CHROMITE

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FOREWORD

This pamphlet has been written in response to a constantly increasing demand for information regarding chromite, its occurrence in nature, and the methods to be used in its production and in marketing. Chromite is one of the most important of the so-called war-minerals, and the necessity for stimulating its production cannot be over-rated. Through the generosity and patriotism of the *Mining and Scientific Press,* which has published this pamphlet at its own expense, it is possible to distribute this without charge to those seeking information. Acknowledgment is also made to Abbot A. Hanks for the chapter on sampling and analysis.

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CHROMITE

Sources and Uses

Chromite, or chrome-iron ore, which is the only commercially valuable ore of chromium, is found in European and Asiatic Turkey, Greece, Russia, India, New Caledonia, Rhodesia, Canada, Cuba, and the United States. Low-grade ores are also found in Germany, and small deposits in a few other countries.

For many years most of the ore used in the United States came from Asiatic Turkey, with the exception of the small amount used on the Pacific Coast, this being mined in California. Later, with the discovery of large deposits in New Caledonia, that island became the chief source of supply, not only for the United States, but for Europe, and still more recently a considerable quantity of high-grade ore has been coming from Rhodesia.

In the United States some important deposits in the Eastern States were worked several years ago, but have apparently become exhausted, so that now almost the only sources of domestic ore are the serpentine areas of California and Oregon, if we exclude from consideration the newly discovered deposits of Montana and Wyoming, the importance of which has not yet been demonstrated.

The chief uses of chrome ore are

(1) As an alloy for hardening and toughening steel,

(2) As a heat and acid-resisting lining for steel-furnaces,

(3) For making dyes to color cloth (as, for instance, khaki), and

(4) For the manufacture of chemicals used in the tanning of leather.

Substitutes may be used for any of the purposes named, but none of them will perform exactly the same function as chromium; and, in order to use them, radical and expensive changes will have to be made in manufacturing equipment and methods.

Why Increased Production Within the United States is a War Necessity

Chrome-steel is used directly in the manufacture of axles, springs, etc., which form parts of gun-carriages, automobiles, auto-trucks, and probably the famous 'tanks', all of which may be classed as 'munitions of war'.

Chrome bricks and raw chrome ores are used to line the furnaces that turn out 36,000,000 tons of steel per annum, for no substitute is known the use of which will not result in reducing the daily capacity of these furnaces.

Chromium chemicals are used for dyeing the cloth that goes into the manufacture of soldiers' uniforms and for tanning the leather from which their shoes are made.

If the ore for these uses is not produced within the United States, or Canada, it must come in ships from abroad, and as the supply obtainable from Canada is quite small, and the output from Cuba only just beginning, this means that it must come from New Caledonia and Rhodesia, the European and Asiatic supplies being either in enemy hands or in such locations that the ports of export are closed by enemy fortifications. The fact that the winning of the war depends upon the number of men the United States can put in the field in Europe is now so well known as to require no comment, and it is also understood that the only limit to the number of men we can send to the front is the number of ships to transport them and keep them supplied with munitions and food. For this purpose, a ship diverted from unnecessary traffic is worth even more than a ship built, because, with its crew, it is immediately available; and because it takes so much longer for a ship to make the round trip with a cargo of chrome ore between the United States and the ports of New Caledonia and South Africa than between New York and the French ports, it is estimated that releasing such a ship is equivalent to the building of five. Reducing this to terms of chrome ore, each thousand tons of such ore produced in California will enable us to face the Kaiser with two thousand more men.

The sudden and rapid growth of the chrome-mining industry in California and Oregon has resulted in drawing into it two classes of men, namely, those who have had no previous mining experience whatever, and those who have gained their experience from mining other ores. It is hoped the remarks that follow may in some cases be of use to the one class, and in some cases to the other. To those who have had no experience, we would say: get, if possible, a good mine foreman who has learned his business from the bottom up, and who has the knack of acquiring and holding the respect and good-will of his men. The services of such a man are invaluable, and the price you can afford to pay for them is limited only by the magnitude of the operation. Next provide as good quarters for your men as the circumstances and probable duration of the operation will permit, and then see that they get good food, even if you seem to be losing money by supplying it.

In detail, the proper methods of mining will be governed by the circumstances surrounding each venture and these will vary quite as much between different mines as they will between those of enterprises based upon the exploitation of other minerals, but the chapter describing the irregularity and uncertainty of chrome deposits emphasizes the fact that in the mining of chromite more than that of any other mineral, the most important thing is to follow the ore. In doing this, any one of three methods may be available, namely, open-cut, tunnel, or shaft, of which the first is always the cheapest and the last the most expensive.

An outcrop, no matter how small, may be the only surface exposure of a large lens, or you may be able to see in it ''all the ore there is''. When such an outcrop is found on a hillside, an open-cut should be started upon it, and, if on level ground, a shaft should be started in the ore. In no case should a tunnel be started in barren ground for the purpose of driving under an outcrop, until it has been demonstrated by shaft or winze how deep the deposit goes, and then only after sufficient other work has been done to prove that enough ore exists to enable one to repay the cost of the tunnel out of the difference between the cost of hoisting or shoveling it and that of handling it by overhead stoping from the tunnel-level.

Again, in the case of a deposit that must be worked through a shaft, two questions may arise: (1) should the working shaft be located in the orebody itself, or on one side; and (2) what hoisting equipment should be used?

The first question cannot be answered until work has been done on the orebody itself to determine its size and shape. Should it prove not to be more than fifteen or twenty feet deep, the hoisting could well be done through an opening in the ore itself, for a windlass would probably be used and it could be shifted from one part of the deposit to another without great expense. Should the ore go to a greater depth, then its width, the shape at the top, and the firmness of the walls would determine where the shaft should be sunk; for, if the orebody is not more than about ten feet wide at the top, does not expand with depth, and has walls of fairly firm rock, then the head-frame may be placed on stringers spanning the entire opening and no outside shaft will be needed. On the other hand, should any one of these conditions be reversed, it would probably be wise, in the case of a large orebody, to sink a shaft in the country-rock a short distance from the deposit after the preliminary prospecting in the ore had been performed.

The second question must be determined by the quantity of ore and the depth from which it is to be hoisted. For depths not greatly exceeding twenty feet, hoisting by windlass is probably as cheap as by any other method, though even to this depth should the orebody be large it might pay to carry an inclined track down through the middle of the deposit and hoist by gasoline-engine, steam, or, in a remote district, a horse-whim or 'whip'. No hard and fast rule can be established, but, as in the case of a proposed extraction tunnel, the probable number of tons available should be multiplied by the cost per ton of hoisting when employing the method involving the smallest investment for equipment, and by the cost per ton for each more expensive equipment. Whenever the difference is sufficient to re-pay the cost of the machinery less its salvage value, it should be installed. Costs of hoisting by different methods vary so greatly with different localities, depths, and tonnages, that no attempt will be made here to list them.

Most of the chromite deposits of California and Oregon are so small that drilling by hand is the method that must be adopted, and actual mining by this method is not as a rule much more expensive per ton of ore broken than by machine-drilling; but the latter method is much more rapid, thus reducing the overhead expense, and where labor is scarce, as it is in war times, the difference in the number of men necessary to produce a given tonnage is important. Therefore, whenever a deposit is found that appears large enough (dividing the cost of installation by the probable tonnage available), we would advise the use of compressed-air drills, for driving which there are several makes of portable and semi-portable air-compressors. It would be manifestly unwise, however, to wait 60 days for the erection of a compressed-air plant on a mine that could be worked out by hand in that length of time.

When the deposit is not large enough to justify building a concentrator for the purpose of separating ore from waste, it will be necessary to cob and sort the ore in order to produce a shipping product. In such mines a good foreman can frequently economize on the subsequent sorting by having his holes so placed as to break the spots of clean ore separate from the mixed material. This can be done more readily where hand-drilling is used instead of machine-work. For the actual cobbing it pays to provide special hammers formed like a geologist's hammer, but a little heavier; and it also pays to dump the ore over an inclined screen, so that the sorting is done upon the coarser material only. It also pays to spray the ore with water before sorting, and it is surprising how much spraying can be done through fine holes in a tin can from a single barrel of water. It may be found that the screening from one lot of ore is sufficiently good to be shipped with the selected ore whereas that from the next lot will fall short of the requirements. If a good foreman be allowed, at the beginning of an operation, to take frequent samples of the screening for analysis, he will soon be able to judge fairly well whether a given pile should be shipped or put aside for concentrating later.

The cost of mining the product from a chrome mine in California varies within wide limits, although the actual breaking and tramming of the material from a medium orebody should not exceed the following prices per ton:

	Hand-drilling	Machine-work
Open-cut	$1.50	$1.10
Overhead stoping from tunnel..............	2.25	1.75
Overhead stoping and hoisting through shaft.	3.00	2.50
Underhand stoping	6.00	5.00

Added to these costs, however, are numerous items of overhead expense, which are frequently overlooked, for example, amortization of plant, workmen's compensation insurance, taxes, loss on boarding house, superintendence, sampling and analysis of samples, and various other items, which, for even a large operation may easily amount to a dollar per ton and for small ones may amount to several dollars per ton. What causes the greatest variation in the cost of mining, aside from differences in the size and form of the orebodies, is the relation between quantity of ore mined and of product shipped, for according as the ore is clean or badly mixed with waste, the sorting may range from as low as two dollars per ton up to as much as twenty.

Methods and Costs of Concentrating

Many deposits of chromite that are too low-grade to be marketable will yield a good product as the result of concentration, but, before building a mill for that purpose, careful consideration should be given to some important questions.

(1) What profit per ton will the ore yield after paying all costs, including mining and concentration?

(2) How many tons are available, and is the quantity sufficient to re-pay the cost of the mill, leaving a profit?

(3) Is there an assured supply of water sufficient for

the tonnage to be treated? About seven tons of water is required for each ton of ore.

(4) Is the ore itself amenable to concentration? What percentage of recovery and what grade of concentrate can be obtained?

(5) What is the type of equipment best adapted to the treatment of this particular ore?

The gravity concentration of chrome ores is an extremely simple operation, because the specific gravity of chromite is nearly double that of the usual gangue, which is mostly serpentine. The grade of the concentrate is determined not so much by the percentage of gangue remaining in it as by the grade of the clean mineral itself, which is variable.

For the final crushing of the ore after it has passed through the ordinary rock-breaker, a machine should be selected that will give a maximum of crushing capacity with a minimum of sliming. For this purpose we favor rolls. This practice has not been followed, however, by most mill-builders in California, where ball-mills and even stamps have been used for the final crushing; but whether this has been the result of careful design or due to the necessity for quick delivery of equipment is not known—the latter reason seems the more probable. Following the final crushing it has been the general practice to pass the material through some type of classifier to separate the sand from the slime. The sand is then passed over tables that discharge concentrate, middling, and tailing, while the slime is treated on tables the products of which are concentrate and tailing. The middling from the sand-tables, without further grinding, is reconcentrated on another set of sand-tables.

Such a concentrator, including a rough building and gasoline-engines for power, can now be erected at points near a railroad in California or Oregon for about $300 per ton of daily capacity, or, say, $15,000 for a 50-ton mill.

It is our belief that, because of the difference in the character of the ore in various deposits, such an important thing as the construction of a mill should not be undertaken without first having made preliminary tests upon the ore in a properly operated testing-plant and that then both the crushing and concentrating equipment should be selected to fit the requirements of the ore to be treated, and as most of the chrome ore that has come under our observation has been comparatively coarse in texture it is believed that for most cases, the equipment desirable will be about as follows: Rock-breaker, rolls working in closed circuit with a 4 to 6-mm. trommel, fine jigs, rolls for jig-middling, working in closed circuit with Bunker Hill or Callow screen, classifier dividing the product to sand and slime tables, stationary canvas plant after slime-tables. Such a plant should not cost much more than the other type and on most chrome ores the percentage of recovery should be higher. Naturally, where fine grinding is really required for the purpose of liberating the mineral, ball-mills will be introduced for this work.

The recovery of chrome ore by concentration in California should be fully 75% of the mineral; with careful work and some refinements in practice it might be brought well above 80%. Too much money cannot, however, be expended upon refinements for the benefit of a short-lived enterprise. The cost of concentration may be expected to range from less than one dollar per ton for a well-constructed 100-ton plant driven by cheap electric power up to two dollars, or more, for a small poorly constructed mill using gasoline-power.

Methods and Costs of Transportation

Under this heading we must note again the great difference in circumstances affecting individual cases. One mine might be large enough and rich enough to justify the construction of several miles of expensive truck-road, or even railroad, while a mile of trail construction might be more than another one could stand. Whether a man shall 'sled' his ore down from a hill at a cost of $10 per ton instead of building a road for $2000 over which it will cost him $2 per ton to haul it, will depend upon whether he has at least one-eighth of 2000 tons to haul. This applies to all other questions relating to the kind of transportation to be used.

The following figures, as to costs in California and Oregon, are believed to be fairly accurate at the present time:

	Per ton-mile
Pack-animals over rough mountain-trail at 200 lb. per animal where all the feed must be imported	$2.50 to $3.50
Pack-animals over rough mountain-trail at 200 lb. per animal when grazing is good	2.00 to 2.50
Hauling by team over mountain-roads too steep for motor-trucks at 1000 to 1200 lb. per animal	0.50 to 0.60
Motor-trucks over hard mountain-roads	0.25 to 0.40

Pack-animals can average not more than 15 miles per day when loaded, and about 18 miles is a good day's work for a freight team.

For pack-animals and freight teams round trips consuming less than one day are less economical in cost per ton-mile than those requiring more time; and for motor-trucks round trips requiring exactly one day are the most economical. For trips of one day or less kyaks instead of bags are recommended for packing, because they are so much cheaper and easier to load and unload.

The cost of roads and trails varies so greatly in mountainous regions that it is not advisable to begin any important construction of this kind without a survey and an estimate of cost by a competent engineer.

Proper Capital Investment

If the reader has studied the chapter describing the nature of chrome deposits, he will realize that the outright purchase of undeveloped prospects and even their development if situated at points remote from transportation, is a risky business; but, aside from the uncertainty of the market, it is perhaps no more risky than that of the average mining exploration and not nearly so risky in proportion to the capital invested as that of the average prospector who stakes his entire fortune (which happens to be his life) on the chance of making a good discovery.

A safer plan, and one fairer to the investor, is the leasing system, with or without an option to purchase; and, except for unusually promising ground to be had for a low figure, it is the only one that we would be disposed to recommend. The risk will then be confined to the money expended for development and as much more as the gambling instinct may cause a man to expend in equipment or road-building before he has actually blocked out enough ore to pay for the money spent. The royalty should not exceed 10% of the value of the ore at the mine. At the risk of being ultra-conservative, we would say that even in the interest of quick production, and presumably of quick profit, the miner should not begin the construction of a road to haul his product until at least half the cost of the road is in sight in the form of ore mined or exposed, and with more than one face in good ore; and that he should not begin the construction of a mill until the whole price is in sight. The reason for this last proviso is that the margin of operating profit on concentrating ore is usually much smaller than on the shipping grades and the other risks incident to the business are large enough.

Characteristics and Surface Indications

Chrome ore is found associated with basic magnesian rocks, usually serpentine. It is, therefore, a waste of time to seek deposits in regions where no serpentine exists. Wherever serpentine is found, chrome deposits may exist and prospecting is warranted.

The ore is heavy and dark. Float is usually found near the deposits, either in the gulches or on the hillsides immediately below them. It may be necessary to dig shallow trenches cross-cutting the zone where 'float' is believed to exist; the soil and rock shoveled from such trenches should be carefully examined for ore. When 'float' is found, it should be followed to the point where it is most abundant, and then, if no outcrop is seen, trenches must be dug in order to uncover the orebody. Occasionally float cannot be traced to ore in place. This is due to the fact that the orebody has been completely eroded.

The prospector should not let this discourage him. Hundreds of tons of such fragmental mineral have been shipped. The ground may be plowed and the soil screened, so that the chrome may be sorted from the waste by hand. If no plow is available, pick and shovel work may take its place. The mining of float ore frequently yields a high-grade product and may prove a most profitable operation.

Miners are beginning to understand the characteristics of these deposits. There are, however, many new ones

VAUGHN CHROME MINE. FROM THIS DEPOSIT WAS COLLECTED 1200 TONS OF FLOAT CHROME

being worked by those less experienced, who make errors in estimating the possible tonnage.

In many cases the miner considers he is opening an orebody occurring in more or less irregular veins, and that the origin of the ore is similar to that of quartz veins. Outcrops may be found for a distance of several hundred feet, and in such alignment as to give the impression that the deposits are continuous. The handy

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The Atchison, Topeka & Santa Fe Railway Company.

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The surrender of this Original ORDER Bill of Lading properly indorsed shall be required before the delivery of the property. Inspection of property covered by this bill of lading will not be permitted unless provided by law or unless permission is indorsed on this original bill of lading or given in writing by the shipper.

The Rate of Freight from ....

to .... *is in cents per 100 Lbs.*

IF..Times 1st	IF 1st Class	IF 2d Class	IF 3d Class	IF 4th Class	IF 5th Class	IF A Class	IF B Class	IF C Class	IF D Class	IF E Class	IF Special per____	IF Special per____

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Destination, ... State of .... County of ....

Notify ....

At .... State of .... County of ....

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If charges are to be prepaid, write or stamp here, "To be Prepaid."

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to apply in payment of the charges on the property described hereon.

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Per...

(The signature here acknowledges only the amount prepaid.)

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(This Bill of Lading is to be signed by the shipper, and agent of the carrier issuing same.)

pencil is then put to work to calculate that the average width of the orebody is, say, 11 ft., the 'vein' can be traced for 800 ft., and the ore ought to persist at least 20 ft. below the surface, giving, therefore, a total of 176,000 cu. ft., which, at 10 cu. ft. per ton, makes 17,600 tons of ore. This amount is then offered for sale.

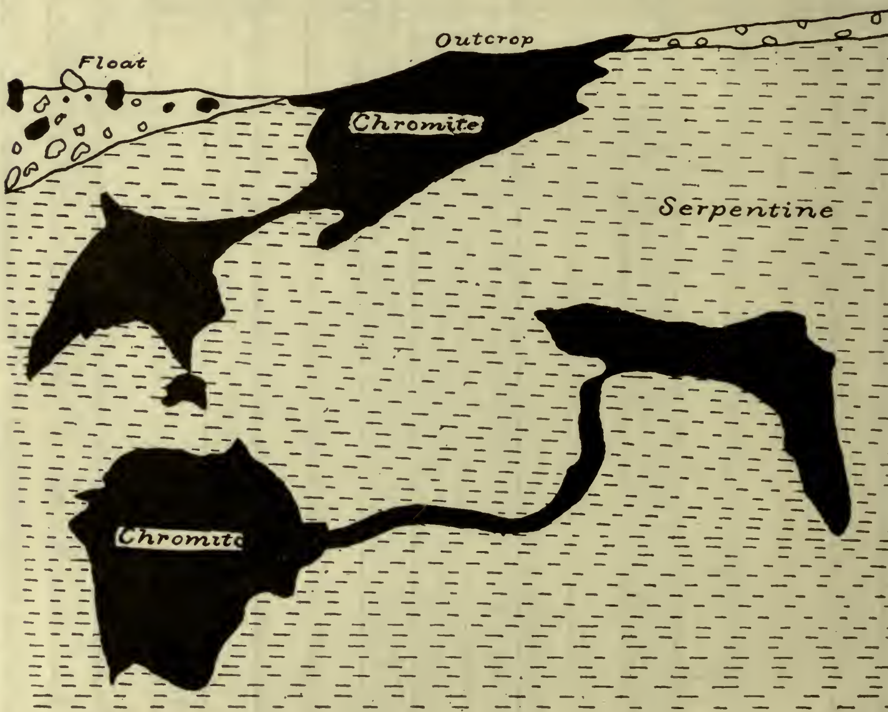

Fig. 4

SECTION OF SERPENTINE HILL SHOWING IRREGULAR OREBODIES

Chromite does not occur in veins. In a few cases long narrow lenses are observed extending 100 ft. or more along the surface, and a few feet wide. The depth of the orebody may be five feet or it may be 50 or more. This can be determined only by development work; this usually involves mining the ore, which, of course, necessitates following the orebody.

Shape of Deposits. The irregular shape of chrome deposits often presents puzzling problems. Figure 4 is an illustration of the peculiar shape of one deposit. The section extends through a serpentine hill containing chrome. The lower deposit may be entirely disconnected from the upper. In such a case the lower deposit might not be found after the upper had been exhausted. When a deposit 'pinches out', a good rule to follow is to dig a little further before abandoning the mine. Under no circumstances should a 'stringer', a small ore-shoot, be left unexplored in the face of the working. While it may not pay to mine so small a shoot, dig it out, as it may lead to another lens. We have followed this rule, and have been handsomely rewarded for so doing.

Origin. To understand why estimates of chrome ore cannot be prepared in the manner stated, it is necessary to know something about its origin. When two substances, one of which is more soluble than the other, are dissolved in water, and the water is then evaporated, the least soluble substance will crystallize out first. During the period when the earth's crust was forming, chrome was in solution, not in water, but in the molten magma which formed rock on cooling. Chrome, being less soluble than other substances present, was one of the first to crystallize from the magmatic solution. During this crystallization, the particles aggregated in irregular masses. When the cooling process was complete, and the entire mass had become solidified, these irregular bodies, which are designated lenses, were probably near the bottom of the formation in which they are found. As the weight of chrome ore is much greater than that of the rocks in which it is found, it seems probable that it settled to lower depths during its aggregation. If this be accepted as correct, the question arises, 'How did it reach the surface?' Folding, faulting, and weathering are the forces responsible for its exposure at the surface.

In Fig. 1 the lens of ore is shown in its normal position on cooling; later folding resulted in the mass assuming the position shown in Fig. 2; dynamic agencies, followed by erosion, resulted in the condition seen in Fig. 3. The dotted lines indicate the former position of the

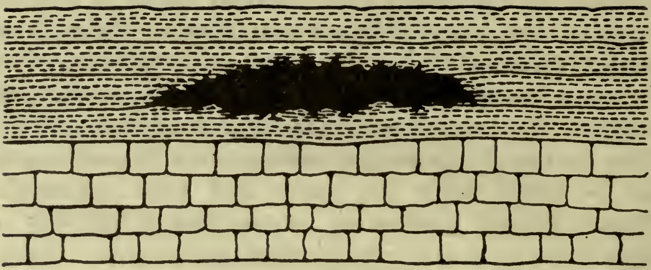

Fig. 1

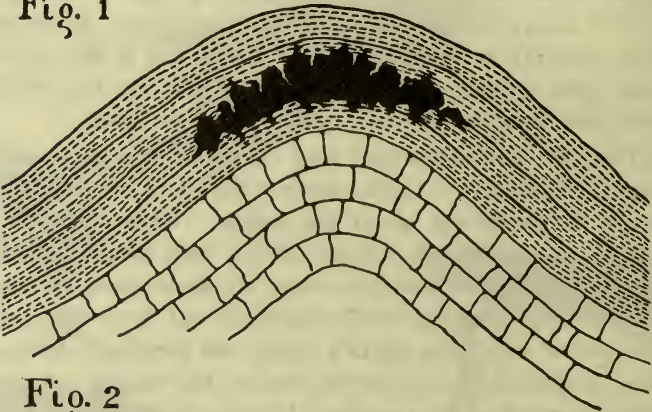

Fig. 2

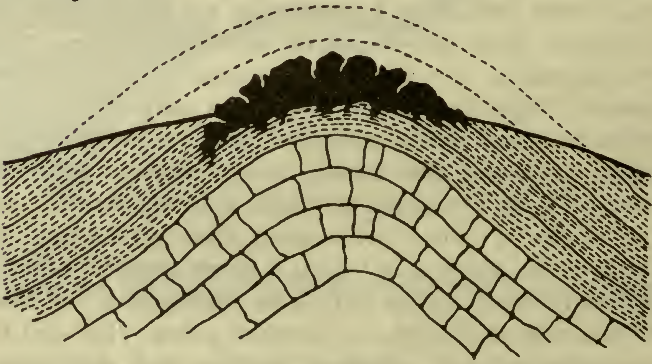

Fig. 3

Chrome Ore

rocks that concealed the deposit as shown in Fig. 1 and 2. The dark portion represents the consolidated mass of ore, surrounded by smaller bodies and segregated particles, which, attracted toward the main orebody, did not reach it because the progress was impeded by gradual solidification of the magma to form solid rock.

All chrome miners are familiar with the gradual increase in the amount of waste-rock in their ore as the limits of their deposits are reached. Occasionally a deposit is found in which the line between the ore and wall-rock is distinct, sometimes separated by 'gouge' or 'miner's talc'. When no chrome ore is found in the wall-rock immediately adjoining the orebody, and gouge is present, it may indicate that the original wall-rock has been removed by displacement. The ore along the wall may be fluted or grooved, and if the disturbance has been sufficient, the orebody may be coarsely fractured, or even so finely crushed as to make it friable, that is, capable of being disintegrated by compression in the hand. Otherwise, if no chrome is present in the wall-rock, it may be due to earlier genetic causes. Some magmas were undoubtedly more fluid than others, just as some smelter slags run freely while others are so sluggish that they freeze readily at the tuyeres. In a particularly fluid magma there would be flow-currents just as there are in water, these tending to carry away chromite particles which had not yet been consolidated with the main mass of chromite. For this reason I conclude that the largest deposits of chrome were probably formed in magmas relatively free from flow currents. Chrome ore is always found in basic-igneous rocks, such as peridotite or its altered form, serpentine. This is probably because chromium is more soluble in basic than in acid magmas.

Distribution of Chrome in Deposits. All parts of chrome deposits are not of equal grade. The question has been asked, 'What may be expected to be the highest grade?' In most deposits the ore near the walls or the bottom is less pure than that in the main orebody. However, there is much variation; and there is no rule to follow. This irregularity probably results from minor influences during the period of formation. The principal impurity is not necessarily silica; it may be iron, magnesia, or alumina. If iron be present as magnetite, the ore may be heavy and black, and may appear to the eye to be high-grade, yet actually low in chromic oxide. Some good ore is found with a film of magnesium carbonate, or silicate, so that it is white in appearance, and such ore has been condemned for that reason, because it was considered to contain too much silica. It is important to remember this: You cannot make an optical analysis of chrome ore.

Field Determination of Chromite. Familiarize yourself with the appearance of typical chrome ore. Scratch a piece of the suspected ore with a knife, deep enough to penetrate any surface film of foreign material. If the streak is dark-brown, the material may be chrome. If the prospector will provide himself with a spirit lamp, two inches of platinum wire fused into the end of a short glass tube, and an ounce of borax, he can make a fair determination. The operation is as follows: Crush a small piece of the ore to a powder; bend a small loop at the end of the platinum wire; heat the wire in the flame, and dip it in the borax. Some borax will stick to the loop. Melt this in the flame, and continue dipping in the powdered borax and melting it until the loop has become filled with a bead of colorless borax-glass. Heat the bead to redness, and, while hot, place it against the crushed ore until a few particles adhere to the bead. Hold this in the flame until the particles are entirely dissolved in the borax, allow it to cool, and then the bead, if chromium is present, will have a bright green color. Having determined that chromium is present, send the sample to a reputable chemist and ask him to determine the amount of chromic oxide and silica. The ore-buyer must know the percentages of these two materials before he can go further.

Minerals Mistaken for Chromite. Magnetite, or magnetic iron ore, is frequently mistaken for chrome ore. It is dense black, highly magnetic, and of about the same weight as chromite. It is much harder, however, and can be scratched with a pocket-knife only with difficulty, and it does not show the brown streak. It may be distinguished also by crushing to the size of a pea. If it can be picked up by a magnet it is not chromite.

Hematite, another ore of iron, is sometimes mistaken for chromite. It is usually softer, and has a reddish brown streak, quite different from that of chromite.

Hornblende-picrite, a rock that is dark-green to black, and quite heavy, is frequently found in chrome districts. Hornblende may be similar in appearance. The simple way to distinguish these rocks from chromite is to scratch them with a pocket-knife; the streak is grayish to greenish-white.

METHODS OF FINANCING OPERATIONS. The prospector finding a chrome deposit usually needs financial help to develop it and put the ore on the cars. Ore placed on railroad cars is as good as cash, for the owner can at once get payment for the shipment, as explained in the section on marketing. Prior to that time, however, one of two methods is commonly employed. The owner of the deposit may seek a partner who, for an interest in the mine ranging from 25 to 75%, will furnish the necessary funds. Whether such an interest should be 25% or more may be determined by the visible profit to be made, and by the ability of the prospector as a trader. Funds are usually required to build roads to make the ore available for shipment, and sometimes for sled-trails or pack-trails which may be used for a part, if not all, of the distance. When the ore in sight is small, and this is usually the case, the prospector should be satisfied to start operations on a small scale, purchasing only such picks, shovels, and drills as are necessary to extract enough ore for the first carload. When that has been done, the shipment, if the ore is a fair grade, will provide $2000 or more as working capital, with which to expand the work. To secure funds enough to buy hoists, cableways, or other elaborate machinery, will necessitate the spending of time in promotion that should be used in mining. Financing small operations as corporate enterprises, and selling stock to get funds, is usually unsuccessful and is not to be recommended.

Several of the larger purchasers of chrome ore are willing to loan money to operators on contracts for the output of the mine. The ore available must, of course, justify the amount of the loan, which may be as much as a quarter to a half of the value of the ore developed.

It is also necessary to know that the money loaned will be used in mining, building roads, in providing necessary equipment or improvements, and that the amount is sufficient to start shipments by rail. The contract for ore is made usually at a price slightly below the market price, as the lender is taking a large risk while the miner, of course, will reap all the profit. The reputation of the miner for honesty and ability must be taken into consideration in making such loans. At this point a word as to fair play will be in order. A considerable number of the loans made in the manner outlined above has been lost because of duplicity and bad faith. Litigation follows and the mine ceases production. The United States government, in these critical times, cannot permit production to cease for such reasons as these, and the owner who becomes involved in these disputes, causing the cessation of production, is little better than a traitor. Honest difference of opinion may sometimes occur, but when this happens, don't rush to the lawyers with your trouble. Sit down on a log with the 'other fellow' and meet him half way in a fair discussion. If the difference of opinion has no honest foundation, and would prevent production, the facts should be reported to the U. S. Department of Justice, for the Government will not permit chrome deposits to remain idle if it can be prevented.

Markets, Selling Conditions, Future

Prices. The following schedule of prices was published in the 'Engineering & Mining Journal' on June 8, 1918, and is stated to be the schedule of a large purchaser, f.o.b. cars at stations on California and Oregon main line railroads.

Cr_2O_3 %	Price Per Unit	Cr_2O_3 %	Price Per Unit
30	$0.85	40	$1.30
31	0.90	41	1.325
32	0.95	42	1.35
33	1.00	43	1.375
34	1.05	44	1.40
35	1.10	45	1.425
36	1.15	46	1.45
37	1.20	47	1.475
38	1.25	48 and upward	1.50
39	1.275		

Another large purchaser gives the schedule below which is somewhat different. In each case, the prices were effective on June 1, 1918, and are, of course, not fixed for any specified period.

Cr_2O_3 %	Price Per Unit	Cr_2O_3 %	Price Per Unit
30	$0.65	41	$1.32
31	0.72	42	1.34
32	0.79	43	1.36
33	0.86	44	1.38
34	0.93	45	1.40
35	1.00	46	1.42
36	1.10	47	1.44
37	1.20	48	1.46
38	1.25	49	1.48
39	1.275	50	1.50
40	1.30		

CONTRACTS. Contracts for ore are made for periods ranging from one month to two years, most of the buyers preferring, it is believed, to limit their contracts to about six months. A fixed schedule of prices is provided in the contract, and such prices remain effective during the term of the contract. The amount of ore to be delivered by the miner is sometimes specified, but, as it is difficult to estimate the probable output of a deposit, it is preferable that the contract should call for the entire production, providing, if the purchaser prefers, a maximum amount to be shipped.

Contracts should specify:

(*a*) Situation and name of mine.
(*b*) Length of time the contract is to run.
(*c*) When deliveries are to start.
(*d*) Amount of ore to be sold.
(*e*) Price.
(*f*) Railroad station where the ore is to be loaded.
(*g*) Method of payment.
(*h*) How sampling of the shipment is to be done.
(*i*) Name of chemist whose analysis shall determine the price.

A satisfactory form of contract is as follows:

(Town) .... State ....
Date ....

JOHN SMITH agrees to sell to John Doe Company and John Doe Company agrees to buy .... tons of chrome ore mined or to be mined from deposits situated ...., to be delivered on cars at .... at prices and terms as follows:

PRICE:

$.......... per unit for ore containing 30% chromic oxide.
$.......... per unit for ore containing 31% chromic oxide.
$.......... per unit for ore containing 32% chromic oxide.
$.......... per unit for ore containing 33% chromic oxide.
$.......... per unit for ore containing 34% chromic oxide.
$.......... per unit for ore containing 35% chromic oxide.
$.......... per unit for ore containing 36% chromic oxide.
$.......... per unit for ore containing 37% chromic oxide.
$.......... per unit for ore containing 38% chromic oxide.
$.......... per unit for ore containing 39% chromic oxide.
$.......... per unit for ore containing 40% chromic oxide.
$.......... per unit for ore containing 41% chromic oxide.
$.......... per unit for ore containing 42% chromic oxide.
$.......... per unit for ore containing 43% chromic oxide.
$.......... per unit for ore containing 44% chromic oxide.
$.......... per unit for ore containing 45% chromic oxide.
$.......... per unit for ore containing 46% chromic oxide.
$.......... per unit for ore containing 47% chromic oxide.
$.......... per unit for ore containing 48% chromic oxide.
$.......... per unit for ore containing 49% chromic oxide.
$.......... per unit for ore containing 50% chromic oxide.

If the silica content should exceed ....%, ...c. per ton for each one per cent of silica in excess of said ....% shall be deducted, and buyer may reject, at his option, any ore containing more than ....% silica. No ore shall contain less than ....% chromic oxide.

TERMS:

Payment in full
(or) Payment of 80% will be made upon presentation at .... Bank at .... of sight draft and bill of lading showing certified railroad weights, with invoice and certificate of analysis by .... attached thereto. If any balance shall remain due, this shall be paid within ten (10) days from receipt of car at destination and completion of sampling and analysis. Sampling by the John Doe Co.

Railroad weights shall govern all settlements.

SHIPMENTS:

Shipments will be started within ...... days from date hereof, and completed ...... days thereafter. All cars to be shipped to John Doe Company, ...

This contract is made subject to such conditions, terms, and price, as may in the future be determined by the United States Government.

(Signature) ....
(Signature) ....

JOHN DOE COMPANY.

By ....

How to Make Shipments. Be certain that you have 40 tons, or more, of ore at the railroad switch before asking the local railroad agent to deliver a car. Gondolas are usually more convenient for loading, although box-cars may be used if gondolas are not available. When the car is spotted, load it promptly. A penalty is charged by the railway company if the car is not loaded within the time allowed. This may be 48 hours, but shippers should load in less time than this. It is of great importance in carrying out our war program to have cars loaded and shipped with great speed. Load the cars to their capacity whenever possible. The local railroad agent will tell you the maximum capacity of the car. The capacity printed on the side of the car is not the maximum capacity. When the car is loaded, notify the railroad agent that the car is released for shipment. The next step is to secure a bill-of-lading. Shipments should be made on an 'order bill-of-lading.' Remember that the consignee shown in the bill-of-lading owns the ore. A shipper should ship the ore to the destination agreed with the purchaser, but should ship it to himself. On the back of the 'order bill-of-lading' is a space provided for endorsements. The bill-of-lading should then be endorsed, as in the case of a bank check. The endorsement should read:

"Deliver to the order of John Doe Company.

John Smith."

A copy of the face of an order bill-of-lading is given on page 16.

Do not surrender the bill-of-lading until your receive payment for the shipment.

Settlements are based on the railroad weights, and this the railroad company will deliver through its local agent. These weights should be noted by the railroad agent on the face of the bill-of-lading, or on a separate certificate of weight furnished by him. Arrangements are usually made with some local bank so that the shipper can present to that bank his bill-of-lading, showing the railroad weights, and his certificate of analysis, in exchange for which he receives cash.

Some purchasers pay but 80 or 90% at the time the shipment is made, the balance being paid on receipt of the car at its destination or as soon thereafter as the car has been sampled and analyzed. If the shipper accepts such terms, he must not be disappointed if his final settlement is delayed for a long period. Freight moves slowly, and the shipment may be caught in embargoes.

SPECIFICATIONS FOR MARKETABLE ORE. Ore containing 28% or more of chromic oxide is saleable. If the silica content exceeds 8%, a penalty of 25c. per ton for each 1% of silica over 8% is sometimes charged, and a maximum of 12% may be allowable. If the ore contains more than 12% silica and the chromic oxide content is fairly high, then the silica is sometimes permitted to run up to 15% or more. Special arrangement with purchasers must be made in such cases.

Occasionally, though rarely, low-grade ore may contain too much iron to be saleable. There is no fixed limit for iron, and most contracts make no mention of the iron content, but iron in excess of 18 or 20% is not desirable.

METHODS OF MARKETING. The sale of ore to brokers, dealers, and middle-men is not encouraged. Consumers of chrome ore are willing to buy direct from the producer, and the producer should not be compelled to divide his profit with middle-men. Many dealers and brokers are without financial responsibility, and some are lacking in honesty. The miner and shipper have suffered so much loss from transactions with them, that a warning should not be necessary.

A list of some of the consumers follows:

American Refractories Co., Pittsburgh, Pa., and Merchants National Bank Bldg., San Francisco.
Binney & Smith, 81 Fulton St., New York, N. Y.
California Chrome Co., Kohl Bldg., San Francisco, Calif.
Carnegie Steel Co., Pittsburgh, Pa.
Colorado Fuel & Iron Co., Denver, Colo.
Crucible Steel Co. of America, Pittsburgh, Pa.
A. C. Daft, Oliver Bldg., Pittsburgh, Pa.
Electro-Metallurgical Co., Niagara Falls, N. Y.
Harbison-Walker Refractories Co., Pittsburgh, Pa.

E. J. Lavino & Co., Bullitt Bldg., Philadelphia, Pa.
Lukins Iron & Steel Co., Seattle, Wash.
Metal & Thermit Corporation, 120 Broadway, New York.
Mutual Chemical Co., 55 John St., New York, N. Y.
Noble Electric Steel Co., 995 Market St., San Francisco, Calif.
Otis Steel Co., Cleveland, Ohio.
Pacific Coast & Steel Co., San Francisco, Calif.
Pacific Coast & Steel Co., Seattle, Wash.
Pacific Electro Metals Co., Balboa Bldg., San Francisco, Calif.
Frank Samuel, Harrison Bldg., Philadelphia, Pa.
Sawyer Tanning Co., Napa, Calif.
The Sherwin-Williams Co., Cleveland, Ohio.
St. Louis Refractories Co., Title Guaranty Bldg., St. Louis, Mo.
The Ferro Alloy Co., 603 Symes Bldg., Denver, Colo.
The National Electrolytic Co., Niagara Falls, N. Y.
Youngstown Steel & Tube Co., Youngstown, Pa.

The above list is supplied by the United States Geological Survey, and, while doubtless not complete, contains all the names of which the Survey has a record.

Some of the above concerns maintain representatives on the Pacific Coast with whom direct contact may be had.

Present and Future Markets. If chrome ore were plentiful enough to supply the demand, there would be used in the United States in 1918, between 150,000 and 200,000 tons. Because of our inability to produce this amount, the consumption has been restricted to some extent by Governmental action. The use of chrome ore by several industries has been reduced in this way, and ferro-chrome, an alloy made from chrome ore, may be used at present only in Government work. This will reduce the demand to some extent. More chrome will be required, however, than can be produced. The question is constantly being asked, 'How long will these prices prevail?' It is not believed that there will be a substantial decrease in price as long as the War continues. How long this may be is a matter of conjecture.

Sampling and Analysis of Chromite

By ABBOT A. HANKS

Preparation of Samples. The sample sent to the assayer, if it represents either a shipment or a lot of ore extracted for shipment, should be taken so as to represent what it is intended to sample. It should weigh 40 to 60 lb., and contain no single piece larger than an egg. When this sample reaches the laboratory it should all be crushed through a rock breaker, set to give a one-half inch product. The rock-breaker product should be thoroughly mixed and cut down with a riffle, a Jones divider, or similar sampler, to one-quarter of its original size. This quarter (10 to 12 lb.) should be put through laboratory rolls, set to give a product of 12 to 16-mesh. This roll-product should again be cut down to a sample of about one pound. The whole of this one-pound sample should be pulverized in a disc-grinder or similar machine to pass 100 or 150-mesh. Before making the analysis the pulp should be dried at 212°F. to constant weight.

Chromium

The analysis of chrome ore may be separated into the following operations:

Fusion in an iron crucible with sodium peroxide.

Dissolving the melt in water; filtering and making acid with sulphuric acid.

Adding an excess of ferrous ammonium sulphate and titrating with standard potassium permanganate solution.

The standard method is described in the following text-books:

"Technical Methods of Ore Analysis," by A. H. Low.

"Standard Methods of Chemical Analysis," by W. W. Scott.

"Principles of Quantitative Analysis," by W. C. Blasdale.

Weigh out ½ gram of 100 to 150-mesh product; place in a 20-cc. iron crucible; add 8 gm. sodium peroxide and mix thoroughly with a small glass rod; cover and slowly fuse over a Bunsen burner by slowly rotating over the flame for about five minutes; when complete, decomposition of the ore will result. When partly cool, transfer the crucible and the melt to a 400-cc. beaker containing 150 cc. to 200 cc. water. When action ceases, rinse the crucible and the cover, then boil the solution at least five minutes, then dilute to 350 cc. with hot water. When partly cool, filter and wash thoroughly with hot water. Dissolve the precipitate with dilute hydrochloric acid to determine if the fusion was complete. If not, start a new portion. Cool the filtrate, transfer to a 1000-cc. beaker and dilute to 500 cc. with cold water, and add 25 cc. sulphuric acid (2 to 1); add 50 cc. standard ferrous ammonium sulphate solution, from an automatic pipette, to the solution in the beaker and then titrate with standard potassium permanganate solution. Standardization is accomplished by weighing ½ gm. of c.p. potassium chromate into a 1000-cc. beaker, dissolve in cold water, and make acid as above and proceed as explained; 50 cc. of the ferrous ammonium sulphate solution is titrated at least once each day by the potassium permanganate to determine their relative strength.

Potassium chromate equals 39.135% Cr_2O_3.

Ferrous ammonium sulphate solution contains 100 gm. ferrous ammonium sulphate crystals and 20 cc. sulphuric acid per litre.

Potassium permanganate solution contains 6.0 gm. c.p. $KMnO_4$ per litre.

1 gm. potassium chromite equals 26.25 cc. $KMnO_4$.

$$\begin{array}{r} 69.45 \\ 26.25 \\ \hline 43.20 \\ 2 \\ \hline \end{array}$$

$86.40/\frac{0.39135}{86.4}$ equals 0.0045296 grams Cr_2O_3 equals value of 1 cc. $KMnO_4$

Silica

One-half gram of ore is fused as above; dissolve in 50 cc. water; rinse off the crucible and the cover; make acid with hydrochloric acid, and take to dryness twice as for silica determinations. Complete as usual for silica.

The Determination of Chromium in Chromite

The following rapid method is in use at the Berkeley Experiment Station of the U. S. Bureau of Mines:

The ore should be ground to 100-mesh. Weigh out 0.5 gm. sample and brush into a 20-cc. spun-iron crucible in which has previously been placed 4 to 5 gm. of fresh Na_2O_2 (technical grade is satisfactory). Mix well with a glass rod, cover with a little Na_2O_2 and fuse at a low-red heat. After the charge has melted it should remain in the molten condition for five minutes. Allow the crucible to cool, place in a 600-cc. beaker of pyrex or other low-expansion glass or in a large casserole; add water and digest until the fused mass has disintegrated, after which remove and rinse the crucible. Boil for 10 minutes to decompose the Na_2O_2. Without filtering, neutralize the solution with 1–4 H_2SO_4 or 1–1 HCl and add 25 to 30 cc. excess. Dilute to approximately 400 cc., cool and titrate with a standard solution (about 0.2 N) of $FeSO_4$. Add a slight excess of $FeSO_4$ solution, as shown by spot-plate tests with a 1% solution of $K_3Fe(CN)_6$, and finish the determination by back-titration with standard $K_2Cr_2O_7$ solution. The $FeSO_4$ solution may be added rapidly without great care, as the approximate end-point is readily recognized by the color-change of the solution. With a little practice two or three spot-tests should be sufficient to determine the exact end-point.

Notes: The quickness of this method is due largely to the omission of filtration before acidifying the dissolved fusion. Manganese is practically the only interfering substance found in Western ores, and when this is present filtration is necessary.

The initial alkaline solution containing the precipitate inclines to bump on boiling. A few chips of fresh unglazed porcelain or a stirring-rod with roughened end, placed opposite one of the points where the beaker makes contact with the hot plate, minimizes this difficulty.

The standard $FeSO_4$ solution is prepared by dissolving 56 to 60 gm. $FeSO_4 \cdot 7H_2O$ in about 800 cc. distilled H_2O, to which has been added 100 cc. concentrated H_2SO_4. After cooling, the solution is diluted to one litre. The 0.2 N $K_2Cr_2O_7$ solution may be made by dissolving 9.806 gm. c.p. $K_2Cr_2O_7$ in one litre. The $FeSO_4$ solution may be standardized with a standard $KMnO_4$ solution based on Bureau of Standards sodium oxalate or against the $K_2Cr_2O_7$ solution, provided this was made from a salt of known purity.

One cubic centimetre of 0.1 N solution is equivalent to 0.001733 gm. Cr, or 0.002532 gm. Cr_2O_3.