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Chromite Deposits in Oregon

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Special Chapters
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FOREWORD.

Oregon chromite at present, in order to be sold, must be shipped to eastern seaboard reduction plants. There, our ore must compete in the market with cheaply-mined foreign ores. The availability of cheap power from Bonneville dam may change this situation by making possible, in Oregon, electric furnace plants to utilize Oregon chromite.

The main purpose of this geological study of Oregon chromite deposits was in anticipation of a demand for the ore by electric furnaces and other electro-metallurgical and ferro-alloy industries which we believe Bonneville power may encourage. As this is written, there is definite evidence that some forward-looking groups are considering the installation of mineral reduction plants on the Columbia.

In recent years, special purpose steels, notably chrome-bearing alloys, are in rapidly increasing demand for the manufacture of the essential parts of modern machines and in making stainless steel with its many uses. With raw materials at hand, and with power for electric furnace reduction on tidewater cheaper than at any other point on either coast, Oregon should support a promising chrome industry, complete from mines to finished product.

Chrome operators and miners should note that when chromite ore of 48% minimum is quoted at east coast market at, say, $20.00 per long ton, about half of that selling price is consumed in freight and various handling charges between their nearest rail point in Oregon and the point of consumption in the east. With a reduction plant near Portland, part of the ocean freight and handling charges would be saved for the producer, but he would still have to compete with ore from New Caledonia and the Philippines, which can be laid down in Portland cheaper than on the east coast. An electric furnace plant in the Columbia area would favor Oregon producers by furnishing a steady market for their ore, which would allow them to cut mining costs by operating on a regular, even schedule.

This department wishes to acknowledge its indebtedness to Mr. C. E. Tuttle, President of Rustless Iron and Steel Corporation of Baltimore, Maryland, who has generously sanctioned the use of private data gathered for his company during the past three years by Mr. Allen, under whose direction the geological reconnaissance was conducted. It is eminently fitting that Mr. Allen should write this report on chromite, and that Mr. H. F. Byram, Consulting Mining Engineer, and Vice-president of the Rustless Mining Corporation, Oregon subsidiary of the Baltimore corporation, should write a special introductory chapter on the economics of chromite to accompany Mr. Allen's report. It is worthy of note and commendation that this corporation has carried on pioneering work in chromite during a depression period and that it is now willing to release the findings obtained to the general public.

Geologists will find Mr. Allen's analysis of the origin of Oregon chromite ores and the evidence he gives of the relation of deformation to the emplacement of orebodies, to be a distinct contribution to the geology of magmatic ore deposition.

Earl K. Nixon, Director

Portland, Oregon,
August, 1938.

Loading high-grade chromite ore at Portland for shipment to Baltimore, October 24, 1937.

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THE PRESENT COMMERCIAL ASPECT OF WESTERN CHROME ORES

by

H. F. Byram
Consulting Mining Engineer.

In the steel industry there is an increasing demand for a wide range of alloys, with properties designed to withstand out-of-the-ordinary conditions of use. Research work has developed new formulae and manufacturers are called upon to furnish a product designed to suit the need rather than to make a standardized material. In this development of the industry chromite bears an ever increasing part. In fact, it has become an indispensable mineral in peace time as well as in war periods. Stainless or rustless steel, containing fourteen percent or more of chromium is becoming more and more acceptable each year on account of its wonderful properties of heat and corrosion resistance coupled with its hardness and toughness. Its use in automobile manufacturing and for decorative purposes in building is well known.

Manufacturers of high refractory materials also consume large quantities of chromite. Methods have been developed to make brick that will resist higher temperatures without spalling, deformation or fusion, and chromite is the raw material found essential. In this field success was attained only after exhaustive studies of the mineral and its behavior at various temperatures and under different conditions of cooling until a way was found to convert into a crystalline form the bond of magnesium silicate present in the ore. The result was a brick with longer life under exacting conditions.

In the chemical field, chrome plating and paint manufacture are important and use considerable quantities of chromite. In commercial use today are sodium and potassium bichromite, chromic acid, chromium chloride and chromium sulphate, each with a specialized use and each the base upon which an industry rests. Ferro-chrome, while more of a metallurgical than a chemical product, is the form in which chromium is used in the manufacture of chrome steel and stainless steel. One manufacturer, however, successfully makes rustless steel by mixing scrap steel and ferro-silicon with chromite in electric furnaces without the primary preparation of ferro-chrome.

In these three fields, namely, metallurgical, chemical and refractory, research continues and each new development accentuates the value of and our dependence on chromite. For this reason it is extremely important to evaluate domestic deposits. An added reason is that practically all of the ore consumed now in this country is imported and there is an ever present possibility that disturbed conditions in foreign countries may at some time interfere with the movement of chromite to our shores. This would cause serious disruption of manufacturing in our plants. This actually did happen during the world war.

In the following article by Mr. Allen, to which this is introductory, a large number of the Oregon chromite properties are described and the geological conditions surrounding their occurrence. It is there shown that the host rocks, serpentine and peridotite, cover wide areas in Oregon. Hence aggressive prospecting for new deposits may be rewarded by the discovery of additional ores. Most of the known properties containing chromite were found because they showed surface float or outcrops, which fact permits the expectancy that ultimate reserves may be materially increased with skillful exploitation of new districts and subsurface formations of the old. It is of interest to mention that geophysical prospecting has already met with some measure of success in locating chromite bodies showing no surface indications.

Unfortunately, while numerous, the known Oregon deposits are for the most part small and widely scattered. The greatest obstacle against production, however, is the cost of transportation for either crude ore of shipping grade or for concentrates. The ore must be hauled by truck to the nearest railroad, thence by freight to a seaport and finally shipped by vessel to the east coast, since the present consumption in the west is very limited. With the world market between $19 and $23 per long ton, delivered at eastern ports, for ore of 48% chromic oxide, it is apparent that the immediate development of Oregon deposits cannot yield much profit, but with an advancing market, exploitation becomes feasible.

Philippine ore of metallurgical grade is currently quoted at $16 per long ton delivered at west coast ports, and new discoveries there of high-grade ore may become increasingly competitive with Oregon ores and prove to be a limiting factor both to marketing and profits.

The apparent resources of chromite on the west coast, even if effect is given to tonnage increases from aggressive development and prospecting, are not sufficient to supply the domestic demand which in 1937 exceeded 400 000 long tons. It is possible, however, that a part of this tonnage can be supplied from Oregon and shipped each year for a number of years. In the event of interruption in the movement of foreign ores, an established industry, stimulated by higher prices would be capable of supplying the needs of manufacturers to a large extent until normal conditions returned.

The best picture of the situation is one of production continually lagging behind an ever-increasing consumption, forcing users of chromite to depend on imports for the major part of their requirements. This foreign ore is satisfactory in quality and has been supplied at reasonable prices.

Development of Oregon deposits has been retarded in the past by the inaccessibility of the properties, lack of roads, distance from a rail shipping point, high cost of transportation and inadequate docking facilities. Should plants be established on the Columbia river or elsewhere in the west, possibly using cheap electric power, the raw material is at hand to supply them, and chromite, one of the most essential of minerals, would then enjoy a profitable local market. Taking all these facts into consideration, there is sufficient incentive to encourage prospecting for new deposits and to warrant development of known ores where there is a combination of favorable factors. There should also be a willingness on

the part of the operator to work on a reasonable margin of profit. Even during normal times it is reasonable to expect a small profit can be won in well conducted enterprises at points favorable to low costs, but bonanza profits are not in sight at ruling prices.

PROBLEMS IN MINING CHROMITE ORE.

Oregon chromite occurs in two main types, which may be roughly classed as "kidney" and disseminated. The first may range in size from a few pounds to thousands of tons of ore. There is usually a sharp definition between the ore and the wall rock, whereas in the second type the enclosing rocks contain grains of chromite frequently in sufficient amounts to constitute low-grade ore of possible milling tenor.

The obstacles to successful mining are not different from those encountered in other ores except the deposits are for the most part in relatively inaccessible places, high on mountains where timber and water are scanty. Mining methods must be devised to suit the individual deposit. They will embrace underground working in the smaller orebodies and open cut, quarry or glory hole in the larger. Since clean bodies of high grade (45% Cr_2O_3 or higher) rarely occur in large quantities, considerable sorting is necessary and advisable.

Because of the wide range of methods that might be used, it is impossible to estimate probable mining costs except thru a study of each individual property. Roughly in open cut and glory hole work where the ore face is wide, a cost of less than $1.00 per ton is attainable since the ore is usually somewhat friable and requires a minimum of powder to break. In underground work, especially where it is necessary to handle the ore more than once and where sorting is required, the cost may exceed $5.00 per ton.

It is readily apparent that a small body of kidney-type ore even if high-grade and without gangue is at present valueless if cost of building a camp and constructing a road to the property must be borne by relatively few tons of ore. It is likewise well to consider that disseminated ore suitable for milling and concentration must be in sufficient quantity to bear the entire cost of a plant from profits before the deposit is exhausted.

The problem is one of balanced judgment and recognition of the fact that low costs are possible through mechanization which in turn requires a heavy investment; avoidance of heavy outlay where adequate tonnages do not exist may prevent a serious loss. The need to consider all cost factors is just as important in mining chromite as in other kinds of mining and cannot be over-emphasized.

CHROMITE CONCENTRATION.

During the World War when the abnormal demand for chromite induced many inexperienced persons to engage in prospecting for chrome properties and to develop them aggressively, considerable progress was made in gravity concentration of this mineral. Unfortunately the need for chromite at that time was so urgent that mills were constructed with little or no research

work to determine proper flow sheets. They were with rare exceptions adaptations of quartz mills. Crushing units were not selected to minimize sliming or overgrinding; little thought was given to sizing and classification; and it was not known how fine the ore must be pulverized to release the mineral grains.

Since 1918 research work has proceeded. Exhaustive tests have been made of ores from many deposits by federal and state agencies and by private individuals and companies in magnetic separation, flotation and gravity concentration. The operator today has a great deal of information available concerning variance in grain size, chemical composition, and behavior under different conditions of milling practice. It is known for instance that some ores needs to be crushed to minus one hundred mesh while others require only minus twenty mesh grinding for a separation of gangue and mineral.

Variation in chemical composition of chromite in different localities and even within the same deposit is often troublesome. Frequently the mineral contains a large percentage of iron, magnesium silicate and other impurities, sometimes to such an extent that concentrates are low-grade even when cleanly separated from gangue. In some deposits the gangue has a fairly high specific gravity and it is almost impossible to make a clean concentrate by gravity methods. In the case of the low-grade chromites approaching picotite in composition, nothing can be done to improve the quality of the concentrates without a chemical break-down of the mineral. This is impractical unless a process for the purpose is perfected and proved commercially feasible.

Where picotitic chromite occurs in small quantities in an otherwise excellent milling ore, the tails resulting from milling operations may run high in chromic oxide content. If re-treated, the resulting concentrate, while comparatively free from gangue, may be disappointing due to the inferior quality of the crystal grains, because various chromites differ widely in their chemical composition and specific gravities. This is very apparent where unaltered olivine is present in the ore as gangue with a specific gravity of 3.37 whereas an impure chromite can have a specific gravity as low as 4.08. It is natural that this type of crystal will flow over with the gangue and if the resulting tails are then tabled the yield may be below commercial grade.

In recent tests of ore with which the writer is familiar, a recovery of 80% of the chromic oxide contents has been obtained by gravity concentration and it is believed this result can be duplicated in well designed commercial plants. The indicated loss of 20% was almost equally divided between slimes and tails. The concentrates assayed above 48% from ores averaging less than 20% Cr_2O_3.

Flotation and magnetic separation tests have been run on many ores with encouraging results in some instances, but further research is required before these concentrating methods can be considered sound practice in treating chromite. It is quite possible they can be applied in the treatment of some ores where tabling has not given good results or where a concentrate is

needed which has unusual specifications or chemical properties. This might occur if it is required that the marketable product be entirely freed from all magnetic material or in the event that a portion of the gangue is valuable to retain. It is deemed advisable to study and test all ores in advance of designing a treatment plant.

While no serious obstacles exist in treating chromite by gravity methods, careful selection of grinding units is very important since sliming is a source of heavy loss. To minimize over-grinding, roll or rod mill grinding is preferable to pulverizing in a ball mill. Since difference in specific gravity between chrome crystals and gangue is relatively small, sizing and classification of the pulp will materially assist table concentration. The flow sheet of a typical mill with almost universal application in the treatment of chromite ores would consist of a primary crusher, rod mill or rolls, hydraulic classifier with three to six compartments, and concentrating tables to treat separately the pulp from each compartment of the classifier. Additional units to treat slimes and to dewater concentrates can be added if desirable. With some ores, a jig placed ahead of the hydraulic classifier might be advantageous if it is found a concentrate of commercial grade can be obtained. In most cases regrinding of table middlings will increase recovery and mill efficiency, and this can be accomplished by returning this material to the rod mill or rolls or by adding a secondary roll or mill to the flow sheet, in closed circuit with table middlings.

Milling costs should be low compared to quartz milling due to the friable nature of most chrome ores and also because a complicated plant or flow sheet is not required. As in treating other kinds of ore, lower costs are obtained in large capacity plants.

The reader is referred to United States Bureau of Mines Bulletin R. I. 3328, Progress Report, Metallurgical Division, by C. W. Davis and staff, also to the California Journal of Mines and Geology of July 1935, page 267, for additional information on the subject of chrome concentration.

CONCLUSIONS.

It can be shown that the deposits of chromite in Oregon are extensive; that mining costs compare favorably with those of other ores; and that milling costs should be lower than in quartz operations. The greatest handicap to commercial exploitation is the distance the ore must travel to reach a consuming market, for transportation charges constitute the greatest item of cost. With world market quotations based on long tons (2240 pounds), it is well to remember that all cost factors should be converted to this base by adding approximately one-eighth to the usual net ton figures of mining costs and freight rates before comparing an estimated price at delivery point with published market price.

The various items of cost necessary to consider are as follows, and some of these are frequently overlooked:

1. Mining.
*2. Transportation of ore to mill.
*3. Milling.
4. Transporting concentrates to railroad.
5. Loading charges.
6. Rail transportation to shipping port.
7. Unloading and storage at shipping port.
8. Loading and trimming cargo.
9. Ocean transportation.
10. Unloading charges at eastern ports.

*These cost factors apply only to concentrates and not to shipment of high-grade lump ore. Sorting is an additional cost factor if crude ore is shipped.

The shipping port charges of unloading, storage, loading vessel and trimming will total in the neighborhood of $1.00 per net ton of ore and the present ocean rate to eastern ports is $5.00, unloading at destination about 65¢. After converting these figures to a long ton basis, the total is close to $7.50 per long ton and this can be considered the present cost of shipping from port to market and will apply to ore shipped through the Port of Portland. It is worthy of comment that these costs which do not include freight charges from mine to shipping port, exceed the average cost of mining and milling the ore. The present all-rail freight rate to eastern ports on chromite is $14.40 per net ton or $16.20 per long ton.

The present market for chromite delivered to eastern ports is between $20 and $25 per long ton for ore containing 48% chromic oxide. Ore with chromic oxide content under this is quoted at several dollars per ton less. Seemingly the higher grade should be worth on board cars Portland from $12.50 to $17.50 per long ton. However, the higher figures represent a price situation in the world market due to disturbed political conditions abroad which cannot be considered permanent, capable of being sustained or normal. It does not seem practicable to ship ores from Oregon to the eastern market that contain less than 48% chromic oxide unless the market advances substantially.

If a large consumptive market for chromite is developed on the west coast, Oregon deposits are favorably situated and will have a more profitable market. Industrialization of the west is expanding rapidly and will be further stimulated by cheap electric power over the next decade which will encourage plant construction to utilize western raw materials essential to industry. Evidences of this trend are at hand indicating this era will not be long delayed. With the elimination of a portion of the present transportation costs, and a further extension of secondary road building programs, Oregon chromite deposits can be operated more extensively than at present and ores now deemed of little or no commercial value can be marketed profitably.

Since industry in this country is at present supplied with ores of foreign origin, it can be expected this competition will continue and probably increase. Trans-pacific chromite ores, especially from the Philippines, are the greatest threat against the development of a chromite industry in Oregon.

PROSPECTING FOR CHROMITE BY GEOPHYSICAL METHODS.

It was thought desirable to ascertain the value of a geophysical method of prospecting in locating chrome orebodies in Oregon. To accomplish this a cooperative arrangement was made between the State Department of Geology and Mineral Industries and the United States Geological Survey, whereby Dr. F. W. Lee, head of the Geophysical Division of the U.S.G.S., visited Oregon and inspected several chromite properties where geophysical prospecting was being conducted by his crew and equipment sent out from Washington. Dr. Lee gave great assistance to the crew in the field supervision and initial work and made many valuable suggestions. Another project was made possible by the cooperation of the Rustless Iron and Steel Corporation, a private company, with the State Department of Geology & Mineral Industries.

The report of Dr. F. W. Lee covering his trip and initial supervision of the work follows.

PRELIMINARY GEOPHYSICAL INVESTIGATION ON THE SOURDOUGH CHROMITE DEPOSIT IN OREGON.

by F. W. Lee.

The purpose of the field investigation was to determine the geophysical reactions in Oregon chromite areas - to use the results of these investigations as a basis for further planning. Tests were confined to magnetic and electrical resistivity observations.

The area selected for this investigation was the Sourdough district in Curry county, Oregon. This area is reported to have furnished in the War period of 1917-18 several hundred tons of chromite ore but has not been in active mining operation since that time. The area is located about 30 miles from O'Brien to the west on forest roads, and any geophysical work which is contemplated can best be done in the dry season. It was necessary to establish a field camp near the chrome deposit as a base for operation.

DESCRIPTION OF MINERALIZATION.

The geologic setting has been carefully described by J. S. Diller 1/. The mineralization here is typical of a great many of the Oregon and California chrome deposits and generally occurs in a well defined zone extending over a considerable distance. The course of this zone, except for landslides and a post-mineral faulting, is continuous and can generally be traced by "float". The width of this zone is generally too broad for easy prospecting, and closer delineation, both across and along the strike, is the immediate problem in question, not only where the zone has a definite strike but also where it is divided into segments, each segment having a definite direction generally not in coincidence with the average direction of the main zone.

The massive chromite occurs in kidneys, the exposed portions of which are in contact with dunite and serpentine, which in turn are contained in peridotite in various degrees of alteration. Of these the dunite and chromite were not magnetic and serpentine was either non-magnetic or only slightly magnetic; on the other hand the peridotite was very highly magnetic and much of it was magnetically polarized.

The mineralized zones, therefore, would be expected on magnetic discontinuities whose edges or boundaries depended upon the configuration of the peridotite. Insufficient work was done to differentiate the chromite from the serpentine in the magnetically disturbed area. However, it was definitely determined that wherever mineralization occurred, it was in a magnetically disturbed area. Further geophysical research on the geophysical features might be used to differentiate serpentine from chrome in this area, and is well worth undertaking.

PLAN OF SURVEY.

Lines were run across the mineralized zone in three places, averaging 300 feet apart. The length of the three lines totalled 1450 feet. The magnetometer stations were separated by equal intervals of 10 feet along the line, and the resistivity stations at 50 feet and also at 100 feet intervals. It would have been very desirable if more lines had been measured, but owing to the inclement weather, work had to be discontinued before such observations could be made.

MAGNETIC PROFILES.

The results of the magnetic observations were presented on separate profile drawings. Similar magnetic anomalies appeared on the three profiles as they crossed the zone of mineralization. The controlling factor is not the value of the anomaly but the length along the line on which it occurs. The form of the anomaly is probably controlled by the polarization and configuration of the peridotite contacts in the zone. The disturbed zone is not very wide, as was indicated by the mining operations. The nearness of the other boundary of the peridotite soon was detected in the magnetic anomaly. In one line a higher average value to the northeast of the anomaly indicates a definite dip of the peridotite boundary in that direction. The other lines indicate vertical peridotite boundaries, or one dipping slightly to the southwest. All indicate a very narrow mineralized portion and an interesting but complicated structure.

RESISTIVITY SURVEYS.

In addition to the magnetic observations, electrical resistivity surveys were made along the three lines. The 5-point partitioning method of ground comparison was used with a direct reading ground resistivity meter. The ground resistivity varied somewhat between the lines. The lower resistivities were of the order of 25,000 ohms and the higher values of 64,000 ohms, with generally increasing values at depth. While the values of themselves in these instances are not controlling in regard to the localization of mineralization, they indicate, when charged as line of equal resistivity, a very definite pattern at each depth. Five maps were

drawn to show the isoresistivity lines at depths of 20, 40, 60, 80 and 100 feet.

At two points which lie within the mineralized zone there is indicated a very definite change of resistivity gradient ranging from 80 ohms per foot to 800 ohms per foot. It may be stated therefore, that the electrically disturbed areas that have been investigated coincide with the magnetically disturbed ones.

The electrical method of examination is preferable to the magnetic method as it permits continuous analysis at each depth and is therefore capable of giving a more detailed comprehensive picture of any anomaly that has a large electrical resistivity contrast. It also has the advantage of affording observations to a greater depth than would be possible with the magnetometer in such areas. On the other hand the magnetometer is faster in outlining the general mineralized area and can be operated more cheaply than the electrical method.

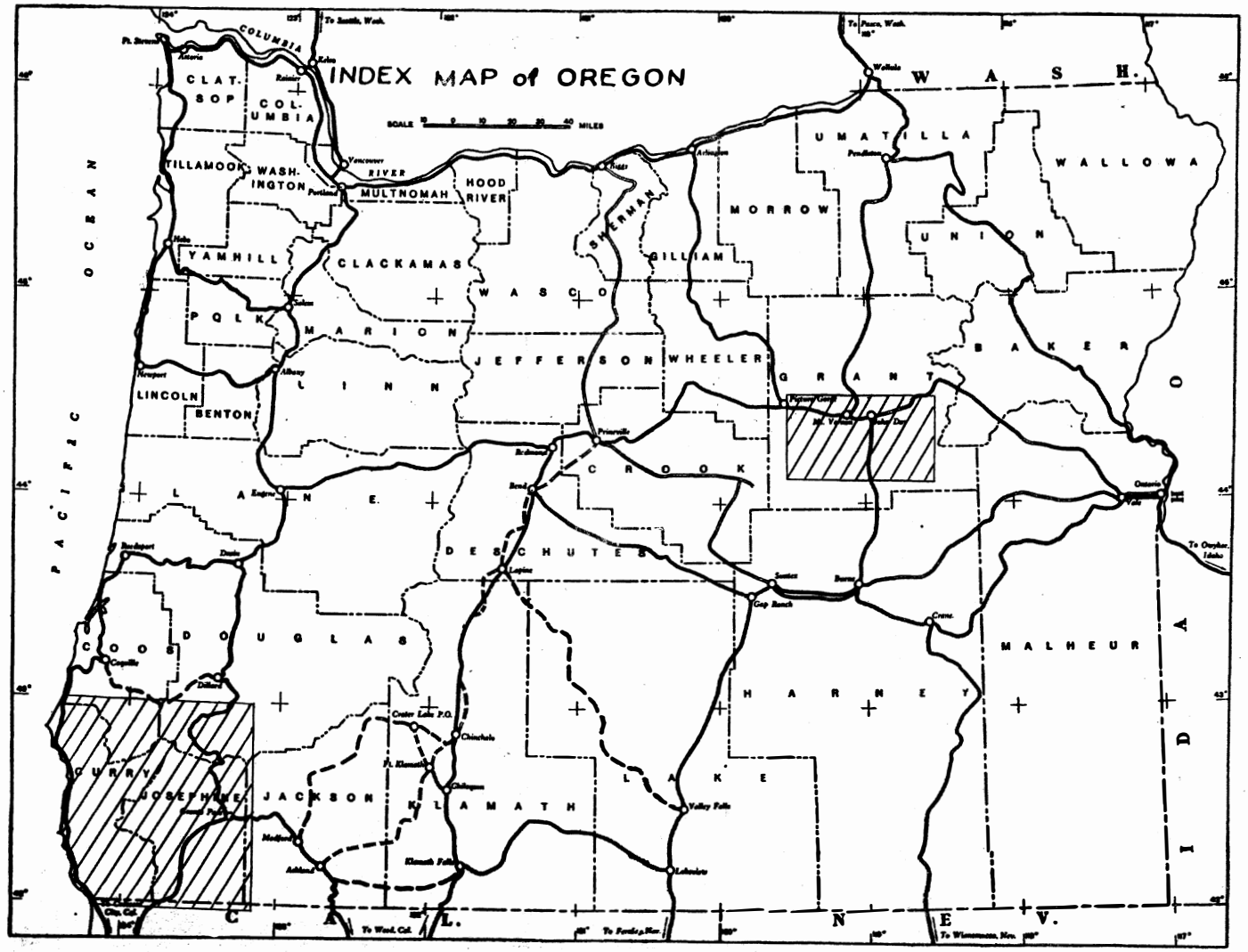
CONCLUSIONS.

The investigation has shown that it is possible to delineate in a banded serpentine-chrome-peridotite complex those portions in which there are marked changes in magnetism and electrical resistivity. If chromite bodies in general are restricted to those portions, it may be possible to eliminate a large amount of unproductive ground; but this statement does not apply to bodies of chromite wholly enclosed in serpentine and not closely associated with a magnetic rock like peridotite. The isoresistivity curves for 20 and 40 feet show a definite break in gradient which appears to coincide with a change in the rock type. The curves for 60 and 100 feet, however, cannot be interpreted in the light of our present meagre knowledge of the area, and leave uncertainties regarding the downward trend and continuity of the change in rock type.

The investigation also shows that there is a certain advantage in following magnetic surveys by electrical resistivity surveys.

Much additional knowledge could be gained if a chromite kidney were found and carefully analyzed by geophysical means before it were mined. Such a procedure would afford much more detailed data and might result in a much more complete means of identifying a chromite deposit.

Fig. 1. Index map showing location of southwestern and northeastern chromite-bearing regions of Oregon.



CHROMITE DEPOSITS IN OREGON

by John Eliot Allen
Field Geologist

ABSTRACT

Domestic production of chrome ore reached a peak of 125,000 long tons in 1918, but has since been negligible, while imports have risen from 90,000 long tons in 1932 to over 400,000 long tons, or nearly 40 per cent of the world production, in 1937. Of the chromite consumed by the United States, 50 per cent is used for metallurgical purposes, of which the manufacture of stainless and other alloy steels is the most important. Refractory uses, such as manufacture of chromite brick for furnace linings, account for 40 per cent, and 10 per cent goes for chemical and other uses.

Most of the chromite bodies in Oregon are of small size and are far from the railroad, or at some distance from coast ports, while the present markets for the ore are at Atlantic ports. The high cost of the transportation is thus one of the most important factors which has prevented development of the local deposits. The development of large and cheaply-mined foreign deposits has prevented the price from keeping pace with the demand.

High-grade ore (over 45 per cent chromic oxide) is usually shipped without concentration to point of consumption. Both this and the lower grades have characteristics making them easily identifiable in the field by the prospector who understands their occurrence and associations. Underground development of deposits, however, should follow the ore except in cases where the bodies are very large or closely spaced.

Chromite in Oregon occurs in the southwestern and northeastern parts of the state, in rocks of the peridotite or serpentine types. The deposits vary in form from thin stringers through narrow lenses to thicker and shorter kidneys; and in size from a few inches up to masses whose outcrops are 40 feet in width and 150 feet or more in length. Only 11 of the deposits visited in Oregon had individual kidneys of ore with visible outcrops larger than 5 feet wide and 10 feet long. When orebodies occur in groups, which is common, individual masses often follow a recognizable scheme of orientation; they may be in line, staggered or overlapping, parallel, or irregularly placed with respect to each other. Nearly all the ore bodies are considerably broken and faulted, and they usually lie in a sheared and altered zone in the country rock.

Chrome ore consists of crystals of the mineral chromite in a gangue predominantly of magnesium silicates. Pure chromite would consist of 68 per cent chromic oxide and 32 per cent ferrous oxide, but ores never attain this richness, as either the ferrous oxide is more or less replaced by magnesia, or the chromic oxide by alumina, or both. The highest grade chrome ore assayed from Oregon gave 59 per cent chromic oxide, and an average of 80 assays gave 39 per cent chromic oxide and 15 per cent ferrous iron. A pink chlorite and a green garnet, as well as several carbonates and

magnesium silicates often accompany the chromite mineral. The texture of the ore is usually even granular, either massive or disseminated. It is less commonly banded or nodular.

No final conclusions have been reached as to the origin of chromite, but its emplacement seems to have occurred largely by injections towards the end of the magmatic cycle, after partial or complete consolidation of the country rock, and mainly before serpentinization.

INTRODUCTION

At the request of Mr. Earl K. Nixon, director of the Oregon State Department of Geology and Mineral Industries, the writer has prepared the following report describing some of the chromite deposits in Oregon and discussing their origin.

Since October, 1935, the writer has been engaged in a field examination of chromite deposits on the Pacific coast for Mr. C. E. Tuttle, president of the Rustless Iron and Steel Corporation of Baltimore, Maryland. It is only through Mr. Tuttle's courtesy that this information, which has taken over two years to gather, has been released to the public.

Over 100 prospects and mines in Oregon have been visited and studied in the field. The results presented in this paper have been reached on the basis of field rather than laboratory study. The theory of origin of the deposits developed has a structural rather than a mineralogical foundation, and it is hoped that this investigation may stimulate further microscopic study of the western ores.

ACKNOWLEDGEMENTS

The writer wishes to express his deep appreciation for the assistance and guidance given by Dr. Warren D. Smith, Mr. Earl K. Nixon, Mr. H. F. Byram, and Dr. Charles M. Gilbert in the preparation of the report. He wishes to take this occasion to thank the numerous owners of properties for their help and friendliness, and Mr. Robert Owen for his loyal assistance in the field. Dr. W. D. Wilkinson has described several thin sections of rock and ore, and his interpretations have been used in this paper.

LITERATURE

The chromite deposits of southwestern Oregon were studied and their origin and mode of occurrence discussed at length by Diller 1/ 2/. Westgate 3/ has reviewed the deposits in northeastern Oregon. A few deposits in Curry county are mentioned by Butler and Mitchell 4/. Deposits in northern California, which are similar to those in southwestern Oregon, have been much more thoroughly studied by Diller 1/, Harder 5/, Logan 6/, Johnston 7/, Maxson 8/, and others. References to pertinent works by authors are made in the text by numbers as above and referring to a bibliography given at the end of this paper.

ECONOMIC CONSIDERATIONS

World sources, production, and consumption.

Chromite was first discovered in America near Baltimore by Isaac Tyson in 1827. From 1827 to 1860 most of the world's supply came from Maryland and the adjoining regions in Pennsylvania and Virginia. With the opening of larger deposits in Asia Minor in 1848, Maryland production diminished and by 1880 had stopped. California ores contribute largely to the domestric production from 1869 to 1873, but of late nearly all chromite consumed in the United States has come from foreign deposits.

New Caledonia, Asia Minor (mainly Turkey), India, Rhodesia, Greece and Canada have contributed largely to the world supply, and ore is also produced in Russia, Cuba, Guatemala and the Philippines. Domestic chromite occurs in California, Oregon, Washington, Montana, Wyoming, South Carolina and Texas as well as in Maryland, Pennsylvania and Virginia.

Annual summaries of foreign and domestic production, shipments, and prices of chromite ore are published in the Minerals Yearbook of the United States Bureau of Mines.

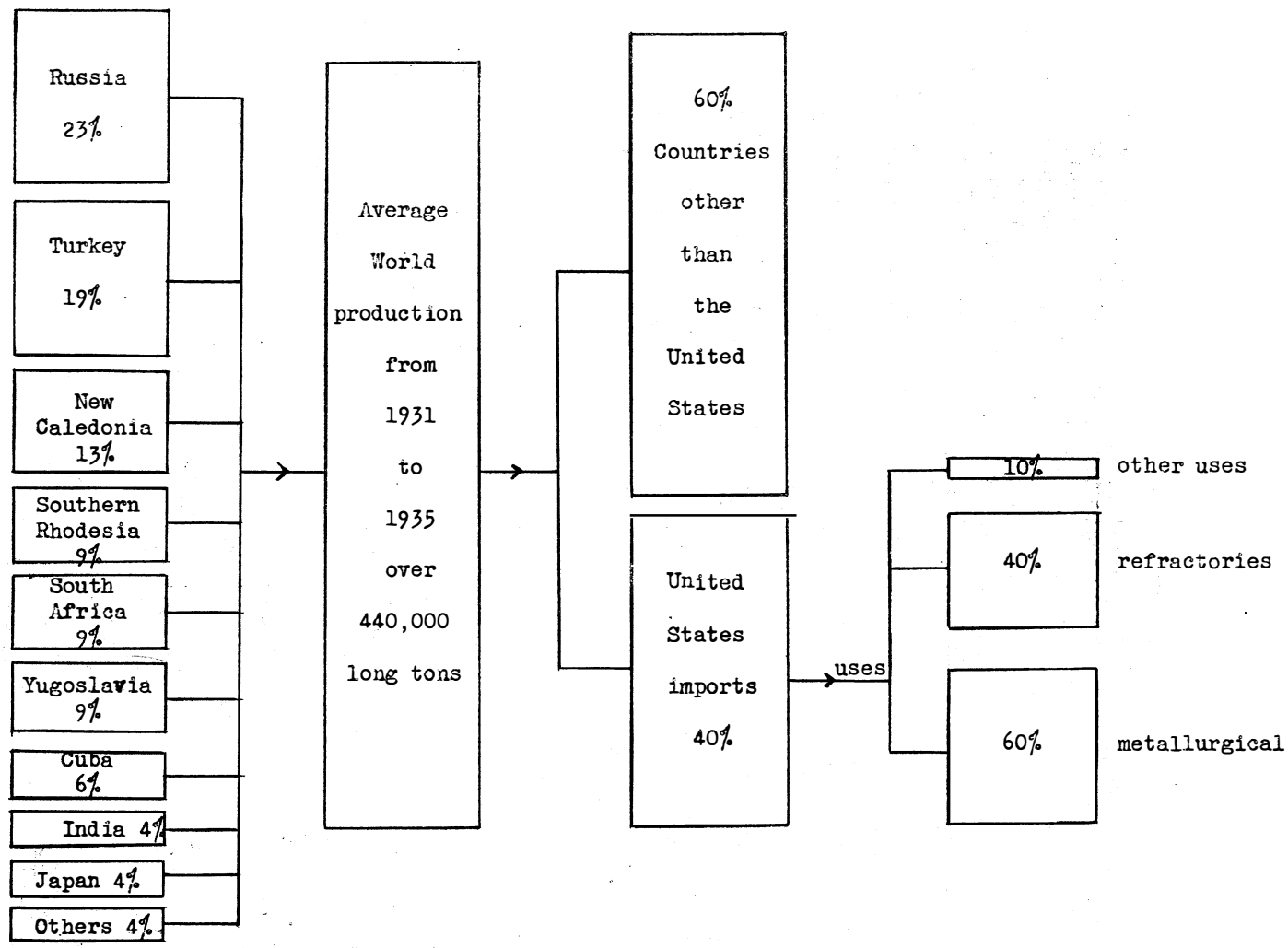


Fig. 1a. Relative production and consumption of chromite.

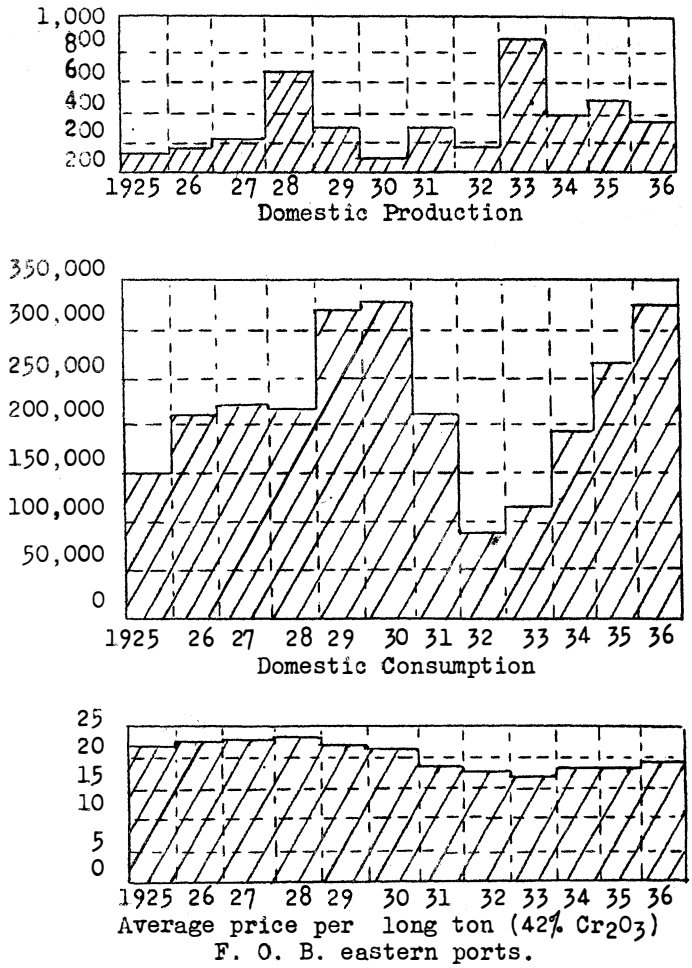


Fig. 1b. Graph showing domestic production and consumption in long tons; and price of chromite in dollars per long ton, 1925-1936. The domestic production as compared to consumption is so small that the two cannot be plotted on the same graph, thus domestic production has been placed on a scale approximately 160 times that used for domestic consumption. (From Minerals Yearbook, 1937, after Schafer.)

A graphic representation of the relative amounts of the world supply produced by the various countries is shown in fig. 1-a. This chart also shows the relative amount that is consumed by the United States, and the main uses to which it is put. The four per cent production represented as "others", consists, in the order of importance, of Greece, Philippines, Canada, Cyprus, Australia, United States, and Brazil.

The more detailed figures of production and consumption from which the above chart was drawn are shown in fig. 1-c, taken from the 1937 Minerals Yearbook.

Fig. 1-c.

Production of crude chromite, 1932-1936, by countries, in metric tons.

Country	1932	1933	1934	1935	1936
Australia (New South Wales)	99	905	1,744	605	(1)
Brazil (2)				5	(1)
Bulgaria		170	85	325	(1)
Canada (shipments)	71	27	101	1,038	(1)
Cuba (3)		24,154	50,162	48,509	71,086
Cyprus (shipments)	1,000		982	1,198	(1)
Greece	1,555	14,784	30,694	31,984	(1)
Guatemala (3)		2,094	805		
India (British)	18,152	15,775	21,922	39,755	(1)
Japan	12,492	19,897	27,222	36,309	(1)
New Caledonia	69,429	50,072	55,182	55,311	(1)
Norway	409	326	42		(1)
Philippine Islands (2)				1,292	5,006
Rumania		29			(1)
Southern Rhodesia	15,692	35,046	72,099	105,913	183,395
Turkey (Asia Minor)	55,196	75,379	119,844	150,514	(1)
Union of South Africa	19,371	34,078	61,357	90,431	173,141
U. S. S. R. (Russia)	65,900	109,400	127,400	177,900	(1)
United States (Shipments)	157	857	375	523	273
Yugoslavia	39,141	26,248	47,352	52,367	54,044
	298,664	409,241	617,368	793,979	(1)

(1) Data not yet available.
(2) Exports.
(3) Imports into the United States.

Importation of chromite from various sources into the United States is shown in fig. 1d, and graphs showing the trends of consumption, price, and domestic shipments of chromite in the United States are given in fig. 1b.

Fig. 1-d.

Crude chromite imported into the United States, 1932-36, by countries.

Country	(All in long tons)				1936		
					Long tons		Value
	1932	1933	1934	1935	Gross Weight	Chromic Oxide Content	
Africa (1)	17,702	13,186	48,848	92,682	120,011	54,179	$2,007,383
Brazil				2			
Canada		49	30	2,888	41	15	247
Cuba		23,772	49,370	47,743	69,963	22,813	358,241
Greece	16,395	11,499	23,301	20,692	26,688	10,879	254,627
Guatemala		2,061	792				
India (British)	7,857	4,152	400	14,926	14,795	6,953	157,526
Netherlands			259				
New Caledonia	11,550	15,150	19,530	55,686	65,450	33,347	1,163,192
"Other" Asia			1,100				
Philippine Islands				787	4,986	2,504	81,668
Turkey	17,602	27,854	28,730	16,060	19,490	9,186	364,668
U.S.S.R. (Russia)	4,800	13,261	19,937	3,412	2,310	1,070	37,310
United Kingdom	13,237			4,185			
Yugoslavia		5,527			524	252	7,036
	89,143	116,511	192,297	259,063	324,258	141,198	$4,431,898

(1) Originated in Southern Rhodesia and Union of South Africa, recorded by Foreign and Domestic Commerce as imported from Union of South Africa, Other British South Africa, Mozambique, Other Portuguese South Africa, and Algeria and Tunisia.

OREGON PRODUCTION

Chromite in Oregon occurs only in two opposite corners of the state. It is found in the southwestern counties of Josephine, Curry, Jackson, Coos and Douglas; and in the northeastern counties of Grant and Baker. The old Tyson properties just across the state line in Del Norte county, California, were worked from 1869 to 1873, but in Oregon there was little production until the World War, when foreign imports were cut off and increased prices stimulated activity. During 1917 and the succeeding year numerous prospects and mines were located in both the southwestern and northeastern parts of the state, and the output increased rapidly.

The signing of the Armistice and the importation of several shiploads of ore demoralized the domestic market, leaving a number of producers with unmarketed ore on their hands. With the exception of a few carloads of this ore, there has been no chrome shipped from Oregon deposits since that time.

In 1918, according to Diller 9/, about 18,000 long tons of chrome ore were shipped, about 6,000 tons being from southwestern and 13,000 tons from northeastern Oregon.

At the end of 1925 the total production of chrome, the available resources, and the total number of deposits located in Oregon were as follows 10/:

Total number of deposits	104
Total production	36,500 tons
Total reserves	62,000 tons

More than two thirds of this production came from eastern Oregon.

USES OF CHROMITE

F. M. Becket has made a comprehensive study of the modern uses of chromite 11/, and a large part of the following section is taken from his discussion of the subject.

Chromite is the only chromium-bearing mineral found in sufficiently large amounts to be of economic importance. About 40 per cent of the chrome ore consumed within the United States is used in the manufacture of refractory chromite and chromite-magnesite brick for furnace linings. Ore with 33 to 43 per cent chromic oxide may be used for this purpose. It is sometimes heat-treated to recrystallize the chromite mineral and the gangue, which decreases the chemical activity so that it will stand up better under high temperatures.

Fifty per cent of the chromite in the United States is used in the metallurgical industries. When chromite is smelted in electric furnaces with a carbonaceous reducing agent, the product contains 68 to 71 per cent of chromium and upwards of 4 per cent of carbon, and is known as high-carbon ferrochromium. It is used whenever a carbon steel alloy is

permissible, chiefly in the mining, milling and automobile industries.

Low carbon ferrochromium includes a group of alloys containing 68 to 72 per cent chromium and a maximum of from 0.06 to 2 per cent carbon. These are produced in the electric furnace with silicon as a reducing agent. One company makes the steel directly without the use of ferrochromium, by smelting ferrosilicon, mild steel scrap, alloy steel scrap, and high-grade chromite ore in electric furnaces. Low carbon ferrochromium has a multitude of uses in the chromium steel field, which may be divided into four groups according to their chromium content.

Steels containing 3 per cent and less of chromium are used for balls, races, and rolls of anti-friction bearings, applications requiring exceptional strength, hardness and resistance to abrasion. They are used for permanent magnet steels, balls and stamp shoes in milling and for metal working tools such as chisels, files and drills. With the addition of nickel, they are used for heavy duty structural parts. The addition of vanadium gives this type a high tensile strength; the addition of molybdenum a greater fatigue resistance. Recently developed alloy structural steels contain small amounts of chromium, manganese and silicon.

A second group of steel contains 3 to 12 per cent of chromium. Those with 4 to 6 per cent chromium are resistant to oxidation at high temperatures, and are used for tubes in the oil-cracking industry. Steels with 8 and 9 per cent chromium and between 2 and 4 per cent silicon have long been used for valves in internal combustion engines. High speed tungsten steels contain 3.5 to 5 per cent of chromium.

The early stainless steels contained from 12 to 14 per cent chromium, which introduced the property of corrosion resistance, and were valuable for cutlery, which is still the best known application of this type. Later when the carbon content was lowered, the product could be more easily worked, and a great many other uses were developed. The blades of the modern steam turbine are an example. When the chromium content is raised to 18 per cent, the resistance to corrosion is increased, as well as resistance to scaling at high temperatures. These steels are more or less acid-proof, and a large amount is used in the production of nitric acid.

One group of steels in this division is the well-known "18-8", which denoted the original percentages of chromium and nickel, although the latter has now been increased to about 9 per cent. The food and associated industries are among the largest users of the chromium-nickel steels, because of the ease with which they can be kept absolutely clean and sanitary and because they do not contaminate food materials. Evaporators, separators, tank trucks, and even freight cars are being made of "stainless". Its use in hospitals, hotels, and restaurants is becoming more and more common. Besides these uses, the automotive, architectural, paper, laundry, aviation and marine fields are among the principal consumers. Many of the new streamlined trains were made possible by this material which combines increased strength with less weight.

Steels with a chromium content of over 20 per cent have the property of withstanding oxidation at temperatures as high as 1000° C. These

heat-resistant steels were the first to be used in cracking gaseous hydrocarbons. They are used as both working and stationary parts of annealing and other types of furnaces, roasters, retorts, and equipment where resistance to heat and acid are especially important.

Uses other than refractory and metallurgical account for the other 10 per cent of the United States consumption.

Chromium-plating for decorative and protective purposes is used in a multitude of ways, probably most extensively in the automobile industry. It is also commonly used in chemical apparatus, machine and engine parts, tools, and printing plates.

Chromium in small proportions alters the properties of aluminum, copper, and other non-ferrous metals. For instance, low-chromium bronze has four times the yield strength and a third greater ultimate strength than annealed copper.

There are numerous chemical uses for chromite. Among its derivatives are sodium and potassium bichromate and chromate, and green, yellow, and red pigments. Chrome-tanned leather is less expensive than other types.

MINING AND MARKETING PROBLEMS.

The outcrop of the average kidney of high-grade chromite in Oregon will have a width of only a few feet and a strike length of only a few yards. Today, deposits of this size can only be mined at a profit when they occur on or near a road, and when there are a number of them so that a full railroad carload can be made up. Low-grade deposits that require milling and concentration before they can be shipped must show tonnages that will yield a profit sufficient to pay for the erection of a mill. At present prices the tonnage required to pay for a $50,000 mill (probably the smallest size that is still economical) is considerable, and deposits of such size in Oregon are exceptional. Large low-grade deposits that seem to fulfil these qualifications must also be tested to make sure that by milling the ore it can be beneficiated to a shipping grade. If the chromite mineral itself is a chrome-picotite, it often cannot be raised to market specifications for ferro-alloy uses by mechanical concentration methods.

Oregon ores must meet competitive low prices of the ores from foreign and particularly trans-Pacific deposits. Transportation is the controlling factor in the estimation of the marketing costs for local chrome, and only the larger and more favorably located properties can now expect to meet the foreign prices.

The cost of hauling from mine to railroad may vary from 3 to over 25 cents per ton mile, depending upon the character of the road traversed and the kind of equipment used. When this cost factor is added to the other transportation and handling charges necessary to deliver the ore to eastern consumers, the total in nearly all cases is great enough to preclude the marketing of ore at prices that exist today.

The small producer may easily, and often does, overlook some of the

various small incidental cost factors that exist between mining the ore and unloading it in eastern ports, and which in the aggregate make up a considerable part of the market price. For instance, it is sometimes forgotten that quoted prices are on a long ton (2240 lbs.) basis, and that a long ton is approximately 1/8 more ore than a short ton. It is a frequent occurrence that the neglect of one or more of these factors may cause the owner of a deposit to consider erroneously the possibility of profit in operation where none exists.

The present low price of chrome ore is due as stated to the existence of large and cheaply mined foreign deposits in such widely separated localities as New Caledonia, the Philippines, India, Rhodesia, Turkey, and Russia. So long as there are ships available and willing to import these ores to the United States at normal shipping rates, there is no immediate likelihood of an advance in price, except through such a rapidly expanding demand as would tax the producing capacity of the world.

At the present time the large foreign deposits are in no danger of depletion, and the smaller or more isolated deposits which were located in Oregon during the World War activity may not produce again for many years, unless the transportation setup were changed by installation of reduction plants in Oregon.

PROSPECTING AND DEVELOPMENT.

Identification of Mineral, Ore, and Host Rocks.

High-grade chrome ore (above 45 per cent chromic oxide) is composed of closely-packed crystals of the mineral chromite, with a small amount of the secondary rock material between the grains. It has a dense black or even bluish-black color, and is easily distinguished in the field from the black manganese ores by its greater weight (specific gravity up to 4.4) and from other iron and copper ores, magnetite, chalcocite, bornite, by its characteristic chocolate-brown streak when scratched with knife or pick point.

In lower grades of milling ore (down to 15 percent chromic oxide) the black crystals of chromite make up only a small part of the rock, so that a specimen has a speckled or streaked appearance but is still predominantly the color of the country rock. When the chromite crystals occur in bunches or in bands it is sometimes called "leopard" or "tiger" ore; when the crystals are scattered evenly throughout the rock it is called "birdseye" ore.

Chromite occurs only in the ultrabasic intrusive igneous rocks such as peridotite ("buckskin") or other members of this iron- and magnesium-rich group, and in rocks derived from them, such as serpentine. These rocks can usually be identified by their color, which is dark green to greenish black on fresh surfaces, and usually tan to buff, or even reddish on weathered surfaces. In the case of serpentine, it may weather to greenish gray.

These ultra basic rocks are heavier than the lighter colored igneous rocks. In most cases they are porphyritic, with large crystals of platy greenish diallage or enstatite in a dark green matrix. All of these rocks alter to or are replaced by such minerals as talc, chlorite, or magnesite, any or all of which may occur with chromite.

Prospecting for Chromite

High-grade chrome ore is more resistant to weathering than the rock in which it occurs, and so may be picked up as "float" on the surface and traced uphill toward its point of origin. The lower grades may weather to black chrome sand, which can be panned from the soil and then recognized by its brown powder when crushed. Some strings of float do not lead to outcrops if the small bodies from which they were derived have been totally worn away, but they usually do lead to a "zone" of more highly sheared and broken rock. This zone can be identified by its softness, by white stringers and veinlets of a brittle asbestos-like pyroxene (tremolite), and by abundant talc, magnesite, and other secondary minerals. If the trend of this zone can be followed, other orebodies may be discovered along it. Deposits have been located by following the trends or directions of such zones for as much as two miles, and general trends may extend as far as thirty miles. In southwestern Oregon the main direction of these zones is almost due north and south, though occasionally it varies slightly towards the northeast. Other cross-zones containing ore croppings may intersect more or less at right angles to these north-south zones to form secondary trends. Some of the largest bodies of ore lie at the junctions of these zones or trends.

Vegetation is often an aid in locating the areas of chromite-bearing rocks, for the latter often support only grass and a few scattered pines, while in other, less favorable areas the rocks may be covered by a dense growth of brush, fir, or deciduous trees.

Development of Deposits.

There has been no extensive underground development of any chromite deposit in Oregon. The deepest mine workings seen by the writer - the Ward (28), Grant county - penetrated only 60 feet below the surface. On the other hand, California properties have been deeply and intensively mined at a number of places. Several mines in San Luis Obispo county, California, have over ten thousand feet of tunnels on as many as five different levels. The orebodies are irregularly lens-shaped, varying in size from a few inches to a few feet in thickness and to tens of feet in length, and usually lie in a more or less broken and sheared zone in the serpentine. While these deposits were being mined, the miners after exhausting one lens of ore often followed narrow, sometimes only paper-thin stringers or seams of chromite, which usually led them to another body, sometimes many feet away. The lenses seem to lie at an acute angle, or sometimes almost at right angles, to the trend of the zone. Some overlap slightly in a staggered manner.

Underground development costs become excessive when orebodies are small or too far apart. A small outcropping lens may sometimes be mined profitably, but it is seldom wise to try to follow the lead underground to another lens unless there is some way of telling from surface indications or otherwise that the orebodies lying in the zone are closely spaced.

Chrome ore usually occurs in bodies that are both irregular and of limited extent so that it is hazardous to try to drift in to meet them at any distance below the outcrop, without first testing the depth and extent of the ore.

As early as 1909 12/ it was recognized that estimation of tonnage beyond the ore already blocked out cannot be made with any certainty, and that all ore outcrops must be explored to depth before any definite idea can be gained as to their extent.

> "The mining of chromite has always been and will be attended with considerable uncertainty on account of the very pockety nature of the deposits. These masses or pockets may or may not be connected with one another, and they are limited in extent, so that when a deposit is exhausted, sometimes a great amount of dead work has to be done before another deposit is encountered. It is, therefore, impossible to give any estimate regarding the amount of chromite on a property beyond that which is exposed by actual work done. The fact that a large amount of ore has been taken from a deposit does not necessarily indicate that the same still contains a large amount of ore; if, however, a deposit has been productive of a large yield, this would serve as a strong indication that other large pockets might be possibly found nearby. Yet, in view of the theory advanced for the origin of chromite, if a large deposit is found in an extensive serpentine formation, there is a great probability that other large deposits may be found elsewhere in the area, and in the majority of cases, close by."

It has often been said that chromite bodies occur like plums in a pudding. It is in large part the purpose of this paper to emphasize that it is often possible by carefully working out the details of occurrence of the ore bodies, to determine a definite scheme for location of further hidden deposits nearby.

OCCURRENCE OF THE ORE

Associated rocks and their origin and age.

Chromite in Oregon occurs in rocks of the peridotite group, or in serpentine derived therefrom. All members of this group are generally called "serpentine" by miners.

In the broad sense, peridotite may be said to include dunite and pyroxenite, and the various intermediate rocks. The composition and specific names of the principal members of this group are listed below 13/:

Species:	Essential Mineral Components.
Dunite	Olivine
Harzburgite (saxonite)	Olivine and rhombic pyroxene
Wehrlite	Olivine and diallage
Lherzolite	Olivine, diallage, and rhombic pyroxene
Amphibole-peridotite	Olivine and amphibole
Cortlandite	Olivine, amphibole, and pyroxene
Pyroxenite	All pyroxene

Such ultra-basic types apparently never occur as extrusive rocks, or lavas. They have been intruded into the crust of the earth in great sheets or lenses, as fluid or viscous magmas, which may be partly crystalline, and which are usually parallel to the general trend of the mountain ranges in which they occur. Some of the wider masses may have been formed by successive parallel intrusions. The peridotite-serpentine areas of southwestern Oregon vary in width from a few hundred yards to as much as eight miles, and are as much as fifty miles in length, although usually less. The peridotite-serpentine mass in northeastern Oregon is thirty-six miles long and over seven miles wide in some places.

In both areas the "serpentine" bodies seem to form great lens-like sills, which have their longest dimension parallel to the ranges, or north and south in southwestern Oregon, and east and west in northeastern Oregon.

By a decrease in percentage of the olivine, the various peridotites merge into an equally varied group of pyroxene rocks which occur associated with the peridotites in Oregon only as a few dikes and lenses.

Harzburgite is perhaps the commonest type of peridotite in southwestern Oregon. It appears at Nickel Mountain and elsewhere. Wehrlite is also abundant, and is usually the "buckskin" rock of the prospector. This "buckskin", so named from its color, has rough, weathered surfaces with crystals of diallage standing in relief above the decomposed olivine ground mass. Weathered dunite, being composed of one mineral, olivine, shows a smooth yellow surface.

The peridotites and dunites frequently have a distinct banded structure, and even occasionally display definite fissility. In the hand specimen this appears to be due to the primary alignment and orientation of the phenocrysts in parallel planes. Whether it is a result of primary or metamorphic flowage or of crystal segregation has not been determined.

At Connor Creek (50) Baker county, Oregon, peridotitic magma was intruded into or alongside of a limestone, resulting in a talc-dolomite rock which contains chromite 3/.

It is generally believed today that the serpentine is due to the alteration of peridotite by ascending hydrous vapours and liquids which are freed in the final stages of the consolidation of the peridotites themselves 14/.

The peridotites are intruded into the Paleozoic and Jurassic rocks of the Pacific Coast. In southwestern Oregon some of these rocks have been correlated with the Franciscan formation of California 15/ and may in part be Knoxville (Cretaceous) in age. Early workers stated that the peridotites and serpentines penetrated the lower Cretaceous sediments, but since then these rocks have in large part been assigned to the upper Jurassic.

Form and Size of the Deposits.

Both the high and low grade chromite ores in Oregon occur in several different typical forms. They may appear as thin irregular stringers and seams which may widen out to form larger masses. They may occur in

narrow sheets and thin lens-shaped bodies, in thicker irregularly kidney-shaped masses, and as blocks or patches of ore mixed with blocks of adjoining serpentine in zones of breccia-like material.

The limits of the rock containing chromite are usually abrupt in all of these occurrences, but in some cases the boundaries may show a gradation from solid ore through low-grade ore to country rock carrying only a few grains of chromite. The limits of the orebodies are usually most sharply defined along the sides of the kidneys or lenses. The ends are not as definitely marked, and either pinch, finger, or grade out into the surrounding rock.

When several orebodies occur in an ore zone, they may be arranged in several ways with respect to each other and the trend of the zone. They sometimes lie with their greatest dimension parallel to the trend of the zone; or they may lie en echelon, each body trending at an equal angle to the zone, and sometimes overlapping each other. This angle may increase until the bodies lie at right angles to the zone, across it, and parallel to each other. In any one district, associated orebodies tend to have the same general trends and attitudes. In Oregon the above occurrences occur in frequency in about the order given, the most frequent being first.

In the banded type of chromite deposit, the layers and bands are nearly always more or less parallel to the trend of the zone in which the orebody occurs.

In Oregon the largest low-grade orebodies seen measured 40 feet by 150 feet, but the average size was only 4 feet by 15 feet. Narrow bands and lenses of high-grade ore are often included in the disseminated deposit. In deposits where low-grade ore is absent, the high-grade bodies usually have sharp boundaries, the largest being about 20 feet by 65 feet, while the average is only 2 feet by 7 feet. Only three high-grade orebodies out of one hundred in Curry County are much over 2 feet by 6 feet in size.

Structures and Deformation

All the areas of chromite-bearing rocks in Oregon show some degree of jointing and fracturing. Even where this fracturing is at a minimum, the rock and ore is broken into blocks that are seldom more than 3 feet in diameter. Movement accompanied the fracturing, recognizable by polished surfaces (slickensides) or by crusts and veins of secondary minerals such as serpentine, tremolite and talc. These surfaces frequently limit the orebodies, and may also have dislocated them.

There seems to be a relationship between serpentinization and movement. Where one is least, so is the other. Where the alteration of rock to serpentine is intense, the rock and ore are broken by a fine network of slip-surfaces. Massive blocks of country rock or ore are seldom seen, and if present are isolated. This sheared rock may appear to be tough and hard when fresh but it quickly breaks down to small fragments and flakes under weathering action.

The "zones" in which the orebodies occur around the Signal Buttes in Curry county are minutely sheared and fragmented. The ore is nearly always bounded by curved shear surfaces, while narrow knobby stringers of ore may represent once continuous bands that have been broken apart. These intersecting north-south and east-west "zones" form a rectangular network (see fig. 5) composed of such thoroughly fragmented and altered rock that they have been eroded to form saddles where they cross the ridges and swales near the stream courses. In the Briggs Creek district the country rock along the ore-zones is only slightly altered and sheared. The zones can be traced by the outcrops of seams of light colored tremolite, chrysotile serpentine, and other magnesium silicates, which make up the "chrome bloom" of the prospectors. In this area the major zones trend N. 48° W. and N. 70°E. The largest of the orebodies both in west Curry county and Briggs Creek seem to lie at the intersections of the shear zones, and to lie parallel to the trend of one of them.

NATURE OF THE ORE

Chromite and its associated minerals.

Chromite is the only mineral used as an ore of chromium. Its formula is usually given as $FeO.Cr_2O_3$, which would contain 68 per cent chromic oxide and 32 per cent ferrous iron, but this is found in nature only in meteorites. The ferrous iron is partly replaced by magnesia or the chromic oxide by alumina or both. The composition frequently varies through chrompicotite to picotite $(Mg.Fe)O.(Al,Cr)_2O_3$, which contains up to 10 per cent of chromium. It may also vary through chromhercynite to hercynite (chromium oxide completely replaced by alumina), and to magnesiochromite and the chromiferous spinels 16/.

Chromite crystallizes in the isometric system as octahedrons. Its specific gravity varies from 4.32 to 4.57, and may be lower in some of the less pure varieties. The color is black, the streak brown, the hardness 5.5 (just softer than quartz), it is generally non-magnetic. Although these characteristics should afford satisfactory identification, a chemical test may be desirable. Chromite gives a green color with a borax bead in both oxidizing and reducing flames, but it must be very finely ground and only a small amount used.

According to Seil 17/ chrome ore is composed of a "primary component", the mineral chromite, which is a chemical entity in which the molecular sum of the FeO and the MgO equals the molecular sum of the Cr_2O_3 and the Al_2O_3; and a "secondary component", the gangue, which consists predominantly of magnesium silicates, some containing iron and aluminum. The following have been found in the gangue of various chrome ores:

Clinoenstatite	$MgO.SiO_2$
Enstatite	$MgO.SiO_2$
Forsterite	$2MgO.SiO_2$
Parasepiolite	$2MgO.3SiO_2.4H_2O$
Chrysotile	$3MgO.2SiO_2.2H_2O$
Antigorite	$3MgO.3SiO_2.2H_2O$
Talc	$3MgO.4SiO_2.2H_2O$
Hypersthene	$(MgO.FeO).SiO_2$
Serpentine	$3MgO.2SiO_2.2H_2O$
Sepiolite	$2MgO.3SiO_2.2H_2O$

Analyses of 43 ore-specimens from 34 localities in southwestern Oregon and of 39 specimens from 16 localities in northeastern Oregon were averaged to give the following:

	Chromic Oxide %	Ferrous Oxide %	Silica %
Southwestern Oregon	42	15	5
Northeastern Oregon	36	15	5

The purest chromite assayed 58.74 per cent chromic oxide, from Eight Dollar mountain, Josephine county.

The crystals of chromite ordinarily vary from microscopic size to about 3 millimeters in diameter, although larger crystals may form. In low-grade ore they are usually irregular and shapeless (anhedral); in the higher grades some possess a few crystal faces (subhedral), but only rare crystals are perfect (euhedral). The grains may also appear irregularly rounded in outline.

A pink platy mineral is often found between the grains in the high grade ores, and on slickenside surfaces. This has been variously identified as either of two chlorites, kammererite ($Hg(MgFeCr)_5Al_2Si_3O_{18}$) a chrome penninite, or kotschubeite ($Hg(MgCr)_5Al_2Si_3O_{18}$) a chrome clinochlore. A sample from southern Curry county has the microscopic characteristics of kammererite.

The chrome garnet, uvarovite ($Ca_3Cr_2Si_3O_{12}$), occurs as minute brilliant grass-green dodecahedrons in open cracks in the ore, or as green polished crusts on fault surfaces.

Various carbonates and zeolites are found in veins or open cavities in or near the orebodies, and magnesite lenses and veinlets are common.

Texture and minor structures.

The texture of chrome ore is usually even-granular, but the structure is either massive and uniform, spotted, banded, or nodular. High-grade ore is composed of chromite grains closely packed together, with but a small and inconspicuous amount of interstitial silicates. In some cases when the ore is very fine-grained, no gangue can be seen in the hand specimen, although even in the best grades of ore a few grains of one or more

of these minerals which make up the "secondary component" of the ore can be seen under the microscope. Most of the smaller deposits are of this type.

Although the texture of the ore remains even-granular, the amount of gangue may increase and completely separate the chromite particles so that they appear disseminated or spotted evenly throughout the rock. Good examples of this type appear at the Chollard (18), Iron King (43) and Marks & Thompson (27) mines. Commonly such orebodies have as sharp clear boundaries as do those of higher grade, but the disseminated ore may also grade into the country rock.

One distinct type of ore consists of alternate layers of varying grades of disseminated ore or of gangue, producing a banded appearance. Sometimes this type occurs as a composite "dike" with sharply defined bands, the lower grade on the outside, and successive bands of higher grade ore towards the center, which occasionally penetrate the outer ones, showing that they are later. This type may be seen in Oregon at the Bald Face (1), Mungers Creek (10), Dry Camp (33)(and see photo) and Marks & Thompson (27) mines, although it is still more common in the California deposits.

"Nodular ore" consists of aggregates of chromite-grains from one quarter to three quarters of an inch in diameter, which are usually rather smoothly oval, although they vary from spherical to lenticular in shape. The grains are usually tightly packed in these nodules, of which some are slightly broken and the cracks filled with serpentine. This type is still rarer, but may be seen at the Celebration (52) and Ajax (54) deposits.

A summary of the frequency of occurrences of the various characteristics of the Oregon deposits is given in fig. 1-e.

Fig. 1-e.

Frequency of occurrence of various characteristics of deposits at 20 localities in southwestern and 17 localities in northeastern Oregon. In a number of cases more than one feature in each group appears in the same locality.

	Number of localities in: Southwestern Oregon	Northeastern Oregon
Maximum size of bodies observed:		
Small (less than 2x5 ft.)	10	7
Medium (2x5 to 2x10 ft.)	6	5
Large (over 5x10 ft.)	4	7
Shape of orebodies:		
Lenses (diam./thickness over 3)	11	12
Kidney (" " less than 3)	7	3
Narrow seams	8	0
Irregular bodies	2	3
Attitude of bodies to each other:		
In line of zone	7	4
En echelon in zone (sometimes overlapping)	6	3
Crossways in zone	7	2
Parallel to zone and each other	1	3
Irregular, no zone seen	1	3
Degree of fracturing:		
Intense (finer than 2 inches)	6	4
Medium (2 inches to 1 ft.)	12	11
Slight (over 1 ft.)	2	2
Minor structures of ore:		
Even granular massive	18	15
" " disseminated	7	9
Banded	3	3
Nodular	0	2

ORIGIN AND EMPLACEMENT OF THE ORE.

Within the last decade some doubt has been cast upon the previously accepted theory of the origin of all chromite as a primary magmatic segregation.

Several authors 18/ have been convinced that the greater quantity of chromite is late magmatic, replacing either partly or completely the groundmass minerals; that parts of the deposits are also hydrothermal in origin, being introduced by the serpentinizing vapours of the last stages of consolidation of the parent rocks with which the ores are associated.

In the study of the origin of chromite deposits a distinction must be made between the time of segregation of the chromite from the magma and its final emplacement as an orebody. The crystallization of the chromite may have begun early in the magmatic stage of the peridotitic intrusion, but it probably continued over a wide range of time, with continuing enrichment. The emplacement of the ore, however, seems to have been in large part after the main period of rock intrusion, and during or just before the period of serpentinization. In other words, a chromite-rich magma, segregated early deep within the intrusion, might be injected into fractures in already consolidated rocks above, without appreciably replacing them.

In the banded chromite ores (Griffin, Valen), the layers of high-grade are often folded and contorted, with later injection, always of higher grade ore, cutting across the earlier. The contorted layers suggest that this type of deposit at least, was in the state of a "crystal mush", rather than a liquid. Intrusive relationships here and elsewhere are also indicated by the frequent occurrence of branching ore stringers having sharp contacts with the barren surrounding rocks.

Orebodies are very commonly aligned within distinct shear zones, suggesting a structural control over their emplacement. When, as at Briggs Creek and in western Curry county, these zones have constant trends over considerable distances and occur in two or more intersecting sets, the evidence becomes impressive. The occasionally overlapping and crosswise orientation of the ore lenses within these zones suggests that they were intruded into shear fractures.

These lines of fracturing,which seem to have governed the emplacement of the orebodies could not have existed before the consolidation of the rocks in which they occur. On the other hand, the movements accompanying serpentinization have in many places fractured and displaced the orebodies. The time of emplacement is thus dated as after the major intrusion of the parent rock and towards the beginning of the period of serpentinization.

Orebodies are frequently found within the peridotite or serpentine a short distance from the contacts with older rocks, or near xenoliths or inliers of schist, chert, or quartzite. If these contacts and inliers acted as "settling tables" for the collection of chromite crystals falling in a liquid magma, the ore would seem to have formed early. An alternative explanation is that the strong and more competent inliers and contacts withstood stresses better than the immediately surrounding rocks with the resulting development of zones of strain near them, during or soon after the rock cooled and solidified. These zones in turn governed the emplacement of the ore. It has been suggested that the orebodies themselves might have acted as competent bodies to localize the fracturing. In most of the Oregon localities they are too small in relation to the extent of the zones to have caused the latter to develop in this way.

In central Curry county the late magmatic minerals tremolite and diallage are often both intimately associated with the ore. Dikes of diallagite parallel the ore lenses. At one locality in southern Curry county large, partly resorbed diallage crystals appear totally surrounded by chromite.

No chromite of definitely hydrothermal origin has been noted. Large veins and vugs of aragonite at the Iron King mine contain chromite crystals which may have been picked up during their later emplacement. The frequent occurrence of orebodies near acid dikes in the Agness district may be explained by their following the same fractures. The hydrothermal minerals such as kammererite in the material between the chromite crystals in high-grade ore may have replaced previous gangue minerals.

By far the greater number of the deposits in Oregon seem to have been emplaced in fractures in the already more or less consolidated rocks, after their partial or complete cooling and before most of the serpentinization, and thus represent injected late magmatic rather than early magmatic or hydrothermal deposits.

CHROMITE DEPOSITS IN SOUTHWESTERN OREGON.

General Description.

Topographically, the region in which these deposits lie is known as the Klamath Mountain province, which was one of the so-called "Two Islands" described by Thomas Condon, the pioneer Oregon geologist. The other "Island" was the Blue Mountains, in which the deposits of northeastern Oregon lie.

The Klamath province is made up of old rocks, and is bounded on the north by Eocene sediments of the Oregon Coast Range, and on the east by the volcanic rocks of the Cascade Range. The province extends nearly to Coos Bay on the north, and although Tertiary rocks appear in places as far south as the Rogue River and along the coast, they do not extend inland. The province extends south far into northern California, where it is finally terminated by the Coast Range.

Geologic and topographic maps of the region published by the United States Geological Survey are listed as follows:

U. S. Geol. Survey Geol. Atlas, Port Orford Folio (no. 89) 1903.
Roseburg folio (no. 49)
Riddle folio (no. 218)

U. S. G. S. Topographic Quadrangles: Kerby
Grants Pass
Port Orford
Ashland

The U. S. Forest Service Map of the Siskiyou National Forest embraces all but the eastern extension of the region.

The rocks of the Klamath province are the oldest in western Oregon, and are related to those of the Blue Mountains of eastern Oregon and the Sierras of California. Diller discusses them as follows 19/:

"The Klamath Mountains consist of two broad belts of closely related rocks, of which the most ancient are pre-Cambrian crystalline rocks, mica and hornblende schists . . . . In a general way these two belts show broad stretches of Paleozoic rocks, including many areas of slate, sandstones, and limestones apparently of Silurian and Carboniferous age, besides great volumes of Paleozoic volcanic rocks and later intrusive rocks of both acidic and basic types. The acidic types are represented by various forms of granitic and dioritic rocks; the basic intrusive rocks are gabbros and peridotites or serpentines".

It is in the last group of intrusives, which are probably late Jurassic in age, that the chromite deposits are found.

The Klamath province is one of predominantly high relief and rugged character. The differences in elevation between the main rivers (Rogue and Illinois) and the ridge tops is well over 3000 feet. The valleys, with the exception of the upper Illinois and Rogue, are nearly all steep-sided and narrow, being in the stage of topographic youth. Remnants of an old erosion surface (described by Diller 20/ in detail) remain at elevations varying from 3000 to 4000 feet, and are especially prominent in southern Curry county. Remnants of a series of raised sea beaches up to 1500 feet elevation can be seen along the coast, and these correspond to at least three erosional intervals shown in the valley profiles of the larger streams in Curry county.

The greater part of the Klamath province in Oregon is drained by the Rogue river and its tributaries, the largest of which is the Illinois. Southern Curry county is drained by the Chetco, Pistol, Winchuck and Smith rivers. To the north the Coquille, Elk, and Sixes rivers, together with the Umpqua, account for the drainage of the rest of the region.

Three kinds of climate meet in the Klamath region of Oregon, each with a characteristic forest growth. The southern fog belt with its redwood forests joins the northern "rain forest" of Douglas fir, Sitka spruce and Port Orford cedar near the Oregon line; and both pass inland into the dry type of forest, with sugar and ponderosa pine, incense cedar and Douglas fir.

The scenic Roosevelt or Coast highway skirts the west edge of the Klamath region; the Pacific highway touches it on the east along the stretch between Medford and Roseburg. The Redwood Highway traverses it from Grants Pass to Crescent City. The central part of the area in Oregon is accessible only in summer time by forest roads and trails. Lack of adequate transportation facilities has prevented earlier development of a number of the chromite deposits in the region, and in turn, several roads in the region have been built to open up chromite properties.

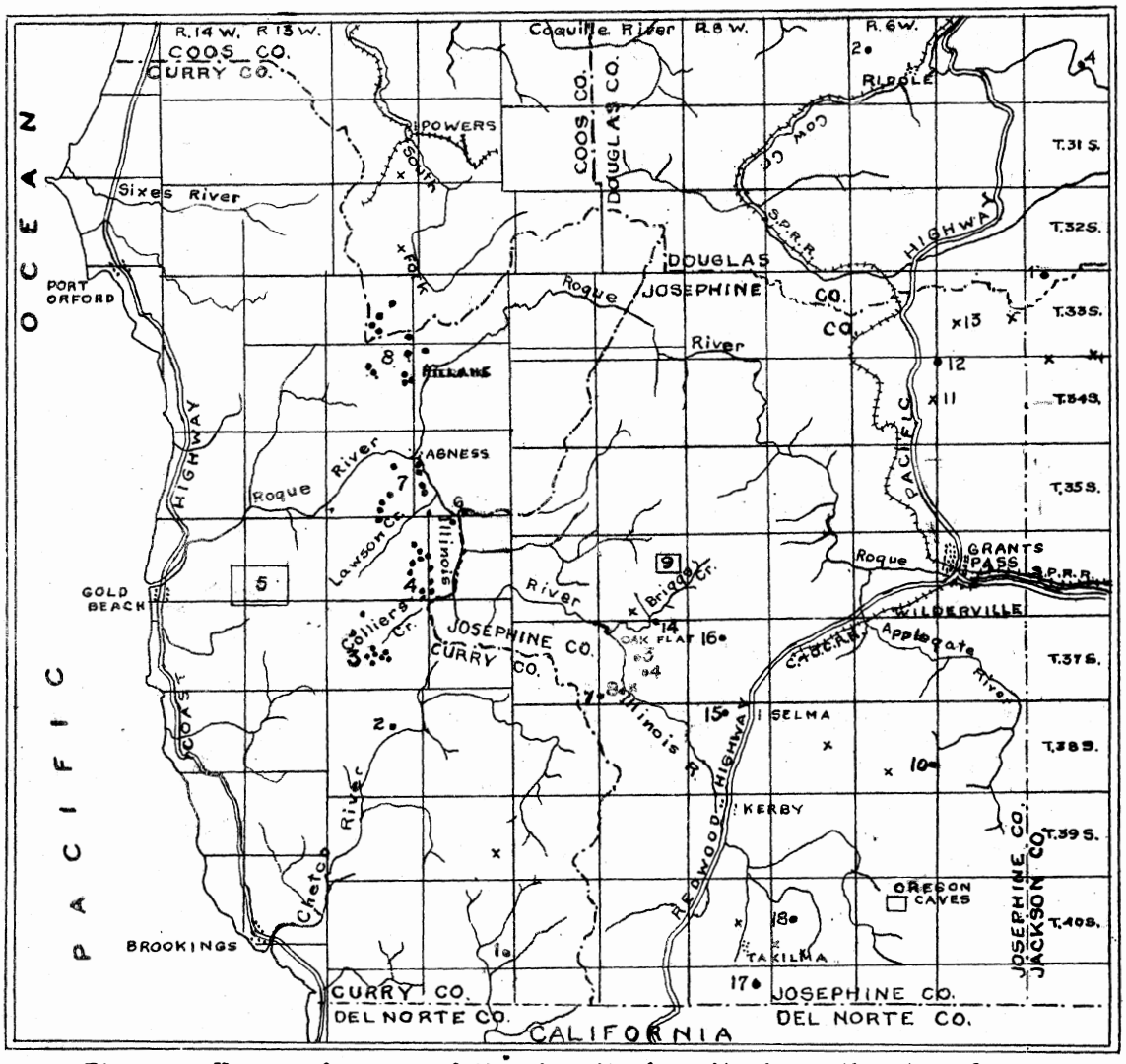


Fig. 2. Key map for some of the chromite deposits in southwestern Oregon. Crosses are deposits not visited.

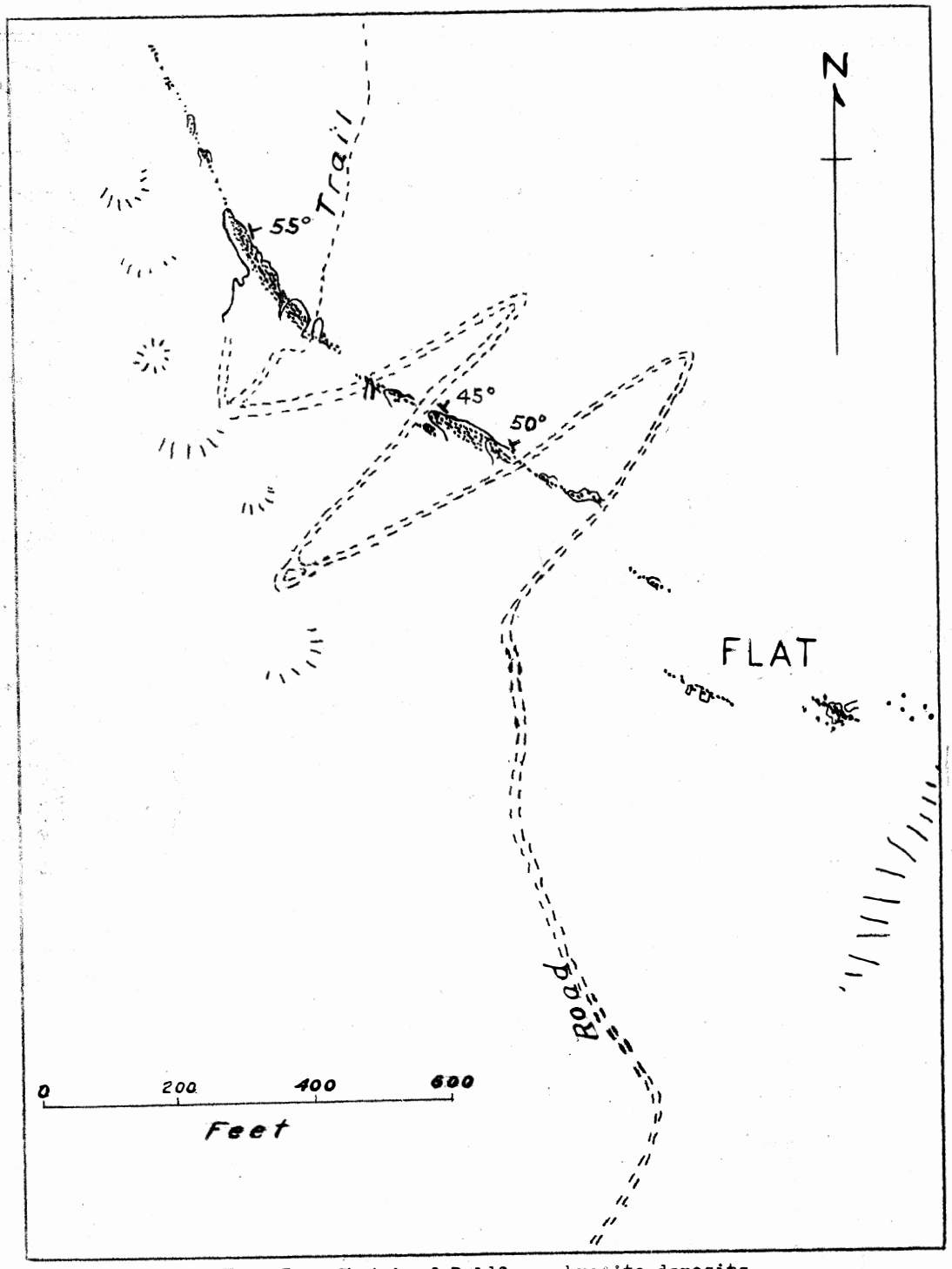


Fig. 3. Sketch of Baldface chromite deposits.

CURRY COUNTY

Baldface (1)

Located in SW¼ sec. 36, T. 40 S., R. 11 W., at end of spur from Wimer road, 2 miles north of Sourdough guard station on Baldface creek, Curry County.

The country rock is a dunite tending to be massive near the zone in which the orebodies lie. There is no green talcy serpentine present (as in other Curry county deposits), and the ore lies in solid and rather coarsely jointed rather than in finely broken rock. The deposits are banded rather than kidney-like, the bodies being very long and narrow, and are offset several times, lying en echelon in the zone. The zone appears to be bounded on the west by an especially resistant ridge of peridotite-dunite which stands up in cliffs and pinnacles. (See fig. 3).

The ore-bearing zone has been developed by pits, cuts, and adits along a horizontal distance of about 1300 feet, and extends another 700 feet southeast to the bed of Baldface creek, and may go farther. The ends of the observed zone are 2000 feet apart, and the difference in their elevation is 800 feet. The zone and the rock structures strike northwest (on an average) and dip 45-50° to the northeast.

The orebodies vary in width from narrow seams up to over 8 feet, the average width as disclosed in the larger cuts being 5 feet. Of this width, perhaps 3 feet is of medium-grade ore and 2 feet of higher grade ore, the latter occurring in bands up to 1 foot wide within the former.

Figures supplied on tonnage shipped in 1918 give 700 tons of unsorted (40-42 per cent chromic oxide) ore; and a small amount of hand-picked (49 per cent chromic oxide) ore. Ore-piles at present total 75-100 tons of unsorted ore.

The Sourdough forest road from the old Wimer road, extends to the deposit. If the bridge over the north fork of Smith river is completed, ore could be trucked to the town of Smith River over a forest road (32 miles) and to Brookings (45 miles). At present the ore can be trucked 33 miles to the Redwood highway at Waldo Junction, and 40 miles to Grants Pass.

Chetco (2)

This deposit lies 1½ miles by trail north of the Chetco river crossing at Tolman's ranch near the center of Twp. 38 S., R. 12 W.

The deposit occurs near the center of the south end of a serpentine band 1000 feet wide, which extends about half a mile north up the ridge. The workings are less than 500 feet from the contact in any direction but north.

The ore appears in four localities lying in a north-trending line. A chromite boulder 2 feet square lies 10 feet from the southern contact of

the serpentine with a thin-bedded sandstone. To the north 300 feet eight trenches and open cuts expose two ore bands which seem to trend northeast. One of them is at least 4 feet wide and 30 feet long, and the other is not so wide or regular, but is possibly 50 feet in length. Near one of these cuts a large boulder of chromite contains crystals of partly resorbed diallage as large as $1\frac{1}{2}$ inches in diameter, completely surrounded by the ore. Two small cuts 50 feet north of here show chromite on their dumps, and 200 feet north the main workings, which consist of eleven cuts of various sizes, expose an ore zone 150 feet long.

The zone trends southeast, and at that end the ore is 15 feet wide and dips 55° N. To the northwest 75 feet, the ore is 8 feet thick, but from here on the main body breaks up into a number of bands and finally splays out in small stringers. Some small float was found 400 feet still farther north.

The ore on this claim is of fair grade, assaying 34 per cent chromic oxide, with a high iron content. The steep Chetco canyon lies between the claim and the Long Ridge Lookout road, whence it is 22 miles to Brookings.

Windy Valley Group (3)

Seven claims east of Windy Valley in T. 37 S., R. 12 W., lie in two north-trending lines, about half a mile apart. Little work has been done, but the orebodies that appear are of fairly high grade, although probably small. Most of them lie in sheared zones in serpentine; four of them lie within a few hundred feet or less of chert and quartzite inclusions in the serpentine, or acidic intrusions.

Game Lake Group (4)

In this area of about 10 square miles, mostly in T. 36 S., R. 12 W., 24 claims were visited and studied, only a few of which are located on fig. 1. One line of claims is a continuation of the north trending line in the Agness group, and two other lines with several deposits in each cross Horsesign and the north fork of Colliers creeks. Many claims in this area were located by following these north trending lines.

The country rock in the southern half of this area is "buckskin" peridotite-porphyry, and the orebodies lie in jointed but relatively unaltered rock. In the north part of the area the deposits are in highly altered serpentine similar to that in the Agness group. Only a few lie near contacts with other rocks. At one locality a string of small orebodies lies parallel to a dike of diallagite, which averages 2 feet wide and 30 feet long, with crystals over $\frac{1}{2}$ inch in diameter.

The extent of the orebodies cannot be determined, as only location work has been done on the claims, but they appear to be rather small, although of fair grade.

Signal Buttes Group (5)

Thirty-five claims, scattered over about 5 square miles around Signal Buttes were visited and several of them studied in detail. These are shown in fig. 4, with section and township location.

The Signal Buttes district is one of considerable geologic complexity. The serpentines were intruded into a series of shales, sandstones, banded cherts and quartzites. The dense highly siliceous members such as cherts and quartzites seem to have been left relatively unaltered; sandstones were replaced in all degrees, and shaly sediments seem to have been more or less completely replaced over large areas with only occasional remaining patches, now altered to schist. The "buttes" themselves are later volcanic plugs and great dikes, which came up along the rectangular lines of weakness which are prominent in the area, and they now stand up as a number of pinnacles and bosses.

Nearly all the orebodies lie in wide zones of more or less completely altered serpentine, which appears as a soft, finely divided and flaky (or clayey when wet) mass, probably in great part talc, chlorite, and various serpentine minerals. Within these zones are stringers of sandy chromite, which occasionally widen to form the ore bodies. Chromite grains also are often scattered through the zones. Magnesite and quartz lenses and stringers of secondary origin are not uncommon.

These zones may be traced by the strings of small chromite float that weathers out along them. South of Signal Butte, the south-trending ridges are cut by east-west trending soft zones. These soft zones have eroded to form a series of the south-trending ridges. The zones are so wide that the more resistant serpentine often stands as pinnacles. These pinnacles occur in regular lines, parallel to the zones, in several areas. North-south trends of the lines of float are prominent in the area around Signal Butte, as well as farther north. To the northeast the lines run east-west.

A vertical section through one prospect cut shows bands of harder serpentine (1) in the altered zone. (See fig. 5-a). Areas of a light green, flaky serpentine with numerous small soft white pellets of magnesite or some other carbonate are present here and in other localities. (2). The chromite occurs as narrow stringers and small kidneys (3) in this cut and elsewhere, all lying in the altered zone material.

In several places banded green chert seems to form the hanging wall of the altered zone, and can be traced for several hundred feet. Its contact with the peridotite grades through a zone of magnesite, and the latter penetrates the serpentine, in a dense network of thin stringers and filaments, for several feet.

The orebodies south of the Butte are uniformly small, rarely being over 5 feet long and 2 feet wide, and not very closely spaced. The assays show about 50% chromic oxide.

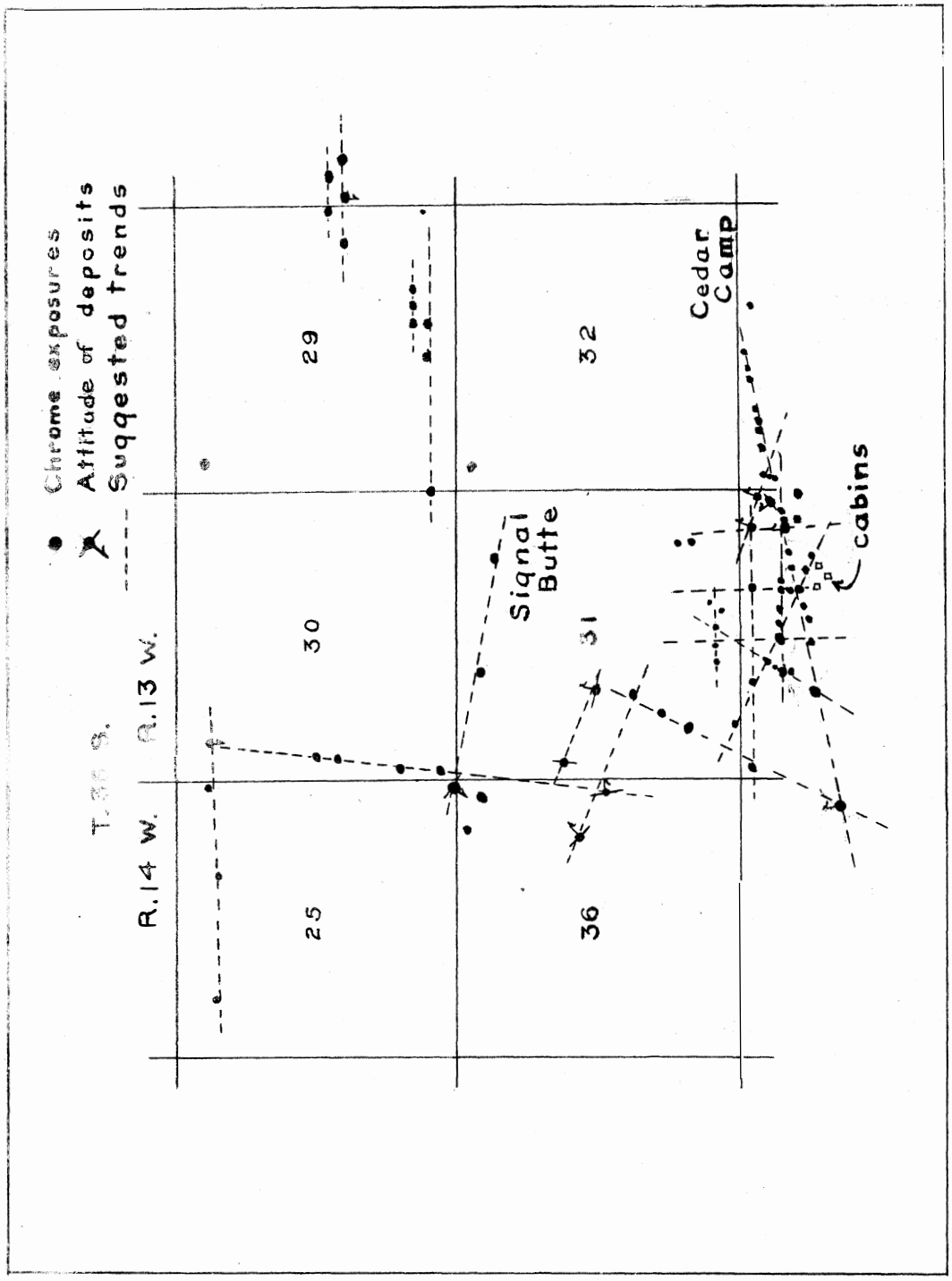
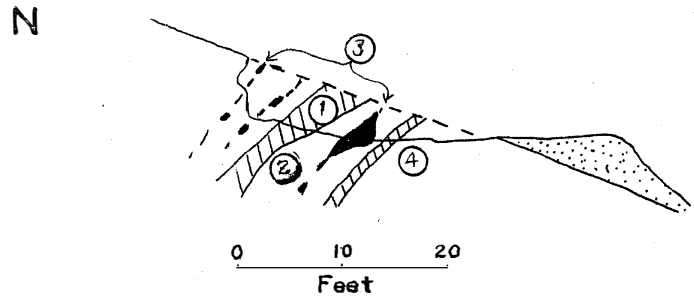
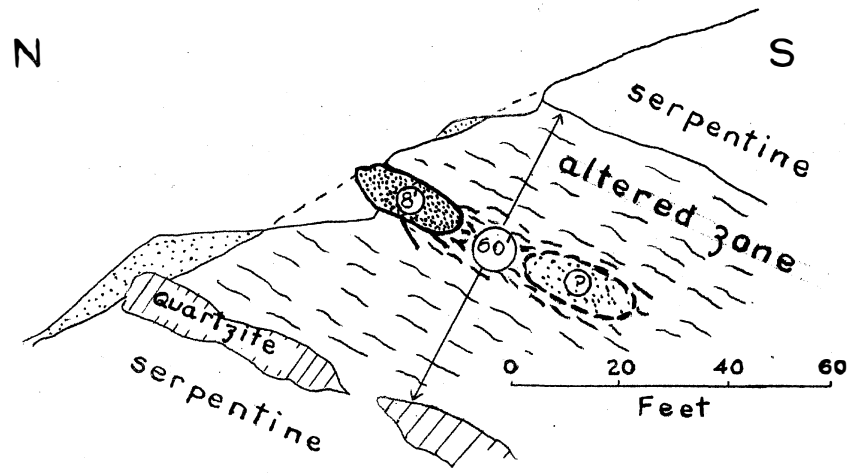


Fig. 4. Chromite deposits near Signal Butte, Curry county. Showing attitudes and trends of orebodies.



A



B

Fig. 5. North-south sections at Signal Butte.
A. Pine Flat.
(1) Massive serpentine
(2) Magnesite lens
(3) Chromite seams and small bodies
(4) Altered zone
B. Section corner 25-36, 30-31.
Section taken through 8-foot high-grade orebody.

One deposit had an orebody 20 feet long, 8 feet thick, and 15 feet on the dip. It strikes N. 70° W., and dips 30° S. The body is rounded at the edges, and lies near the center of a zone of soft green talcose serpentine, with iron-stained seams and chromite grains scattered through its entire width of 60 feet. (See fig. 5-b). A discontinuous 10-foot ledge of quartzite forms the footwall of the zone 30 feet below.

The ore from eleven of the deposits in the Signal Buttes area averaged over 50 per cent chromic oxide; from 14 to 18 per cent iron protoxide; and from 3 to 9 per cent silica.

Indigo Claims (6)

One of these claims lies on the point between Indigo creek and the Illinois river, and the other lies directly south on the west bank of the river, in T. 36 S., R. 11 W. Both are within a few hundred feet of the contact of the serpentine with sandstone and gabbro to the east. A small high-grade body was mined from the north deposit, which lay in a sheared green serpentine. A narrow quartz dike lies above it on the top of the ridge. The southern deposit consists of a small kidney 5 feet thick and at least 5 feet long, striking east and dipping 50° S. Lenses of white siliceous rock also appear above and can be traced for 500 feet south. The ore from these properties assayed 35 and 39 per cent chromic oxide.

Agness Group (7)

Nine claims south of Agness and north of Lawson creek were visited. Four of these lie in a line trending almost south from Agness and continuing into the Game Lake group. Four others make up a similar line four miles long, lying about two and a half miles to the west of the first. These lie in T. 35 and 36 S., and R. 11 and 12 W.

All the deposits appear in zones of sheared green talcose serpentine. Irregular areas of dark brown serpentine with a pitchy lustre, and thin lenses of white siliceous magnesite are frequently found near the deposits. In five of the localities the contact of the serpentine with greenstone, schist, sandstone, or dacite porphyry was within 200 yards of the deposits. At two localities the chromite, besides occurring in small high-grade bodies was found in narrow seams in the zone, as well as disseminated through more massive porcellaneous serpentine nearby.

Illahe Group (8)

Eleven claims were visited in this area. They lie within the north-trending narrow bands of serpentine mapped by Diller 21/ to the west and northwest of Illahe.

The country rock is either a sheared green serpentine in the narrow mapped areas, or yellow weathering "buckskin" peridotite-porphyry in the wider areas, such as the one north of Red Mountain.

On claims where ore was found in place, it lay in north-trending zones of soft talcose serpentine, in the form of small lentil-shaped bodies, not over 2 feet thick and 8 feet long. One exception consisted of a soft friable ore in a band 15 feet long and 2 feet thick. Most of the claims showed only float of high-grade ore, but in a few places there was also low-grade banded ore. An assay of ore from one property gave 48 per cent chromic oxide.

JOSEPHINE COUNTY

Elkhorn Creek (9)

There are two deposits east of what is known as the Briggs creek chrome deposit: (1) The Nigger, lying north of the old chrome trail and (2) Rose City, near the corner common to Secs. 13-14-23-24, both in T. 36 S., R. 9 W., Briggs Creek Mining District, Josephine county.

1. Nigger. An open cut, about 15 feet deep, extends for 30 feet into the rather steep hillside, with a tunnel (now caved) continuing in a N. 50° W. direction, probably not for any great distance. The banded metaperidotite appears to strike N. 85° W., dipping 37° N. The contact with the older metamorphic rocks (quartzites and schists) lies only a hundred feet or so downhill to the east. Some chlorite schist float nearby suggests inclusions of this older rock within the peridotite. A smaller cut 20 feet above the first shows rock with the same attitude, and a few pounds of float ore.

This deposit is said to be the only one in the Briggs creek area from which chromite was actually shipped in any quantity. It is said that about five or six carloads (250-300 tons) of ore were taken from the large cut and tunnel, and packed by mule to the road, over five miles away. Now only a few hundred pounds of loose chromite remain. It is probable, however, that the deposit is not exhausted. The ore is said to have averaged just above 47 per cent chromic oxide.

2. Rose City. One shallow location cut has exposed a face of ore in the bottom, said to be (it was filled with snow when visited) limited on only one side of the cut, the boundary cutting across the bottom at an angle, N. 80° E. Only about 200 pounds of ore have been taken out. Heavy float (boulders from 6 inches to 2 feet in diameter) extends for 200 feet to the east, and for 100 feet to the west, perhaps as much as one ton in all. It is said that smaller float extends further east down the hill for another quarter mile.

The ore appears to be of good grade, and assays 45.87 per cent chromic oxide.

It is about one mile down a very steep trail to Briggs creek, and thence one and a half miles to the forest road at the Ferren Ranger station. By forest road it is about 16 miles to the Redwood highway at the foot of Hayes Hill (Butcher Knife creek) and thence about 14 miles to Grants Pass. The total is about 41 miles from claim to town.

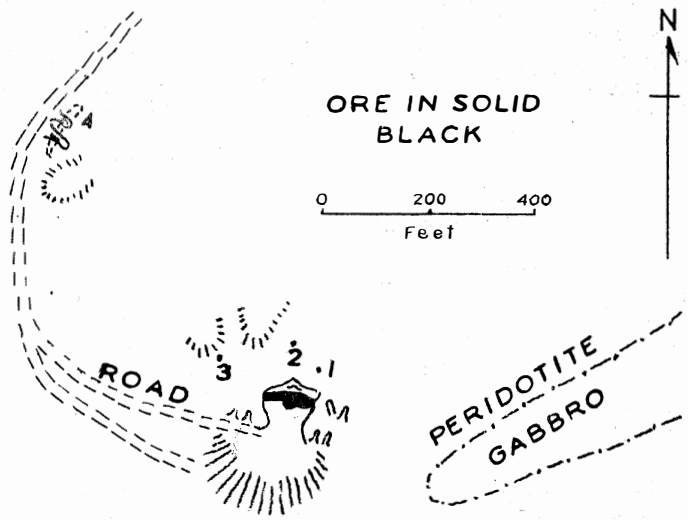


Fig. 6. Sketch of Iron King workings and orebodies (see p. 55)

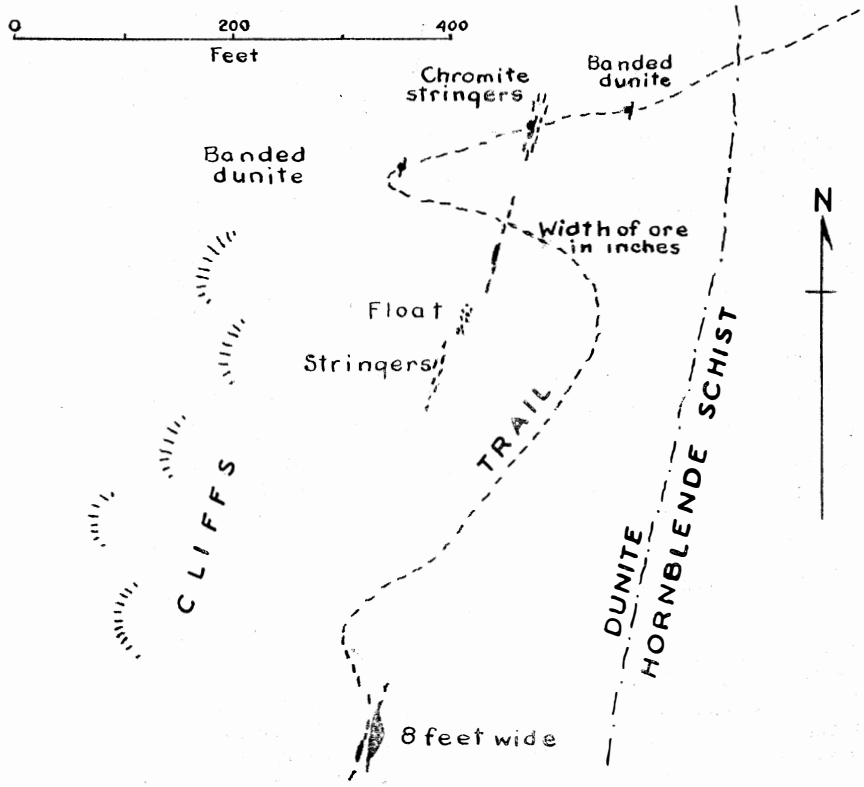


Fig. 7. Sketch of Horse Mountain chromite deposits.

Horse Mountain (14)

Located near the center of NW¼ of Sec. 3, T. 37 S., R. 9 W. The deposits lie at elevations of 2500 to 2700 feet on the northwest ridge of Horse mountain, east of Briggs creek, Josephine county.

The chromite lies in narrow bands, stringers, and fatter lenses occurring along a fairly narrow zone for 600 feet, in a country rock of medium to fine-grained banded dunite which strikes generally north-south, varying from N. 15° E. on the lower (northern) part of the zone to N. 8° W. on the upper (southern) portion. The narrow stringers and lenses within the zone occur en echelon, being offset progressively as one goes southwards.

The zone lies approximately parallel to, and 100 to 200 feet from, the contact of the dunite intrusive with the older schists lying to the east. This contact governs the course of a small creek, and outlines the ridge upon which the zone lies. To the west the ridge drops off steeply in a series of cliffs to Briggs creek, 1000 feet below.

The ore appearing in all the chromite outcrops was low-grade, disseminated in character, and soft. A few portions towards the center of the larger bodies are more compact with less gangue, but the average is perhaps not over 35 per cent chromic oxide. The characteristic occurrence in this vicinity seems to be in narrow stringers, which vary from the center, where the chromite grains are fairly well-packed, outwards to the edge with more and more olivine being included and the individual grains becoming more and more sparse.

Although the Briggs creek chrome bunkers and road are only 3/4 of a mile to the north, and lie at about the same elevation, the steep-sided 1000-foot valley of Swede creek lies between. From the bunkers to the highway it is about 12 miles, thence 14 miles to Grants Pass.

Illinois River (3)

Located near the center of N½ sec. 21, T. 37 S., R. 9 W., on Illinois river road, Josephine county.

At the present time the underground workings are covered by a large slide which has broken down since cessation of wartime operations and completely masked the several drifts which intersected the orebodies. According to Ed Cox, who was in charge of operations for the California Chromite Company during the war, there were three kidneys (now almost completely mined out) which yielded over 5000 tons of ore, averaging 47 per cent chromic oxide.

Of this Diller says: 22/

> "The largest body of ore found in the county was on Illinois river (3), and the mining of this body was begun in 1917 and completed in 1918, yielding a total of about 4,600 tons of shipping ore. The orebody was made up of a number of parallel lenses, one of which was 65 feet in length N. 10° W. and 20 feet thick and dipped

about 45° E. The ore generally contained 50 per cent or more of chromic oxide, and but little lower grade ore was found. No purple chrome chlorites or green chrome garnet, such as are commonly seen elsewhere, was noted at this locality. The country rock, dunite, is completely changed to serpentine."

The ore zone extends downward to the river and across to the other side, but the croppings are small.

The mine is about 18 miles by road from Selma which is 22 miles from Grants Pass.

Jack Shade (4)

Located in Section 21, T. 37 S., R. 9 W., Josephine county.

The country rock is a massive serpentine, the chromite-bearing zone lying between two hard outstanding cliffed ridges. The deposit lies 1700 feet above the Illinois river, within 400 feet of the top of the mountain, on an extremely steep slope.

The ore crops at the surface in several small irregular patches and bands, the largest 4 feet long and 2 feet wide, whose general trend is E-W, dipping about 20° S. They are cut and offset by several steeply dipping faults. A 40-foot drift has intersected the ore about 25 feet below the surface, and perhaps 150 tons have been removed, leaving at least that much in place. The face of the stope at the end of the drift is nearly all ore, which measures 20 feet wide by 8 feet high, with the same attitude as at the surface.

The mine is located practically on a cliff face; during the war the ore was chuted down 200 feet to the end of a sled road a mile in length to the main river road, and trucked 16 miles to Selma on the Redwood Highway, which is 22 miles from Grants Pass.

Daley Creek (7)

The Black Bear and Chrome King claims are at an elevation of about 3000 feet; near the center of E½ sec. 36, T. 37 S., R. 10 W., 1½ miles northeast of Pearsall Peak, Josephine county.

The country rock in this area is a peridotite porphyry; and north-east trending ore zones are recognizable by a deeper red color of the overlying residual soil. In these zones a green non-porphyritic dunitic rock often appears. Near the kidneys small lentils and stringers of low-grade ore from ½ to 3 inches wide commonly extend outwards for short distances from the kidneys. The rock often can be seen to contain minute chromite crystals.

Chrome King Claim. (800 feet to the southwest of the Little Bear claim and 200 feet higher in elevation). The ore-bearing zone on the Chrome King seems to be 30-50 feet wide (judging by the red soil, abundant chromite float, the physiographic saddle and flat) and extends N. 70° E., dipping

steeply south. Some float was found over a distance of 200 feet, and it is thickly scattered for at least half that distance along the zone. A narrow (4-6 feet wide) ledge of hornblende schist appears to parallel the zone on its south side for part of its extent, trending N. 65° E.

In this area as elsewhere, the kidneys seem to lie more or less at right angles to the zones. At present the kidney as exposed in one side of the badly caved pit about 10 feet below the surface is 4 feet wide and seems to strike N. 60° W. and dip 80° S. Mr. Cox says that the pit originally was 20 feet deep (and at least 6 feet wide and 10 feet long) and that at that depth the kidney, which widened downwards, was 8 feet in width. The ore is medium in appearance, and during the time since it was mined has slacked down and become very soft and friable, so that at present it is mostly in small pieces or sand. It assays 43.5 per cent chromic oxide.

Little Bear Claim. At present no ore shows in the pit, now caved in, but which was originally about 12 feet deep, 10 feet long, and 6 feet wide. The ore removed seems to have come from a kidney striking N. 65° W. and dipping 80° N., which was about 2 feet wide. Ed Cox, one of the owners, says that it widened downwards, and when operation ceased it was 2½ feet wide and at least 8 feet long in the bottom of the 12-foot pit. The ore is fair in appearance, with only a small amount of interstitial rocky material, and fairly coarse crystallization. This ore has stood up under weathering, and after 18 years exposure is still for the most part in solid blocks and chunks. It assays 40 per cent chromic oxide.

Unclaimed locality 600 feet to the northeast of the Chrome King claim along zone, and 450 feet due south of the Little Bear claim. At this undeveloped spot several large boulders of medium grade ore lie on the ridge-top, just north of a ledge of hornblende schist which strikes N. 60 E.

The claims lie a little over two miles and 2000 feet in elevation from the nearest road, about half of this two miles being over steep and rugged terrain. From the Illinois river crossing it is about 10 miles by good forest road to Selma, and thence 22 miles by paved highway to Grants Pass; a haul in all of about 35 miles.

Squaw Creek (15)

Located one-half mile up Squaw creek, north of Illinois river road, about two miles west of Selma, near the center of Sec. 4, T. 38 S., R. 8 W., Josephine county.

The deposit lies in diallage-peridotite porphyry, composed of crystals averaging 2-3 mm. in diameter, in a fine-grained olivine matrix. Locally the rock has been highly altered, both irregularly and along east-west areas, into sheared and broken green shiny serpentine. Elsewhere in other areas it apparently grades into dunite.

The chromite deposit lies within a sheared, faulted, and altered zone at least 500 feet wide; and the orebodies themselves are broken and displaced. The ore appears as various sized lenses within the more or less serpentinized peridotite. The centers of the broken blocks of country rock

often remain unaltered, but their rims are of dense, porcellaneous serpentine. The cross-section of one small lens of chromite exposed in the cut is 6 inches wide and 2 feet long, dipping to the east, and striking north-south. A larger body is exposed on three sides, apparently being 30 inches thick, and having minimum other dimensions of 6 by 7 feet. Its lower surface strikes north-south and dips 30° E. Little can be told from structure, due to the broken character of the rock.

These two deposits appear in place near the end of a 50-foot open cut, which extends northwest into the hillside, and probably was dug to follow a "lead", or stringer, of chromite. It is over 10 feet deep at the end, coming in under the larger ore-body. Another shallow ditch runs N. 70° W. for 50 feet, 20 feet south of the first, and a third cut lies 300 feet down the hill to the southeast. No ore appears in either of these.

Although the ore is of fair appearing grade in uncontaminated pieces, it is usually somewhat mixed with and frozen to associated serpentine, which would make cobbing necessary. It also varies from compact near the center to disseminated at the edges of the bodies.

Charles Owen (17)

Located in the N½ sec. 11, T. 41 S., R. 5 E., two miles south of Takilma.

The soil mantle is very heavy, and both drifts, dug during the war, have collapsed so that all data are taken from surface indications, or by word of mouth from Mr. Owen.

The north-south trending ore-bearing zone of sheared serpentine is about 35 feet wide, bounded by outcrops of massive gabbroid rock on both sides. It lies on a south slope, near the top of the east-west ridge. A change in the vegetation 200 feet north of the tunnel entrances on the level ridgetop also apparently marks the edge of the serpentine in that direction.

According to Mr. Owen, most of the ore was taken from the drift driven along the east wall of the zone, following along a chromite seam located by a small ore outcrop. Three kidneys, each larger than the last, were taken out as the drift progressed over a distance of about 75 feet; the last giving about 50 tons of ore.

Another tunnel driven in at a level ten feet below and twenty feet to the west of the first, intersected a kidney at thirty feet, at a point only ten feet from the end of the first tunnel.

No estimate of reserve can be made, as no ore outcrops and both drifts are closed. C. Owen says that when the mine was closed down they were working in solid chromite in the east drift, and the west drift had just reached a solid face of ore. One hundred and fifty tons were said to have been taken out by that time, thirty tons of which remained piled at Takilma and was taken out in 1936.

A sled road leads from the deposit one mile to the main road; thence

two miles to Takilma and six to Redwood Highway at Waldo Junction; thence 40 miles to Grants Pass.

Chollard (18)

The main workings lie at an elevation of about 2300 feet, on the southwest bank of Sowell creek, across from the Kerby Queen mine, in Sec. 17, T. 40 S., R. 7 W.

The deposits lie within a wide band of dense fine-grained serpentine and dunite, the borders of which are over a fourth of a mile to the east, and west from the main workings. Occasional variation of composition (such as magnesitic bands) within the serpentine indicates that the formational dips are about 45° to the east, with a strike approximately north-south. The main orebody lies upon a gently north-sloping ridge, at its upper junction with the larger main ridge to the west. On the east there is a steep drop of about 200 feet to the bed of Sowell creek. The chromite-bearing zone seems to vary in width from a few feet to as much as 30 feet.

The previous somewhat extensive operations seem to have been confined to a north-south lenticular area at least 80 feet long with a maximum width of 30 feet. The opencut and glory hole workings are now 15 to 30 feet in depth. Unreliable indications are that the orebody was in the shape of a north-south elongated chute, plunging to the north or northeast.

About 1600 cubic yards of material (rock and ore) have been removed from the two large pits. They were tapped from the north by a tunnel, driven at a 20 to 30 foot level. Another 200-foot tunnel was driven from the northeast, at a depth of at least 40 feet below the first. The pits were in part stoped out from this level.

The narrow lentils or bands of high-grade ore run as high as 49.44 per cent chromic oxide when analyzed, but apparently these compose only a small part of the ore-bearing zone, within which an average cross-cut sample might run only 10 per cent.

Apparently when the mine was previously in operation, the procedure was to run the ore through a jaw crusher which operated at the mouth of the lower tunnel, and then chute the ½ to 1 inch material 200 feet down the hill to bins at the mill just above the creek, where it was ground and concentrated. The method of concentration could not be told from what evidence still remains, but a sample of the concentrates assayed 45.51 per cent chromic oxide.

The concentrates were formerly trucked down the creek bed about one mile and thence another mile by third-grade road to graveled county road and six miles on this to the paved highway near Cave Junction, 31 miles from Grants Pass. The total haul is 39 miles.

Esterly Chromite Mine.

Located near the center of the N½ of section 22, T. 40 S., R. 8 W., Josephine county. Elevation 1600 feet.

The main workings lie on a gentle south slope at the north edge of the Esterly swamp.

The country rock is composed of irregularly north-south trending ledges of more massive and resistant peridotite porphyry alternating near the deposit with at least two zones of more highly serpentinized and sheared rock. This terrane slopes gently southward under the overlapping gravels of the Esterly placer mine. The workings lie in a serpentine-talc-magnesite zone from 6 to 10 feet wide within one of these serpentinized areas. Numerous kidney shaped bodies of white magnesite averaging perhaps 2 feet in diameter are exposed in both walls of the main cut.

The ore-bearing zone may be traced N. 20° E. up the hill for 1000 feet by means of these lenses of magnesite and the higher degree of serpentinization of the country rock.

The main workings are 100 feet long, striking N. 20° to 30° E. Two ore bodies appear to have been mined, the southern (smaller) having been bounded on the east by a well defined vertical fault trending N. 30° E. At the present time the pits are filled with water, but they appear to be of considerable depth. It is said that the ore was mined down to 40 feet in depth, and not bottomed. Very little ore can be seen in place.

A shallow cut in green sheared serpentine 100 feet north up the hill shows no ore.

Three hundred and fifty feet north of the main workings a 30-foot north-south cut shows some magnesite lenses but no ore in place. Several shallow prospecting ditches apparently failed to pick up any ore here.

Eight hundred and twenty five feet north of the main workings (175 feet from the top of the ridge) about half a tone of ore has been mined from narrow lenses, only a small one-inch stringer now appearing in place.

If the ore-bearing zone has an eastward dip, all these workings would lie accurately upon a N. 20° E. strike.

The ore varies from the predominantly spotted and nodular medium grade variety to a small amount of dense massive high grade with a metallic lustre on fresh surfaces.

The property is ½ mile west of the market road (old highway) at a point 6 miles south of Cave Junction, which is 33 miles from Grants Pass, south on the Redwood Highway.

Mungers Creek (10)

Three claims, named Silver Tip 1, 2, and 3, lie at an elevation of 3700 feet, near the center of W½ sec. 25, T. 38 S., R. 6 W.

This deposit lies in a north-south band of serpentine, bounded on both sides by older schists, sandstones and limestones. The band is at least half a mile wide and the rock is a much sheared non-porphyritic serpentine,

in which fine disseminated chromite is not infrequently found. The ore occurs principally in two areas, an eastern and western, lying about 400 feet apart. These will be discussed separately.

Eastern: Two and perhaps three high-grade ore-bands have here been mined by open cuts for a distance of perhaps 200 feet, to an average depth of 10 feet and a maximum of 20 feet. The bands strike N. 30° to N. 40° E., and dip from 30° to 60° SE. They are more or less discontinuous and lenticular at their widest points; those that could be measured were 18 to 30 inches in width. An average continuous width would be about 6-8 inches. The more or less parallel bands are about 3-4 feet apart.

Western: Two ore-bands about 8 feet apart have here been mined by tunnel and open cut for a distance of 50 feet and a depth of 10-20 feet. These bands strike N. 15° E., dip 75° E., average 1-4 feet wide and consist of smaller sheared irregular lenticular bodies of ore (40%) lying in a matrix (60%) of broken serpentine.

Another ore-body lies 100 feet to the N. 40° E. This body strikes N. 50° E. and apparently is vertical. It is over 20 feet long as exposed, and 12-20 inches wide.

From the end of the road at the deposits, it is four miles to the valley by forest road, and from there (near Williams) 22 miles to Grants Pass, a total of about 26 miles.

Graves Creek (12)

Located in the NW¼ sec. 6, T. 34 S., R. 5 W., Josephine county.

The deposits lie on the east slope of a south-trending ridge at an elevation of about 3000 feet, perhaps 200 feet below the top of the ridge. The country rock is an extremely hard serpentine, which, although broken somewhat by shear planes, still is very tough, and stringers of green pyroxene are not uncommon.

Several parallel lenses of ore strike north and dip about 45° W. Two of these lenses show in cuts. The soil is 1-2 feet thick and may easily cover other bodies.

During the wartime, ore was apparently taken from a crosscut reached by two short adits, as well as from the surface cuts. The tunnel entrances are now nearly hidden, and their location can only be inferred. Three new cuts lie about 6 feet above the old workings. At one place a cut breaks into the old subterranean crosscut, but the latter was not entered.

Fifteen tons of ore have been taken from the new cut and lie piled on the dump. A still more recent slide has covered the ore face in one cut, but has exposed a kidney which is at least 5 feet long and 1-2 feet wide. This kidney was the only ore seen in place on the property.

The ore is very hard, dense, and tough. It is coarse-grained, and

assays 35 per cent chromic oxide. It breaks cleanly from the wall rock.

The deposit lies about 1½ miles by sled road and 2 miles by graveled road from the Pacific Highway at Graves Creek (18 miles from Grants Pass, or 6 miles from the railroad at Leland), a total distance of only 22 miles from Grants Pass.

DOUGLAS COUNTY

Starveout Creek (1)

Located near the center of W½ of sec. 5, T. 33 S., R. 4 W., on Quartzmill Peak.

The country rock is a dark greenish black serpentine, highly sheared and broken, and shot through with veins of magnesite and light-colored pyroxene. The largest diggings lie at the southern end of an indistinct ore-bearing zone perhaps 2000 feet long, extending N. 20° E. This zone is covered by the first two claims, Black Boy and June Bug. At the southernmost end, two large open cuts are found fifty feet apart, on the crest of a steep ridge, at about 4000 feet elevation on the east slope of Quartzmill peak. Only a small amount of ore appears in place in these cuts, which are about 100 feet long, 20 feet wide, and 30 feet or more deep in the back ends. What ore does appear lies in irregular much-sheared patches. The highly disturbed nature of the rock indicates that the ore deposit must be much adulterated by rock material and irregular in outline.

Smaller cuts show some ore cropping for 200 feet to the north; and 2000 feet still farther north several ditches cutting across the top of an east-west ridge expose low-grade (10-20 per cent chromic oxide) disseminations and fine streaks of ore, also running N. 10° E.

On the third claim, Grey Boy, which lies a half mile to the east and 500 feet lower down the hill, another large open cut exposes ore in place in its face at least 3 feet wide, the other dimensions not being discernible. A rather large ore pile also lies at this cut. Other conditions are similar to those above, the kidney here apparently striking N and S, and dipping 45° E.

The large amount of development work (including old chutes, tracks, dump piles, etc.) suggest that considerable tonnage of ore was mined from this deposit, perhaps as much as several thousand tons. Some ore was shipped in the fall of 1937.

Ore still appears in the cut face on the lower claim, and 50 to 75 tons of ore lie mined and piled.

The ore is almost entirely of a medium grade which may not run much over 40 per cent chromic oxide on the upper claims (where it is of the soft chocolatey fine-grained variety), or 35 per cent on the lower claim.

A steep, third-class road about 2½ miles long leads down the mountain 2000 feet to Starveout Creek. From there it is six miles by logging road

to the Pacific Highway at Azalea, and thence 12 miles to the railroad at Glendale, a total of about 21 miles from mine to railroad.

Days Creek (4)

Located in the center of Sec. 22, T. 30 S., R. 4 W., on the Umpqua river.

A chrome-bearing zone lies within 50 feet of the eastern contact of a band of green, non-porphyritic, highly sheared and altered serpentine which trends somewhat east of north. The main outcrop of ore consists of a kidney striking E-W and dipping 70° to the south. It is 2 feet wide, at least 8 feet long and of uncertain depth, these dimensions not being completely exposed by the diggings. Thirty feet below this cut to the S. 35° E., chromite is exposed in another cut, about 200 to 300 pounds having been removed. The cut is caved, and at present no ore shows in place.

The ore in both cuts appears low-grade, but a sample assayed 45.84 percent chromic oxide. It includes considerable rock material and is much sheared and broken.

The outcrop lies about 200 yards north of (and 300 feet above) the Umpqua river road, which is a good secondary highway, at a point about 13 miles from the railroad at Riddle, Oregon.

OTHER DEPOSITS NOT VISITED.

A number of chromite deposits in southwestern Oregon were not visited by the writer. Twelve of those mentioned by Diller 23/ have not been reported upon, and are listed as follows:

Coos County:
1. Black Sand.
2. White Rock.

Douglas County:
1. Oregon Nickel Mining Co.
2. Cow Creek.

Curry County:
2. C. & O. Lumber Co.
Meservey.

Jackson County:
1. Applegate group.
2. Horseshoe group.
3. Stray Dog.
4. J. H. Pease

Josephine County:
5. J. B. Harvey
6. Logan.

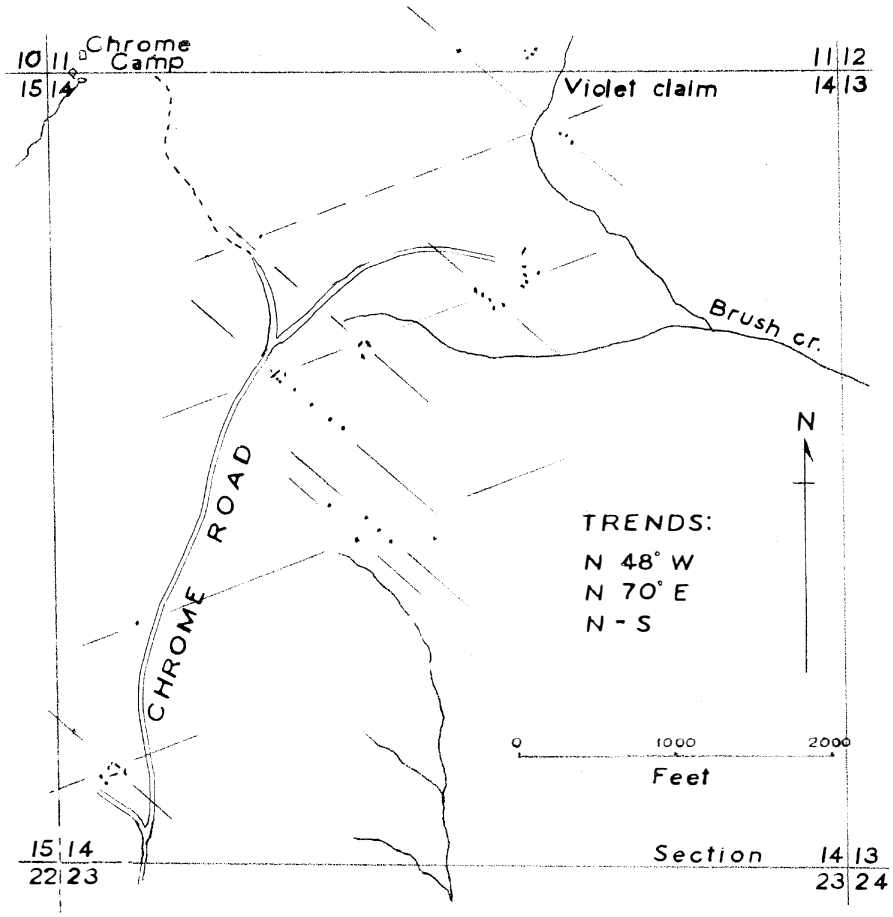


Fig. 6a. Sketch of Briggs Creek Chromite Deposits, showing trends of ore-zones.

Sordy's, Briggs Creek (9)

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(not in proper position
(in text.

These are located along the summit of "Chrome Ridge", west of Briggs Creek, mostly in section 14, T.36 S., R.9 W., Josephine county.

Deposits in eleven localities, with a total of about 40 openings (tunnels, open cuts, pits) were visited. All of these deposits lie upon the surface of or just below the rim of the plateau, with averages 4000 feet in elevation, rising steeply from an average drainage level of about 200 feet. All the deposits visited lie within section 14.

The country rock of the region is the usual "buckskin" or peridotite-porphyry, which commonly varies, especially near the orebodies, to a dense dunite, and more rarely to the non-porphyritic equigranular peridotite or the equigranular pyroxenite.

Serpentinization is present occasionally, but it appears that in this region it is more or less linear in its extent rather than regional, being restricted to zones of movement or shearing.

As can be seen in fig. 8-a (and emphasized by the lines) the ore croppings fall into three main trends. The first and most definite lies about N. 48° W., the alignment of the bodies in five of the areas studied (3, 4, 5, 9, 10) being on this order.

The second and less distinct alignment is N. 70° E., which represents a trend from deposit to deposit (6-0, 2-3-4-5, 10-11) and the third alignment is even less distinct in a N. 10° E. direction (2-8, 3-7, 4-10, 5-6, 11-12). This last corresponds with the trend of the peridotite-schist contact, which lies half a mile to the east, and dips to the west.

Structures in the region are shown by distinct flow-banding in the peridotite, common but not always present, and by banding in some of the low-grade ores. These trend in all directions, but those in the 80° of azimuth around north are most frequent. These usually have dips from 60 to vertical, more commonly towards the east.

In this region jointing is on a rather large scale of several feet, and apparently quite irregular. Locally (especially when complicated with faulting movements) it grades through highly broken rock into true shear zones.

Faulting is present in most of the openings examined, although not to a prominent degree. Those noted all strike between N. 40° and 75° W. and dip 60-80° N.

The orebodies are of two distinct types, of low-grade (10-30 per cent chromic oxide) disseminations, (often more or less distinctly banded), which sometimes grade into deposits of fair grade (30-35 per cent), and small

lens-shaped kidneys of high-grade ore (above 35 per cent and averaging 40.37 per cent chromic oxide, according to a list of 23 assays taken in 1918 and furnished by the owner). Quite often small kidneys of high-grade occur within deposits of the predominant low grade.

The low grade usually occurs disseminated in fine-grained to aphanitic dunite, in bands or streaks of what might be called "birdseye" ore. In the largest deposit the zone is 6 to 10 feet in width, and at least 190 feet long, depth undetermined. Some of the ore here is of fair grade, with a few high-grade bodies. Other deposits are of smaller size, not opened up or developed, and are also usually more irregular and discontinuous, with the banding broken, with some good grade ore showings.

What is said to be the largest showing of high-grade ore, described by the owner as "an open cut 5 feet deep with high grade full width and still going down", lies one mile north by trail and was not visited for lack of time.

The genetic and practical significance of the trends or alignments of the orebodies might be interpreted as follows:

1. The north trend is primary, and represents the original schlieren formed during the intrusion of the liquid rock.

2. The N. 48° W. trend was established during the late or deuteric stages of the cooling, when viscous chromite was squeezed up from the basal contact (below and to the east) along major strain lines delineated by this trend. It may be that the set of N. 70° E. cross fractures was established at much the same time, and helped govern the emplacement of ore at the intersections with the first trend.

3. In development of individual prospects, the trend lines (especially N. 48° W.) must be kept in mind as the ore is followed down.

Most of the deposits lie within a few hundred yards of the "chrome road", built by Harry Sordy during the war, and shown on Siskiyou forest map, in T.36 S., R.9 W., Josephine county, as it passes through section 14. This three miles of road was built to connect with the mile-long cable across the Briggs creek canyon, 2000 feet deep and 5000 feet wide, in sections 26 and 35. The cable was used for carrying over the trucks and for getting out one car of ore before the armistice of 1918. From the old bunkers at the south end of the cable, it is 13 miles by forest road to the highway at the foot of Hayes Hill, and thence 16 miles to Grants Pass.

It is four miles by trail on steep switchbacks to the end of the forest road at Ferren Guard station on Briggs creek, and thence 27 miles to the highway at the foot of Hayes hill.

It is three to four miles by trail north along the ridge to the end of the Galice creek forest road at Lone Tree mountain; and thence six miles to Galice, and thirteen miles by gravel highway to the railroad at Merlin.

Thus, the property can be approached from two points, one from the Redwoods highway near Waters creek, and the other from Merlin on the Southern Pacific.

Abstract of Report by F. B. Caldwell
for the U. S. Bureau of Mines Engineers
June 17 and August 11 and 12, 1918.

This property is located in Josephine county in the Briggs creek district on the divide between Briggs creek and Silver creek. Water, fuel, and power are abundant. The property is upon a fairly level plateau, and roads are easily built. There is little overburden.

The ore is associated with serpentine and occurs in kidneys of various shapes and sizes, all strikes, and dips. The ore varies from heavy, black, clean high grade to disseminated ore. Better grade is said to run 43% Cr_2O_3.

There are over 60 openings and all contain ore in place, several situated distances apart with good cropping between.

"Reasons for estimate of probable and possible ore:

"Since last visit more work has been done on the Violet Claim and those adjoining at the writer's suggestion, with the result that an apparently almost continuous orebody of mixed high and second grade has been opened, over a distance of over 200 feet in length, an average width of over 20 feet, and to a depth of over 20 feet, with every indication that it will extend in each dimension."

"For a lineal distance of over 1500 feet wherever pits or cuts have been sunk, ore has been found of varying grades, with croppings between. Croppings and workings would indicate that more than one zone of mineral, more or less parallel, will be opened with more development."

"The ore is of the sandy disseminated character, 40 to 48%, mixed with lower 15 to 30% grade. It is fairly soft, easily broken, and mining costs will be very low. Believe the possibilities are by far the largest of any mine visited, particularly as to good concentrating grade. . . . . "

"The property, although it will produce a large tonnage of shipping grade ore, looks like a concentrating proposition, and should be tested for treatment and a mill installed without delay to make available the low grade chrome ore."

Note:- In line with our policy of describing the location, geology, ore genesis, and deformation in relation to these various chrome deposits and of omitting estimated tonnages and recommendations as to the relative values of the properties as mines, we have deleted from Caldwell's report references which he makes to his tonnage estimates. The reader may refer to the original of Caldwell's report (No. 16, No. 71, Briggs Creek Swede Basin Mines) for full particulars.

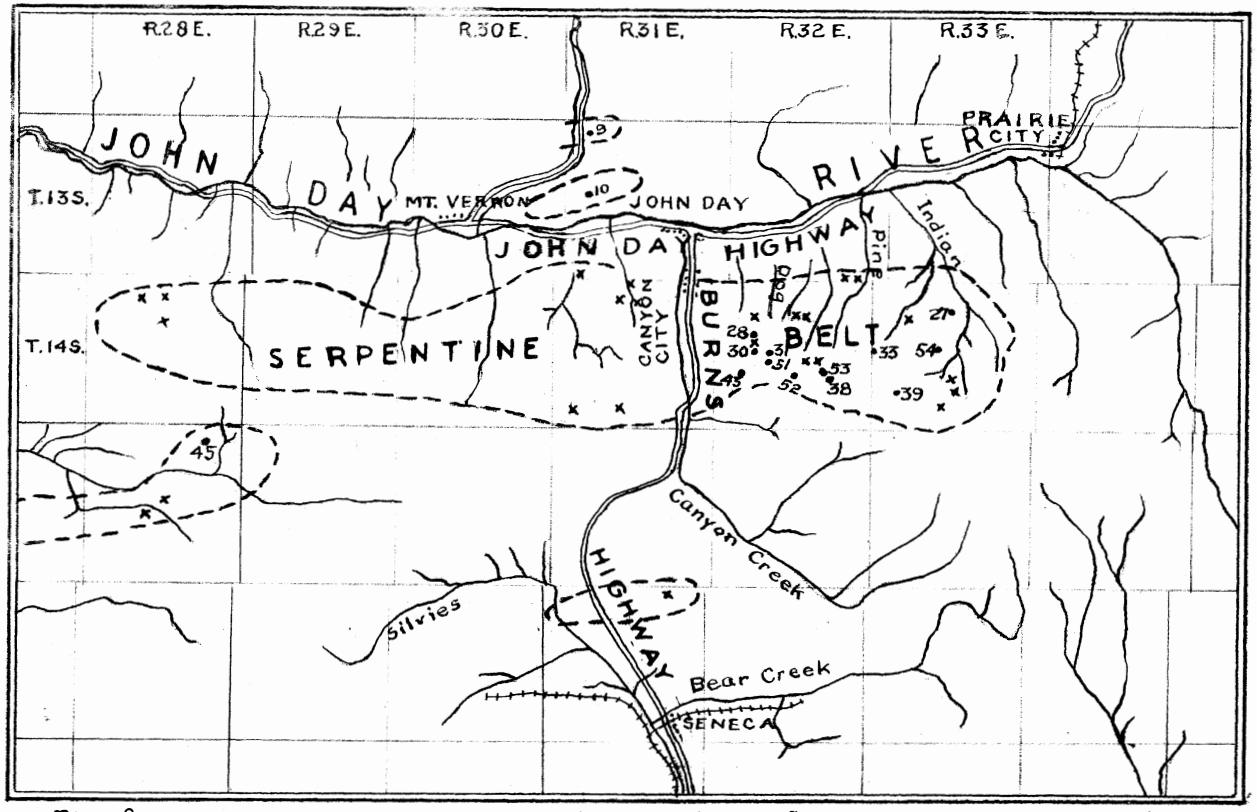

Fig. 8. Key map for some of the chromite deposits in Grant county, northeastern Oregon. Outline of serpentine belts and numbers after Westgate. Crosses show deposits not visited.

CHROMITE DEPOSITS OF NORTHEASTERN OREGON

General Description.

The Blue Mountain province is essentially an area of high relief and old rocks, bounded by later overlapping lavas of the Columbia River lava plateau. It comprises most of northeastern Oregon, but the chromite deposits are restricted to areas of serpentine and related rocks lying within Grant and Baker counties. The most important of these areas are outlined in fig. 8 (after Westgate 24/). There are three other small areas within 15 miles of Granite, and two on Connor creek, a small tributary entering the Snake river from the west, 12 miles north of Huntington.

There is no topographic map of the Strawberry Range serpentine area, but the U. S. Forest Service map of the Malheur National Forest is available. The Connor creek locality is in the southwest corner of the Pine quadrangle.

The older rocks of the region are composed of schist, slate, and shale, with small amounts of limestone. In places they are interbedded with lavas and pyroclastics, and are all highly folded and faulted. Fossils are rare, but the rocks are believed to range from Carboniferous to Jurassic in age. These sediments and lavas were intruded by both acidic and basic rocks, the latter consisting of the gabbros, peridotites, and serpentines with which the chromite deposits are associated. These intrusions are thought to be upper Jurassic in age, although they may be as early as Triassic.

The great lava flood of the Miocene rose around the mountains of that time and covered their flanks on all sides. Lake beds of gravel, sand, and volcanic ash lie upon or are interbedded with these lava flows. In places the lavas have since been eroded away, but they still cover great areas of northeastern Oregon, leaving the Blue Mountains as an irregular sprawling island of older rocks.

The Blue Mountains are an area of high relief, some of the peaks rising to over 9000 feet above sea level. The Strawberry Range, the crest and north flank of which is largely serpentine and includes most of the chromite deposits under discussion, rises 5000 feet above the John Day valley, which parallels it on the north for over 40 miles from Prairie City to Dayville.

The climate of the John Day valley is semi-arid, although the summits of the Strawberry Range collect enough moisture to supply nearly all of the streams with water even during the dry season. The upper slopes are well timbered except on rocky crests. Ponderosa pine and Douglas fir are the most abundant trees.

The John Day highway parallels the Strawberry Range on the north, and the Burns-Pendleton highway follows Canyon creek to bisect it. Numerous forest roads reach many of the deposits and sled or wagon roads were built during wartime operations, to others.

Plate 1. (A) Quarry at Iron King mine, Grant County, showing outline of orebody, below the dark line

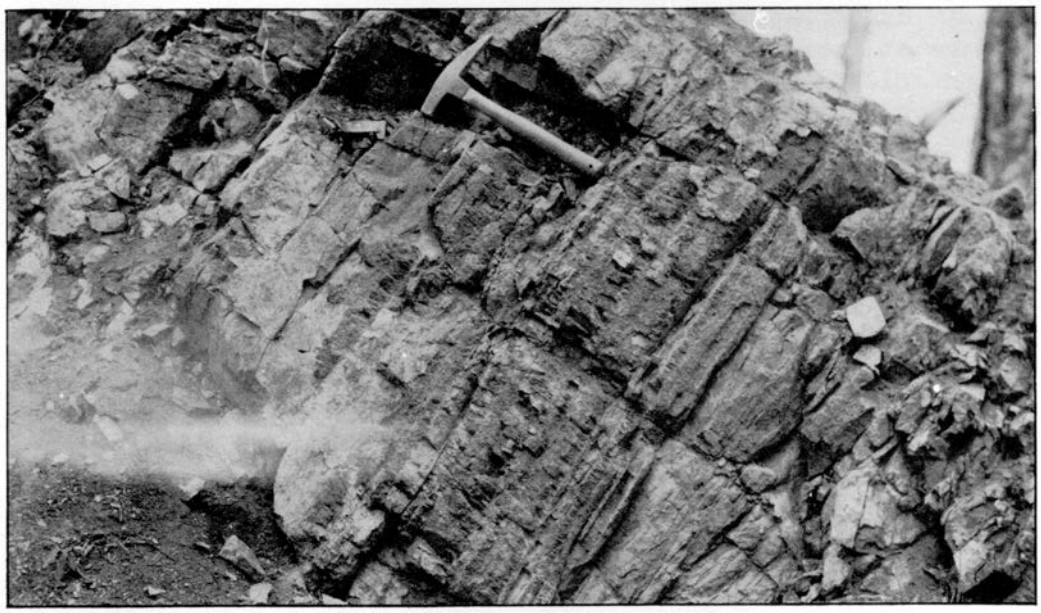

Plate 1. (B) Banded ore dipping south, near entrance to eastern tunnel at Dry Camp mine, Grant County (See p. 62)

GRANT COUNTY

Iron King (43)

Located on the southwest slope of Canyon mountain, 3½ miles southeast of Canyon City, in the SE¼ of sec. 20, T. 14 S., R. 32 E., Grant county.

The claims are on a very steep south slope near the head of Dry Gulch. The country rock is a dark green, completely serpentinized but not highly sheared rock, originally probably a peridotite, in several areas grading into a pyroxenite. Three hundred feet to the east a large gabbro body lies within the serpentine and forms a clear-cut contact up and down the slope. Both rocks stand out locally as cliffs and bluffs.

The ore in the main quarry at the end of the road is exposed in the face for 125 feet, with a minimum thickness of 8 feet, and an average of over 10, although at the east end of the cut it is at least 20 feet thick. (See plate I-a). The ore appears to be bounded on the west by several faults and appears to lie nearly horizontal, or dip gently to the north. It is much sheared, faulted, and broken, and in places hard to distinguish from the dark serpentine. It has undergone much movement after emplacement, with formation of secondary uvarovite, calcite, aragonite in vugs, etc. There has been some brecciation. Banding, when present, is very indistinct. There are several isolated smaller flattish bodies in the face above the main ore.

Besides this body in the main cut, chromite outcrops in four other localities (1-4 in fig. 6) as follows:

(1) Ore at least 8 feet long and a maximum of 3 feet wide, although rather irregular in outline.

(2) Ore exposed 3 feet long in a N. 40° E. direction, the 1½ foot wide band dipping 60° W.

(3) Magnesite dike 6 inches wide, associated with narrow chromite stringers.

(4) Ore exposed in two cuts for a distance of 60 feet, in a N. 60° W. direction. The banding is N-S, dipping 20° West; with a maximum width of 8 feet, and a minimum of 4 feet.

Most of the ore is medium or low in grade, averaging 34 per cent chromic oxide. It is hard, tough, and brittle. Some areas of disseminated ore appear better than they really are, as the dark serpentine is much the same color as the chromite.

A steep, third-class road leads from the deposit to Canyonville, about 6.5 miles.

Ward (28)

Located in the N½ sec. 17, T. 14 S., R. 32 E., Grant county.

The country rock near the orebody is a dense, yellow-weathering, dark green dunite, cut by numerous small veins of chrysotile serpentine. A massive ledge of peridotite parallels the orebody on the south. All of the rock is slightly serpentinized.

The orebody has been mined out to a depth of over 50 feet, along a vertical zone extending N. 62° W. for 120 feet, with a width of from 4 to 15 feet. The lower portion of this zone was tapped by a 70-foot tunnel (crosscut) running S. 30° W. The westerly extension beyond the orebody is cut off by a series of parallel faults, along which several movements have taken place.

Westgate discusses the mine as follows 25/:

> "The Ward mine, southeast of Canyon City, started as an open cut 80 feet long on a veinlike body that bears N. 70° W. and dips 70-80° S. Mining has been carried to a depth of 71 feet, and the ore is now reached by a tunnel. The country rock is serpentine, and here the ore is hard. The ore is banded; in places the bands are thick and massive; elsewhere they are narrower and lie parallel in the serpentine matrix. Near the surface at the west end of the property banded ore 2 feet thick narrows to nothing at the top. Here several vertical narrow chromite stringers pass off into the serpentine at an angle of 20°, as if following cracks in the serpentine. At the east end the body is cut out at the surface by a fault. At the depth of 50 feet it is slightly displaced by a horizontal fault, and it may be faulted at the bottom. Most of the ore is spotted, though in this spotted ore lie masses of black ore. The ore assays from 31 to 47 per cent of chromic oxide; the best ore shipped contained a little over 40 per cent, and large amounts of 31 to 32 per cent ore have been shipped."
>
> "The Ward mine and the McIntyre mine are the only mines in the district that reach any considerable depth (both about 70 feet) . . . Both mines are on the point of being abandoned".

The ore now visible is of the disseminated type, and would probably run only 20-30 per cent.

The mine is reached by a road (now much in need of repair) about four miles from the highway between John Day and Prairie City.

Kingsley (30)

Located on the headwaters of the east fork of Dog Creek, just outside the forest boundary, in the SE¼ of sec. 17, T. 14 S., R. 32 E., Grant county.

The country rock is a much broken and sheared peridotite; with the main ore zone consisting of very irregular and small discontinuous high-grade kidneys striking east-west and dipping 45° N. in a northwest sloping hillside. The zone averages not over 3 feet in width, usually less, and has been mined for over 30 feet horizontally (into the hill) and about 25 feet vertically. Ore seems to have been taken from other small cuts and tunnels for a distance

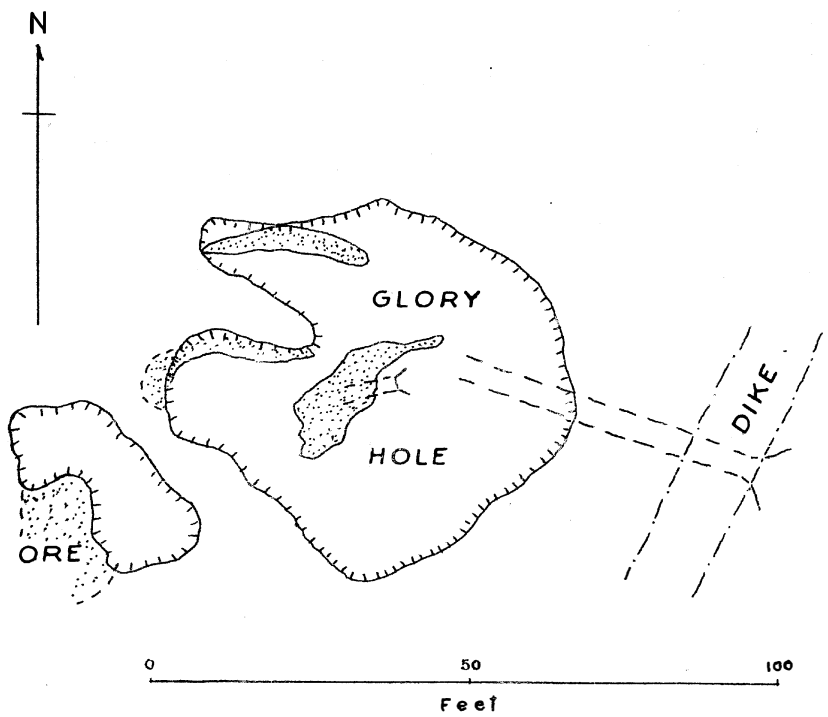

Fig. 9. Sketch of chromite deposit and workings at Silver's mine (see p. 66)

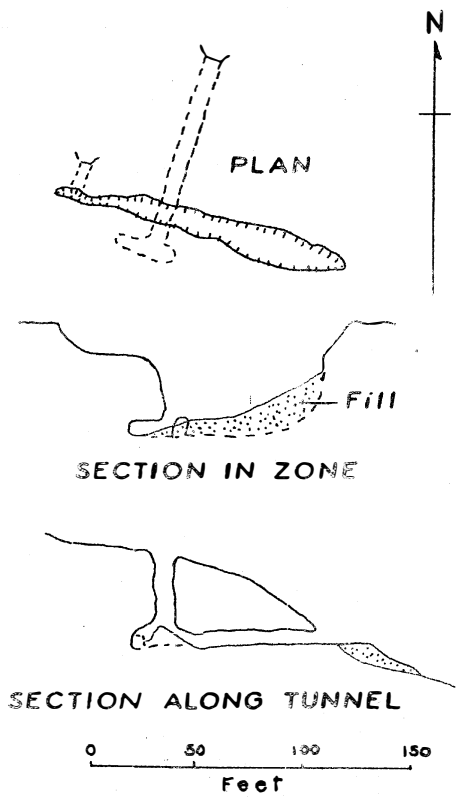

Fig. 10. Sketch map and sections of Ward mine.

of 150 feet along a N. 70° W. line. Only a small tonnage has been removed.

Westgate says of this 26/:

> "The Kingsley prospect consists of lenses of chromite in sharp contact with serpentine. The shattered serpentine, with no well-marked wall, is in contact with more massive basic rock."

The property is reached by the same road that taps the Haggard and New and lies about 1 mile north of that property.

Haggard and New (31)

Located on the headwaters of the east fork of Dog creek, in the northwest corner of sec. 21, T. 14 S., R. 32 E., Grant county.

The country rock is of normal "buckskin" peridotite, varying to a fine-grained aphanitic dunite, and is relatively unaltered and massive, with widely spaced jointing.

Two main openings lie about 250 feet apart, one being N. 40° W. of the other and almost 60 feet below.

The lower opening consists of a tunnel and immediately superjacent open cut running into the hill S. 70° E. for 65 feet, along what appears to have been a zone of low-grade ore perhaps 2-4 feet wide and nearly vertical. At the end of the tunnel a 30-foot raise reaching to the surface, is said to have extended along a high-grade (46 per cent chromic oxide) chute of ore 4 by 6 feet across, cut off on the east by a vertical N. 10° W. trending fault.

Up the hill to the southeast lie the main workings. Here considerable work was done during the war, including a tunnel into the hill and pointed S. 30° E. for 80 feet, thence N. 20° E. for 50 feet, with a 15-foot winze at the turn. At this point there is evidence of stoping and square setting above, and extending to the surface. Another tunnel 30 feet above the first, lies just above one of the stopes and trends approximately south for 50 feet.

Small kidneys of high grade, apparently striking northeast and dipping up to 45° to the southeast, make up the ore which was mined. The main zone, which includes both deposits and another cropping of small stringers 150 feet farther up the hill to the southeast, trends northwest.

The ore in the small kidneys is of rather soft, friable chromite with very little gangue. These are said to have run over 45 per cent chromic oxide. The ore also occurs in larger disseminated bands which may not reach 30 per cent in grade.

The mine is reached by a thirdclass road, now much in need of repair, or by sled road from down creek. It is located at an elevation of 3000 feet above the valley about 4½ miles from the highway at a point about midway between John Day and Prairie City.

Present Need (51)

Located 1000 feet south of the Haggard and New mine and 300 feet higher, in NW$\frac{1}{4}$ of sec. 21, T. 14 S., R. 32 E., Grant county.

The country rock is a rather massive aphanitic dunite, somewhat faulted and jointed but not badly sheared.

A short tunnel and a parallel open cut 10 feet to the west extend due south into the hill for about 30 or 40 feet, and expose ore 3 or 4 feet wide which appears to strike a little north of west, and which dips gently to the north. High-grade ore (assaying 51 per cent chromic oxide) and probably 3 feet thick, is exposed along the strike for at least 15 feet, and for 25 feet along the dip. Some ore is exposed at a lower level and may be another kidney.

The deposit is located on a very steep slope, 1000 feet from the nearest road (at the Haggard and New). Timber and water are abundant.

Celebration (52)

Located on the east fork of Big Pine creek, 500 feet south of the creek and trail, at the three-mile trail marker, in N$\frac{1}{2}$ sec. 27, T. 14 S., R. 32 E., Grant county.

The country rock is a yellow-weathering dunite, varying locally to a pyroxenite, gabbro, or, more commonly, serpentine.

The orebody is from 5 to 8 feet thick, possibly thicker in places, and extends for at least 50 feet in length, dipping 25° S.E. into the hillside, and striking N. 65° E. It is rather irregular in outline, being considerably jointed and faulted in blocks up to 4-5 feet across. Often the ore is infaulted with blocks of serpentine and dunite.

Two large open cuts about 20 feet apart expose the ore-face and one incline goes down into the ore for 35 feet.

The ore is of the nodular type, consisting of round aggregates averaging 5 mm. in diameter, in a matrix of more or less altered fine-grained olivine. It is quite uniform in grade. An average of 60 chip samples from the piled ore and from the exposed faces of the orebody assayed 40 per cent chromic oxide.

This deposit is now relatively inaccessible. The nearest roads are three miles distant along a gently graded trail down Big Pine creek, or one and a half miles by steep trail over the ridge to the Chambers mine.

From the end of the present road it is another three miles out by a third-class road which joins the highway, at a point midway between John Day and Prairie City.

Chambers (38)

This deposit lies on the northwest slope near the west end of Bald Mountain, just at timberline, and at an elevation of about 6300 feet. It is in the N½ sec. 26, T. 15 S., R. 32 E., Grant county.

A dark-brown, locally yellow-weathering, fine-grained dunite forms the country rock. It is frequently cut by minute serpentine stringers. In some places it varies from dunite toward a porphyritic peridotite and in others becomes more or less completely serpentinized.

The rock has a platy character caused by its being genrally broken by joints which are often prominent in one direction. It is intruded in a few places by veins of a dioritic rock. Several gabbroid boulders were found near the deposit.

The ore-zone strikes about N. 45° E., and probably dips steeply to the southeast, although this is only to be surmised by the alignment of the outcrops.

The southwestern orebody is exposed in six pits and cuts for at least 100 and possibly 150 feet, with a width of from 40 to 45 feet. It strikes N. 45°E., and is cut off abruptly at right angles on the southwest. On the northeast end it apparently pinches out less abruptly, although there are no prospect cuts there. No work has been done in the 100 feet between the two main orebodies, but ore shows in a cut 20 feet southwest of the central body, so it may be covered with soil or lie at depth. The southwest orebody has only been opened by shallow cuts, and is practically undeveloped.

The central orebody, 150 feet to the northeast of the first, has been stoped to a depth of over 30 feet through a tunnel from the north, in a glory-hole about 100 feet long by 70 feet across. Ore still appears in place on two walls of the pit and appears as a massive body extending from top to bottom with a 20-30 foot width in the northeast wall. (see plate IIa). It is much more broken and irregular on the southwest, where at one place it is about 20 feet wide, with other more or less isolated patches. Even in these good exposures, the numerous faults in the ore and the color and broken character of the rock made it impossible to work out any definite structure under the conditions existing when the deposit was visited.

This orebody seems to widen as it goes down (as also indicated in Westgate's section and plan, 27), and is probably over 100 feet in length.

Two pits cut into low-grade ore at a point 50 feet lower in elevation and 300 feet to the northeast from the central workings. No croppings were observed between.

The ore varies from the extremely low-grade disseminated (10-20 per cent chromic oxide) up to a medium high grade of 40 per cent. The highest grades show only about 5 per cent of interstitial rock material on the surface of the specimen, although the lowest grades may show only 20 per cent chromite. The main orebodies average about 35-36 per cent chromic oxide.

Plate II.

(A) Orebody in east end of glory hole at Chambers mine, Grant County.

Plate II. (B) Old trestle and bunkers at Chambers mine, Grant County.

Since the orebodies are considerably sheared and faulted, their outlines are rather indefinite. Uvarovite garnet is common on the shear planes, and secondary magnesite in veins occurs with light green magnesian pyroxene and calcite not infrequently. Antigorite also appears in long brittle fibers.

The deposit is reached by a third-class road, about 8 miles long, which takes off south from the main highway, at a point midway between John Day and Prairie City.

Bald Eagle (53)

Located in the SW$\frac{1}{4}$ sec. 23, T. 14 S., R. 32 E., about $\frac{1}{2}$ mile down the ridge, northwest of the Chambers mine.

Geologic conditions are much the same here as at the Chambers mine. Apparently the orebody strikes almost north and dips about 35° to the west. It lies on the relatively flat top of a north-sloping ridge. Two pits 10 to 15 feet long and 6 feet wide expose the ore, at points about 20 feet apart.

Dry Camp (33)

Located on the NW slope of the ridge, at about 4000 feet elevation, in the NW$\frac{1}{4}$ of sec. 19, T.14 S., R. 32 E., Grant county.

The country rock is more or less serpentinized peridotite, apparently varying towards a dunite near the orebodies. Two or possibly more parallel zones of banded chromite occur, both striking N. 55°-60°E, dipping steeply to the south and lying about 220 feet apart.

The western (lower) zone has been only partly stripped on its surface exposure, and is practically undeveloped. Float appears for over 100 feet, and at the south end ore in place has a total width of 1 foot of high- and 3 feet of low-grade, in a band about 8 feet wide. The high-grade occurs in narrow bands 1-3 inches wide, which strike N. 55° E., and dip 60° to the south.

The eastern (main) workings lie about 230 feet uphill to the southeast. Here a zone of banded ore from 8 to 20 feet in width which has been mined to an average depth of about 10 feet, seems to have averaged at least 2 feet in width for that distance. This zone strikes N. 60° E. and dips about 75-80° S. near the southwest end. Thirty feet northeast from the pit which was opened, the entire zone is 8 feet wide and the zone of highest grade totals at least 30 inches in width. At the northeast end the ore-zone is 20-25 feet wide and strikes N. 30° E., dipping 45° south. (see fig. 11). Over the entire distance, the highest grade ore appears to lie nearest the "hanging wall" or south side of the zone.

Near the northeast end of the working what was apparently a "cross vein" was mined by tunnel extending 80 feet into the hill in a S. 60° E. direction. It is said that the orebody was very irregular, varied from

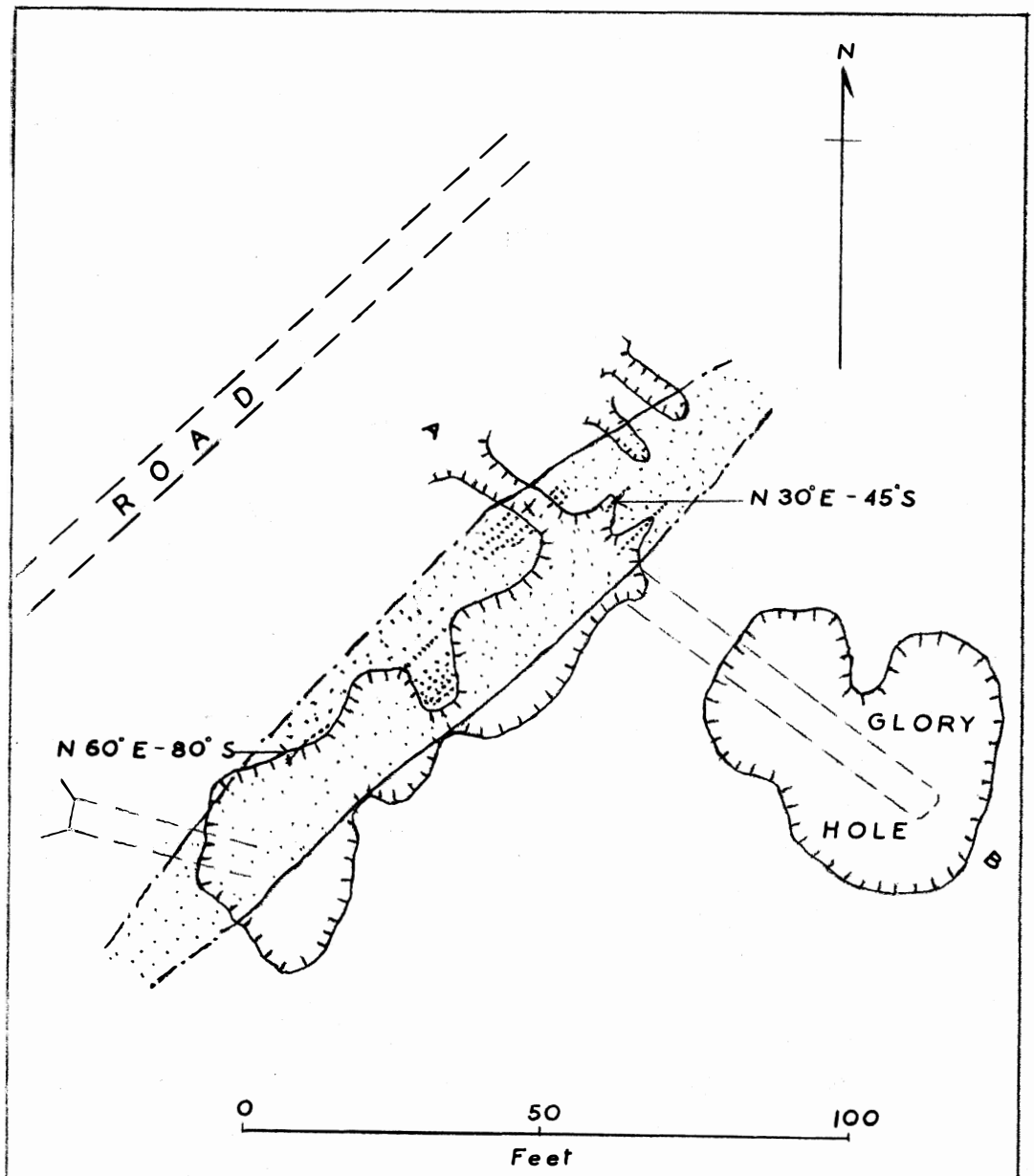

Fig. 11. Sketch of eastern chromite deposit and workings at Dry Camp Mine. A-B is line of Westgate's section. Banding is indicated where visible.

8 to 20 inches in width, was somewhat discontinuous, and sloped upward as the tunnel went in and the ore was stoped down. No ore was seen in the tunnel or face. It is said that 200 tons were removed from this body. Westgate gives one interpretation of the structure here 28/.

From 10 to 20 feet farther to the northeast of the main workings, two shallow cuts expose the extension of the orebody in that direction, making a total ore zone length of well over 120 feet.

One other orebody, probably small but high-grade, appears in a small cut 70 feet west of the main workings.

The ore is nearly all of the disseminated and banded type, occurring in parallel bands which vary in chromite percentage from 10-20 to about 80 per cent, and in chromic oxide content probably from 10 to 40 per cent.

The deposit lies about 1 mile by sled road and 3 miles by third-grade road from the highway at a point 3 miles west of Prairie City, and 10 miles from John Day.

Ray Chromite Deposit (39)

Located near top of ridge on north side, at the end of the chrome road in the E½ sec. 30, T. 14 S., R. 32 E., Grant county.

Close to the orebody, the country rock is a fine-grained, somewhat altered dunite, but predominantly it is a serpentinized peridotite, often showing primary platy structure and medium fine jointing, which strikes E-W and dips 48° S. on the ridge-top.

The upper open cut of the mine was completely covered with snow at the time the mine was visited, so the following data (which corresponds to Westgate's observations 29/) is by word of mouth from Clint Haight. The main orebody, as exposed in the upper cut, was 125 feet long with a maximum width of 75 feet. It strikes about E-W and dips steeply to the south. This body is figured by Westgate 30/.

A 60-foot prospect tunnel, started at a point 150 feet S. 65° E. from, and 50 feet below, the bunkers, has intersected the ore. The tunnel runs from east to west, and its last 15 to 25 feet exposes a large body of ore.

Another pit lies about 500 feet northwest of the main workings (over the ridge). Here a long prospect cut was dug for 60 feet in a N-S direction. Another cut lies 300 feet farther northwest.

The ore from the tunnel is soft, more or less friable, and rather fine grained. Interstitial serpentine is visible, but usually does not seem to make up more than 15% of the ore. Ore from the upper cut is harder, but otherwise similar. Westgate reports 32-45 per cent chromic oxide content 31/.

The deposit is about nine miles by third-class forest road from the

highway, at a point halfway between Prairie City and John Day. The road drops about 3000 feet in this nine miles.

Ajax (54)

Located half a mile east of the chrome road to the Ray mine, on the west side of Indian creek, near center of south half of sec. 16, T. 14 S., R. 33 E., Grant county.

The deposit lies on a cliffed hillside, in porphyritic peridotite, often platy in character, and locally somewhat serpentinized. Close to the chromite bodies the rock loses its porphyritic character and becomes fine-grained and dense in appearance, with a fine blocky cleavage. Large boulders of peridotite lie included within this zone.

Three open cuts and numerous surface outcrops expose the ore over a distance of about 140 feet. It is predominantly low-grade and disseminated in character. The trend of the ore-zone is about N. 10° E., but the three or more main segregations within the zone lie en echelon, striking N. 50° to N. 60° and dipping steeply to the northwest. The country rock is much broken and jointed, and the orebodies quite irregular, changing abruptly in size and shape.

About 25 tons have been mined from a cut 25 feet long and 5 feet wide and 5 feet deep. The orebody is from 4 to 6 feet wide in the end of the cut. In another cut 30 feet southwest, the maximum width of several small ore-bands is 6 inches, the intermediate rock being altered dunite. Farther south about 20 feet, more or less contiguous kidneys appear, their maximum width being 4 feet, and their total length being about 15 feet.

In a cut 50 feet north of the others, the orebody stands nearly vertical, strikes N. 60° E., and its exposed dimensions are 2-3 feet wide and at least 6 feet long and 6 feet deep. Farther to the north, the chromite zone may be indicated by a prominent dark ledge of serpentine in peridotite.

The ore is of the nodular and banded type, as well as a type in which small, elongated and parallel but isolated fragments of dunite, up to 40 per cent, are included within the ore. The ore assayed 34 per cent chromic oxide.

The distance over the Ray road to the highway is about seven miles. From the point of junction with the John Day-Prairie City highway, it is about seven miles to either of these towns.

Marks and Thompson (27)

Located in the W½ sec. 10, T. 14 S., R. 33 W., Grant county.

The deposit lies half way up a fairly steep ridge on the west side of Indian creek 200 feet above the valley bottom. The ore was mined in two large open cuts, the southern one being later glory-holed from a tunnel at road level. A 20-foot (or longer) tunnel was started from which the operator expected to work the other pit by the same method.

The country rock is predominantly a more or less completely serpentinized peridotite.

The ore lies in an area 125 feet long and averages 15-20 feet wide. It is discontinuous in at least one place, and may actually represent two or more adjacent kidneys. The banded chromite in the northern portion strikes N. 20° E. and dips 50° E., and is about 10-15 feet thick. The ore in the southern cut strikes N. 30° E. and dips 30° E., being at least 20 feet wide at the surface. Westgate gives a good diagram of these deposits 32/.

In a N. 60° E. direction 160 feet down the hill from the area noted above, two other shallow cuts expose a body at least 10 feet wide and possibly 50 feet long, striking N-S.

The ore is rather low-grade and disseminated, with local segregations of massive chromite of medium grade assaying 35 per cent chromic oxide. One specimen of the disseminated ore assayed 19.51 per cent chromic oxide.

The deposit may be reached by a road which takes off from the main highway at a point 6 miles west of Prairie City and leads a matter of 5 miles southwest into the hills. It can be reached also by a road leading eastward from Seneca a matter of 35 miles. Seneca is on the railroad.

Silver's (10)

Located two miles north of the John Day highway in the SE¼ sec. 18, T. 13 S., R. 31 E.

The country rock is serpentine, which near the ore and above it is black, but which grades into a yellow dunite below the ore. A north-trending gabbroid dike penetrated by the glory-hole adit lies to the east of the deposit. There has been considerable faulting and slickensiding, but not enough to make mining too difficult.

The orebody consists of bands and irregular bodies of chromite which seem to strike about N. 60° W., and dip 55° N. The band which lies from 2-5 feet above the main exposed kidney, varies in thickness from 15 inches to 3 feet, and is rather continuous for 30-40 feet. The kidney is very irregular, but it is at least 4 feet thick where it crops at the surface and has apparently been followed by a cut to a depth of 20-30 feet. Ore appears over a horizontal distance of about 75 feet, and the average total thickness may be as much as 10 feet. The deposit is by no means exhausted, since the ore appears prominently from top to bottom (see fig. 9) in the west face of the glory-hole. It was mined, as has been indicated, by an adit which taps the glory-hole at about 30 to 40 feet in depth.

The ore appears to be of average medium grade, above 30 per cent, but probably not over 45 per cent chromic oxide.

The deposit may be reached by a road leading from Mt. Vernon up Buck Creek. It is about 3 miles from the main highway.

Benson (9)

Located just west of divide at head of small creek running west into Beach creek, in Sec. 6, T. 13 S., R. 31 E., Grant county. See map.

The deposit lies in sheared and slickensided, green serpentine. A few large, massive boulders are present in the predominately broken and altered material. Much secondary magnesite and lime are present.

The ore zone extends for 100 feet in a N. 75° W. direction, apparently dipping about 45° to the north, but actual croppings of ore appear only in two very small isolated kidneys, and in one elongated irregular band, about 25 feet in length. These bodies now appear to be exhausted, as no ore appears in place.

The ore, like the country rock, is much broken and sheared and cut by calcite and magnesite veins, but it is rather soft, very fine-grained, and a deep black which gives a rich chocolate brown streak. It assays 30-36 per cent chromic oxide.

Spring and Chrome Ridge (45)

Located about one mile north up Oregon Mine creek from Murderers creek; near the top of the ridge on the west; in the SE¼ sec. 2, T. 15 S., R. 28 E., Grant county.

The deposit lies in a zone of highly sheared dark green to black serpentine about 100 feet wide, which cuts N. 20° W. across a southwest-trending ridge spur between more massive outcrops. The ore occurs regularly in small rounded kidneys with clean walls, and is fine-grained, dense, and fairly high-grade. There are no seams or veins which the miner could use to follow from one body to another, and there seems to be no regularity in their location. The largest lens seen was 6 inches thick and about 2 feet in diameter. Another was 2 by 8 inches. Other larger bodies may have been removed from the workings which consist of one shallow cut 50 feet long across the zone ending at its eastern terminus in a 20-foot shaft. There are four other prospect cuts and ditches.

A sled road extends the last mile to the property from the forest road on Murderers creek. It is too steep for a motor grade. From its junction with the Murderers creek road, it is 15 miles to the John Day highway to a point about nine miles west of Mt. Vernon.

Record (1)

Located 31 miles west of Sumpter on the Olive lake road, and about two miles north of the lake, in the SW½ of Sec. 3, T. 9 S., R. 34 W., Grant county.

A series of shallow pits has been dug along a roughly north-south line for a distance of about 800 feet across the wide, gently-sloping saddle of an east-west trending ridge. The pits do not vary in elevation more than 50 feet.

The country rock is a dark green to brownish-black sheared and slickensided serpentine, in which the ore appears as a few small concentrations of rather soft, black, very fine-grained chromite, and as irregular, indistinct and discontinuous bands of disseminated crystals. The largest of the high-grade bodies, if such were mined, could only have run a few hundred pounds at the most; and the disseminated ore, even when well sorted, does not appear to run much over 10 per cent in chromic oxide.

Six pits were examined and no ore was seen in place in four of these, although collected float and some sorted ore was piled at the sides of two of these pits. Disseminated ore shows in bands totalling not over 3 feet in one of the cuts. No assurance of any continuity is indicated.

The deposits are located 31 miles by forest road to the narrow gauge railroad at Sumpter, Oregon.

BAKER COUNTY

Connor Creek (50) (Lambert and Flick)

Located four miles west of the Snake river, up Connor creek, 13 miles north of Huntington, Baker county.

Here chromite occurs with a length of 175 feet, striking N. 55° E. and dipping steeply to the south, or standing vertical. Throughout most of this length only small stringers are in evidence, but the kidneys toward the center are as much as 3-4 feet thick, and irregular in outline and location. They lie in a highly silicified and sheared formation composed apparently of broken, elongated and sheared fragments of chalcedony (white, greenish, and bluish), dolomitic lime, and buff-weathering serpentine. There are many opaline veins and open vugs, the rock having the appearance of a typical "calc-silicate" rock. One-quarter of a mile to the north, an intrusive appears in contact with a wide limestone band of supposedly older age. There may be a fault near this contact as indicated by a saddle in the ridge, by numerous springs, as well as by gold mineralization.

The ore is predominantly of the nodular type, and probably does not run much over 40 per cent chromic oxide. The kidneys all seem to be small, the maximum observed width being 5 feet, with lengths only slightly greater.

According to Westgate, there is another larger body across the creek a mile to the southwest 33/, but this was not visited, as its presence was not known at the time.

OTHER DEPOSITS NOT VISITED.

Twenty-eight of the chromite deposits and prospects noted by Westgate 34/ were either not identified or not visited. These are listed as follows:

Sheep Rock: Hanenkrat's (40), Morgans (36), Campbells (37), Howard (26), Norway (20).

Small properties on lenses: Lyon (41), Patterson and George (42), Smith and Getsfield (18), Reed (13), Campbell (14), Powers (21) Louie (32), Accident (35), Anderson (34).

Properties near west end of belt: Queen of the May (16), Uncle Sam (15), Stone and Hawkins (17).

South fork of the John Day river: East Side (11), Mascall (12).

Sumpter belt: Gardner (8).

Granite belt: Meadows and Duckworth (2), Ford and Meyers (3).

Greenhorn belt: Campbell (6), Coombs (5).

Connor Creek: Kromite Mining Co. (49)

Seneca belt: Vancils (48)

Murderers Creek belt: Shelby and Hamer (46), Delore (47).

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