the latter agencies no form of local endeavor will prove as effective as the important mineral discoveries announced from time to time by the pioneer prospectors of Casper Mountain. In time their fundamental findings should also be utilized for combating the more recalcitrant opposition thus far organized against the construction of the Casper-Alcova project.

Last winter a discovery of chrome was blazed abroad from Rock Creek, one of the topmost tributaries of the North Platte, and within whose altitudinous drainage area the old Atlantic City gold mining district is also included.

A chrome strike at the latter point was not entirely unexpected. A number of years ago extensive seams of short asbestos fiber were first reported. As the immediate vicinity is an archaic igneous complex mainly consisting of strongly metamorphosed crystalline schists, acid and basic gneissoids, quartzite and serpentine contrarieties; later favorably invaded by granite masses as well as by a contrasting series of exceptionally high-content magnetite schist intercalations, it is anticipated that the local geology will also be found suggestive of the chrome-asbestos rock deposits frequently notated herein for African localities.

Recently, the leader of the group of Princeton graduate students advised the State Geologist of a newly discovered chrome location in the Big Horn basin. In the past two years those subsidized students have surveyed, mapped and geologized extended areas in southern Montana. In tracing out one of the more promising boundary deposits of chromite onto lands of this state, their labors may likewise be deemed as having much practical value within the gratuitously invaded Wyoming field.

Pressing and multifarious duties have so far precluded personal inspections of the several chromite discoveries announced in Wyoming during the past two-year period.

CHAPTER IX

MANGANESE

Introductory—Wyoming Deposits—Sheep Creek Mine—Iron Mountain Manganese—Manganese Tariffs

Introductory

Manganese is absolutely essential in the manufacture of steel. Neither experiment nor research has developed a substitute. In the ferro-alloy form manganese doubtlessly produces the hardest and toughest of all steels.

The United States consumes 800,000 tons of manganese ore in a normal year. About 750,000 tons are used as a deoxidizer, desulphurizer and hardener in steel. The remaining six per cent is used in the manufacture of non-ferrous alloys, batteries, bricks, tiles, glazes, enamels, paints, dyes, drugs, fertilizers and sundry other chemical products.

About half of the manganese ore imported into this country comes from the Soviet mines in Georgia, Russia. Most of the remainder is shipped from Brazil, India, Africa and Cuba. Less than 8% of the manganese ore consumed in the United States comes from domestic mines. In recent years all continents aside from Australia have supplied this country with manganese ores.

So far only one state has supplied the American market with its full quota of ore. In 1929 the Philipsburg and Butte districts of southern Montana produced 70% of all manganese ore mined in this country. Within the last few years the largest deposits of manganese in the United States were discovered near Chamberlain in central South Dakota. Federal geologists have already estimated the total quantity of the ore at 100,-

000,000 tons. The deposits are low grade and chemical processes must be relied upon for the recovery of the metallic values. Additional mining expansions in the two states that adjoin Wyoming may eventually make the United States independent of foreign sources of supply.

The reduction of manganese ore is likewise an energy consuming process. Before choosing the site for a metallurgical works a survey should be made of the ore supplies, chemical deposits and power resources of a general territory. The Wyoming sector of the North Platte basin occupies a midway position between the two points that respectively define the largest producing areas and the greatest undeveloped reserves of manganese ores in the United States. Furthermore, the Wyoming basin contains large beds of alkali metal salts suitable for metallurgical operations as well as for the manufacture of important manganese chemicals. Immense deposits of iron and ferro-alloy ores are also located in the valley. Future development of these closely interrelated resources will largely depend on the availability of low-cost power.

Wyoming Deposits—Sheep Creek Mine

Few manganese deposits are known in the North Platte basin. The only deposit from which ore has been mined is located at the head of Sheep Creek in Albany County, about 38 miles northeast of Medicine Bow. Records of the United States Geological Survey show that only 112 tons of ore were shipped from the property prior to 1922. Most of this ore was of the chemical grade and it analyzed better than 35% in metallic manganese.

No examination has been made of the property by the author. In Bulletin No. 715 of the U. S. Geological Survey the ore is described as occurring in two chert beds of the Casper limestone formation, the average width of each being six feet.

At places, both beds are highly impregnated with fine grained crystals of pyrolusite and manganite. These oxides generally appear as mammillary crusts and nodular aggregates on the displaced chert, and all ore samples recently examined show the familiar arborescent growths. Barite occurs in vugs in the ore in large tabular crystals, and calcite is also present as a gangue mineral. As mentioned in a prior chapter, barite is the source of barium sulphide. The latter compound is used in the manufacture of titanium paints.

The Government geologist describes several cycles of solution and replacement in the chert. Ores of such complicated origin are generally too erratic in composition to meet the specifications of the average buyer. For shipping a uniform product much of the unsalable low-grade material in the mine should be subjected to the sodium sulphate fusion generally known as the Ellis treatment. Large beds of crude lake salts occur in the vicinity of the property and simple treatment of the ore with the cheap salts would yield a soluble manganese product of high value. Among other things the extractable salt is said to exert a profound influence on vines, tobacco and on other valuable forms of plant life. Manganous sulphate also occupies essential roles in several dyeing and paint operations. For the manufacture of late type pigments and powerful plant foods no state possesses a wider variety of basic raw materials than Wyoming.

Iron Mountain Manganese

The old analysis of the Government shows the huge dike of alloy ore at Iron Mountain to contain 1.53% sesquioxide of manganese.

In ordinary carbon smelting all of the preceding manganese would either be volatilized or else carried away in the slag. In the sodium sulphide fusion process, hereinbefore suggested for the extraction of the titanium, ways and means would have to be devised for the removal of the manganese. At Iron Mountain the manganese content is doubtlessly too low to produce appreciable revenue.

At the present time the Iron Mountain deposit is of no concern to the manganese industry. But as soon as big operations are started at that point the sodium sulphate fusions would produce chemicals that would be suitable for the treatment and beneficiation of nearby manganese ores. With one exception, all states that surround Wyoming have extensive deposits of low-grade manganese ores. One of these states has been previously accredited as containing one-half of the manganiferous material so far recognized in the United States. Commercial processes for handling most of these neighboring ores have not been developed.

A wholesale sulphate fusion of the Iron Mountain ore would chiefly produce ferro-sodium sulphide. This soluble matte should be of service in recovering values from low-grade manganese ores. Simple ignition would form the sulphurous gas utilized by the Vadner process for the conversion of 5 to 35% oxide ores into the purified manganese dioxide form. Higher oxidation of the Iron Mountain soluble sulphide would yield acids suitable for leaching the low-grade manganese carbonates recently discovered in South Dakota.

Moreover, it must not be forgotten that iron and sodium sulphides readily oxidize to the sulphate form. Simple exposure of the Iron Mountain matte to moist air should produce sulphates of iron and sodium. When finely ground low-grade oxide ores are digested, with either one or both of the latter salts in the presence of steam, the manganese is readily recoverable as a soluble sulphate. Apparently, numerous methods of production are found possible by evaporation, acid treatment, and other minor modifications.

Manganese Tariffs

Several years ago a propaganda agency circulated considerable anti-Soviet literature in this country. Most of its criticism was directed against the domestic steel makers who bought ore from Russia and an international banking group who obtained concessions to exploit manganese deposits in that country. For rectifying the evils of the past a greatly increased duty on manganese ores was demanded by the patriotically inspired organization.

The tariff act of 1930 substantially raised the duties on many grades of commercial ore but that simple expedient has not noticeably aided manganese mining operations in this country. Regardless of all propaganda to the contrary many domestic deposits will likely continue to remain undeveloped until cheaper treatment processes can be devised.

The western states contain a superabundance of low-grade manganese ores, but their metallic content will not permit the purchase of specially prepared leaching chemicals. A sodium sulphate fusion of the Iron Mountain ore would, however, yield considerable quantities of manganese extraction reagents in the form of waste liquors. Such incidental operations at Casper or at other strategic points may in time produce chemicals that will fall within the price range of the western manganese miner.

CHAPTER X

VANADIUM

Introductory—Uses—World Resources—Peru—Africa—Mexico — United States — Wyoming — Iron Mountain Dike — Metallurgical Treatments—Interrelated Processes.

Introductory

Vanadium is a toughener for steel. Vanadium steel is strong, can be stamped, formed and folded without cracking. Before it was incorporated into many grades of steel it was not an uncommon calamity for the more daring pioneer motorist to pull out the back end of his automobile. About the time that a manufacturer of a popular car announced to the world . . . axles of vanadium steel . . . it became noticeably safer to negotiate the steeper grades out here in the Rockies.

Uses of Vanadium

As an alloying element for steel, vanadium has been widely used for armament and for automobile construction. Research has, however, found many new applications for the metal since the World War. As southeastern Wyoming has previously been accredited as containing the largest and most promising reserve of vanadium ore in the United States, and as the consumption of the metal seems destined for consistent expansion, a number of publications were scanned in order to file a passable list of current and prospective uses.

The earlier issues of the Vancoram Review, a research journal published by the Vanadium Corporation of America, record the largest number of uses for vanadium. The information appearing in the next two paragraphs is mainly culled from the preceding publications.

In general the applications for vanadium may be divided into two fields, metallurgical and chemical. In the former field carbon-vanadium drill steel, shafts, and castings are used in mining; chrome-vanadium connecting rods, springs, gears, and steering mechanisms in automobiles, with carbon-vanadium crankshafts; chrome-vanadium gears, shafts, and spindles in industrial machinery, together with low-alloy and high-speed tool steels; chrome-vanadium tubing, valve parts, and boiler plate for steam generation, with vanadium steel for high pressure steam drums; chrome-vanadium still tubing, valve parts, and reaction chambers in oil refining; carbon-vanadium drill bits, jars, and sucker rods, with chrome-vanadium tool joints, in oil well drilling; chrome-vanadium propellers, shafts, gears, connecting rods, and landing gear parts in airplanes; chrome-vanadium tubing, catalyst chambers, and bolts and nuts in nitrogen fixation. In the railroad industry the applications of vanadium are numerous, including carbon-vanadium steel for frames, pins, piston rods, axles, crossheads, and side rods; chrome-vanadium for piston rods and springs; nickel-vanadium steel for frames; and silicon-vanadium for springs.

The applications already found for vanadium and its compounds in the chemical industries include its use as a drier for linoleum and varnish, an accelerator for rubber and as a catalyst in the manufacture of contact sulphuric acid. In the latter role purified vanadium pentoxide has appreciably replaced costly platinum. Satisfactory substitutes for platinum have been sought for a long while by the larger industrial nations that have no deposits of the precious metal. In several respects the vast vanadium bearing deposit of Wyoming warrants investigation by major departments of the Federal Government.

Vanadium chemicals also enter into the synthesis of various organic compounds. Some forms serve as a catalytic agent in oxidation for soil improvement. For information on the use of vanadium in chemo-therapy the reader should consult recent medical summaries. For abbreviated advice on late technological applications, references should be made to the leading vanadium salts listed in unabridged chemical dictionaries of recent date.

World Resources

Peru

All late mineral annuals generally agree that this country has been relying on Peru to supply 70% of its vanadium ore requirements. At no time has our debt of gratitude been unduly esteemed by the neighborly Latin Republic.

All of the preceding ore comes from the mine of the Vanadium Corporation of America situated on the high Andes at Minas-Ragra. Formerly this ore was brought to the coast on the backs of llamas but in the January, 1930 issue of the corporation's publication, the modernized haulage system is described as follows:

> From a mine on the eastern slope of the Peruvian Andes, over 16,000 feet above the sea, yet somewhat less than 50 miles from the headwaters of the great Amazon, comes the principal portion of the world's supply of vanadium. First by narrowgauge, then across the world's highest navigated lake, once again by rail over the backbone of our great South American Continent and finally by a tortuous descent to the coast, ore finds its way to the start of the long sea journey to New York. With few of the necessary raw materials supporting modern civilization, does transportation alone present such a difficult problem. And this is only one of many to be overcome in the preparation of vanadium for the market.

The original ore mineral at Minas-Ragra is patronite, a vanadium sulphide. So far this mineral has been found only in Peru where it has formed the largest vanadium deposit in the world. At Iron Mountain, large quantities of the same mineral would be manufactured as a by-product by the cheap metallurgical process repeatedly suggested herein for the recovery of all ferro-alloy values known to occur within the southeastern Wyoming depository.

Mention has already been made of the many difficulties encountered in preparing vanadium in the final marketable forms. Since the discovery of the Minas-Ragra deposit, about 1905, monopolistic tendencies have been observable in regard to the production of vanadium ore. Containing the only deposit of recognized importance, Peru has been in a position to levy export taxes on all ore that leaves its shores. The last raise on ore exports was promulgated on October 28, 1930. Filing complaints against such decrees would do no good to any Wyomingite. In time foreign handicaps may mount to a height sufficient to bring the big vanadium deposit at Iron Mountain into the limelight.

So far no state has revealed a wider diversification of resources for disrupting the mineral monopolies of foreign governments than Wyoming. Its potential assets for breaking down two long established international cartels of the past were reviewed in a bulletin published four years ago. In the meanwhile geological and technological achievements in the United States and elsewhere have tragically wiped out the export mineral tributes hitherto exacted from an easy going world by two unusually covetous nations. In this sequel the capabilities of Wyoming for relieving the country from the rising imports of a third foreign mineral monopoly are given consideration.

The discovery of vanadium in Peru was an important stepping stone in the advancement of the metallurgical science. Manifestly, without the revelation of an adequate and comparatively cheap source of ore supply the technological world would be 25 years behind the times in regard to accumulated knowledge relating to the individualized merits of a growingly important chemical element. All of that hard pioneer work should have some constructive bearing on the future industrial picture of Wyoming.

The Bureau of Mines mentions that all vanadium ore imported into the United States usually comes from the great deposit in Peru. Their latest records disclose the following imports during the past decade:

Vanadium Ore (steel-hardening) imported for consumption in the United States, 1921-1930

Year	Pounds	Value
1921	10,307,540	$543,061
1922	611,170	86,776
1923	4,177,115	229,210
1924	14,116,596	722,731
1925	4,735,461	339,468
1926	16,735,040	914,114
1927	13,885,760	561,051
1928	1,104,320	49,771
1929	19,519,360	794,734
1930	11,576,320	491,633

Elsewhere the Bureau records the Peruvian imports as containing 12 per cent vanadium metal.

Africa

Important deposits of vanadium have recently been opened in Africa, the single continent hereinbefore accredited as having all of the minerals. In the past few years increasing shipments of vanadium ores and metals have been made from Rhodesia and South-West Africa to European ports. Federal annuals record the ores to be in the form of complex vanadinites. In such combinations it is doubtful if their metallic contents are as high as the patronite concentrates commonly imported into this country from Peru.

Mexico

Mexico is the only remaining foreign country in which vanadium ore has been mined. In recent years its production has been either spasmodical or else inconsequential.

United States

Vanadium ore mining operations were conducted in Colorado, Utah and Arizona during 1930. Unfortunately, the Bureau of Mines has ceased publishing the production totals for the United States. Since the collapse of the once all-powerful American radium industry, annual production of vanadium ore in this country probably does not exceed 1500 tons in the final form of mineral concentrates. There is good reason to believe that most of the ore is now being mined in Colorado and Utah, two states that adjoin Wyoming. Our neighbors have the best known domestic deposits of carnotite and when this country led the world in radium production, considerable quantities of vanadium were recovered in the by-product form.

Wyoming

Geological literature contains but few references to Wyoming deposits of vanadium minerals. On page 12 of the 1914 Mineral Resources, the following notation appears:

> The president of the company (Chromium Mines) stated that a sample of the ore from the Deer Creek locality analyzed by the Electro Metallurgical Co., of Niagara Falls is reported to contain 3 per cent of vanadium.

The only vanadium occurrence in the preceding locality is on the carnotite and scheelite mining claims that are now held by Charles Wells. Mr. Wells is an expert prospector and several years ago he sought similar vanadium, radium and tungsten minerals in well known localities of the Andes Mountains.

Fifteen miles west of the Deer Creek locality the distance between vanadium and chromium occurrences is considerably narrower. About 100 yards north of the Casper chrome dike, David Crockett sank a shallow slope into a small ledge of carnotite-bearing rock. He reported his best ore as assaying 2 per cent in vanadium metal. The deposit is covered by a flat shelf of top-soil. Exploration operations completed to date have failed to establish a continuity for the outcropping.

In 1919, five carloads of radium ore were shipped from an old mine located within the municipal limits of Lusk, county seat of Niobrara County. The miners received $33,857.48 for their ore shipments. During the few months that operations were unmolested by litigation and other extraneous influences the canary yellow ore was thought to be carnotite. At the reduction works the pay mineral was however identified as uranophane, a hydrous silicate of uranium and calcium.

In recent years, Federal publications contain frequent references relative to the small amount of vanadium carried by the huge beds of phosphate rock that occur at Lander, Cokeville and at other points in this state. Their long-range commercial possibilities have already been considered by Frank L. Hess, rare mineral technologist of the Bureau of Mines. His conclusion, as recorded in the 1927 Mineral Resources, follows:

> Before $10 a pound was reached some millions of pounds of vanadium would undoubtedly become available from ilmenite-magnetite mixtures, of which the United States has many millions of tons that carry from 0.1 to 0.3 per cent, and the phosphate deposits of Idaho, Montana, Utah, and Wyoming, would also be made to yield large quantities of vanadium from the 0.1 to 0.2 per cent which they carry.

Patents have recently been granted for the separation of vanadium from phosphorous solutions. Vanadium sells for $3.50 per pound and until it can approach the $10 figure previously calculated, it will be necessary to treat the rocks chiefly for their phosphate value. At the present time the Anaconda

Copper Mining Company is the only concern that operates a plant for the chemical treatment of the Western phosphates. For a description of the patent that the company purchased for the separation of vanadium from phosphate solutions, the reader is referred to Waggaman's Monograph on Phosphates recently published by the American Chemical Society.

Iron Mountain Dike

The problem of separating vanadium from local phosphate rocks sounds quite engaging. However, a vast mineral deposit in the North Platte basin offers a wider margin for profit. Today chemists are finding appreciable quantities of vanadium in titano-magnetites regardless of whatever point on the surface of the globe such unusual egressives may have arisen from the profound depths of a common core zone.

The 1868 analysis of the Government failed to account for the presence of vanadium at Iron Mountain. Two analyses published 61 years later by the Union Pacific railroad first disclosed the spectacular dike to carry 0.367 per cent and 0.402 per cent, respectively, in "vanadium oxide."

The preceding determinations indicate the presence of four pounds or more of vanadium metal in each ton of the uniform mineralization at Iron Mountain. Among other things, the contract for this discourse called for the citation of procedures by which the recently announced vanadium value of $14 per ton could be isolated from its long repose in the Wyoming entombment. Heretofore, all investigators have agreed that such an obstinate ore body would never prove amenable to the routine treatments practiced in the ordinary metallurgical works. The acclamations of record must likewise preclude all discussions of unduly complicated, high-cost recovery processes. Manifestly to extract the vanadium content from the exhaustless deposit at Iron Mountain, methods must be devised that will exclusively consume the raw chemicals and other forms of energizers known to abound directly within the southeastern Wyoming depository.

Metallurgical Treatments

In recent years metallurgical specialists have been unusually busy in taking out patents for the extraction of values from low-grade vanadiferous material. A superficial preview of their labors is sufficient to reject 90 per cent of the ensuing patents as being either too costly or too involved for successful operation even in an area known to contain the diversified chemical resources of southeastern Wyoming.

So far only one worthwhile vanadium deposit has been discovered. It is at Minas-Ragra. If it is permissible to take a leaf out of the handbook of nature, the problem at Iron Mountain would merely involve the manufacture of the singular Peruvian mineral by the most expeditious route available. As the Peruvian patronite could form a component of a metallurgical matte, there is no occasion to discuss unnecessary entanglements at this time.

Hereinbefore a wholesale sodium sulphate fusion has been suggested for the simplest recovery of all values contained in the ferro-alloy ore at Iron Mountain. In the prior furnace charge calculations, sufficient Casper coke was included to transform all metallic oxides to the amenable matte form. That extraordinarily powerful reducing agent would have precisely similar action on the vanadium content. Moreover, the preponderance of alkali sulphide materials formed would cause both the vanadium and the iron to go into solution shortly after the top matte section was subjected to a simplified water treatment.

For reducing overhead to a minimum, the foregoing solution is the right place to put the vanadium. Simple addition of a crude, acid-form, lake-salt or some other satisfactory dual precipitant of the locality would cause both metals to fall down from the preceding waste liquor in the correct proportion for the subsequent manufacture of an extra tough vanadium steel by the modern electric-furnace way.

To give vanadium a chance to compete with the far less costly ferro-alloy steels now in style, simpler and more direct ways must be evolved for placing the metal on the market in the final finished form that most of it is consumed. As stated before, the ideal ore for future metallurgical practice will likely be a raw mineral in which the vanadium and iron are already blended in the correct ratios for the direct manufacture of merchantable electric steels. Some other states are believed to have vanadiferous titano-magnetites; but none of them are as large or as easily mineable or as free from useless gangue material or better blended for low-cost metallurgical procedures as the giant dike that looms above the horizon in bold relief at Iron Mountain.

In a commentary of this scope no advice can appear as to the course metallurgists should adopt for the treatment of titano-magnetites known to occur in smaller volumes in other states. Manifestly the reduction of such perverse and unyielding material should never be attempted in localities not visibly endowed with tremendous volumes of extraordinary and multifold forms of basic energizers.

The preceding all-Wyoming process was primarily selected for the appreciable local market it would provide for the pioneer sodium sulphate producers in this state. On last visit to Casper, the leading marketer offered to deliver the anhydrous salt at $5 per ton in whatever carload lot quantities it may be desired at that prospective reduction site. As the suggested method calls for three tons of dried sulphate for each ton of ore, the extra vanadium content recently discovered would do its share towards underwriting the major chemical cost of the basic decomposition process. Of course the bigger revenues and the big profit margins would have to come from the predominating values in the ore. A discussion on the total extractable values will appear in a subsequent chapter.

Interrelated Processes

Other methods are known for breaking down vanadium ores with simple fusions of sodium sulphate, the native reagent on the southeastern Wyoming terrain.

The process, hereinbefore selected, yields great volumes of alkali sulphides suitable for automatic regeneration and other chemical pursuits of primary importance within the Wyoming field. Incidentally such "waste liquors" are now known to exercise a vigorous solvent action on many stubborn sorts of vanadium ores. In the next chapter, generalized sodium sulphate processes are recommended for breaking down nearly all ores of the constantly growing list of ferro-alloy metals. At other points such fusions seem to carry esteem regardless of the distance that primary mining operations are conducted from beds of natural salines.

In considering the robust action of sodium sulphate on highly intractable materials it is preferable to reserve some of the vanadium processes for the interrelated discussions of the next chapter.

CHAPTER XI

OTHER SODIUM SULPHATE PROCESSES

Introductory—Metallurgical Processes—Nickel—Other Siderophiles—Radium—Beryllium—Vanadium—Other By-Product Utilizations—Alkali Redundancies—Sulphuric Acid—Oil Refining — New Phosphate Market — An Integrated Chemical Industry.

Introductory

At times the chemical industry is variously referred to as the country's newest or fourth largest or most rapidly growing industry. For 1929 the combined output of chemical and allied enterprises was evaluated as high as 11½ billion dollars. Since then dividend payment continuities would indicate that the U. S. chemical industry has suffered in smaller measure the effect of curtailed business than have most other manufacturing groups.

During the past decade different factors have been quietly revolutionizing basic operations within the chemical industry. Rebuilding of chemical engineering plants has occurred at very frequent intervals. No other manufacturing group has paid a higher penalty for progress. Writers drawing from widely different personal backgrounds offer equally diverging views on the complexities and extensive ramifications now at work within the chemical industry. An extremely sound and comprehensive interpretation of present-day chemical trends appears in the 1931 edition of the Mineral Industry. Consent to reprint the following summary has been obtained from the McGraw-Hill publishing concern.

GREGORY, ARNOLD WILLIAM. Treatment of ores for the recovery of titanium. U. S. Patent 1,734,034, Nov. 5, 1929. Jour. Am. Ceram. Soc., Abs. Bull., vol. 9, No. 1, January, 1930, p. 69.

Process of removing the iron from titanic iron ores which consists in pulverizing the ore, mixing the pulverized ore with sufficient free carbon to combine with substantially all of the oxygen in the iron oxide of the ore and with a fusible alkaline salt, heating the mixture in the absence of free oxygen to a bright red heat to cause combination of the carbon with substantially all of the oxygen of the iron oxide content and production of free iron in a dispersed state, and immediately treating the whole mass with dilute acid capable of combining with the free iron in quantity at least sufficient to combine with all the free iron, and to neutralize the alkaline salt whereby to resolve all the iron content of the ore to an iron salt in solution.

MATHESIUS, W., and MATHESIUS, H. Production of titanium steel. British Patent 329,705, Feb. 25, 1929. Chem. and Ind. (London), vol. 49, No. 32, Aug. 8, 1930, p. 720.

Steels containing not more than 1% C and 0.8% Ti with small additions of silicon, manganese, chromium, and other metals which improve the properties are claimed, a preferred composition being 0.1% C, 0.2% Ti, 0.5% Si, 0.5% Mn, and 0.5% Cr. The steel is produced by deoxidizing a bath containing less than 0.1% C by the addition of carbon-free silicides of ferromanganese, ferrochromium, or ferromanganese-chromium having such a carbon content that 0.1% C remains in the bath; the requisite titanium is then added as carbon-free ferrotitanium.

——————— Titanium. British Patent 333,816, Oct. 8, 1930. Jour. Am. Ceram. Soc., Abs. Bull., vol. 9, No. 12, December, 1930, p. 1105.

In a process for producing homogeneous titanium or ferrotitanium melts by alumino-thermic reaction, salts of the acids derived from the oxides of the heavy metals are added to the mixture in order to effect a regular decomposition of the regulus. Chromates, tungstates, manganates, permanganates, and uranates are specified, either as salts of iron, nickel, cobalt, manganese, uranium, tungsten, molybdenum, vanadium; in the latter case, the metallic radical passes together with the metal of the acid radical into the titanium or ferrotitanium regulus.

RYAN, L. W. (to Titanium Pigment Co.) Titanium compounds. British Patent 308,725, Mar. 27, 1928. Chem. Abs., vol. 24, 1930, p. 473.

Hydrolytic precipitation of titanium compounds from aqueous solutions containing inorganic acid is effected in the presence of organic acids or of H_3PO_4 or of salts of these or similar acids. The hydrolysis product may be calcined at 700-1000° to obtain a white pigment of TiO_2, which may contain, e. g., 0.6-1.3 per cent P_2O_5. Various details of procedure are given.

Nothing is known to the author regarding the workableness of these recent patents either on the Iron Mountain ore material or on the products recoverable therefrom. These patents were listed for only one reason. With one exception, all requisite ingredients could be cheaply produced in either the native or manufactured form from raw materials that are characteristic of the North Platte valley depository. The exception is the aluminum required for the new ferrotitanium melt. If only a small amount of the latter material is made, it is likely that the various sodium sulphate fusions will yield sufficient soluble alumina directly from the alloy ore itself. If larger quantities are desired, this material would have to be sought in the huge leucite reserve of southwestern Wyoming which is accredited in several Governmental publications as containing 197,000,000 tons of extractable alumina.

No single patent so far examined could possibly yield satisfactory results on the Iron Mountain complex. To recover all of the values within that huge dike of mineral, analyzing 92.50% in iron, chromium, manganese and vanadium oxides, a new series of patents will likely be devised.

The situation at Iron Mountain requires further investigation. To date, the state of Wyoming has produced its full quota of distinguished chemists. Should the leading talent in this field of endeavor call a conference for a discussion of Iron Mountain technology, sufficient ingenuity should be revealed to make visible headway towards the solution of a growingly important problem of Wyoming.

No additional patented processes of recent origin can be listed within the remaining space of this paper. For the separation of other values in the ore, only the analytical procedures of school laboratories will be outlined from time to time. For conducting recoveries on a volume basis, reliance should first be placed on those raw chemicals and other forms of energizers already known to occur in quantity within the local Wyoming basin.

CHAPTER VII

USES FOR TITANIUM COMPOUNDS—STATUS OF THE INDUSTRY

Uses for Titanium Compounds

As hereinbefore stated, no uses have so far been found for titanium metal outside of the laboratory. In course of time industrial applications are bound to be disclosed for the special properties of this elemental substance. Tungsten, for example, long essayed the role of a useless element. However, for the present twentieth century plane of civilization it suddenly skyrocketed to 5th place in the list of indispensable metals.

On the other hand to record all of the uses recently developed for titanium compounds would require the recopying of entire chapters from the latest handbooks. The best domestic volume consulted in this field was Thornton's ''Titanium'' published in 1927 by the American Chemical Society. In the cited circular of the Bureau of Mines, much of the foregoing material appears to be condensed in a single paragraph. Excluding remarks that obviously are unfulfillable by the Wyoming ore type, the Bureau's paragraph with one explanatory insertion essentially reads as follows:

> *General*—Titanium and its compounds are employed chiefly in the manufacture of pigments (paints) and of metallic alloys (principally ferrotitanium) for use in the metallurgy of iron and steel. The metallic uses have already been described herein and in ensuing quoted matter the uses of the new paints are duly considered. Other lesser but also important uses include titanium salts as reducing or stripping agents and as mordants in the dyeing industry (textiles and leather), as a refractory pigment in the ceramic industry, and as incandescent media. * * * Miscellaneous minor uses are the following: Certain titanous salts as acid-reducing agents; titanous sulphate in de-

> colorizing old paper and dyed fabrics and in detecting copper in dyed goods and fluorine in analytical work; titanous chloride in removing iron stains in laundries and in clearing goods that have run in the washing; titanium dioxide in the manufacture of catalysts, used in the esterfication of acetic acid; logwood-titanium compound in making a permanent ink, deep-black in color, which undergoes no change after using; certain salts, especially the sulphates and salicylates, in therapeutics titanium nitride as a basis for fertilizers; and titanium tetrachloride in forming smoke screens. * * * Quick-hardening and chemically resistant cement has been obtained as a by-product of smelting titanium-iron ores in a blast furnace or an electric furnace, limestone being used as a flux.

Status of the Industry

With the exception of the pigmentation division, the markets for titanium products seem to have reached a stabilized level some years ago. Lately, a broader degree of receptivity has been noticeable for the new lines of durable paints and enamels now being made from the titanic dioxide base. This visible trend caused the following conclusion to appear in a statistical review published last February by the Bureau of Mines:

> Countercurrent to the general business depression that engulfed other industries, the titanium industry made marked progress in 1930.

Since the foregoing statement was printed, a wide assortment of trade journal, financial, mineral, chemical and metallurgical reviews, company earning reports, etc., found their way to this desk. The latest literature reviewed the larger titanium operations for the year of 1931. An impartial analysis thereof would lead one to believe that at least one domestic industry is able to stage a sizable program of expansion during the bitterest depression the world has ever known.

In a former annual review published by the State Geologist on the Wyoming Mineral Industry, a thorough-going revolution was prematurely predicted within the national pigmentation industry. No corroboration of that forecast appeared in the public prints until July 6, 1932. On that date, the ultraconservative financial journal known as "The Business Week" released the following summary in regard to current drifts within the titanium industry:

> ### *Titanium "Goes Further" in Paint and in Market*
>
> Sales of titanium oxides are increasing steadily, and capacity of the industry is being increased by the construction of new plants. At the same time, the sales of paint materials in general are declining. Nothing could more strikingly bring out the fact that titanium is making great inroads upon the markets of the other basic paint pigments, white lead, zinc oxide, and lithopone.
>
> This is part of the revolution in the paint industry that has included the introduction of new synthetic oils, and the development of lacquers that have cut into varnish sales.
>
> Titanium oxides are produced by Commercial Pigments, which is a merger of the DuPont and Commercial Solvents interests, by the Vanadium Corporation, and by National Lead Company. Vanadium Corporation has a new plant at Piney River, Va., not yet in full operation. National Lead is about to build an additional plant. Perth Amboy, N. J., was the site first selected, but this decision is likely to be altered.
>
> For many years, white lead was the only white pigment, and still is used in greatest volume. Next in point of time came zinc oxide. Lithopone, a zinc compound, follows in seniority, but has passed zinc oxide in volume. Titanium oxide is youngest. Figures as to its total production are carefully guarded. Best estimate is that they still are small as compared with white lead's half billion pounds in 1929, but doubling yearly.
>
> #### **Still a Secret Process**
>
> More or less secrecy surrounds the whole titanium industry. The sources of supply in this country are Virginia and Florida. Visitors have not been welcome at mines, and even the technique of mining titanium ore never has been described.

> The pure metal is both rare and unimportant. As an alloy in steel making titanium has some use. But the ores from which oxides may be produced are plentiful—titanium has been estimated to be more abundant than copper, zinc, lead, tin, or manganese.
>
> The great virtue of titanium oxide as paint pigment is its covering power. Expensive by the pound, it is inexpensive in square feet painted. It is highly elastic, in fact needs the addition of zinc oxide or lithopone as hardener. It resists attack from the impurities in city air, full of sulphuric acid, sea air, and even salt spray. It is brilliant white, and non-poisonous.
>
> As long ago as 1870, a British investigator painted ships' bottoms with titanium paint. American patents were granted in 1916, and National Lead pioneered in Niagara Falls in 1917.

It would hardly be necessary to evolve some mysterious "technique" to mine the high-grade titanium ore at Iron Mountain. As a matter of fact the output of a few steam shovels judiciously placed atop of the giant dike of solid mineral would shortly inundate established markets with Wyoming ore. Such an economic dislocation might cause a noticeable curtailment in Norwegian, Brazilian, Indian and Senegalese ore shipments. Heretofore these countries have supplied the raw material for operating titanium plants at the more favorable power sites in the United States.

Hereinbefore, a modified recipe has been formulated for manufacturing titanium dioxide, the base of the new paint industry, by simply introducing an all-Wyoming mixture of titanium ore, sodium sulphate and petroleum coke into an electric furnace. For the operation of the latter contrivance, it had to be admitted that Wyoming was yet unable to produce any sizable volume of low-cost electrothermal energy. But during the present year the Senior Senator from Wyoming paved the way for the early construction of the Casper-Alcova hydro-project. Titanium concerns now scouring the nation for plausible plant sites may learn too late that Wyoming alone can supply everything used in the manufacture of the latest paint products.

An unbiased appraisal of basic raw material resources, competitive interregional rivalries, and other overshadowing fundamentals clearly indicates that Casper, Wyoming will be the optimum location for titanium paint plants as soon as the hydropotential of the North Platte River is developed at that strategic point.

CHAPTER VIII

CHROMIUM

Uses of Chromium — Ore Deposits — Deer Creek Mine — Iron Mountain Chromium—Crockett Chrome Claims—Geology —Ore Deposit—Assays—Ore Reserve—Mining Proposals — Ore Concentrations — Metallurgical Factors — Metallic Chromium—Ferrochrome—Sodium Chromate—All-Casper Process—Private Chrome Investigations—Recent Chrome Discoveries

Chromium, manganese and vanadium are the remaining ferro-alloy metals found in the big dike at Iron Mountain. Other occurrences of all of these increasingly important metals are also recognized within the mineral depository, geographically defined as the Wyoming drainage sector of the North Platte River.

Uses of Chromium

Latest statistical charts disclose that the United States consumes from 55 to 60% of the world output of chromium. In recent years American miners produced 1/10 of 1% of the ore required for domestic consumption. At the present time the remaining 99.9% of the ore supply comes into this country from African Rhodesia, the South Sea Island of New Caledonia, and other points equally remote. This disparity between consumption and production will likely continue until sizable mining operations are started at Iron Mountain and at other chromiferous sites herein held to be exploitable within the North Platte River basin.

In the Good Book mention is made of a kingdom in which neither moth nor rust doth corrupt. In recent years it, however, has been possible to buy increasing quantities of a steel that does not rust. In 1930 the leading journal of the iron trade published the following encomium on a new rustless steel containing at least 18% chromium metal:

> Consider a steel with such a remarkable range of adaptivity that it can be used as a setting for a jewel, a watch case, or a dental plate, and in innumerable forms all the way up in size to gigantic ornaments to glisten from the peaks of skyscrapers or for railroad-car tanks to carry safely the most corrosive liquids. A steel retaining indefinitely a silvery luster, and possessing extraordinary corrosion resisting properties! Impossible as it would have seemed a few years ago, modern metallurgy has here accomplished something better than the alchemists of old tried to create with their magic. This steel has the properties of many other metals, and that it is fulfilling its promises is evident from the fact that it is approaching a large production basis.

By this time rustless steel is familiar to everyone. Up to three or four years ago all of the decorative parts of automobiles were plated with easily scratched and tarnishable nickel. Today the radiator finishings, lamps and other bright parts of even the cheapest cars are either plated with hard and rustless chromium or else made entirely of a high content chromium alloy apparently possessing equally ornamental and everlasting merits.

Strangely enough the introduction of the sensational chrome steels was a slow and tedious process in this country. As early as 12 years ago a well known surgeon and student of the ballistical science in this state became exasperated with the grade of pot metal that was in his various fowling pieces. For continuing his experiments in the latter field, a half dozen stronger, rust-proof rifle barrels were imported from the German Krupp works, who were the original patent holders and producers of chromium steels. Those early and severe tests met all expectations, and since then the doctor has replaced out-of-date professional equipment with more durable products made of chromium. At the present time a soft silvery tone is likewise noticeable from metallic fixtures and pieces of bric-a-brac lately installed within his modernistic home.

In addition to rustless steels other important uses for chromium have been found in the metallurgical field. This miraculous metal also enters into the manufacture of the steels that possess the highest degrees of hardness and heat resisting qualities so far developed. In fact some of the latest chromium alloys contain no iron at all. Without their employment it would be impossible to conduct the high-pressure, high-temperature processes lately installed in the larger oil refineries and chemical synthetic plants of the world. For these and other reasons growing schools of metallurgists are of the opinion that the long dominant age of steel has already been supplanted by the neo-alloy age on the timetable usually accepted for denoting the progressive stages of civilization.

Large quantities of imported chrome ore are also consumed by the domestic refractory, ceramic, dyeing, tanning, pigment, and chemical industries. Outside of the chemical market none of the preceding uses can be considered in this paper.

In southeastern Wyoming large deposits of low grade chrome ore are known to occur in the immediate vicinity of important beds of chemicals. For certain metallurgical operations in Wyoming the greater portions of the furnace charges would necessarily consist of local chemicals. In the following pages a brief amount of space is likewise allotted to the basic chromium chemicals that are feasible to manufacture wholly from Wyoming raw materials.

Ore Deposits

Deer Creek Mine

In the 1932 chromium circular of the U. S. Bureau of Mines Wyoming is recognized as one of the seven states in which deposits of chrome ore are known to occur. The listing for this state is as follows:

> Wyoming has one known deposit, in Converse County, which has produced 1,080 tons of ore averaging around 40 per cent of Cr_2O_3. The reserves are estimated at less than 2,500 tons of ore of about the same grade.

By itself, the foregoing deposit serves to rank Wyoming in the fifth place among the states in known chrome ore reserves. The listing simply refers to the old Deer Creek Mine that is located 13 miles due south of the point where the North Platte River crosses the Big Muddy oil field.

During the World War small quantities of ore were mined from the short, 5-foot wide vertical dike or lens of solid chromite that is located on the property. Shipments of the ore to distant points soon proved unprofitable, and resumption of mining activities cannot be expected until local reduction works are constructed to treat the much larger chrome deposits that are located in Casper. As developments now stand the preceding reserve warrants no further mention in this paper.

Iron Mountain Chromium

In the single complete analysis so far published by the Government, the big dike of solid titaniferous magnetite at Iron Mountain apparently contains 2.45% sesquioxide of chromium. Considering the uniformity of texture of that gangueless geologic formation as well as the tonnage reserve figure, hereinbefore calculated, no less than 1,000,000 tons of chromium metal would appear to be locked-up in the spectacular deposit of ferro-alloy ore. In the cited appraisal of the Bureau no deposit of chromiferous mineral approaching this magnitude is recorded in the United States. Admittedly, the extraction of the calculated chromium metal in the Iron Mountain dike is yet an unsolved problem. At current quotations the chrome content of the Iron Mountain mineral is only worth $1.00 per ton. Clearly, that value is far too low for devising an independent metallurgical treatment for the huge body of Wyoming ore.

In a prior chapter a sodium sulphate fusion was suggested as an all-Wyoming process for decomposing the Iron Mountain mineral. Apparently, the indicated reactions would leave the Cr_20_3 content in the undissolvable residue of the fusion. From that much higher degree of concentration it should be possible to evolve inexpensive separation processes for recovering sizable quantities of chromic oxide as a valuable by-product.

Nationwide surveys recently completed by the Bureau of Mines appear to carry an unduly pessimistic tone in regard to the establishment of a sound chrome mining operation in the United States. As soon as big scale mining operations are started at Iron Mountain, primarily for the extraction of titanium and other ferro-alloy metals, sufficient chromium should be recovered as a by-product for finally providing this country with a steady and lasting supply of a growingly important metal. Obviously, an operation at Iron Mountain would serve to fortify the self-sufficiency factor of the nation in several respects.

The Crockett Chrome Claims

For a number of years past Mr. David Crockett, a lineal descendent of the great scout, has been doing development and assessment work on two chrome mining claims that either adjoin or conflict with lands in the municipal park system of Casper, the second largest city in the state.

An examination of Federal literature discloses but one brief reference to the grounds long occupied by Mr. Crockett.

In regard thereto the following joint notice is extracted from Bulletin No. 470 of the U. S. Geological Survey:

> Chromite—There is a deposit of iron ore said to contain chromium of economic importance on the border of the serpentine in Deer Creek Canyon, 15 miles southwest of Glenrock, Wyo. A similar deposit occurs on Casper Mountain. Both of these masses are within the asbestos areas of the Casper region and add another likeness in comparing the asbestos-bearing rocks of Casper with those of the Thetford-Black Lake region of Canada.

The preceding comparison between local and Canadian geology has always been of much interest to the people of Casper. At no other point in the United States does geology so nearly approach the set-up prevailing in the Thetford area. From the latter district this nation has been importing 97% or more of its asbestos requirements for many years past.

Geology

Mention has already been made of the location of the chromite deposits within the asbestos areas. Elsewhere in the cited Survey bulletin the immediate rocks are described as follows:

> ### *Rocks of the Asbestos Areas*
>
> The rocks of the asbestos areas are hornblende schist, diorite granite, and serpentine. The black hornblende schist is a well-defined, medium-grained schist in which hornblende is somewhat more abundant than the altered feldspar and quartz. The diorite differs from the hornblende schist generally in being finer grained and without definite schistose structure. Much of it is compact with the habit of greenstone.
>
> Granite is perhaps the most distinctive rock of these areas. It is medium to coarse grained and generally red, owing to the color of the abundant feldspar. Much of it is composed of quartz and feldspar, with only a trace of hornblende or other ferromagnesian silicates. The structure, though generally even granular, is in places graphic, and here and there the rock passes into pegmatite and appears in the form of more or less distinct dikes. The gran-

> ite is generally regarded as one of the important rocks in the great Archean mass of the Laramie Range and as older than the diorite and serpentine. This may well be true for the main body, but in the asbestos areas, especially in the divide between Smith Creek and Deer Creek, the granite locally appears as large dikes and sends tongues into the adjacent serpentine.
>
> Serpentine being the source of the asbestos, it is by far the most important rock of the area. It occurs in belts which, at least in the Smith Creek area, where their distribution has been noted most fully, extend northwest and southeast. This is true both of the mass which is now being worked at the west end of the area and of the one farther east running through the property of the International Asbestos Mills & Power Co. The western belt is about 1,500 feet long and from 150 to 300 feet wide. In general the trend of these belts is toward the asbestos area of Casper Mountain and suggests the connection of the two areas beneath the syncline of sedimentary rocks that lies between them.
>
> The most common type of serpentine in this region is bluish and impure, but the more typical form is that which is associated with asbestos. It is generally very much crushed and sheared. The serpentine where examined contained no remnants of the rock from which it was derived. Its microscopic structure, however, clearly indicates that the original rock was composed almost wholly of olivine. It was not only a peridotite but practically a dunite.
>
> The rocks of the asbestos areas, ranging from granite to peridotite, with a number of intermediate forms, have resulted apparently from the differentiation of a single magma, of which the asbestos is one of the final products.

In this digest the economic potentialities of the preceding geology are matters not to be lightly dismissed. The pre-Cambrian primaries referred to come from the earth's core, and hence better values and better ore bodies should logically be expected than from the localized, less consistent, secondary or replacement enrichments often exploited elsewhere.

In the United States, geology of the preceding type is none too common. But in Canada and in more distant countries, a number of sensational discoveries of precious minerals have recently been made in ultrabasic dunites, dynamometamorphosed serpentinized peridotites and other rocks that characterize the Casper extrusive system. Moreover, in regard to abysmal origin, primordial antiquity, chemical basicity, general physical make-up, and in other likenesses yet to be pointed out it is probable that the City Park area of Casper is also comparable to geology previously cited for the great Bushveld complex, along the marginal boundaries of which the world's largest deposits of medium grade chromite ores and certain other commonly associated minerals were first mined as late as seven or eight years ago.

Ore Deposit

Mr. Crockett filed his two mining claims on the top of a basic dike that outcrops in an east and west direction for a distance of 4,500 feet near the summit line of Casper Mountain. The width of the dike is said to vary from 60 to 170 feet and in one of the central workings a vertical dip of 85° to the north was observed for the formation. Its central section of 3,000 feet is covered by the Crockett claims and the remainder of its length extends into the City Park system and other lands already deeded to private holders.

The dike rock readily weathers and throughout its entire length it is buried by a rich dark loam that supports dense growths of grasses and shrubbery as well as larger arboreal stands. Before its exact dimensions can be measured considerable trenching and prospecting work remains to be done. Apparently, the soil overburden averages 4 feet in depth. For systematic cutting of the trenches the use of a light steam shovel may prove expedient. Obviously, the Crockett dike does not loom above the horizon in the bizarre and spectacular manner hereinbefore described for the larger dike at Iron Mountain.

Mr. Crockett described his dike as a semi-weathered, talcose, basic formation. Casual field examination, however, classified it as a greenstone mainly consisting of a gray-green, compact, fine-grained, schistosity-free groundmass in which signs of incipient serpentinization are observable. In this dike rock the only mineral that could be identified by the eye or with pocket lens was chromite. It is liberally disseminated throughout the mass as lustrous, jet-black, rounded anhedral crystals, or say, embryonic spherulitic forms about the size of dust shot. The local phenocrystal development offers strong support to the general mineralization theory recently propounded by Singewald that deposits of chromite represent a direct segregation and are the first product of crystallization from a molten magma.

Upon the single mineral identification notated, the ore body of Mr. Crockett was tentatively designated as a dike of dunite rock. Subsequent microscopic examination may place the rock in a slightly different category. In the end it may prove to be some other variety of peridotite or possibly a pyroxenite. Specimens of the unfavorable texture examined require the use of costly microscopic equipment in making the determinations of essential and accessory mineral constituencies.

Ore depositions of the Casper type are not common in this country. The local geology is radically different from that of the chrome occurrences in California, Oregon and Washington. Those three states are generally considered as containing the most promising reserves in event our foreign ore supplies are cut off by war or by more recent forms of international taboo.

All told, the Casper occurrence is more likely a miniature edition of the belt of pyroxenite that traverses Sweet Grass and Stillwater Counties, Montana, in an easterly and westerly direction for 27 miles. In that more extended eruptive, granitoid texture is predominant. In Montana, the cooling interval was likewise sufficient for the formation of more pronounced segregations of chrome within the solidifying magma.

To expedite development private engineers have already filed financial reports on the Montana properties. The reduction of chrome ores is mainly an energy consuming process, and provision for low-cost power rather than a cheap supply of local ore will likely remain the deciding factor for the establishment of a new metallurgical operation in Montana, in Casper or elsewhere. Of course the rock bottom cost of production may reasonably be expected only within a municipality that has everything. In this resumé Federal hydropower, chrome ore, exceptionally high grade furnace fuels and fluxes, and a varied line of raw chemicals suitable for the manufacture of electrolytes and important finished compounds are among the items listed under the industrial inventory for Casper.

Assays

Several years ago the Casper Chamber of Commerce had analyses made of the chrome deposit covered by the Crockett mining claims. The returns disclosed Cr_2O_3 contents ranging from 12 to 22.5%. Subsequent correspondence conducted by the Chamber revealed no existing markets for ore of the tenor described.

On the afternoon of August 18, 1932, the writer made a casual inspection of the Crockett claims. Mr. Crockett was not at home and did not return until the examination was completed. A sample of the rock taken from one of his major trench workings was coarsely ground for a panning test with equipment available in his nearby cabin. The partial recovery yielded a concentrate that was deemed far too magnetic for the possible carriage of chromium in commercial ratios. Nevertheless, the concentrate, as recovered, was mailed the next day to Victor Blanc, long recognized as the foremost rare mineral analyst in Denver. Four check assays ran by him disclosed a 42.77% content of Cr_2O_3 in the submitted concentrate. No determinations were made for the iron and other contaminating agents. But the preceding content happens to approximate the 40-43% averages reported for the great Bushveld belt in which the largest known segregations of chromite have so far been discovered.

In the past some enthusiasts have mined chromite, seemingly for the privilege of paying 75% or more of the gross intake for the transportation of their raw ores to a distant reduction works in the East. Space in this paper precludes a discussion on the economic merits of procedures generally belonging to the category aforementioned.

No chromite mining and concentration operations should be started in Casper until sizable volumes of low-cost hydro energy are delivered into that city. African as well as Soviet ore of the tenor indicated by the Casper concentrate is highly desirable for the manufacture of those soluble chromate compounds for which annually broadening markets have arisen ever since the arrival of the chromium plating age, several years ago. As soon as requisite facilities are provided either city ore or ores commonly shipped from remote foreign climes should command a minimum value of $20.00 per ton, F.O.B. at local chemical works, for direct fusion with the natural sodium sulphates and carbonates that form the lake beds within the Greater Casper trading area.

Ore Reserve

In reply to various interrogatories addressed to him, Mr. Crockett mentioned that his big rock dike carried mineral values at all points where he has so far unbared its surface. According to his previously recorded measurements the surface area of the ore body, generally buried with three or four feet of rich top soil, is only half as large as that of the titano-magnetite dike hereinbefore described as standing out in bold relief at Iron Mountain.

In making the calculation at Iron Mountain it was only necessary to consider the ore visible to the eye. No depths were considered below the level of the ore exposed in the deeply eroded creek canyon. Above that point the average surface elevation of the dike was 400 feet. Going downward the same distance at Casper would account for an ore reserve of half the size previously calculated at Iron Mountain. As the Casper dike is not over two-thirds as heavy as the Iron Mountain formation, the weight of rock above the conservative and easily mineable 400-foot level calculates 20,000,000 tons. If systematic prospecting and pilot plant tests will yield a 10% chromite recovery, a potential ore value of $40,000,000 would be indicated for the preceding dike.

At present writing a conservative calculation can only be filed on the rock content of the Crockett dike. In lieu of uniform dissemination, chromite segregations are generally recorded as occurring as irregular masses, erratic bunches, and ill-defined streaks or "schlieren" in magmas of the peridotic type. Past assays of record likewise indicate an uneven distribution in the local dike. Ordinarily, best conditions for chromite phenocrystal development would be expected within the central core section of a dike that apparently cooled very rapidly. On the other hand the great African segregations seem to occupy the marginal areas of more extended basic belt systems. The latter precedents should serve to fortify Mr. Crockett's observations that grains of chromite up to the size of bird-shot appear everywhere within his dike formation.

Mining Proposals

In ensuing conversation a system of small-scale selective mining was suggested for initial operations on the local dike. Mr. Crockett maintained that the cost of such a system would prove prohibitory, and to cut down overhead as well as to eliminate all non-essentials and other manifold complexities he is now soliciting capital to mine the entire content of his dike as undiluted feed for the mill by modern wholesale mining methods. In the latter light practical operations on the Crockett claims would involve the handling of disseminated low grade mineralization extending throughout a long dike varying in width from 60 to 170 feet.

Among other things the preceding proposal would forestall the presence of a mine dump, a familiar scene of the usual mining camp. In the vicinity of valuable park holdings the elimination of such an unsightly object would likely be demanded by the civic authorities. In regard to value Mr. Crockett stated that a ton of the run-of-mine rock would carry 200 pounds of chromite. According to current quotations the chromiferous dike rock of Mr. Crockett has a prospective value of $2.00 per ton. Obviously, in its present form it must still be regarded as unpayable rock. For conversion into profitable ore it would be necessary to complete the big Casper-Alcova hydro-project without further delay.

To develop low grade ore deposits of the character outlined, provision must be made for tremendous mill capacity. For the latter operation a continuous supply of cheap power is essential. For handling large quantities of rock at the lowest cost, the Alaska Juneau mine has long been the holder of several world records. In the November 30, 1931 issue of Barron's Weekly, mining and milling costs at Alaska Juneau were summarized as follows:

> Prior to the discovery of the rich north ore body Alaska Juneau had made a remarkable record in the treatment of low-grade ore. Up to January 1, last, some $25,000,000 had been recovered from ore averaging little over $1.00 in gold per ton. In undertaking the exploitation of so low-grade a deposit, Pres. F. W. Bradley and associates were not deterred by the previous failure of the distinguished mining and banking sponsors of Alaska Gold Mining Co. Methods which had achieved remarkable success in the case of Utah Copper Co. and the other porphyries

> failed to yield profits for Alaska Gold Mining Co. The Alaska Juneau management, however, devised a method of stoping which yielded exceedingly low mining costs. In 1930 it cost only 28 cents to handle a ton of ore. Character of the ore permits hand selection from picking belts, discarding about 45% of the ore mined and bringing milling costs down to 23 cents per ton in 1930. From 1911 to 1930 Alaska Juneau, therefore, spent only 65.3 cents on mining, milling, and administration for each ton of ore mined. Its low-grade south ore body has consequently been developed to an annual earning capacity of some $1,500,000, equal to approximately $1.00 per share on 1,500,000 shares of stock.

In Circular 6186 of the Bureau of Mines, the average gold assay value of the ore milled during the 50-year history of the Alaska Juneau is stated at 89 cents per ton. During the present depression a number of metal mines are operating in ore worth less than the preceding assay value. Lately, one of the major copper properties in the United States was forced to mine and finely pulverize 54-cent ore, but unlike the Alaska Juneau, our second largest gold producer, it had to stop paying dividends.

To achieve the sensational cost records quoted, it was necessary to adopt wholesale mining operations on a large scale. From mineralized bodies somewhat shorter, but apparently two or three times as wide as the Casper dike, approximately 11,500 tons of gold ore is mined daily for shipment to the Juneau concentrators. To operate the mine and the giant pulverizing mills three shifts per day for 361 days of the year, the combined output of 3 hydroelectric plants, owned by the company, is now being utilized.

In the Bureau circular the cost of the preceding power is stated at 0.439 cents per kwh. That exceedingly low cost is 10% higher than the figure calculated for Seminoe dam power, delivered in Casper, as per the report of the U. S. Reclamation Service engineers, hereinafter incorporated as one of the basic cost chapters of this paper.

To produce all of the chrome ore annually imported into this country from rock carrying nothing higher than the $2.00 per ton Casper value, a mining operation of the cited Alaskan magnitude would just about fill the bill. Economically speaking, a wholesale operation like that should never be instituted in a region possessing the relatively high industrial potential of the Casper City district, regardless of the ease in which daily profits may be figured beforehand with pencil and paper.

In the Casper district the preceding type of automaton mining may offer but little interest. At that point a straight-line chrome operation capable of providing a local market outlet for the varied lines of fuels, fluxes and raw chemicals long produced in the city is certain to receive a wider welcome. But before attempting to mine chrome rock on the cited scale and before power consumption calculations may be justified for the spot reduction of all of that highly refractory ore to the metallic form, it would be advisable for Casper organizations to make early arrangements for two hydro plants in place of the one long sought at the Seminoe site.

All will agree that the cited gold operation does much direct good in strengthening the financial structure of this country. Indirectly, a domestic chrome operation might prove equally as beneficial so long as this country is satisfied to depend on foreign purchases for 99.9% of its costly ore supply. As yet, not enough rustless gold or rustless steel is being distributed to keep step with the tempo of the current alloy age. On the other hand the national marts and money-changing places still seem to be surfeited with pot metal and similar dim reminders of civilizations, otherwise long forgotten. For showing the way out of existing economic chaos much is dependent on the candor of thought, courage of action, and virility of leadership that Wyoming will display in the development of the new type industrial areas distributed, here and there, within her boundaries.

Ore Concentrations

Many low grade chromite ores frequently yield disappointing recoveries on the concentrating table. In fact some of them are hopeless for beneficiation by any mechanical process.

Chromite is a member of the spinel family of minerals. Theoretically, it is merely iron chromate bearing the formula $FeO.Cr_2O_3$. In many ores, however, the chromium of the molecule is partly replaced by aluminum and other contaminants. When the gradation from the true formula is considerable not enough chromium can remain for the classification of the mineral as a commercial ore. So far many futile attempts have been made to step up the grade of such minerals. Unfortunately, their chemical composition is never disturbed by any simple physical or mechanical procedure.

As before stated the assay of the concentrate recently taken at random disclosed a chromic oxide content of 42.77%. That test showed that the local mineral contains sufficient molecular metal to be acceptable as an ore in the Casper district. In view of general theories hereinbefore set out on the origin and behavior of integral minerals in certain igneous rock masses, the Casper chromite may be expected to maintain a uniform chemical composition regardless of what point the peridotite or dunite dike is sampled. If anything, the metallic content should test higher than the recorded assay as soon as due steps are taken to obtain a clear-cut concentrate of the mineral.

At other places concentration operations failed to prove successful on account of the heavy fines and disseminated impurities carried in the ore rock. Unlike other chromites, all of the Casper concentrate was observed to possess an appreciable degree of magnetism. Thus it would appear that a combined tabling and magnetic treatment would yield an exceptionally high recovery on material possessing the added amenability of the Casper chromite.

In all low grade chromite deposits percentage recoveries on the concentrating table are always of far more significance than analyses of the ore in place. Manifestly, before definite certainties can be reported on the preceding economic factor, actual tests will have to be run not only on the miniature laboratory table but also in the pilot plant. As yet, no tests like those have been performed on the Casper dike.

Metallurgical Factors

The ores, fuels, fluxes and raw chemicals of the Casper district are of sufficient variety to permit the practice of the chromium reduction operations generally appearing in the latest handbooks of the metallurgical science.

As previously stated, the dominating factor for a going chrome industry is a cheap supply of hydroelectric energy. Exploitation of the more promising chrome deposits in Wyoming, and possibly those conveniently situated in an adjoining state may be expected as soon as provisions are made for the complete development of the hydro resources of the glacier-fed, precipitous, river channel on which the City of Casper is built.

Pending development plans for the North Platte River call for the construction of three dams at favorable canyon sites all of which are within 50 miles of the city. Already one of these towering structures is completed and the construction of the remaining two is expected within the next four years. Upon completion, from 50,000 to 150,000 horsepower of firm and secondary energy will be delivered to Casper at the estimated cost of 3.9 mills per kwh for the firm power. Apparently, the preceding Casper maximum is as low as existing rates at Niagara Falls where most of the foreign chrome ores have long been reduced in this country.

Metallic Chromium

Increasing quantities of chromium are consumed for plating other metals. The deposition is based on the electrolysis of chromic acid and other suitable compounds of the metal.

Metallic chromium for utilization in non-ferrous alloys may be obtained by direct reduction of the oxide with carbon in the electric furnace. Both the oxide and acid compound of the two preceding processes are prepared from soluble chromates. In ensuing paragraphs the manufacture of a suitable chromate wholly from local raw materials is described.

It appears that some chromium is manufactured by thermic processes using either aluminum or magnesium for the reducing agent. The chemistry involved in aluminothermic reductions has already been discussed in one of the preceding titanium chapters.

If magnesium is preferred for operations within the Wyoming depository, the metal may be sought from the huge lake of pure magnesium sulphate that is located near Medicine Bow at a point 65 miles due south of Casper. At present writing a California concern is constructing an $80,000 evaporating and refining plant for the extraction of the many thousand tons of crystallized salt that now form the bed of that 94-acre lake. At 972° C the raw Wyoming sulphate, as mined, would be energetically broken down into a pure white electrolyte entirely suitable for the preparation of the final metal regardless of whatever volume or quantity an infant chromium industry may call for it.

The richer dolomitic limestones and marbles located within the environs of Casper might likewise serve as suitable ores for spot manufacture of metallic magnesium. As yet, no analyses of those sundry raw materials have been published by the Casper Chamber of Commerce. Lacking that basic information it may be safely assumed that no possible Wyoming raw material could produce a cheaper or finer fused electrolyte than the Medicine Bow lake crystals consisting of 99.56% pure hydrous magnesium sulphate in the natural form.

In a compilation of this scope the Medicine Bow lake is simply viewed as a huge surficial deposit of epsom salts of the technical standard usually demanded by the chemical and pharmacopoeia trades. In a broader correlation it might pass as one of the essential spokes in the wheel for the operation of a full and complete, self-supporting, chromium industry entirely within Wyoming. For other pursuits it is but one of the multifold forms of high potential energizers which will be released as soon as hydro-energy is available in the North Platte basin.

To reduce the salts to the form acceptable for a prospective chromium industry, adequate provisions must be made for a relatively high power consumption. If this were not so, the energetic degree of chemical violence previously described for an aluminothermic reduction never would be displayed. Before a chromium industry is started at Casper, steps should be taken for the conversion of the Bow lake salts into metallic magnesium, now quoted on the domestic market at $600.00 per ton. By such arrangements a class ''A'' local market would be provided for the output of the costly evaporation plant that is now being constructed on the lakeside by California capitalists. For offering material encouragement to groups of industrialists now pioneering in the Wyoming chemical field, no factor is as important as the early completion of the Casper-Alcova power project.

Ferrochrome

The Casper chromite contains sufficient metal for making ferrochrome, the basic alloy used in the manufacture of rustless steels. In the process ore and coke are introduced in the electric furnace, and at a temperature of 1185° C an alloy of iron and chromium is reduced directly from the ore. For a commercial reducing agent no material would be more effective than the brand of petroleum coke long turned out by the Casper refineries in quantities exceeding local market demands. In a prior chapter the Casper coke was described as practically ash-free, and, as such, to possess a calorific efficiency fully 25% higher than most grades of metallurgical cokes that are made from coal.

For many years Wyoming has continuously led all states west of the Mississippi River in the production of iron ore. All of this ore has been produced from the Sunrise Mine which is located on the North Platte River less than 100 miles east of Casper. For making common steel Wyoming does not have a coking coal suitable for ordinary blast furnace practice. For the manufacture of the more costly and stronger alloy steels, a far wider assortment of essential raw materials will be available as soon as hydroelectric energy is produced in quantity.

Sodium Chromate

The array of raw materials in the Casper area is also complete for the low-cost manufacture of sodium chromate, the base salt of the chromium chemical trade.

The customary manufacturing operation consists in treating chrome iron ore in a reverberatory furnace with soda and lime in the presence of air, as per the equation below:

$$2FeCr_2O_4+4Na_2CO_3+4CaO+7O=Fe_2O_3+4CaCO_3+4Na_2CrO_4$$

In practice, the chrome ore is finely ground and thence mixed with powdered quicklime and less than the theoretical amount of sodium carbonate required. Finally, the fused mass from the furnace is dissolved in water together with the remaining sodium carbonate. After purification of this solution the sodium chromate may be recovered by crystallization for direct sale to the ink and dyeing industries or to the chemical trade for the manufacture of the higher chromates, oxides, acids and other compounds that are now utilized in the electroplating, tanning and pigment industries.

It is noted that the preceding process calls for finely ground ore. The Casper ore must be milled and it would be recovered in the specified form directly from the concentrating tables. In regard to lime it may be mentioned that the rocks of the chrome deposits are flanked by huge beds of Pennsylvanian limestones. In the positions described contiguous ore-mining and lime-quarrying operations could be conducted simultaneously.

At present chromate manufacturing sites the remaining ingredient of the furnace mix, sodium carbonate, is generally expensive. In the natural chemical laboratory of Wyoming, it would be quite superfluous to use the costly Leblanc and Solvay processes for the manufacture of that salt. Casper is the county seat of Natrona, the name the Greeks had for sodium. Within the confines of the last named county are more soda lakes than in the remainder of the entire state. Fifty to sixty miles southwest of Casper are many lakes ranging in size from one to 160 acres that contain from one to 10 foot beds carrying from 50 to 87 per cent sodium carbonate intimately mixed with varying amounts of bicarbonates, sulphates, and other solubles.

Outside of Natrona County, lakes of the preceding category are seldom found in nature. At times a much advertised state, rather remote from Wyoming, boasts of having one or two lakes of the Natrona County variety. Out there chemical concerns frequently endeavor to isolate the more valuable salts from the admixture by refractory crystallization processes. In Wyoming such exasperating procedures may be entirely obviated. For accelerating chemical action, and for obtaining higher recoveries, the naturally blended lake admixtures of Natrona County will serve as more efficient fusion agents than the purified soda usually prescribed in the dictionaries for the manufacture of sodium chromate.

In the theoretical equation cited, the weight of the soda equals 95 per cent of the weight of the chrome mineral. Ordinarily, for making soluble chromates below prevailing costs of production no locational total resultant would seem as desirable as finding a big dike of chrome rock and a series of natural soda lakes both occurring within the confines of a single county in Wyoming. However, if the salt from another lake type is utilized it would hardly be necessary to go beyond the city limits of the Natrona County capital to secure all requisite raw materials.

An "All-Casper" Process

In one sense Natrona County differs from all other counties. During the past 16-year period that preceding civic entity of Wyoming paid into the National and State treasuries the total sum of $40,000,000 wholly in the form of mineral royalties. Private tabulations not yet fully completed will likely show the Natrona County tribute to exceed the grand aggregate of mineral royalties so far collected from all of the remaining 3,071 counties now organized within the United States.

The preceding mineral royalties did not cause noticeable bulges in the girth dimensions of the public strong-boxes. On the other hand if every county had made the Natrona County payments in extraordinary taxes many of the financial enigmas that now confront the Nation never would have been born. Similar assessments from 3,000 counties would soon reach the colossal figure that is now utilized for recording the National Debt. The same source of supply would likewise serve to extinguish all bonus obligations that were recently filed against the people by the soldiers.

From the unexpended tabulations an even broader program of constructive effort could be financed. From such funds actuaries could provide for a sum sufficient to grant a life pension to each income taxpayer for the fiscal year last past and still have enough left to build 6,000 powerworks of the style and size recently proposed for the Seminoe canyon site. As yet no arithmetician has attempted to calculate the potential continuum of Natrona County as a gathering ground for the collection of an exceedingly ingenious form of public revenue.

Some optimistic taxpayers would naturally expect the selection of Natrona County as an inviting theatre for carrying on several types of economic surveys. It has not been selected for the conduct of such pursuits. Regardless of the magnitude of imposts so far exacted, Natrona County looks no better or worse than any one of its numerous sister communes to research agencies mainly financed by withdrawals from the public funds. Nevertheless, no citizen of Wyoming should presume that all innovations so far heralded by academic bureaus are of no significance for the future welfare of Natrona County.

Take for example Research Report No. 2999, published in 1930 by the U. S. Bureau of Mines under the title of "Roasting Chromite Ores to Produce Chromates." That booklet was designed to show ways and means by which low-grade domestic chrome ores could be converted into soluble chromates, acid and other compounds of intrinsic worth by practical procedures. Therein, the results of no less than 153 separate and independent recoveries are tabulated in comparative form. In some instances the various ingredients that went into the furnace batches might have represented an overland and overseas haulage totaling not less than 5,000 miles. On the other hand had those experiments been conducted within the Natrona County natural laboratory, all of the ore, chemicals, fuels, fluxes and the more ubiquitous raw materials utilized could have been obtained in unlimited quantities almost within the shadow of the Natrona County Court House.

CHAPTER III

GEOLOGY

Visible Ore Reserves—Academical Inquiries

The Government bulletin contains numerous abstracts from prior reports filed on the Iron Mountain deposit by Lindgren, Kemp and Ball. After duly weighing his own observations and finding that the views of the previous geologists were essentially in accord except for "a few inconsistencies in details of descriptions," Singewald published the following concise summary on the geology of the main Iron Mountain deposit in his bulletin:

> ### *Iron Mountain Deposits*
>
> Iron Mountain forms part of the eastern edge of a pre-Cambrian area cut off on the east by Paleozoic limestones and sandstones. The prevailing rocks of the pre-Cambrian area are gneisses and granites, and these have been intruded by a large mass of anorthosite, which has itself been intruded by granitic dikes. Iron Mountain is a ridge a little over a mile long with a direction a little west of north, and an altitude of about 1,000 feet. It is made up principally of anorthosite into which has been intruded a large mass of magnetic ore, which, on account of its greater resistance to erosion, forms the summit of the ridge. The width of the ore body varies considerably, ranging from 50 to 200 feet. The ridge of the mountain is not a straight line but consists of a series of knolls which correspond to the wide parts of the ore body, such places offering greater resistance than where the ore body is narrow. The southern part of the hill is cut through by Chugwater Creek, forming a steep gorge, in the sides of which the ore body is well exposed. About 500 feet before reaching the creek the dike takes a sudden turn of 200 yards to the west and then resumes its normal strike. Plate X, A, shows the part of the dike south of the offset as seen from the south side of Chugwater Creek. The hill in the right background is the main ridge of Iron Mountain. The plate shows clearly

the manner in which the ore projects above the adjacent rock. About 400 feet south of the creek the ore body suddenly terminates.

In thin section the anorthosite is a medium to coarse grained rock consisting almost entirely of plagioclase feldspar. As accessory constituents it contains small amounts of magnetite, biotite, and a monoclinic pyroxene. All of these minerals have been somewhat altered, giving rise to the usual secondary minerals. A little south of the center of Iron Mountain are two intrusions of a biotite granite which seemingly cut the ore body. This rock in thin section is seen to consist of microcline and quartz, with considerable orthoclase and biotite.

At the same part of the hill where the granitic intrusions occur, are three smaller ore bodies on the west slope. One of these is only 200 feet below the summit, and the others nearer the foot of the hill.

On the south side of Chugwater Creek, 300 feet east of the main dike, is a smaller dike which is characterized by an unusually large amount of olivine and plagioclase, and shows exceptionally well the contact of ore and anorthosite. Plate X, B, is a view of the contact here exposed. The rock on the right is normal anorthosite, which abuts directly against the iron ore without showing any change whatever. That the ore body is not a segregation in situ but an intruded body is evident from this exposure. On the left side of the plate a part of the dike is shown. Against the contact is a band of ore about 1 foot wide that contains such a large quantity of olivine that the olivine in places makes up half of the bulk. Next to this is an extremely crumbly layer about 2 feet wide. This contains, in addition to olivine, considerable plagioclase of the same gray color characteristic of the anorthosite. This part is a granular aggregate of magnetite, olivine, and feldspar, though the magnetite and olivine tend to be more intimately associated with each other than either is with the feldspar. Following this is another band consisting of magnetite and olivine, and then solid ore containing no more gangue than the main ore body. A thin section of the olivine-rich ore from this locality consisted principally of magnetite and olivine. In the magnetite were a few dark-green spinels and two small flakes of biotite. The biotite occurs intimately associated with spinel, the spinel almost surrounding and thus separating them from the magnetite. In general the ore of the main ore body is a medium to coarse grained magnetite containing little visible gangue. Locally, olivine is rather abundant, especially on the northern end of the mountain. Biotite is also widely distributed, but not in great amounts. On polished surfaces considerable spinel is seen disseminated through the magnetite, and in thin sections this is still more prominent. The crystals attain a diameter of as much as 1 mm. In one slide containing more olivine than the normal amount several small crystals of hornblende occurred in the olivine. A white crust of calcium carbonate frequently coats the ore, especially in crevices. In the northwest corner of the large outcrop on the highest point of Iron Mountain is a layer from 1 to 2 inches thick which cuts across the ore body at an angle parallel to the hill slope. This is an intimate mixture of fragments of ore and bunches of chlorite in a matrix of the white calcium carbonate.

The following results of analyses of the ore from Iron Mountain and from Shanton Ranch are available:

Results of analyses of Iron Mountain ore.

Con. stituent.	1	2	3	4	5	6	7	8	9	10
	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.
TiO_2	23.49	23.32	23.18	49.47	22.43	21.75	19.47	21.85	21.08	19.98
SiO_2	.76	....	[a]2.15	....	1.21	....	....	....	....	....
Fe_2O_3	45.03	....	48.97	....	47.21	....	....	....	....	....
FeO	17.96	....	24.55	....	25.80	....	....	....	....	....
Al_2O_3	3.98	....	....	....	....	....	....	....	....	....
Cr_2O_3	2.45	....	....	....	....	....	....	....	....	....
Mn_2O_3	1.53	....	....	....	....	....	....	....	....	....
CaO	1.11	....	....	....	....	....	....	....	....	....
MgO	1.56	....	....	....	....	....	....	....	....	....
ZnO	.47	....	....	....	....	....	....	....	....	....
P	Trace	....	....	....	....	....	....	....	....	....
S	1.44	....	.03	....	1.14	....	....	....	....	....
	99.78	....	98.88	....	97.79	....	....	....	....	....
Fe	45.49	50.83	53.33	34.29	51.72	52.31	54.48	51.93	51.50	52.98

[a] Insoluble.

Analyses 1, 2, 3, 4, and 5 have been cited in the foregoing pages, 1 being from Hayden's report, 2, 3, and 4 from Hague's, and 5 from Bulletin 14 of the Wyoming experiment station. Kemp suggests that 4 may be from the Shanton ranch occurrence. Analyses 6, 7, 8, 9, and 10 were computed from analyses of concentrates and tailings made by A. C. Fieldner, of the Bureau of Mines. They are analyses of specimens of ore that were studied metallographically. The first three were from Iron Mountain and the last two from Shanton ranch.

With the exception of analysis 4, the analyses show considerable uniformity in the composition of the ore. Analysis 4 contains iron and titanium in almost the exact ratio in which they are present in ilmenite, but the metallographic study has failed to reveal any ores of that composition at either Iron Mountain or Shanton ranch. It is more likely, therefore, that the sample was obtained from some other small deposit running unusually high in titanium, and it will be left out of consideration. The average composition of the ores from both occurrences is, then, 51.38 per cent Fe and 21.84 per cent TiO_2. The titanium content is somewhat higher than the average for titaniferous magnetites. The average composition is equivalent to an ore composed of 49.84 per cent magnetite and 41.5 per cent ilmenite. With the exception of analysis 1, all the analyses are so incomplete that little further comment can be made on them. The high percentages of sulphur in analyses 1 and 5 are noteworthy, as is the unusual percentage of ZnO in 1, and the presence of several per cent of Cr_2O_3.

The contact between the ore and the wall rock is not usually exposed, but wherever the relations can be seen it is sharply defined. There is no transition from ore to wall rock. The anorthosite in contact with the ore shows the same features that characterize the anorthosite at a distance from the contact. The ore also is the same at the contact with the anorthosite as farther within the ore body. That the deposit is not a magmatic segregation in situ is evident, and the relations are such as to establish beyond doubt the intrusive character of the ore. The relations existing between anorthosite and deposits of titaniferous iron ores in other regions as in Canada, the Adirondacks, Minnesota, and elsewhere, make it most probable that the anorthosite and iron ore came from the same parent magma. Deep-seated magmatic segregation took place. The anorthosite was intruded, and subsequently the iron ore body was intruded into it in the same manner in which the igneous dikes were intruded. The Iron Mountain deposit is therefore the analogue in basic igneous rocks of the large deposits in acidic igneous rocks, of which Kiruna, in Sweden, is the most striking example.

Visible Ore Reserves

Neither Singewald nor any prior geologist quoted by him made an attempt to calculate the ore reserve visible in the spectacular Iron Mountain deposit. Nevertheless, a tonnage calculation can be made from their recorded dimensions.

All of the mentioned geologists described a sharply defined dike mass of solid, heavy, black, granular, holocrystalline ore, apparently pure and free of accompanying gangue minerals, that outcrops with a width varying from 40 to 300 feet over a meridional distance of one and one-fourth miles. In vertical displacement the dike is cut at its south end by the canyon of the Chugwater Creek. From the top of this 200-foot gorge, the outcropping rises an additional 400 feet to its northern terminal which forms the extreme summit of Iron Mountain.

Singewald has previously recorded the mineral composition of the big dike as 49.84% magnetite and 41.5% ilmenite. Using an indicated specific gravity of 5 and the visible length and the width and height averages mentioned, the actual weight of the two commercial minerals in the dike above its widening basal point so far eroded in the creek channel slightly exceeds 61,000,000 tons. This huge exposure caused Singewald to rate Iron Mountain as the largest titaniferous ore reserve in the United States and elsewhere to pronounce it as "most attractive as to size and ease of mining."

In view of its widening depth tendency, the actual ore in the dike below the superficial basal point arbitrarily selected for the preceding computation may extend to unfathomable limits. Should a reasonable figure be desired on the underground reserve, it would be essential to resort to gravitational, magnetic and electrical differential surveys. A combination of such procedures recently served to locate a much smaller metallic mass in the Comet Crater of Arizona. As both of these remarkable ore bodies happen to possess common physical properties, similar methods should accordingly be adopted in the measurements of their more striking potentials.

Academical Inquiries

In recent years a number of professors and scientists have conducted academic investigations in regard to the origin of the Iron Mountain deposit. Their voluntary labors are by no means ended. Elsewhere, titaniferous magnetites are looked upon as basic segregations, but long ago Singewald established the intrusive character of the Iron Mountain ore reserve. In the big dike he has titanium playing the role almost universally occupied by lowly silica in the formation of ordinary eruptives. As a result the heavy Iron Mountain extrusive was duly classified as an iron titanate, a magma of radically different chemical origin than the useless admixtures of ferromagnesium silicates that commonly compose ancient plutonics in other parts of the world.

An extensive occurrence of heavy dike rock within a coarsely crystalline basement complex may justify further studies by pioneer branches of the geological science. The Iron Mountain egressive is nearly twice as heavy as ordinary rock and as such, its specific gravity more nearly approaches the figure determined for the entire globe than any type of outpouring so far observed by the writer. After all, Iron Mountain may prove to be an unusually clear window for peering most deeply into the central core sections of the world itself. In that event many opinions published on the nature of sublithosphere zones would be subject to revision.

CHAPTER IV

CHEMICAL ANALYSES

A Recent Discovery—Present-Day Platinum Geology

As may be noted in the preceding abstract, Singewald published only one "complete" analysis of the Iron Mountain ore body. As stated therein, that analysis was performed in 1868 by some pre-Survey assistant in the then school of mines, Columbia College. Since 1868 nearly 30% of all of the chemical elements have been discovered, but regardless of that conclusive progress, the most recent publications of the Federal Bureaus record no complete analysis of the Iron Mountain ore later than the one reprinted, hereinbefore.

Should a 60-ounce meteorite be observed to fall in the United States, it would immediately be tested by costly, complicated methods for each one of the 30 or more primary elements so far identified in said variety of celestial visitants. In the meanwhile the ancestry of the 60,000,000-ton dike at Iron Mountain, herein looked upon as a terrestrial cousin of previously described matter, will likely remain untraced by the present schools of geochemists.

A Recent Discovery

The economic importance of up-to-date analyses of the Iron Mountain outpouring cannot be stressed too strongly. An analysis published three years ago by Wyoming's largest taxpayer first disclosed the local formation to contain 0.40% vanadium oxide. By itself, that content is nearly sufficient to mine the big dike for vanadium, an indispensable alloy metal used in the present-day steel industry. Heretofore, the United States has relied upon a single deposit of the Peruvian Andes for 75% of its supply of vanadium ore, but large-scale operations at Iron Mountain for titanium and other metallic values may recover sufficient vanadium as a by-product to make the importation of the ore no longer necessary in this country.

Applying the reserve figure hereinbefore calculated, the private analysis would account for 250,000 tons of vanadium oxide in the dike at Iron Mountain. That volume is of sizable concern. At recent rates of consumption the content would meet national requirements for many decades yet to come.

In late years, small amounts of vanadium as well as chromium have been found in all ilmenites analyzed. The big irruption at Iron Mountain is of sufficient dimensions to make it the largest depository of low-grade vanadium ore so far described in the United States. In actual tonnage, the private analysis indicates a vanadium content much larger than the total recently published for the high-grade deposits of Peru. Heretofore, Peru and vanadium have generally passed as synonomous terms to the geologist.

Present-Day Platinum Geology

In more recent years it has sometimes paid to make complete analyses of the older and more complicated extrusive systems. In Africa, the continent that has all of the minerals, the deeper-seated eruptives have already revealed the siderophile elements ordinarily looked for in current planetesimal debris. Bureau of Mines Circular No. 6389 summarizes African geology as follows:

> The dunite pipes, of which the Onverwacht mine represents the best known example, are pipe or parsnipshaped segregations (hortonite-dunite in olivine-dunite) enriched in platinum. The core of such a deposit may average 1 ounce or more per ton in platinum, and the platinum content becomes progressively less and less as the distance from the center increases until the rock becomes too lean to work. Associated with these deposits masses of platinum-bearing dunite may also occur as irregular sheets,

> lenses, and "schlieren" in coarse pegmatitic diallage or diallage-*ilmenite*-pegmatite.
>
> The Merensky horizon is in the upper part of the differentiated zone of the Bushveld complex. It is almost as regular as a coal seam, taking the form of a thin layer of dark-platinum-bearing rock (or rocks) intercalated with beds of light-colored norite and anorthosite. There is a pseudostratification that gives the formation the aspect of well-bedded sedimentary stratum. The Merensky horizon has been traced (at intervals) for 180 miles in the Rustenburg and Pretoria districts, 100 miles in the Lydenburg and Peitersburg districts, and some 40 miles in the Potgietersrust district. As it probably persists on the dip for scores of miles the tonnage of ore on it is almost beyond calculation. It attains its best development in the Rustenburg and Lydenburg districts. The ore contains considerable amounts of nickel and appreciable quantities of gold but it is valuable chiefly for the platinum metals content. The platinum metals of the ores range from a trace to as much as 13 ounces a ton in picked specimens. Over considerable areas in the Rustenburg district, this horizon carries an average of 6 dwt. of platinum metals over a stoping width of 30 inches and an average of 10 to 12 dwt. over a milling width of 12 inches. Palladium is also present; the proportion of palladium to platinum ranges from 12:76 to 62:38 and is highest on the Potgietersrust fields.

To date, no platinum and palladium metals have been produced in Wyoming nearer than 40 miles along the main axial trend of the Iron Mountain complex. Genetically speaking, nearer factors are more significant.

In his writings the late great Professor Vogt described the titaniferous deposits of the world as occurring in central eruptive masses into which they gradate as irregular "schlieren" or as distinct dikes with sharp contacts against adjacent eruptive rocks. Coupling one part of his generalized definition with the more specific descriptions of Singewald, Iron Mountain geology is genetically comparable to two of the cited African districts in which a great connecting fissure was repeatedly reopened to permit the egress of platiniferous material at favorable points.

In his quoted abstract Singewald pointed out the difference between Iron Mountain and the usual titaniferous deposit. For his proof that the Wyoming ore bodies are not local segregations from an ordinary gabbriotic magma, he described the auxiliary dike on the south side of the creek. He particularly noted that at places half of the bulk of the chromiferous dike was olivine, and elsewhere stated that the presence of this mineral proved puzzling to Professor Vogt as well as to Lindgren. Vogt was unable to locate a similar association within the differentiated ores of his native Norway. Lithologically speaking, such non-cumberlandite segregations are conveniently classified as extra-basic dunites of the Onverwacht order. In the ensuing metallographic discussions, other remarks will be filed in support of the preceding classification.

Going back to olivine, it may be safely said that its presence at Iron Mountain is no longer as puzzling as in 1913. Of course, olivine is not found everywhere, but when it occurs as a major constituent of primary rock intrusions in the form of minor dikes, sheets, small stocks, African pipes, etc., present-day rockhounds are justified in starting a systematic search for the ores of titanium, vanadium, chromium, nickel, platinum and of the diamond.

In more recent years astronomical savants appear to esteem this mineral more highly than geologists. Of all terrestrial minerals, olivine is the one most frequently identified in the meteoric stones. In that capacity it serves as a major tool for fortifying planetesimal theories and other celestial hypotheses in vogue at this day.

From what has been said hereinbefore, a liberal deposition of olivine should be expected at Iron Mountain.

In a sense the intercalations of the described Merensky horizon are also analagous to the minor transversals outcropping at a four-mile or more interval within the main Iron Mountain fissure. In both complexes ultrabasics are intruded into limited belts of a common light-colored, thoroughly pre-leached rock known as anorthosite. Apparently, the decidedly contrasting egressions happened in much the same manner and sequence in both of the widely separated Wyoming and African plutonic complexes. However, for complete deep-seated differentiation of magmas or clean separation of the remelts, no terrestrial example could be more spectacular than Iron Mountain.

Up to the revolutionary discoveries made in Africa 10 years ago, all of the world platinum was recovered by ordinary placer operations. The genesis of such simple deposits is self-explanatory. Small particles of the native metal are found in juxtaposition to olivine, chromite, ilmenite and magnetite, the heavy residual minerals of the ultrabasic mother rock. At Iron Mountain, fully 92% of the giant dike consists of the four prospective platinophile residuals, above listed.

The quoted circular also mentions a since economic deposit discovered six years ago in Sierra Leone in which crystals of platinum are found in stream gravels and alluvial flats "associated with ilmenite, magnetite and scanty chromite." Using the ratios recorded in the 1868 analyses of the Government, the same type of mineral picture may be expected at Iron Mountain as soon as that durable eminence is completely base-levelled.

In a good year American platinum miners are capable of producing, chiefly in the form of a by-product, ½ of 1% of the domestic demand normally created for the precious metal. At the present time, systematic prospecting activities are seemingly justified within the more logical ultrabasics of this country. But haphazard explorations at Iron Mountain will do no good. Before testing samples in that area, due attention should be paid to the mineral associations, enriched central core zones, etc., hereinbefore outlined for the African complexes. Other disappointments are bound to follow. In their various publications, the Bureau of Mines repeatedly makes the statement that the recognition, separation, and correct determination of platinum in the small quantities in which it is normally found in lode deposits, are by no means simple. Apparently, one of their recent bulletins lists the limited number of assayers duly qualified to perform such tests in this country.

CHAPTER V

METALLOGRAPHIC INVESTIGATIONS

The Bureau of Mines bulletin contains six microphotographs of etched polished sections of Iron Mountain and Shanton ranch ore. Nearly all of the ilmenite grains were found to be about 0.25 mm. in diameter, but distinctly elongated phenocrysts up to an area of 104 sq. mm. were noted.

In the metallographic studies an abundant development of intersecting lamellae were observed along certain lines in the magnetite which seem to be the outlines of unusually large grains. Two of the photographs displayed this development in a remarkable manner. The relief of the octahedral and equilateral network looks much like the Widmanstatten lines brought out on the etched surfaces of the meteoric irons. Strangely enough, the latter material is invariably conceded to be structurally different from any substance yet found on the earth. On the other hand no evidence of undue dynamo-metamorphic influences can be detected on the illustrated microphotographs.

The microstructural investigations also served to establish the general freedom of the ore from gangue. The one exception published is:

> Except for a few sections in which olivine was present in considerable amount, little gangue is visible. The most prominent mineral besides the olivine is spinel. Though not present in large amount it occurs throughout the ore in small particles.

The foregoing presence of the spinel accessory should partially fortify the dunite classification hereinbefore made of the more pronounced olivine localizations in the auxiliary dike.

No personal inspection was made of the Shanton deposits repeatedly referred to in the Government publication. For hypothetical discussions, these important ore bodies are doubtlessly most intriguing. As none of the five plotted exposures are over 500 feet long and 60 feet in width, but little notice can be devoted to them in this paper. Comparatively speaking, the prodigious outpouring at Iron Mountain stands out as the Triton among the minnows in the way of titanium depositions in Wyoming.

The miniature eruptions are, likewise, plotted within the anorthosite belt, four miles southwest of the main Iron Mountain dike. Macroscopically and microscopically the ores of both localities were considered identical by Singewald. As such, both effusions must be connected to a common source zone by a network of subterranean ramifications that doubtlessly descends to the realms of King Pluto.

Small outcrops of gangue-free magnetites containing much visible apatite are also known to occur near the Shanton deposits. Hand samples examined therefrom appear to be relatives of the Nelsonites from Virginia. Their apatite content probably averages 5%, but in lieu of rutile, the matrix of the Wyoming mineral is magnetite, which likely carries an appreciable volume of titanium.

No printed descriptions appear to be available on these interesting deposits. In time, microstructural investigations supplemented with complete analyses may disclose the unusual mineral association as logical source material for carrying paying quantities of vanadium metal. In other valleys temporarily confronted with the problem of finding a local outlet for hydro potential, such an odd natural combination would likely receive a good deal of study. It is suitable for the manufacture of ferro-phosphorous by considerably simplified modifications within the electric furnace. In a recent publication of the State Survey the manufacture of limited amounts of this quite costly alloy from other more abundant Wyoming raw materials was held to be seasonable.

CHAPTER VI

METALLURGICAL PROPOSALS

Concentration Tests—Magnetic Methods—Thermal Separations —Natural Gas—Hydrogen—Chemical Processes—Sodium Sulphate Fusions — Casper vs. Niagara Falls — Metallic Sodium Processes — Aluminothermic Reactions — Electrochemical Practice—Recent Metallurgical Patents

Concentration Tests—Magnetic Methods

Singewald conducted a number of interesting metallurgical tests with the view of finding a feasible method of transforming the titanomagnetites of Wyoming into prospective sources of high-grade iron ore. At that time, ores containing more than 1% titanium required excessive consumptions of fuel for their reduction in the blast furnace, and consequently, the sole object of his tests was to free an otherwise valuable iron ore of a nuisance by the most expedient means available.

Today, titanium ore sells at a much higher figure than iron ore. Under ensuing economic alterations, ways and means must be devised to separate two values at Iron Mountain. In this paper a number of new separation processes are suggested. In all of them the recovery of the iron value occupies the minor role. For making such separations a considerable number of processes have lately been patented. Space in this paper is confined to such methods that would yield commercial recoveries by the exclusive use of Wyoming resources. All energizers herein designated are already known to abound in partially developed form in the local valley in which the ore deposits are situated.

Before proceeding further, it is necessary to consider the predominant physical and chemical characteristics of the Iron Mountain ore. Certain impelling influences of the mineral constituents were disclosed by the magnetic separation tests long ago conducted by Singewald. His account follows below:

Possibilities of Utilization

Five specimens of the ore were crushed and separated with a hand magnet. The first three were from Iron Mountain and the last two from Shanton ranch. The results follow:

Result of magnetic separation of Iron Mountain and Shanton ranch ore.

		Ore through 50-mesh, over 100-mesh			Ore through screen finer than 100-mesh	
	Unscreened ore	Magnetic	Nonmagnetic	Proportion through screen	Magnetic	Proportion through screen
	Per Cent	Per Cent	Per Cent	Per Cent	Per Cent	Per Cent
Proportion		84.2	15.8	48.8	83.6	51.2
Fe	52.31	56.75	28.74		56.75	
TiO 2	21.75	18.30	40.12		17.25	
Proportion		77.7	22.3	46.3	76	55.7
Fe	54.48	60.76	32.61		61.97	
TiO 2	19.47	12.58	43.47		10.32	
Proportion		87.3	12.7	46.6	86.5	53.4
Fe	51.93	55.35	28.43		55.44	
TiO 2	21.85	20.03	34.33		20.03	
Proportion		84.7	15.3	48.0	82.2	52.0
Fe	51.50	55.05	31.83		55.63	
TiO 2	21.08	17.85	38.93		17.85	
Proportion		84.1	15.9	47.5	78.6	52.5
Fe	52.98	56.93	31.96		57.30	
TiO 2	19.98	17.22	34.58		16.72	

Of these five samples the average Fe content is 52.64 per cent, and the average TiO_2 content, 20.83 per cent. Of the 50-100 mesh concentrate the average Fe content is 56.97 per cent, and the average TiO_2 content, 17.20 per cent. Of the concentrates finer than 100-mesh the average Fe content is 57.42 per cent, and the average TiO_2 content, 16.43 per cent. The average composition of the 50-100 mesh tailings is Fe 30.71 per cent, TiO_2 38.29 per cent. This corresponds to a composition of the original ore of 52.56 per cent magnetite and 39.58 per cent ilmenite; of the 50-100 mesh concentrates, 62.05 per cent magnetite and 32.68

per cent ilmenite; of the concentrates that passed through a 100-mesh screen, 63.41 per cent magnetite and 31.22 per cent ilmenite; of the 50-100 mesh tailings, 72.75 per cent ilmenite and 5.40 per cent magnetite. It is again seen that there is little advantage in grinding finer than 50-mesh. This is what one could predict from the size of the ilmenite grains, as practically all are larger than the size passing through a 50-mesh screen, and the ilmenite intergrowths in the magnetite are too minute to be separated by the 100-mesh crushing.

The disappointing feature is the small amount of titanium removed. A careful study of the ore, however, reveals the cause of this. Polished sections of the five specimens of ore subjected to magnetic concentration were carefully measured, and it was found that ilmenite grains of separable size formed 15.3 per cent of the surface. If we calculate the titanium in the tailings in terms of ilmenite, we find the average by weight to be 12.1 per cent of the original ore. Allowing for the difference in specific gravity between magnetite and ilmenite, this is equivalent to 12.7 per cent of the original surface. In other words, 15.3 per cent of ilmenite was measured, and 12.7 per cent was separated, which is equivalent to a separation of 83 per cent of all ilmenite present in a separable condition. When the crude method of making the separation is taken into account, the result is all that could be expected.

It was shown above that 39.58 per cent of the original ore consisted of ilmenite, and that an equivalent of 12.1 per cent of ilmenite was removed. Consequently 27.48 per cent of ilmenite remained in the concentrates, which is equivalent to 69.4 per cent of the original ilmenite content of the ore. Hence the result of the separation tests was to separate 30.6 per cent of the titanium and to leave 69.4 per cent in the concentrates. It was further shown that by measurement 15.3 per cent of the ore was present in a separable condition. This was equivalent to 14.56 per cent by weight, or 36.8 per cent of the total ilmenite content of the ore; that is, only 36.8 per cent of the titanium of the ore is in a separable condition. The remaining 63.2 per cent of the titanium is so intimately intergrown and included in the magnetite as to make separation impossible. Even if a perfect separation of all ilmenite grains of separable size were obtained, there would still remain a concentrate with 13.2 per cent TiO_2 and 7.96 per cent Ti.

> It is therefore apparent that it is impossible to make from this ore a concentrate low in titanium. However, the deposits are most attractive as to size and ease of mining.

Singewald considered the results of the foregoing tests as chiefly negative. As a matter of fact, the removal of only 30% of the then titanium deleterant left products totally unacceptable for reduction in blast and electric furnaces typical of either the 1912 or 1932 periods of construction.

Apparently, the clean separation of magnetite and ilmenite by magnetic methods is yet an unsolved problem. Both of these minerals possess high magnetic potentials. Assuming the iron value at 100, their attractive forces have recently been determined at 40.18% and 24.70%, respectively.

For purifying magnetic admixtures hitherto considered untreatable, the Dings Magnetic Separator Company has this year placed on the market a super-high intensity separator that has a rated capacity eight times greater than any machine previously made. As this new apparatus has developed a heretofore unattainable degree of separating intensity, and as it has successfully removed a mineral as feebly magnetic as dolomite from gypsum, it doubtlessly represents a decided improvement over the crude equipment used for the local tests of 20 years ago. Before magnetic technology is condemned too prematurely, owners of the Iron Mountain deposits should investigate the merits of the latest model machinery with the view of ascertaining its efficiency on ore in which comparatively high magnetic contrasts are known to exist.

Thermal Separations—Natural Gas

In the past year a movement has been gaining ground to pipe Montana natural gas to the Lake Superior iron ore fields. As everyone knows, the ore shipments from that premier producing region have been gradually falling off in quality. To step up the product to the grade accepted by blast furnaces 30 years ago, it has been thought advisable to install magnetic roasting concentration equipment on a big scale. As yet, no similar gas tests have been conducted on the Iron Mountain ore.

The reducing power of the Wyoming natural gas flame is extremely vigorous. If operations are conducted at sufficiently high temperatures, the ilmenite molecule should be broken down with ease. Moreover, should future tests disclose that the refractory Wyoming ore will succumb to the type of thermal treatment suggested, it would not be necessary to construct a pipeline 750 miles long. As hereinbefore stated, the distance from the present Wheatland terminal to Iron Mountain is only 43 miles. In fact, if the franchise for the extension to Laramie is exercised, considerably less than 5 miles of additional construction would be required to reach the giant dike of solid ore. If more efficient separations are yielded by the suggested treatment, the cost in gas consumption would not prove unreasonable. In current Bureau of Mines manuals, Wyoming is duly accredited with having the lowest natural gas rates in the Union.

Hydrogen

Lately an attache of one of the Federal bureaus is said to have passed hydrogen over titaniferous iron ore. His experiment produced a pure iron entirely free of titanium metal. Such a result is extremely interesting, for somewhere in his later writings Singewald held that in the local ore types the magnetite molecules are never entirely free of titanium. His failure to obtain cleaner magnetic separations at Iron Mountain was partially laid to this intimate association then first suspected.

The production of industrial hydrogen in huge volumes is now a routine procedure at the larger chemical sites of the world. For future Wyoming practice only two nearby examples need be cited. For the manufacture of their cheap synthetic fertilizers, the Shell-Union Oil Company in their new California chemical plant merely cracks the natural gas molecule into its component elements, hydrogen and carbon black, much along the same thermatomic lines that crude oil is now being handled in the big refineries at Casper. At the $10,000,000 phosphate plant that was also completed last year at Trail, British Columbia, over 3,100,000 cubic feet of hydrogen are produced daily by the electrolytic decomposition of water. Incidentally, this gas is used for treating Idaho phosphates for the reason that those rocks lie approximately 50 miles nearer to the Canadian plant than the equally high-grade deposits of western Wyoming.

Within the favored North Platte River basin, both of the preceding processes appear to be feasible for hydrogen isolation at the rock-bottom cost of production. Transmission line terminals for both natural gas and Government hydro power are now located in Wheatland and throughout the summer either type of service would be available on a highly competitive basis. At that time of the year, the pipeline loses 90% of its domestic heating load, and for seasonal industrial pursuits a rate far below the Wyoming state minimums quoted in the Federal statistical publications would be in effect on the idle transmission capacity.

Irrigation control on the North Platte develops fully 4 times the power potential in the summer than is permissible during the reservoir impoundment period of the winter. As the operations of hydrogen electrolytic plants are rather flexible, and as units can be cut in or out as the off peak power varies, it is certain that an extremely favorable rate would prevail for hydrogen manufacture in Wyoming throughout the entire summer period. Such huge supplies of secondary energy should never be sold for more than one quarter of the full year rates as soon as additional power houses are built at the Pathfinder Dam and other feasible sites along the North Platte River.

For the preparation of the titanium compounds now most in demand, it is essential to obtain iron-free products. For a clean separation of the titanium from the iron deleterant, elementary hydrogen seems to be the most efficient potentializer so far mentioned. A discussion of its robust attacking power on other metallic combinations in the Iron Mountain ferro-alloy complex would unduly prolong the length of this preliminary paper. In course of time the foregoing Wyoming problem may receive further attention in the experimental laboratories maintained at the State University. Obviously, preheating the ore with cheap Wyoming natural gas having twice the calorific value of the ordinary artificial product would appreciably lessen operating costs of a straight or combined ''hydrogenation'' process in the Casper area.

Chemical Processes—Sodium Sulphate Fusions

For commercial separation of firmly united iron and titanium molecules, chemical procedures have progressed far more rapidly than physical methods. Thanks to American financial expansions, several of such processes have lately been operating in widely separated countries. Some of these processes are based on the purchase of high cost reagents. After sizing up the local situation, it was concluded that no operation would be successful on Iron Mountain ore unless it would preponderantly consume the cheapest raw chemical that occurs in immense quantities, and already in a natural state of purification directly within the North Platte basin itself. For that reason one of the patented processes of the Titanium Pigment Company as recently printed in Bureau of Mines circulars, various trade journals and industrial chemical handbooks, is deemed safe material for inclusion in this paper:

"*Titanium Pigment Co. (old process)*—One hundred parts of ilmenite are finely ground and mixed with 300 parts of sodium bisulphate (niter cake) and 50 parts of petroleum coke. This charge is melted in an electric furnace. It is assumed that the two principal reactions taking place are of the nature,

(1) $FeTiO_3 + Na_2SO_4 + 2C = FeS + Na_2TiO_3 + 2CO_2$, and

(2) $2FeTiO_3 + 2Na_2SO_4 + 6C = 2Na_2FeS + Ti_2O_3 + CO + 5CO_2$,

the first predominating. The melt is cast and slowly cooled. Because of differences in specific gravity, the melt separates into two layers, provided solidification is sufficiently delayed, an upper layer containing the greater part of the iron, and a lower layer of sodium titanate being relatively free of iron. The upper layer is brittle and is mechanically separated from the lower. The titanate layer is broken up, leached with water, and the final residue treated with dilute sulphuric acid at the boiling point. The titanium content is hydrolyzed and remains as hydroxide or basic sulphate. This is dried and treated with 2.5 to 2.6 parts of 95 per cent sulphuric acid at 100-150° in cast-iron pots. The resulting mixture is diluted to three times its volume in lead-lined vats and filtered. A portion of this solution is electrolyzed, reducing the titanium from the tetravalent to the trivalent state. The reduced solution is added to the main portion of the solution, thereby reducing the iron content to the ferrous state.

"A paste of precipitate barium sulphide is added, in such quantity that the final pigment will be 25 per cent titanium oxide and 75 per cent barium sulphate (marketed as Titanox). The mixture is maintained at the boiling point for several hours, effecting hydrolysis of the titanium and thereby precipitating hydrated titanium oxide upon the barium sulphate particles. The mixed precipitate is filtered, thoroughly washed, dried, and finally calcined in rotary furnaces."

It may be noted that the preceding equations account for the action of only sodium sulphate and petroleum coke on ilmenite. For years past, several concerns have been conducting excavations in the natural sodium sulphate deposits that form the surface beds of dry lakes at various points in Wyoming. The most widely known of these workings is the 22-foot thick layer of the pure salt which lies eight miles northeast of

Casper. For 15 years or more the large oil refineries of that city have been turning out excess supplies of the finest grade of petroleum coke made in the United States. A typical analysis discloses that the ash content of the Casper coke is only 0.21%. The calorific value of that remarkable fuel is 15,350 B.t.u.s. This rating is over 1,000 points higher than that of pure carbon. Obviously, the heating and reducing values of the Casper product is much superior to the ordinary runs of coal and petroleum cokes that most frequently find their way into the electric furnace.

In the quoted text it is noted that the use of acid bisulphate, in lieu of the Wyoming natural salt, is prescribed. That deviation from indicated equational procedure should prove to be entirely immaterial in a region like Casper in which an excess supply of hydro power should shortly be placed on the market. True enough, the acid salt melts at 300°C, but as soon as the Wyoming sulphate would be elevated to its liquefaction temperature of 888°C, the Iron Mountain mineral would be subjected to an equivalent degree of chemical violence. For Casper practice the cost differential in respective thermal consumptions should be an inconsequential item. If opinions to the contrary should arise, a second paper could point out cheap ways and means for the conversion of the abundant Wyoming salt into the previously prescribed acid form. For the preparation of the final pigment product but two other chemicals, sulphuric acid and barium sulphide enter into the process. So far, neither one of these reagents has been made in Wyoming.

At other places, the dilute acid specified has been successfully manufactured by the electrolysis of sodium sulphate. At a temperature of 500°C, the salt is reduced by hydrogen, forming a mixture of sodium hydroxide and sulphuric acid. Apparently, no steps have been taken to commercialize the latter process but as soon as a chemical industry is organized in Wyoming, its huge beds of natural sodium sulphate will serve as logical raw material for the manufacture of the two leading products of the chemical world; namely, sulphuric acid and sodium hydroxide. No longer should prejudices be entertained against the use of the Wyoming natural salt for the manufacture of these two great extremes of the chemical science that would be consumed on the spot. Hereinbefore, the requisite steps for the local production of cheap hydro power and low cost hydrogen have been outlined. The unusually favored Wyoming sphere also offers exceptionally attractive possibilities for the manufacture of acid and alkali by the older processes or by slight modifications therefrom that need not be pointed out in this paper.

The barium sulphide required for the final mix would be prepared by simply roasting barite and coal in a furnace and lixiviating the melt with hot water. In the North Platte basin baryta spar is found near Wheatland and also in the Medicine Bow Mountains in Albany County. As no demand has so far originated for barite in Wyoming, no information is available on the magnitude of the deposits. Should the Wyoming resources prove inadequate, it is here mentioned that veins of barite are frequently reported as occurring in the adjoining states of Colorado, South Dakota and Idaho. In fact, an up-to-date barium refinery is already in operation a few miles south of the Wyoming boundary at Johnstown, Colorado.

It is noted that the described fusion mixture calls for 2 parts ore; 6 parts sodium sulphate, and one part petroleum coke. The prescribed mix would require the hauling of the Iron Mountain mineral to Casper in which city the largest sodium sulphate and petroleum coke operations of the state are located. It is understood that the United States Reclamation Service stands ready to construct a power house at the Pathfinder Dam and a 38-mile long transmission line to Casper as soon as a market can be created in that city for the local energy.

The big Pathfinder Dam was completed to a height of 218 feet about 20 years ago. From the present structure 40,000 horsepower of continuous energy could be generated at an exceedingly low cost throughout the summer period. Economically speaking, no good would be done by selling the local power to industries already known to be suffering from overexpansion evils within the domestic field. A titanium plant in Casper would provide a logical outlet for the seasonable energy.

Casper vs. Niagara Falls

Latest records of the Bureau of Mines disclose that 50,045 tons of ilmenite ore were imported into this country from India, Senegal, and other points during 1929 and 1930. So far as known, most of this distantly transported mineral was reduced at Niagara Falls. Without a doubt the reduction of various sorts of foreign ores consumes too much high-cost energy in this country.

Within the environs of Greater Casper a dam of masonry and steel, 53 feet higher than the falls at Niagara, has long spanned the largest river in the state. As soon as it is discovered that power may be had in the highly mineralized Wyoming area below the rates prevailing in the famous eastern district, nothing should stop the development of the huge ilmenite deposits.

From an investment standpoint, precedents for the foregoing proposal are by no means lacking. In recent years even larger outlays of American capital have been expended on the development of both titanium mines and power dams in Norway. In time, investments in similarly interconnected projects may be deemed justifiable and expedient wholly within the domestic Wyoming field.

The location of a titanium works at Casper would stimulate demands for products made by the infant industries of this state. As an example, for each ton of ore mined, 3 tons of sodium sulphate would be consumed by the all-Wyoming raw materials fusion process hereinbefore described. Accordingly, a plant annually handling 25,000 tons of ore would require 10 times the output of sodium sulphate that is now being produced in the state. Fortunately, the surficial deposits of the Wyoming natural salt are of sufficient consequence to withstand the degree of expansion herein calculated.

Metallic Sodium Processes

Chemically pure titanium metal is prepared by heating the tetrachloride with sodium in a closed vessel. This action is rather violent, and as such, the reduction is performed within a firmly braced bomb of machine steel capable of withstanding an internal pressure of 80,000 pounds. By way of comparison, it may be stated that the confined energy from this reaction approaches the gas pressures developed in modern artillery field pieces.

As soon as an electrochemical industry is organized within the North Platte basin large quantities of sodium will likewise be produced from the lake beds of the sulphate salt which occur here and there within the valley. Admittedly, little of it will be required for making metallic titanium which so far has found no market outside of the laboratory. At other places aluminum is used in the manufacture of the more costly titanium ferro-alloy that has long been on the industrial market. For future metallurgical practice in Wyoming, the applicability of the far more potent and yet cheaper alkali metal warrants investigation. Sulphate fusions of the Iron Mountain complex will yield a variety of solubles, and use may be found for the energetic sodium elementary in reducing the costly alloy metals from the lesser precipitates. Moreover, it may also have a value as a local separatory agent. If the previously appearing 1868 analysis of the Government still holds water, one or two of the more troublesome metals would expeditiously disappear in vapor form from the Group III precipitates as soon as a sodium reducing mixture would be ignited.

In this paper sodium is cataloged as one of the more robust energizers that will be released on a low-cost basis as soon as hydroelectrical development is started along the channel of the North Platte.

Aluminothermic Reactions

A number of alloys of titanium with other elements have long been known. However, the only alloys that have been recognized as articles of commerce and which could be made from the raw materials of the North Platte basin are ferrotitanium, ferrocarbontitanium, cuprotitanium and manganotitanium. Economically, the two iron alloys are of the more importance. They alone are entitled to further notice in this paper.

Both ferrotitanium and ferrocarbontitanium are used as purifying agents for steel due to the great affinity of titanium for oxygen and nitrogen at the higher furnace temperatures. Generally speaking, the sole values of these alloys are as cleansers, and unlike the usual ferro-alloy, little or no titanium remains in the finished steel product. However, in some of the more costly chromium, manganese and vanadium steels, the presence of a limited amount of titanium often seems desirable. Incidentally, in the big ore dike at Iron Mountain all four of the preceding alloy metals occur in attractive quantities.

As soon as ways and means are devised for impoverishing the overwhelmingly high titanium content, the remaining proportions of contained alloy metals appear to closely approximate an analysis of an electric furnace steel recently patented abroad. In lieu of following orthodox text-book procedure, the big problem at Iron Mountain is to evolve metallurgical modifications for salvaging all values contained in the huge dike of solid alloy ore.

For purifying steels, ferrotitanium is a more efficient agent than the less costly carbon containing alloy. In this country it is made by the Metal and Thermit Corporation by the aluminothermic reaction that was first utilized by Dr. Hans Goldschmidt for the operation of his previously patented high temperature welding process. By this time the simple principles of the preceding powerful and spectacular reaction appear in all elementary chemistries.

Electrochemical Practice

At the present time the Titanium Alloy Manufacturing Company specializes in the manufacture of ferrocarbon-titanium. Their process for making this leading titanium alloy of the domestic steel industry is set forth in the U. S. Bureau of Mines, Titanium Circular, No. 6365, as follows:

> In accordance with patented processes by Rossi, titanium ore, scrap iron, and coke are mixed together in the proper proportions and charged into an electric furnace of special design. This furnace is peculiar in having only one electrode—the hearth and a small part of the wall being composed of conducting substance, such as graphite, the rest of the lining being a nonconducting and sufficiently refractory material. The current is so regulated as to maintain the necessary temperature (about 3,500°F.), and as soon as the reactions are complete the metal is tapped at the bottom vent. From 600 to 1,000 pounds are obtained at each run. There is almost no slag, and such amounts as are obtained are returned to the furnace with another charge. The material is then broken, crushed, and screened —it being sold to the trade in different sizes according to the purpose for which it is intended.

Successful operation of the foregoing metallurgical process is mainly based on the availability of low-cost thermal energy. If other factors were more important, some site considerably distant from Niagara Falls would have likely been selected for the location of the main plant of the titanium company. The people of Wyoming may be proud of the fact that the largest reserve of high-grade titanium ore known in the United States is in their sector of the North Platte River valley. That occurrence will continue to be of little industrial significance until proper steps are taken to utilize the large volume of hydroelectric potential that still remains unharnessed within the leading river channel of the state.

According to the cited circular of the Bureau of Mines, production of titanium treated steels varied from 600,000 tons in 1912 to over 2,000,000 tons in 1930. Carbide-free ferrotitanium is quite costly and quotations for it have not been maintained in domestic trade journals since 1920. Apparently, the British steel industry still consumes this more efficient titanium alloy and lately the London quotation has hovered around $400 per ton. In recent years the price of the cheaper carbon containing alloy has varied from $160 to $200 a ton in this country. Manifestly, these values are sufficiently high to permit national distribution for an alloy made in Wyoming. On the other hand current quotations for raw titanium ores still remain too low for paying the freight from Wyoming to existing reduction plants located at distant hydroelectric sites.

The preceding comparison points out one way in which the chemical science is quite capable of converting a form of still worthless Wyoming rock into products of intrinsic worth. Transformations of similar magnitude are known to be possible at a number of other sites in this state as soon as the multifold energizers that go to make up the natural Wyoming powerhouse as a whole are released in sizable volumes.

In recent years, outside technologists and plant engineers have displayed a more appreciative attitude in regard to potentialities that distinguish Wyoming from other states. In recent years, citizens of this state have, likewise, demanded more explicit facts in regard to the location of sites belonging to the preceding category. If the publicity literature of other states is marked by a milder tone, all should remember that the average Wyomingite would not have to travel very far to find states that have none of the chemical and mineral deposits, hydrosites, and the like, that are correlated for the first time in the present commentary.

Recent Metallurgical Patents

During the present period of pronounced stress and strain, a steadily increasing demand has arisen for new titanium products. Such countercurrent economic influences are not entirely of accidental origin. In these days rapid technologic progress is observable within the titanium industry.

For a comprehensive recording of the latest scientific, technical and industrial advancements, the reader should consult the yearly statistical volumes, entitled, ''Mineral Resources of the United States,'' published by the Bureau of Mines. In recent years, the more important titanium patents have been listed in those reviews. From the considerable number of patents reviewed in the 1929 and 1930 annuals the following six were selected as possessing varying degrees of local merit for the recovery of values at Iron Mountain.

Soc. Miniere ''La Barytine'' and Raffin, Maurice. Paint. French Patent 655085, October 14, 1927. Chem. Abs., vol. 23, August 20, 1929, p. 4088.

''Ti white is prepared from Fe-Ti ores, by heating the ores with Na_2CO_3 and coal to reduce the Fe to the metal, which is removed by treatment with dilute H_2SO_4. The Ti is converted to the sulphate by treatment with stronger acid and to TiO_2 by addition of BaO.''

Bancroft, G. J. Treatment of ferrotitanium (ilmenite) ores. U. S. Patent, 1,745,732, Feb. 4, 1930. British Chem. Abs., vol. 49, No. 30, July 25, 1930, p. 669.

Titaniferous iron ores are ground with fluorspar and carbonaceous material and the mixture is heated in a reducing atmosphere to produce iron sponge and calcium fluotitanate. The reduced mass is discharged through steam into water containing a small proportion of sodium hydroxide, and the granular product is ground wet, screened to remove coarse iron, and concentrated on Wilfley tables or by means of a magnetic separator.