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THE MAGNESITE DEPOSITS OF CALIFORNIA

BY

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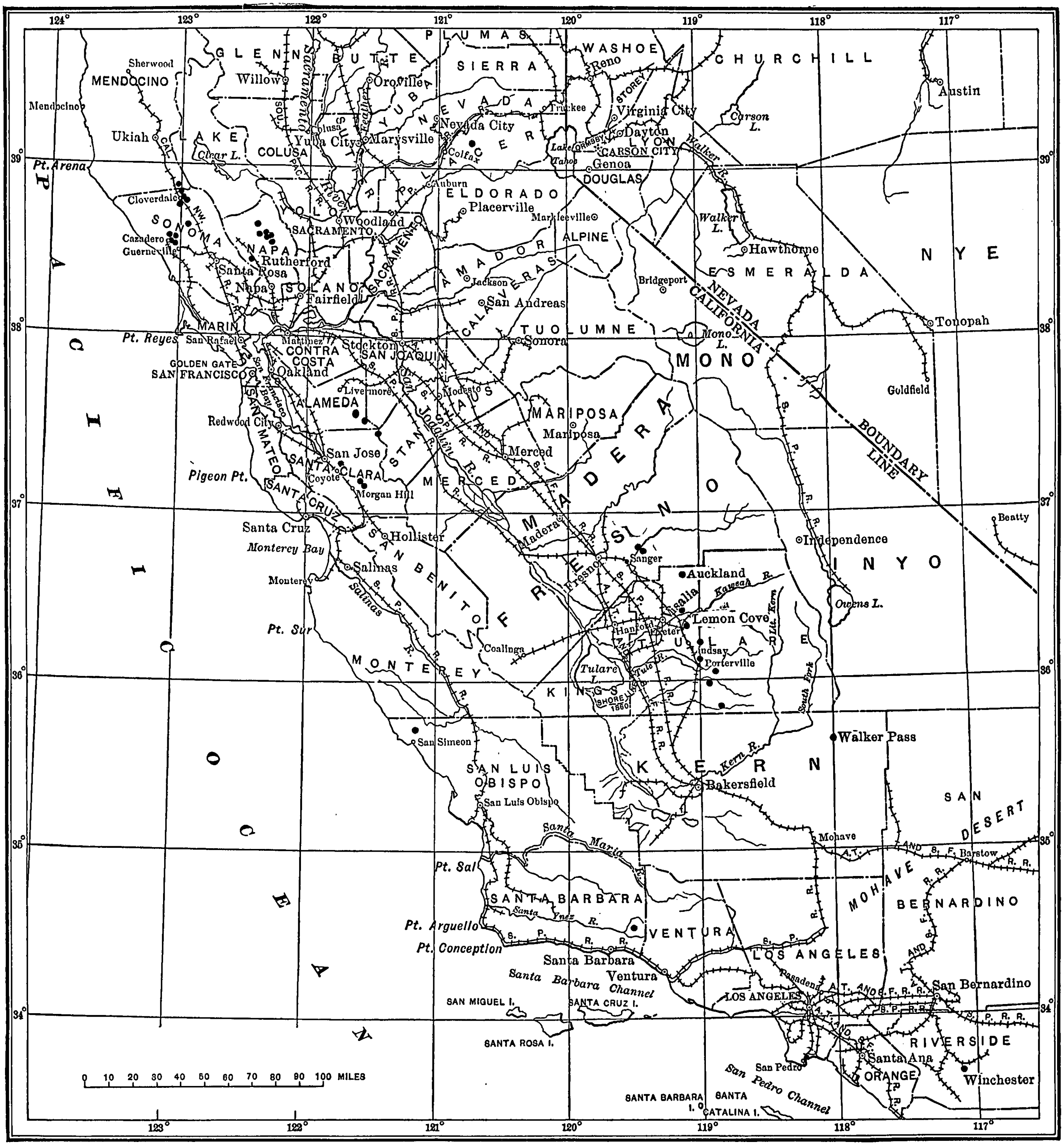


MAP OF CALIFORNIA, SHOWING DISTRIBUTION OF MAGNESITE DEPOSITS (•).

THE MAGNESITE DEPOSITS OF CALIFORNIA.

By Frank L. Hess.

GENERAL REMARKS.

INTRODUCTION.

Magnesite, or magnesium carbonate, ordinarily occurs in veins or in masses replacing other rocks rich in magnesia, though it seems probable that a few isolated and impure deposits in Quebec are of sedimentary origin. (See p. 53.) Although it can hardly be classed as a common mineral, it exists in comparatively large deposits at many places in various parts of the world. The principal foreign deposits now worked are in Austria, Greece, India, Italy, Norway, Russia, and South Africa. Other deposits which are either not worked or from which the output is small occur in Africa, Australia, British Columbia, Lapland, Mexico, Quebec, and Venezuela.

In the United States the only important deposits known are in California. Small veins of mineralogic interest only have been noted in Pennsylvania,[a] Maryland,[b] and Massachusetts,[c] and veins of unknown extent are reported to exist in Nevada and Arizona.

The Maryland and Pennsylvania deposits were at one time worked in a small way, the product being used for making Epsom salts (magnesium sulphate) and other chemicals, but magnesite from Austria, Greece, and South Africa can now be imported so cheaply that it no longer pays to operate them.

In California the deposits are scattered along the Coast Range from Mendocino County, and possibly farther north, to a point south of Los Angeles, and along the western slope of the Sierra Nevada from Placer County to Kern County. (See Pl. I.) Deposits are worked in Sonoma County near Cloverdale, in Santa Clara County near Livermore, and in Tulare County near Porterville. Mines were formerly operated in Chiles and Pope valleys, Napa County, and

[a] Frazier, P., jr., Lancaster County: Second Geol. Survey Pennsylvania, Vol. CCC, 1880, pp. 89, 97, 176–179, 196.

[b] Bascom, F., The geology of the crystalline rocks of Cecil County: Cecil County report, Maryland Geol. Survey, 1902, pp. 96–97.

[c] Dana, J. D., A system of mineralogy, 6th ed., 1892, p. 275.

considerable prospecting and preparatory work has been done at several other places with desultory production.

The field work on which the present article is based was done in November, 1905, and during the winter of 1906–7.

The literature of magnesite deposits is scanty, and aside from paragraphs and short general articles appearing in current periodicals from time to time, but little has been published on the California magnesite deposits.

COMPOSITION, PROPERTIES, AND USES.

GENERAL CHARACTER.

Magnesite is a carbonate of magnesium ($MgCO_3$), having, according to Dana,[a] a specific gravity of 3 to 3.12, and a hardness of 3.5 to 4.5. It is somewhat heavier than calcite (2.714 specific gravity), and is about one-third harder, the hardness of calcite being 3. It contains 52.4 per cent of carbon dioxide (CO_2) and 47.6 per cent of magnesia (MgO).

As it occurs in the California deposits, magnesite when comparatively pure is ordinarily a beautiful, white, fine-grained rock, with a conchoidal fracture that looks like a break in china. (See Pl. II.) It will take a fine polish and when so treated is an opaque white. Locally a portion of the magnesite occurs in a fine powder in what seem to be decomposition cavities and upon surfaces exposed to weathering.

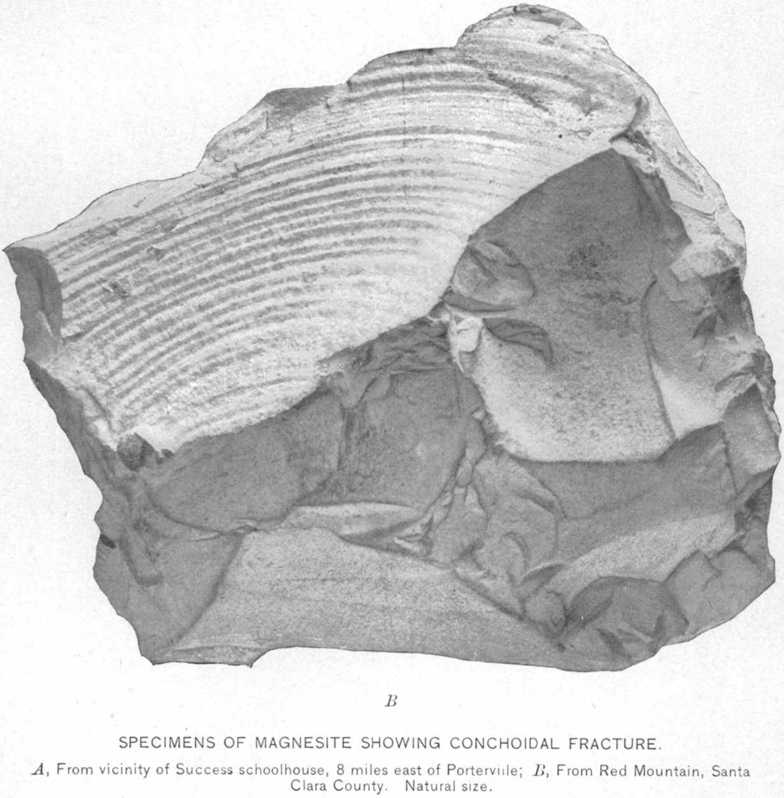
MANUFACTURE AND USE OF CARBON DIOXIDE.

Magnesite gives off carbon dioxide on strong heating and is used in preference to limestone for the production of this gas, as it contains a much greater proportion than calcium carbonate, which carries but 44 per cent. Other advantages of magnesite are that the residual magnesia left after calcination is more valuable than lime, and that the amount of heat required to drive off the carbon dioxide is much less.

Considerable amounts of liquid carbon dioxide are manufactured in Oakland from magnesite. As made at the Western Carbonic Acid Gas Company's plant at Sedan (Emeryville post-office), a suburb of Oakland, the magnesite is fed into a kiln with about one-tenth its weight of coke, and the gas from the combustion of the coke, together with that driven off from the magnesite, is pumped into scrubbers, of which there are three, filled with broken limestone to counteract any sulphuric acid, and washed with sea water. The use of sea water rather than fresh water is merely an economy. The gas then passes to an absorption tower where it comes into contact with a sprayed solution

[a] Dana, J. D., A system of mineralogy, 6th ed., 1892, p. 274.

A



B

SPECIMENS OF MAGNESITE SHOWING CONCHOIDAL FRACTURE.

A, From vicinity of Success schoolhouse, 8 miles east of Porterville; *B*, From Red Mountain, Santa Clara County. Natural size.

of potassium carbonate, by which it is absorbed. The "loaded solution" is then pumped into boilers where it is raised to a temperature just below the boiling point of water. The solution gives up its gas and is pumped back to the absorption tower for another load, while the gas is pumped through cleansing tanks and cooling pipes to a gasometer. It is then liquefied by a three-step compressor and run into steel cylinders, holding 25 to 60 pounds each, for shipment. In this process the weight of gas obtained is about 50 per cent of the weight of the magnesite used. The accompanying diagram (fig. 1) will probably make the steps clear. The gas is shipped throughout the Pacific coast and Southwestern States. It is used in refrigeration and in making soda water and other carbonated beverages. The magnesia left as a residue is shipped to paper mills in Oregon, where it is used, after being changed to a sulphite, in the digestion and whitening of wood pulp for paper. This is the chief use to which California magnesite is put, and almost the entire output of the Porterville deposits eventually finds its way to these mills.

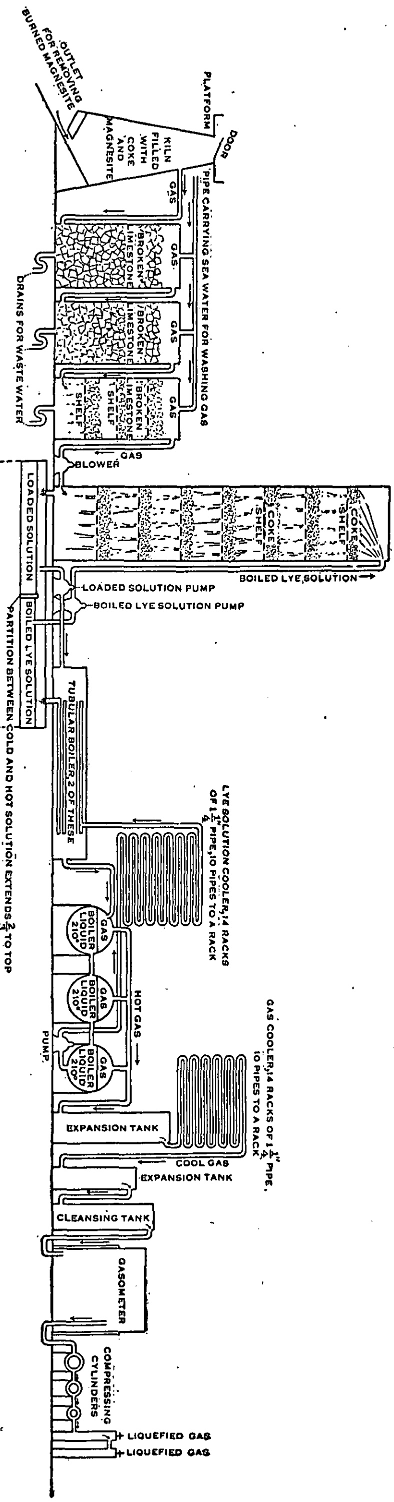


FIG. 1.—Diagram of Western Carbonic Acid Gas Company's plant at Sedan, Cal.

CALCINATION OF MAGNESITE.

Among men engaged in calcining magnesite, a difference of opinion has existed as to the temperature at which the carbon dioxide can be driven off. In recent experiments Otto Brill[a] has determined this point and made a number of interesting discoveries as to the behavior of magnesite when heated. His experiments were carried on with small amounts of carefully prepared and purified materials, so that his results are not exactly analogous to those that would be obtained by using the raw natural material. He showed that calcium carbonate (as ordinary limestone) gives up all of its carbon dioxide at 825° C. (1,517° F.), but that magnesium carbonate (magnesite) begins to give off carbon dioxide at about 237° C. (465° F.). A certain quantity is given off at this temperature, after which little or none is exhaled until the magnesite is heated to 250° C. (482° F.), at which point another certain quantity escapes. On raising the temperature a third partial dissociation point is reached at 265° C. (509° F.). Other such stages were marked at various points, and these were considered to show the successive formation and breaking up of various basic carbonates. The last of the carbon dioxide is given off at 510° C. (950° F.), a temperature much below that needed to calcine limestone. Brill's table showing the different carbonates formed is given below. The reduction to the Fahrenheit measurement of temperature is added by the writer of this paper.

Basic carbonates formed in burning magnesite.

	Calculated MgO.	Obtained MgO.	Dissociation temperature.	
	Per cent.	*Per cent.*	*°C.*	*°F.*
$10MgO, 9CO_2$	50.64	50.58	265	509
$9MgO, 8CO_2$	50.79	50.98	295	563
$8MgO, 7CO_2$	51.20	51.37	325	617
$7MgO, 6CO_2$	51.51	51.69	340	644
$6MgO, 5CO_2$	52.36	52.35	380	716
$5MgO, 4CO_2$	53.41	53.03	405	761
$7MgO, CO_2$	86.53	86.31	510	950

The temperature at which magnesite gives up the last of its carbon dioxide, 510° C., is below a red heat, but the time required to drive off all of the gas is not stated by Brill, and this, of course, would vary with the size of the material used. The important point, however, is that at this temperature all of the carbon dioxide will be driven off, so that, although higher heating will undoubtedly remove the gas more quickly, because the heat will reach the inner portions of fragments sooner, it ordinarily means a waste of fuel.

After magnesite is calcined the resultant magnesia takes up CO_2 from the air, again returning to the form of magnesite or magnesium carbonate, but it does this so slowly that it can not compete with lime or hard plasters in structural work.

[a] Ueber die Dissoziation der Karbonate der Erdalkalien und des Magnesiumkarbonates: Zeitschr. anorg. Chemie, vol. 45, part 3, June, 1905, pp. 277-292.

MAGNESIA BRICK, SHAPES, AND CRUCIBLES.

Calcined magnesite (magnesia) is used for making refractory brick and shapes for furnace linings. These products will stand exceedingly high temperatures, above any heat that can be obtained in regenerative furnaces, so that they are much used for lining electric furnaces. A considerable number are also employed in cement kilns and fire boxes for burning crude oil, uses in which intense and long-continued heat must be endured. They are also exceedingly resistant to corrosion by basic slags and most molten metals. These qualities make them desirable for linings in furnaces used for copper smelting and in the manufacture of basic steel. In the latter process the lime added to remove phosphorus and silica attacks clay or silica fire brick severely, but magnesia brick are little affected.

Furnaces built of magnesia brick or shapes must, to prevent cracking, be heated evenly and as gradually as possible, so that the inner ends will not be raised to a high temperature while the outer portions are still cold. The same care must be used in cooling off, and the furnace must lose its heat gradually and evenly if the shapes are to be preserved. Sometimes considerable trouble is caused by the swelling of magnesia brick and shapes on heating and a corresponding shrinkage on cooling, and copper converters are reported to have burst from this cause. This difficulty seems to be due largely to insufficient sintering, for very strongly sintered brick are said to give little trouble.

A plant for the manufacture of magnesia brick was erected at Clinton, a suburb of Oakland, in 1905, and is still in operation. Most of the magnesia brick made in this country are manufactured from European magnesite. Some magnesia brick of foreign manufacture were formerly imported each year, but none are shown in the customs returns for 1907.

Magnesia crucibles are made of various forms and different degrees of fineness. Crucibles made from pure magnesia have much the appearance of fine biscuit ware. If heated to incipient melting they have the appearance of translucent glass. When the ordinary European commercial calcined magnesite is used for crucibles, it has little strength above a red heat, but crushes in the tongs like so much putty.[a] Dr. Oliver P. Watts, in a long series of experiments in the preparation of metallic alloys, used magnesia crucibles as linings for carbon or graphite crucibles to prevent the absorption of carbon by the charge, and found that they answered the purpose excellently. In such crucibles alloys of iron with aluminum, cobalt, chromium, copper, manganese, molybdenum, nickel, silicon, silver, tin, titanium,

[a] Watts, Oliver P., in letter to author.

and tungsten were made. Chromium, silicon, and titanium, when forming 10 per cent or more of the charge, seemed to attack the linings, to judge from the failure of a number of them.

"These linings are extremely refractory, so that the maximum temperature at which they can be used is fixed not by their melting, but by another phenomenon, the reduction of the magnesia by carbon."[a] The carbon attacks the magnesia and corrodes it, especially if iron oxide be present, in which case, under very high temperatures, the iron oxide is volatilized and, coming into contact with the graphite crucible, is reduced and collects as microscopic spheres of iron. These grow and roll down the sides, carrying absorbed graphite, which vigorously attacks the magnesia after the equation $MgO+C=Mg+CO$. At a lower temperature this action is reversed, and for this reason magnesium can not be obtained from magnesia by reduction with carbon.

Magnesia crucibles made under such temperatures are white, even when much iron oxide is present in the raw materials, for the iron oxide is volatilized and driven out.[b] Mr. A. J. Fitzgerald, of Fitzgerald & Bennie, Niagara Falls, N. Y., states in a letter of March 21, 1908, to the writer, that his firm melts charges of 6 or 7 pounds of alloys in magnesia crucibles in electric furnaces by withdrawing the charge through the bottom. Cracking from change of temperature is not likely to take place in small, well-fused magnesia crucibles.

Much mystery has been attached to the binders used in making magnesia brick, shapes, and crucibles, to cement the particles together when burned. It is a common belief among persons handling magnesite that to make brick which will hold together when burned it is necessary to use magnesite containing impurities consisting of iron oxides or serpentine. It is undoubtedly true that such impurities will allow the sintering of brick at very much lower temperatures than are necessary with pure magnesite, but they also make the brick more fusible and more easily corroded by molten materials. A pure magnesia brick demands a very high temperature for sintering, but bricks can be made without the impurities mentioned or others, and when so made are extremely refractory. Dead-burned magnesite—that is, magnesite from which the CO_2 has been entirely driven off—has little or no plasticity, so that it is hard to handle. It is said that its plasticity is much improved by using partly calcined or caustic magnesite with it. Heavy pressure will bind the material sufficiently to allow it to be sintered; 240 tons per brick is used in the works at Snarum, Norway.[c]

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[a] Letter cited. See also paper by Doctor Watts, The action of carbon on magnesia at high temperatures; Trans. Am. Electrochem. Soc., vol. 10, 1907, pp. 279-289.

[b] Watts, O. P., op. cit., p. 287.

[c] Daumann, E., Magnesit fran Snarum: Bihang till Jern-Kontorets Annaler for 1905, Stockholm, 1905, pp. 222-225.

Magnesia may be melted to a glassy substance in an electric furnace, but when so treated contains many bubbles. It seems highly probable that it would be profitable to sinter magnesia brick and similar products in an electric furnace, where electric power is as plentiful as it is in California.

MAGNESIUM CARBONATES.

For some of the purposes to which magnesite is rather extensively put, dolomite, the calcium magnesium carbonate, may be used, as in the making of magnesia alba levis (light magnesium carbonate) and Epsom salts. The light carbonate is well known as a toilet preparation and is also used in medicine. Mixed with various amounts of asbestos it is used for pipe covering and boiler lagging; 85 per cent of light carbonate to 15 per cent of asbestos is a common proportion. The asbestos is needed to hold the powdery carbonate together. For this purpose water glass (sodium silicate) is also sometimes added to the mixture. The heavy carbonate is sometimes used instead of the light carbonate, in which case the efficiency of the covering is probably diminished owing to the lesser degree of porosity. The light carbonate is said to make an excellent absorbent for dynamite manufacture, as it does not readily allow the nitroglycerine to "sweat" out. Powdered magnesite is introduced to prevent scale in boilers in which sulphurous waters are used, as the magnesium sulphate (Epsom salts) formed is highly soluble.

OXYCHLORIDE CEMENT.

For many years it has been well known that a moistened mixture of magnesium oxide (magnesia) and magnesium chloride will form an exceedingly strong cement, and numerous attempts have been made to use it in manufacturing tiles, artificial stone, flooring, wainscoting, etc. Many of these attempts have met with failure owing to an unlooked-for decomposition of the manufactured product, and this has prevented the industry from becoming important as quickly as had been expected. The failure of the cement seems to be due to the presence of lime either in the magnesium chloride or in the magnesia, which in the form of chloride is hygroscopic and by taking up water swells and destroys the usefulness of the material, and so where magnesite is to be used in the manufacture of cement efforts are made to obtain it as free from lime as possible.

At the Malelane deposits, South Africa, the magnesite is calcined, ground, and mixed with imported German magnesium chloride at the mine and shipped ready for use as cement.[a]

In using the cement for flooring, wainscoting, etc., it is mixed with sawdust or sand and coloring matter to give it the desired tint. It

[a] Hall, A. L., The magnesite deposits of Malelane: Rept. Geol. Survey, Transvaal Mines Dept., 1906, Pretoria, 1907, pp. 127-132.

may be laid in a continuous sheet over considerable areas and is said to crack much less easily than cement. The use of sawdust makes the material very much lighter in weight than cement, less hard, and more resilient. The surface is commonly waxed and polished, like a wooden floor. At the present time a large part of the Grecian magnesite imported into this country is used for making such floors. The material has also been used for wall plaster, and in specimens seen by the writer would stand severe abuse without breaking. In these preparations the sawdust particles are well separated, so that the material is in a high degree fireproof. The same mixture is used for making stationary washtubs and for similar purposes.

OTHER USES.

Sintered magnesite tubing of assorted sizes, up to 31.5 inches in length and 2.8 inches in diameter, is regularly made for chemical and electrometallurgical work.

The fusing point of magnesia has been determined by Goodwin and Mailey[a] as about 1910° C. The same experimenters found that the fused material is not acted upon by fused silver, sodium, potassium, or barium nitrates; nor by sodium, potassium, or zinc chlorides, bromides, or sulphate, even after an hour's exposure of a polished surface to their action. Barium chloride has a very slight action on it, but sodium carbonate, potassium sodium carbonate, potassium hydrate, and cryolite attacked the fused oxide energetically. Cold dilute hydrochloric, nitric, and sulphuric acids attack the fused oxide slowly, and concentrated acids are less active than dilute acids.[b] The fused magnesite takes up but little CO_2 from the air, and it is possible that if pure material were used it would be found that there is no recombination with carbon dioxide. In experiments performed by Fitzgerald & Bennie,[c] during which they found specimens to take up 0.42 and 0.63 per cent CO_2, the magnesia used contained 1.10 and 2.48 per cent of lime, respectively, which may have been the combining substance. According to the experiments of Goodwin and Mailey the coefficient of linear expansion of fused magnesia is almost the same as that of platinum, and but little more than that of quartz parallel to the optic axis. They find the coefficient of linear expansion between 120° and 270° C. to be—

$$a_t = 10^{-8} [1140 + 0.92 (t - 120°)],$$

while for platinum they quote Holborn and Day as giving—

$$a_t = (8889 + 1.274 t) 10^{-9} \text{ for } t = 0° \text{ to } 1000°.$$

[a] Physical properties of fused magnesium oxide: Trans. Am. Electrochem. Soc., vol. 9, 1906, pp. 92–93.
[b] Op. cit., p. 98.
[c] Discussion of "Physical properties of fused magnesium oxide:" Trans. Am. Electrochem. Soc. vol. 9, 1906, pp. 101–103.

In these formulæ a_t stands for the coefficient of expansion at any given temperature, t standing for temperature.

A coating of crushed magnesite is laid on hearths used for heating steel stock for rolling, to prevent the scale formed from attacking the fire brick of the hearth.

When heated to a high degree magnesia becomes incandescent like lime and the rare-earth oxides. On account of this property numerous efforts have been made to construct an incandescent lamp, similar to the Nernst lamp, which uses a glower made of zirconia and yttria, but not much success has been attained. A patent[a] has been taken out for the construction of electrodes for arc lamps from a mixture containing 90 per cent of magnesia and 10 per cent of iron oxide. Magnesia is a poor conductor of electricity,[b] and the iron oxide is introduced to increase the conductivity. Owing to its nonconductivity magnesite mixed with iron dust has been used for the manufacture of rheostats.[c]

Magnesia has been used for an adulterant in paint, but it has little virtue as a pigment. Its covering properties are poor, and it settles badly in the mixture.

Magnesium (metal) is not obtained from magnesite, but from magnesium chloride, which is obtained in large quantities from the Stassfurt salt deposits in Germany and from sea water at other places.

MARKET FOR CALIFORNIA MAGNESITE.

The market for California magnesite is at present limited to the Pacific coast and Rocky Mountain States, as the necessarily high freight rates, due to the long railroad haul to the eastern portion of the country, preclude its shipment in competition with imported magnesite. Moreover, the California deposits are handicapped in the competition with foreign deposits by the much higher scale of wages paid in this country. Day laborers in California receive $1.50 to $2 for a ten-hour day, and if miners are hired for the work, $2.50 to $3 must be paid. In Hungary the wages paid in 1906 at the works of the Magnesite Company (Limited) were 40 cents per ten-hour day for common labor and 80 cents for foremen.[d] Besides these drawbacks, none of the California veins compare well in size with the reported width of the Hungarian veins. In quality, however, the comparison with the foreign material is favorable; in fact, the California article is ordinarily better.

Magnesite from Porterville now costs about $6.50 per short ton laid down at San Francisco; probably that from the Gilliam Creek (Sonoma County) deposits can be delivered for somewhat less. Pro-

[a] Lewis J. Jones, letters patent No. 484553, dated October, 1892.

[b] The conductivity of magnesia when heated is treated in the article by Goodwin and Mailey, to which reference has been made (p. 14).

[c] E. W. Gilbert, letters patent No. 439939, dated November 4, 1890.

[d] Private letter.

duction at the Kings River deposits will cost about the same as at Porterville. Magnesite from Sonoma and Napa counties can probably be calcined and laid down in San Francisco at $15 per short ton. Imported magnesite is now (April, 1908) quoted in New York City at $7.25 to $8 per long ton, equal to $6.38 to $7.08 per short ton; calcined magnesite is quoted at $16.75 to $25, and when comparatively free from lime, ground, sells in small lots at the latter price. With this difference in price for calcined magnesite of about $5 to $6 between San Francisco and New York, it seems possible that this product could sometimes be shipped at a profit to the eastern coast of the United States on vessels that would otherwise sail without a full cargo and would for this reason be willing to carry the material at low rates.

In spite of the fact that the California magnesite is ordinarily purer and cheaper, calcined Grecian magnesite is shipped into Los Angeles as "white cement" for use in oxychloride cement.

PRODUCTION.

The production of magnesite in California since 1891, the first date for which figures are available, has been as follows:

Quantity and value of crude magnesite produced in California, 1891–1907.[a]

	Short tons.	Value.		Short tons.	Value.
1891	439	$4,390	1900	2,252	$19,333
1892	1,004	10,040	1901	3,500	10,500
1893	704	7,040	1902	2,830	8,490
1894	1,440	10,240	1903	3,744	10,595
1895	2,220	17,000	1904	2,850	9,298
1896	1,500	11,000	1905	3,933	15,221
1897	1,143	13,671	1906	7,805	23,415
1898	1,263	19,075	1907	[b] 7,762	50,453
1899	1,280	18,480			

[a] Yale, C. G., Magnesite: Mineral Resources U. S. for 1906, U. S. Geol. Survey, 1907. The figures for 1907 were also kindly furnished by Mr. Yale.
[b] From this amount 3,234 tons of calcined magnesite, worth $20 per ton, was produced.

IMPORTS OF MAGNESITE AND ITS PRODUCTS.

The imports of magnesite into the United States for the last three years have been as follows:

Imports of magnesite and magnesite products into the United States in 1905, 1906, and 1907.[a]

	1905.		1906.		1907.	
	Pounds.	Value.	Pounds.	Value.	Pounds.	Value.
Magnesia:						
Calcined, medicinal	13,554	$2,778	30,788	$5,689	49,489	$9,005
Carbonate of, medicinal	21,901	1,360	39,487	5,844	85,467	3,994
Sulphate of, or Epsom salts	9,039,099	38,084	5,830,224	22,471	4,532,713	16,256
Magnesite:						
Calcined, not purified	134,595,334	575,355	141,314,682	740,585	151,137,661	688,371
Crude	14,152,466	63,264	39,477,766	122,908	46,878,740	186,988

[a] Figures furnished by Bureau of Statistics.

There is no duty on magnesite or calcined magnesite, nor on the salts of magnesium mentioned in the table. For some reason the calcined magnesite imported in 1907 is declared of much lower value than the market price ($8.11 per ton as compared with $16.75 to $25).

DESCRIPTION OF DEPOSITS.

GENERAL STATEMENT.

The California magnesite deposits, so far as known, all occur as veins in connection with serpentinized magnesian rocks. By far the larger part are in the Coast Range, in the serpentinized rocks that stretch from southern California into Oregon. These rocks, although in few places wholly altered, will be referred to as serpentines, the name by which they are ordinarily known. Those in the Coast Range are probably lower Cretaceous in age[a] and cover large areas, Becker[b] estimating that between Clear Lake and New Idria, a distance of about 200 miles, there are more than 1,000 square miles of serpentine. Through a large part of this area magnesite veins of various sizes are found. Veins large enough to be more or less workable are known to occur at many places in Mendocino, Sonoma, Napa, Alameda, Stanislaus, and Santa Clara counties. Along the western side of the Sierra Nevada magnesite is found in Placer, Fresno, Tulare, and Kern counties, and in southern California in Riverside County.

The serpentines of the Coast Range are ordinarily greenish or bluish, greatly broken and faulted, a solid block a foot in diameter being a rarity in many localities. They are derived from olivine-pyroxene rocks, in which the amounts of the minerals vary in ratio at different localities. Here and there the rocks still carry considerable portions of only partly altered minerals, though the general decay is far advanced. There is great difference, both in the comparative amounts of the original minerals from which the serpentine is formed, and in the degree of serpentinization, even in small areas. Some rocks are almost wholly made up of partially serpentinized olivine, in places carrying chromite and chromic mica, while near at hand other specimens show large quantities of orthorhombic pyroxene. Along the Sierra Nevada the serpentine at the Fresno and Tulare County localities is of a dull drab or brown color and that in Tulare County is much less broken than the Coast Range serpentines.

Magnesite is probably formed both from the breaking down of the serpentine-making minerals and from the serpentine itself. In a specimen from the northeast corner of Santa Clara County enstatite has been replaced by magnesite. Many of the cracks in the olivine are filled by magnesite. These cases seem to show the derivation of

[a] Fairbanks, H. W., San Luis folio (No. 101), Geologic Atlas U. S., U. S. Geol. Survey, 1904, p. 6.

[b] Becker, G. F., Geology of the quicksilver deposits of the Pacific slope: Mon. U. S. Geol. Survey, vol. 13, 1888, p. 103.

magnesite directly from the original minerals, but the ordinary tendency shown by magnesite bodies is to occur in only those portions of the serpentine which show great decay, the magnesite being probably formed mostly from the serpentine.

Van Hise[a] supposes that in the decay of olivine a third of the magnesium may pass into magnesite, in which case he would write the reaction for olivine containing magnesium and iron in the atomic ratio of 3:1 as follows:

$$\underset{\text{Olivine}}{3Mg_3FeSi_2O_8}+\underset{\text{Carbon dioxide}}{3CO_2}+\underset{\text{Water}}{4H_2O}+\underset{\text{Oxygen}}{O}=\underset{\text{Serpentine}}{2H_4Mg_3Si_2O_9}+\underset{\text{Magnetite}}{Fe_3O_4}+\underset{\text{Magnesite}}{3MgCO_3}+\underset{\text{Quartz}}{2SiO_2}+\underset{\text{Heat}}{k}.$$

Here "k" signifies that heat is liberated.

This equation is largely theoretical, and as a matter of fact little magnetite is found in many of the specimens examined. Hydrated oxides of iron are common, however, and it seems probable that to such an equation water should be added to the unknown amount necessary to hydrate the iron. At the same time it is to be remembered that vastly more carbonated water is ordinarily present than is required to supply the amount demanded by the equation, so that it seems possible that under certain conditions, with this excess of carbon dioxide at hand, the entire amount of magnesium contained in olivine carrying equal numbers of magnesium and iron atoms may pass into magnesite. Such a change may be represented by this equation:

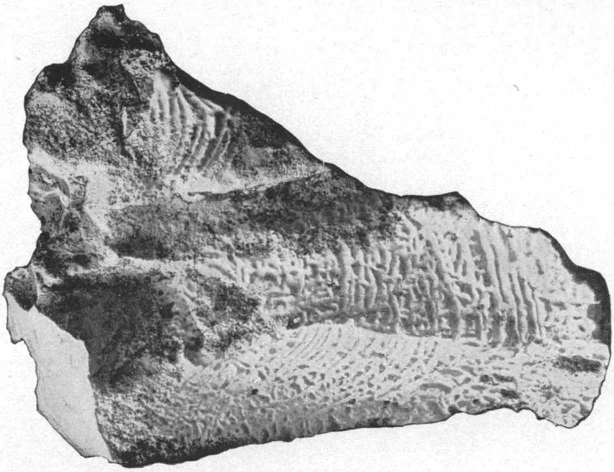
$$\underset{\text{Olivine}}{4Mg_2Fe_2Si_2O_8}+\underset{\text{Water}}{6H_2O}+\underset{\text{Carbon dioxide}}{8CO_2}+\underset{\text{Oxygen}}{4O}=\underset{\text{Limonite}}{2(2Fe_2O_3.3H_2O)}+\underset{\text{Magnesite}}{8MgCO_3}+\underset{\text{Quartz}}{8SiO_2}.$$

Enstatite also alters to magnesite, and in a few specimens is wholly replaced by it. Probably other pyroxenes also form magnesite on weathering.

It seems probable that as a rule both serpentine and magnesite are formed in the process of decay of the original minerals in peridotites and allied basic rocks, and that during the decay of the serpentine the formation of magnesite is continued. In any case the magnesia or magnesian mineral is changed to the carbonate, dissolved by percolating water charged with carbon dioxide, and precipitated in cracks and crevices as veins. The silica is carried away in solution by the water and is often deposited in other veins or with the magnesite veins as opal or quartz.

Many magnesite veins stand out prominently from the surrounding serpentine, as they weather less readily than the serpentine, and also because in the vicinity of a magnesite vein the surrounding serpentine is generally much decomposed and therefore erodes rather easily. The boldness of outcrop and the snowy whiteness of the veins form a

[a] Van Hise, C. R., A treatise on metamorphism: Mon. U. S. Geol. Survey, vol. 47, 1904, p. 309.



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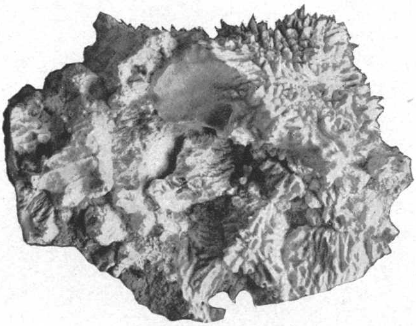

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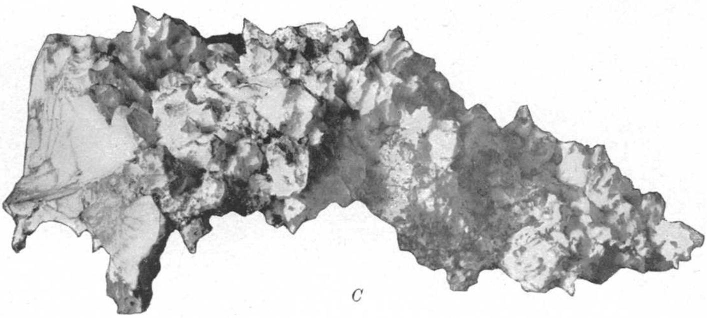


C

WEATHERED SURFACES OF MAGNESITE.

A, From Red Mountain, Santa Clara County; *B*, *C*, From locality 4 miles northeast of Porterville. All natural size.

strong contrast with the dull-colored surroundings, so that their occurrence at once attracts the eye.

Surfaces of comparatively pure, even-grained magnesite, exposed to the weather, are in many places fluted by the rain, similarly to limestone under like conditions, but the flutings or channels are much narrower. Other surfaces are covered with sharp-angled irregular projections, due probably to impurities. (See Pl. III.) At Red Mountain, Santa Clara County, earth-covered pieces attacked by percolating water have weathered into designs resembling mud cracks, with the spaces between the cracks convex and a little over half an inch across. (See Pl. IV, *B*.)

In many of the larger veins there is a central portion of comparatively pure magnesite, and in the same veins on one or both sides there may be many inclusions of serpentine. This mixed condition of the magnesite and serpentine is common in the large veins seen along the Coast Range. Small inclusions of serpentine in many places extend well into the vein. Toward the side the inclusions form a gradually larger proportion of the mass until the magnesite appears only as a great number of small veins in the broken serpentine. Or, if the main mass is approached from the side, as along a tunnel, a stockwork of small veins first appears, growing thicker toward the large vein, until the larger part of the mass is magnesite and the pieces of the serpentine are so separated as to become inclusions in the magnesite. This may result from two forms of growth. If any particular group of anastomosing veins grows greatly, the fragments between the veins become so separated that they lose their predominance as compared with the magnesite, and the magnesite forms the greater part of the mass. In the other form of growth the serpentine fragments may be partly or wholly replaced by magnesite. Still other large veins and masses are clear magnesite from the center to one or both sides, either of which may be formed by much slickensided faults.

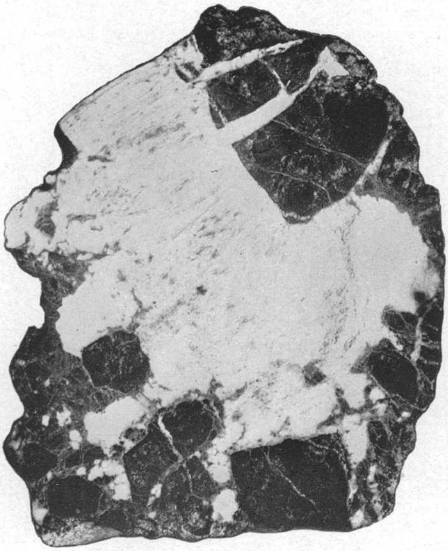
There is considerable difference in the purity of the veins at different places. Some are beautifully white and contain but a small percentage of foreign matter; others contain iron oxides, silica, clay, or serpentine in varying amounts and proportions.

Near the veins the serpentine has almost without exception lost its normal color and is badly rotted and porous as the result of its decomposition by percolating surface waters. The rock shrinks through the gradual removal of its components and the magnesite fills the enlarging spaces between the fragments. The magnesite produced through the decomposition of serpentine occupies about four-fifths of the space of the original rock, so that a magnesite vein may be and probably is formed very largely from the serpentine which formerly occupied the space now filled by the vein, the remainder coming from the rock in a comparatively narrow zone on each side. The large width of some of the veins may thus be explained, by supposing that they occupy the spaces made by the disintegration of the serpentine almost as fast as they are left, rather than natural fissures or cracks in the rocks. The veins are thus, in a sense, partly residual from the serpentine. In specimens collected fragments of serpentine are to be seen in various stages of decomposition and replacement; in others the fragments are as sharp angled as if freshly broken. Belts of disintegration naturally occur along the channels with greatest circulation of water, generally coincident with the larger faults. Every crack and joint along the line makes a feeder for the trunk channels. Among these reticulations the same process of decomposition is going on, and in places abrupt enlargements of the veins occur, making so-called "bowlders" of magnesite, which may be 2 or 3 feet or even more in diameter and nearly equidimensional. The formation of such a deposit, on a small scale, is shown in Pl. IV, *A*. This lack of linear extension in the small deposits, together with the number of faults known to cut the Coast Range serpentines in every direction, makes the following of veins by widely separated outcrops very uncertain, as the outcrops may be, and many of them are, distinct deposits, though they happen to have a certain alignment. Abrupt terminations are known to occur in the large deposits as in the smaller ones, and it is unsafe to expect the same continuity as would be thought probable in a quartz vein of equal width.

Two modes of precipitation of magnesite from solution suggest themselves. Brucite ($Mg(H_2O)_2$), formed through the decomposition of magnesian minerals without carbonation, may take the CO_2 from carbonated water carrying magnesite and thus precipitate both the newly formed molecule and the magnesite carried in solution, owing to the loss of excess CO_2 in the water; or magnesite may be precipitated from carbonated water owing to the loss of CO_2 through evaporation. Nothing resembling brucite has been seen, either in microscopic sections or in hand specimens, so that the latter hypothesis seems more likely, though possibly it applies only to the veins deposited in more open places, the former process going on in the small threadlike veins.

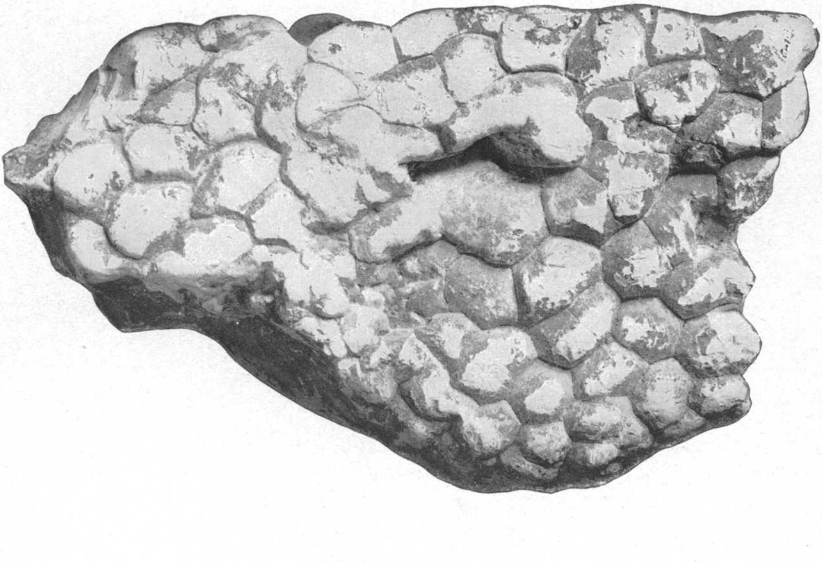
Little is known of the depth to which the veins extend. If they are formed through the agency of percolating surface water, which seems most likely, the manner of precipitation probably has little to do with the depth to which they extend. It seems fair to assume that the deposits may be found down to the limit of easy circulation of these waters, a depth of several hundred feet in favorable localities, their size being modified by the time through which such circulation has existed, by differences in the hardness or composition of the rock, etc. Faulting is as likely to cut the veins off in depth as in length.

Cinnabar and chromite occur in the serpentines in the neighborhood of many of the magnesite deposits.



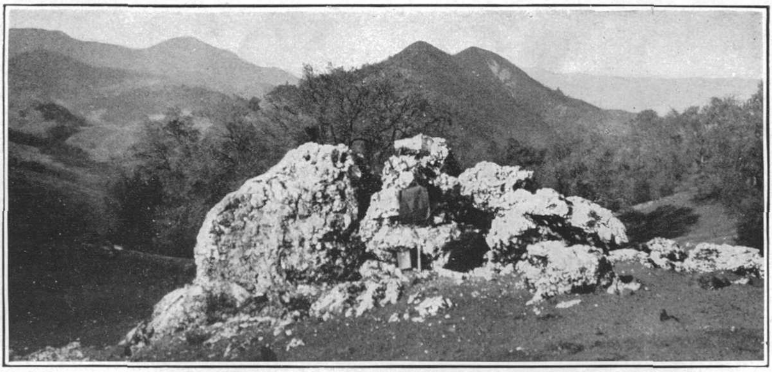
A. SMALL IRREGULAR VEIN OF MAGNESITE IN SERPENTINE.

From Red Mountain, Santa Clara County.

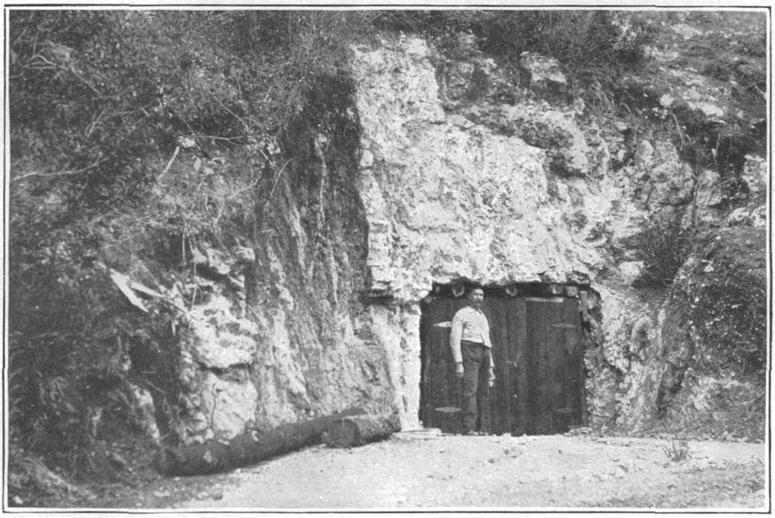


B. MAGNESITE WEATHERED UNDER SEVERAL INCHES OF CLAY.

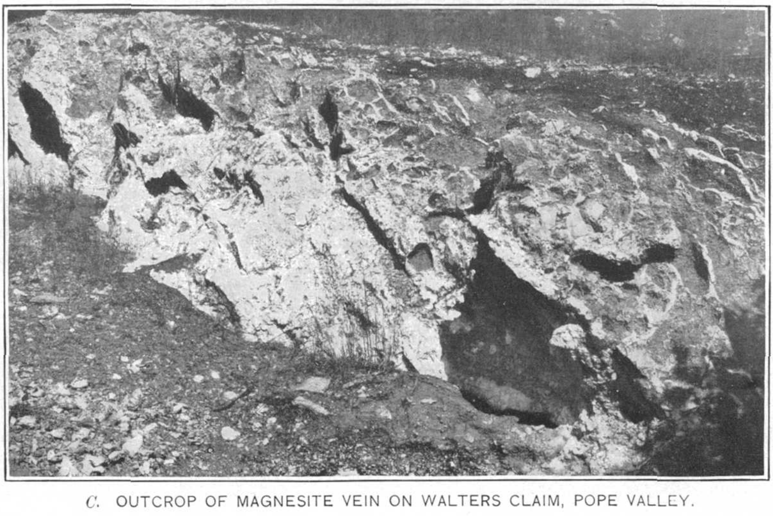
The surface is soft. From Red Mountain, Santa Clara County.



A. OUTCROP OF MAGNESITE ON HIXON RANCH, MENDOCINO COUNTY.



B. ENTRANCE TO LOWER TUNNEL ON SONOMA MAGNESITE COMPANY'S CLAIM, NEAR CAZADERO.



C. OUTCROP OF MAGNESITE VEIN ON WALTERS CLAIM, POPE VALLEY.

The face exposed is about 6 feet high.

THE COAST RANGE OCCURRENCES.

The individual California deposits will be treated by counties, beginning with the northernmost in the Coast Range and going southward to southern California, then northward along the Sierra Nevada.

MENDOCINO COUNTY.

Hixon ranch deposits.—On the Hixon ranch, on the east side of Russian River, 12 miles north of Cloverdale, there are a number of outcrops of magnesite, about 600 feet (barometric measurement) above the river, near the crest of a long ridge whose east side slopes steeply to a deep canyon and whose west side falls away more gently toward Russian River. The ridge at this place is formed entirely of serpentine, and it has broken off in successive blocks which are faulted downward toward the river, about 1½ miles away. Behind the fault blocks are hollows in which ponds form. The wagon road following the river crosses the serpentine, which is here reduced to mud and is excessively wet much of the time, owing probably to water that follows the faults and oozes out at this place.

The principal outcrop of magnesite (see Pl. V, *A*) is almost at the top of the ridge. It is apparently 15 to 20 feet thick and 30 feet long, standing between 4 and 5 feet above the surface, with a westerly dip. On the west side of the vein slickensides in two directions are plainly marked. Two smaller outcrops within 100 yards S. 35° E. (magnetic) from this one may be a continuation of the same vein.

Several other veins from a few inches to 1 foot thick outcrop within a few feet of the main exposure, and 200 feet farther west are a number of smaller, less pure, and less continuous veins. It seems probable that the veins are not continuous to great depth owing to the recency of the faulting, by which they would have been cut off.

No work has been done on any of the veins.

The magnesite in the main outcrop is white and remarkably pure, especially as regards its freedom from lime. A partial analysis by A. J. Peters, at the St. Louis laboratory of the United States Geological Survey, gave the following result:

Partial analysis of magnesite from J. M. Hixon ranch.

[Solution of air-dried material.]

Silica (SiO_2)	0.41
Alumina (Al_2O_3)	.28
Ferric oxide (Fe_2O_3)	.12
Lime (CaO)	.03
Magnesia (MgO)	47.16
Carbon dioxide (CO_2)	51.88
	99.88

As occasionally noted at other places, the magnesite shows shrinkage cracks (see Pl. VI, *A*) as if it had shrunk after deposition. This suggests the probability that it may have been deposited in the form of a hydrous carbonate.

Smaller deposits are said to occur near by, but they were not seen by the writer.

SONOMA COUNTY.

Creon deposit.—Four miles north of Cloverdale a number of magnesite veins outcrop in extremely irregular serpentine dikes, on a spur running southwestward from the mountains on the east side of the Sonoma Valley. The deposits are about 1,000 feet (barometric measurement) above Cloverdale, on a steep road, but the haul is all down hill.

The dikes in which the serpentine occurs are in places but a few feet wide, cutting an arkose similar to that in San Mateo and other Coast Range counties, where the rock is Cretaceous in age. They also cut some finer sediments. Other dikes are of diabasic character, and there is considerable glaucophane schist débris, though none was seen in place. The relations of the serpentine to the country rock are obscure, but it seems probable that the dikes are so faulted as to be locally discontinuous.

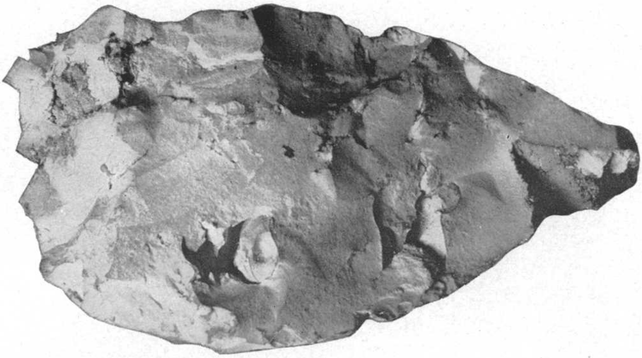
At the time this deposit was visited (November 29, 1906) work was being prosecuted by the Magnesite Products Company, of West Berkeley, Cal.

Magnesite veins, from 6 inches to a foot wide, outcrop on the surface at a number of places, but they show little continuity. At the main outcrop, which was close beside the road, a short tunnel cut a pocket of magnesite which was about 10 feet wide, 15 to 16 feet high, and 40 to 50 feet long. The serpentine is so faulted that if the mass ever continued onward it is now impossible to predict where the remainder may be found. About 500 tons was taken out and the workings abandoned.

One-fourth mile N. 10° E. a vein 8 to 12 inches thick is exposed alongside the road, and half a mile east of the main workings a face of magnesite 9 feet high is exposed below the road. A tunnel 15 feet long had been driven into it, at the end of which the magnesite thinned and contained serpentine.

Besides these veins there were a number of smaller outcrops at other points in the neighborhood.

The magnesite in the worked deposit is but little discolored and portions are pure white, but all through it is scattered some serpentine only partially altered to magnesite. The mass has been much crushed and the pieces have been recemented by crystalline magnesite of a slightly greenish yellow color, which forms a layer



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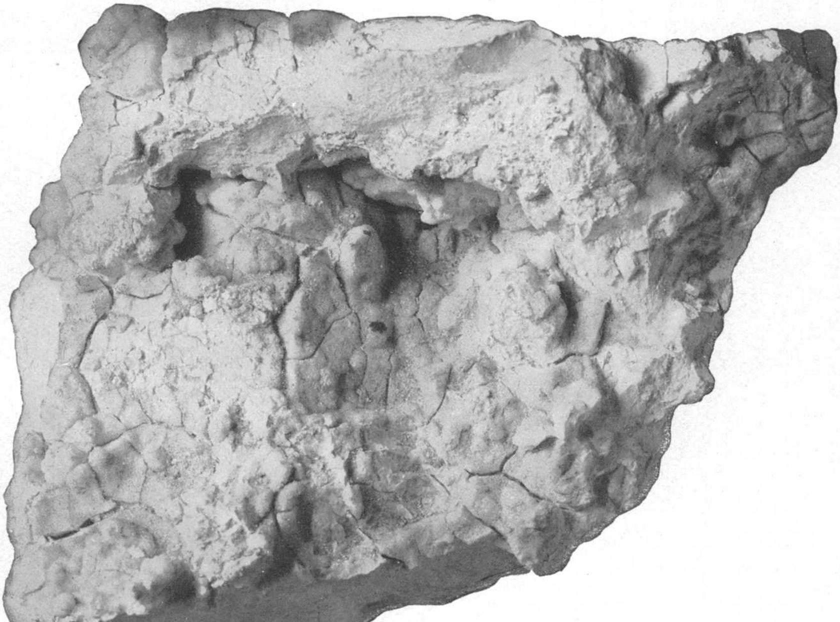

B

CRACKS IN MAGNESITE APPARENTLY DUE TO SHRINKAGE.

A, Compact magnesite from Hixon ranch, Mendocino County; *B*, Less compact magnesite coated with a thin layer of quartz, also cracked, from locality 4 miles northeast of Porterville.

about one thirty-second of an inch thick around the fragments. In places colorless fragile platy crystals coat the cavities. A partial analysis by A. J. Peters of a sample as nearly representative as could be selected gave the following results:

Partial analysis of magnesite from Creon deposit.

[Solution of air-dried material.]

Silica (SiO_2)	1.60
Alumina (Al_2O_3)	.25
Ferric oxide (Fe_2O_3)	1.09
Lime (CaO)	1.04
Magnesia (MgO)	45.20
Carbon dioxide (CO_2)	50.43
	99.61

No analysis was made of the magnesite from the other veins, which is less pure, part being yellow in color.

Eckert ranch deposits.—Three deposits of magnesite are said to occur on the Eckert ranch, on the edge of the valley 2 miles east of Cloverdale, but only two were seen by the writer. The more northerly is not more than 200 yards from the public road. Here on a soil-covered hillside a considerable amount of magnesite, roughly estimated at between 100 and 200 tons, has been excavated and piled up. The hole from which it was taken has been so filled with dirt that nothing could be seen of the rocks nor of magnesite left in place. The mineral is considerably stained, brownish and yellow, and gives the impression of being much more impure than it really is. Here too the magnesite is considerably cracked and the apertures are coated with a transparent crystalline magnesite, which at first glance looks like quartz.

A partial analysis by A. J. Peters is as follows:

Partial analysis of magnesite from north outcrop on the Eckert ranch.

[Solution of air-dried material.]

Silica (SiO_2)	0.51
Alumina (Al_2O_3)	1.98
Ferric oxide (Fe_2O_3)	.16
Lime (CaO)	.59
Magnesia (MgO)	45.84
Carbon dioxide (CO_2)	50.80
	99.88

In a plowed field, a quarter of a mile southeast of the occurrence just described, several rounded outcrops of magnesite, up to 4 or 5 feet across, occur in a line through a distance of about 75 feet. There has not been enough excavation to show whether they belong to one vein or whether they are merely nodules of large size. No relationship between these outcrops and the northern deposit can be traced.

The magnesite is much whiter and purer than that in the northern deposit, and is nearly free from lime. A partial analysis by A. J. Peters is as follows:

Partial analysis of magnesite from southern outcrop on Eckert ranch.

Silica (SiO_2)	0.23
Alumina (Al_2O_3)	.04
Ferric oxide (Fe_2O_3)	.20
Lime (CaO)	.19
Magnesia (MgO)	46.88
Carbon dioxide (CO_2)	51.57
	99.11

George Hall ranch deposit.—About 3 miles southeast of Cloverdale, on the George Hall ranch, in the south bank of a deep ravine running toward Russian River, there is a small outcrop of magnesite about 20 feet above the bed of the stream. Although the magnesite is white and appears to be of good quality the outcrop is only 4 or 5 feet broad in greatest dimension, so that it gives little promise of value.

Pat Cummings claim.—The Pat Cummings deposits are in a serpentine hill 2½ or 3 miles S. 35° W. (magnetic) from Cloverdale, at a height of about 1,200 feet (barometric) above that town. At the northernmost occurrence a few tons of magnesite has been mined and thrown out, but none can be seen in place. The magnesite is white, but like that in most of the other deposits has been much brecciated. The cracks between the fragments, however, instead of being coated with crystalline magnesite as is usually the case, are lined with clear colorless chalcedony, so that the percentage of silica present is large.

About one-fourth of a mile farther south are two outcrops of impure magnesite 8 to 12 feet in diameter.

Gilliam Creek deposits.—In the northwest corner of sec. 6, T. 8 N., R. 10 W., Mount Diablo base and meridian, on the steep western side of Gilliam Creek, 400 or 500 feet above the stream and about 7 miles northwest of Guerneville, are a number of large outcropping veins of magnesite. They occur in a space about 300 feet long, following the creek, and about 100 feet wide, measured along the slope. The country rock is as usual a serpentinized basic rock. The veins stand out boldly; one near the southern side of the claim is 6 to 8 feet thick and rises more than 20 feet above the hillside. Great masses of magnesite have fallen from the outcrop and lie on the surface or are partly buried in the débris. There are many smaller veins and probably one or two as thick as that from which the outcropping portions have broken, so that, as float or outcrop, several thousand tons of magnesite in large pieces are in sight. Other veins undoubtedly occur north of this deposit, as there are many bowlders of magnesite in the creek. Smaller deposits are said to occur down the creek (south) from the main outcrops. Except the deposits at Red Mountain, these are from surface indications the most extensive seen by the writer in California. The magnesite here, however, contains a greater amount of impurities than that at Red Mountain. (Compare analyses on p. 36.)

A partial analysis, made by A. J. Peters, of a sample picked to be as nearly representative as possible, was as follows:

Analysis of magnesite from west side of Gilliam Creek.

Silica (SiO_2)	3.51
Alumina (Al_2O_3)	1.10
Ferric oxide (Fe_2O_3)	.80
Lime (CaO)	1.46
Magnesia (MgO)	43.65
Carbon dioxide (CO_2)	49.16
	99.68

This magnesite is probably too impure for use as a material for cement, but should make brick which would compare well with the Austrian, and is good for gas and wood-pulp bleaching.

The property is owned by the Western Carbonic Acid Gas Company. About a mile of new road was necessary to connect the deposit with an established highway, and this was being constructed at the time of the writer's visit (December 3, 1906). No magnesite had then been shipped from the deposit.

Madeira deposit.[a]—The Madeira deposit was unknown to the writer at the time of his trip into Sonoma County, and so was not visited. It is in sec. 31, T. 9 N., R. 10 W., which adjoins on the north the section in which is located the Western Carbonic Acid Gas Company's claim, and is said to be a rather extensive deposit of magnesite containing considerable silica. The best exposures are said to be along a small tributary of Gilliam Creek. It will be necessary to build between 1 and 2 miles of wagon road before the magnesite can be hauled to the railroad.

Unnamed deposits.—About three-fourths of a mile northwest of the Western Carbonic Acid Gas Company's deposit, probably in sec. 36, T. 9 N., R. 11 W., near the top of a high hill, are a number of magnesite veins from 2 to 10 inches or more in thickness. One vein about 10 inches thick is exposed broadside along the face of a bluff perhaps 30 feet high. The quality of the magnesite here is apparently very good, though a number of the veins contain much serpentine. At one place there is a reticulated vein whose individual members are from 4 to 8 inches thick. This vein, which was formerly made up of

[a] Data furnished by Chester Naramore.

opaque white magnesite containing some serpentine, has been much broken. Around the fragments light-green, radially crystallized magnesite has formed, and cavities that still remained have been filled with milky chalcedony. The mass now consists largely of the green crystalline magnesite and is striking in appearance. It is said that at one time an attempt was made to work the deposit for ornamental stone, under the impression that it was Mexican onyx (onyx marble). There are too many imperfections in the material to make it desirable for this use. An old road, now fallen into bad repair, leads past the deposit to another road running to Healdsburg, which is about 11 miles distant. Should it become desirable to work these veins, the railroad could probably be reached more easily at Healdsburg than at Guerneville. Magnesite float was seen in a number of creeks in the neighborhood, showing the existence of other deposits, whose extent is unknown.

Red Slide deposits.—The Red Slide deposits are situated near a natural feature known by that name in the valley of East Austin Creek, in T. 9 N., R. 11 W., about 8½ miles by road north of Cazadero. The serpentine on the high hill in which the deposits are situated is stained with iron oxide, and there is so much slipping of the rock that vegetation can not exist on that portion of the hill, whence the name "Red Slide." It may be seen from other hilltops for long distances and so is a familiar landmark.

A large belt of serpentine, whose limits are unknown, runs through this portion of the country, and in it occur the magnesite deposits. In the group examined, which lies on the west side of the creek, there are several outcrops up to 5 and 6 feet wide and a number of smaller ones.

At the time the deposits were visited (December 4, 1906) the Sonoma Magnesite Company was doing development work on them. Two tunnels had been run into the hill, one a few feet above the creek and the other about 80 feet higher up the hill and 100 feet or so upstream.

The upper tunnel was well driven, 93 feet long, 6 feet high, and 7 feet wide. Three veins 5 to 6 feet thick and a number of smaller ones had been cut. There was but little work to show the extent of the veins beyond their thickness and they could not be followed on the surface. Much more development work is said to have been done since then. At one point magnesite was said by Mr. E. W. Arnold, the superintendent, to have formed during the preceding winter, and it gave much evidence of being a recent deposit. Water trickled over a face of magnesite exposed by mining, and a soft nodular deposit, somewhat resembling a spring deposit of calcite, covered that portion of the wall. Owing to the fact that shrinkage cracks are frequently found in magnesite, the question arose in the writer's mind as to whether magnesite was not deposited as a hydrous carbonate, and a specimen of the material was collected and later tested in the Geological Survey chemical laboratory, where it was pronounced anhydrous. Evidence of considerable faulting appears in the upper tunnel and small veins show dislocations of a foot or less. One of the larger veins was followed for but a few feet before it gave out.

The lower level was 200 feet long and of the same cross section as the upper one. It started in on a vein of magnesite which appeared to be about 9 feet wide (Pl. V, *B*), but the entrance is not at right angles to the vein, and the magnesite on the right side of the vein grades into serpentine. There is probably not more than 6 feet of clear magnesite. The tunnel did not follow this vein far and only one other was cut. This second vein has been faulted, and though apparently about 6 feet wide, but little could be told of its extent. The attempt to crosscut the veins cut in the upper tunnel was unsuccessful. It seems altogether likely that the general remarks about the indefinite extension of magnesite veins in any direction will apply with full force here. These veins will probably be found to be of much less length and depth than might be expected from their width, if they were to be judged by the ordinary characteristics of quartz veins.

The magnesite is of a creamy color and contains considerable silica. It is, however, remarkably free from lime. A partial analysis, by A. J. Peters, of a sample selected to represent as nearly as possible the average rock gave the result stated below. There is no doubt that better or worse specimens might be taken.

Analysis of magnesite from Red Slide deposits.

Silica (SiO_2)	7.67
Alumina (Al_2O_3)	.26
Ferric oxide (Fe_2O_3)	.29
Lime (CaO)	.04
Magnesia (MgO)	43.42
Carbon dioxide (CO_2)	48.08
	99.76

A large quantity of magnesite, estimated by Mr. Arnold to be almost 2,000 tons, though this figure seemed somewhat large to the writer, lies on the dumps. There is also a good deal of float magnesite in the creek. The road from the workings to Cazadero crosses a mountain with grades so steep that it is impossible to haul the magnesite out at a profit. The road to Guerneville is as bad, or worse, and longer, so that at present the magnesite can not be marketed. Should a way to haul the rock out be obtained, the company expects to make artificial stone and tiles. The company claims to have a much better deposit 2½ miles farther up the creek, where a vein is said to be from 10 to 25 feet thick and to have been followed for 900 feet.

Norton ranch deposits.[a]—On the Ed. Norton ranch, along Dry Creek, 10 miles northwest of Healdsburg, is a deposit of rather siliceous magnesite in large rounded chunks lying upon serpentine and overlain by clay and black soil. There is no outcrop, and the magnesite is exposed only by trenches.

NAPA COUNTY.

General remarks.—Like all the other counties along the Coast Range, Napa County has a rough topography, so that railroad and wagon-road building over most of it is difficult. The beautiful Napa Valley, from 1 to 4 miles wide, runs the whole length of the western side of the county, and east of it, separated by rough hills, lie Chiles and Pope valleys, of much less extent. Only in the Napa Valley is there a railroad, though projects for an electric road to traverse both of the other valleys on its way to Lake County have been agitated for many years. At one time grading was done over a part of the route, and later another company constructed a road for a portion of the distance through the Napa Valley.

All the known deposits in this county are situated east of the Napa Valley, with rather long and, in some cases, difficult hauls to the railroad. Rutherford is the most easily reached station and the road through Conn Canyon is the first stretch of the route to any of the deposits.

Walters or White Rock deposit.—The deposit bearing this name is located in the NE. ¼ sec. 11, T. 9 N., R. 5 W., on the east side of Pope Valley, 22 miles northeast of Rutherford. The distance from the railroad makes hauling expensive, and the claim, which was never worked on a large scale, has made no production for several years. The proposed electric road from San Francisco to Lake County, if built, will pass within 4 miles or less of the deposit, and the claim will then be in an excellent position to ship magnesite.

The deposit is situated about three-fourths of a mile from a public road in a hill of serpentinized lherzolite, about 400 feet (barometric measurement) above the valley. It is composed of a large number of veins whose exposures range in width from a fraction of an inch to 12 feet and lies on both sides of a small ravine that forms an amphitheater, with an easy, straight southward grade to the valley, making an almost ideal place to work with an aerial tram.

The veins are in three principal groups, two of which lie on the east side of the ravine and the other on the west. The main group on the east side comprises three large veins of magnesite that can be definitely traced for distances of about 140, 250, and 230 feet, with strikes of N. 28°, 30°, and 45° W., respectively. At their north ends the western and eastern veins are but 30 feet apart, and the middle

[a] Description furnished by Chester Naramore.

vein probably converges with the eastern one. A shallow shaft on the western vein shows its dip to be 50° N. 62° E. The veins stand out boldly and can be seen from any part of the valley not hidden by hills. (See Pl. V, *C*.) Longitudinal faults occur in both of the outer veins. Between the large veins are many smaller ones having a general parallelism to the main bodies. At its widest exposure the western vein is about 10 feet thick, of which about 5 feet on the foot wall is solid white magnesite, although the upper 5 feet on the hanging-wall side contains many inclusions of serpentine. The structure of the eastern vein is similar, and in places the magnesite may be seen grading into the country rock; it is about 12 feet wide where exposed in a shallow crosscut. In the middle vein a width of 18 inches to 5 feet of clear white magnesite is exposed. There has been some crushing of the magnesite and the broken particles have been cemented with yellowish, less pure material. Part of the magnesite has formed in yellowish botryoidal masses that are rather impure. Some crystalline magnesite, similar to that of Chiles Valley, is found in the crevices. It is said that 1,250 tons was mined between 1894 and 1899, being simply broken from the exposed faces of the veins.

A second group with a more northerly strike lies 100 feet or more above the veins just described. The veins forming this group are smaller, running from 2 inches to 2 feet in width, and the larger of these are impure. There are also many scattered veins in the intervening space.

On the west side of the ravine, 200 to 250 feet from the veins first described, is a third group with a strike between north and northwest. The largest vein is 4 to 6 feet wide; and seven others from 1 to 2 feet wide occur within 125 feet. All appear to be of excellent quality. It would seem possible to blast out the whole of the rock through this distance and hand-pick it at a profit should the deposits again be worked. A prospect tunnel was run into the hill near these veins and struck an irregular vein of crushed magnesite at the end.

Snowflake and Blanco claims.—Magnesite was mined by Bartlett & Stanley at a place about 2 miles south of the old Chiles mill, in Chiles Valley, and 10 miles from Rutherford, for a number of years, but the mine has not been operated since 1900, as it is too far from the railroad to compete with points having better shipping facilities.

Here also the country rock is the serpentine of the Coast Range, inclined to a dark-green or blue-black color. The deposits are on the west side of the valley, in a small serpentine hill skirted by a public road, and consist of a number of veins which range in thickness from 1 foot to 6 feet and are said to have been as much as 12 feet wide. Where seen, however, the larger veins were considerably mixed with serpentine and other impurities. Marked faulting occurs with the veins, and both the hanging and foot walls are generally fault planes. The serpentine is much broken and greatly decomposed in the neighborhood of the veins, the interstices being filled by smaller veins of magnesite.

On the foot walls of several of the veins extensive silicification has taken place, the serpentine being hardened through 2 or 3 feet. The veins are locally brecciated and cemented with less pure material of yellowish color, the original magnesite being a clear white. At many places in the brecciated portions each fragment is covered by magnesite in radial crystals, forming a coating up to half an inch thick and varying in color from crystalline clearness to delicate green and yellowish green. Cracks in the serpentine are also filled with the same crystalline magnesite. This material is strikingly different from the ordinary magnesite, which shows no crystal form to the unaided eye. In places crevices in the veins have a velvety black coating of pyrolusite (manganese dioxide), making the rock look as if it were coated with lampblack. A small amount of chromite has been found in the neighborhood, but not in paying quantities. Partial analyses of magnesite from this mine are given below:

Partial analyses of magnesite from the Bartlett & Stanley mine, Chiles Valley.

	1.	2.	3.
Silica (SiO_2)	2.15	1.81	6.68
Alumina (Al_2O_3)	1.22	.08	15.10
Ferric oxide (Fe_2O_3)	1.16		
Lime (CaO)	5.28	Trace.	....
Magnesia (MgO)	41.01	46.55	37.23
Carbon dioxide (CO_2)	48.72	51.25	40.98
Water and undetermined	....	.32	....
	99.54	100.00	99.99

Analysts: No. 1, P. H. Bates, United States Geological Survey; Nos. 2 and 3, Abbott A. Hanks, San Francisco, October 1, 1903.

Specimen No. 1 was collected by the writer and was as nearly representative as was possible to select; No. 2 was probably a picked sample, and No. 3 was of a poor quality, not shipped. The lime content of the first specimen is very high.

During the time that the mine was worked probably 10,000 to 12,000 tons of magnesite was taken out and calcined. As pure magnesite loses more than half its weight by being calcined, a large saving was made in haulage by getting rid of the carbon dioxide when the material was to be used as magnesia. A four-sided shaft furnace, built of serpentine and sandstone blocks and lined with firebrick, was used. It was about 15 feet high and from 3 to 5 feet across. The furnace was fired from the four sides at the base of the shaft, largely with manzanita, a hard-wooded shrub making a hot fire, and the calcined magnesite was withdrawn from below. The waste magnesite fines below the furnace have compacted noticeably from recarbonation.

Priest deposit.[a]—D. C. Priest has a magnesite deposit in Chiles Valley, in sec. 23, T. 8 N., R. 4 W., about 13 miles from Rutherford. One 2-foot and one 18-inch vein are exposed, well up a hillside, and magnesite of a rather poor quality is exposed in a lower opening. No work has been done on the deposit for a number of years.

Russell deposit.[a]—E. T. Russell holds a claim in sec. 24, T. 8 N., R. 4 W., on which several small magnesite veins outcrop. About 25 tons was shipped at one time. The deposit is 4 miles from a road and 15 miles from Rutherford.

Matthai deposits.[a]—Frank Matthai formerly held a claim known as the "North mine" in Soda Creek canyon, in the NE. ¼ sec. 35, T. 8 N., R. 4 W., near the public road. Irregular veins and masses of magnesite several feet thick outcrop in serpentine on this claim. Bartlett & Stanley mined the larger masses by open cuts in 1895, but the property has been idle since. Much magnesite still remains in sight.

The "South mine," also held by Mr. Matthai, lies a quarter of a mile southeast of the "North mine," on the other side of a low ridge, on the north bank of Greasy Camp Creek. A 5-foot vein of clear white magnesite outcrops along the creek for about 30 feet, dipping into the hill at a low angle. At the time the mine was visited (1905) two open cuts and a short tunnel had been made, and about 100 tons of magnesite was piled up.

SANTA CLARA COUNTY.

Deposit near Coyote.—A small deposit of magnesite occurs on W. W. Burnett's ranch, about 3 miles northeast of the Coyote railroad station and half a mile north of the summit of the Metcalf road. The deposit occurs near the top of the east slope of a hill several hundred feet high in a belt of impure serpentine, which weathers in rough, irregular forms. The exposed portion of the vein is about 100 feet in length and 4 to 10 feet wide, striking N. 35° W. (magnetic), apparently with a nearly vertical dip. A ravine cuts off the vein on the south, but some pebbles of magnesite were found on the south side, so that there may be on that side either another deposit or an extension of this one. The main part of the vein is of good quality, but a part of the magnesite is rather siliceous and contains fragments of serpentine now almost entirely replaced by silica and magnesite. The fragments on the surface south of the ravine are still more impure.

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[a] Data furnished by Chester Naramore.

A partial analysis by A. J. Peters of a specimen from the large vein gave the following result:

Partial analysis of magnesite from W. W. Burnett's ranch, Coyote.

Silica (SiO_2)	0.30
Alumina (Al_2O_3)	.16
Ferric oxide (Fe_2O_3)	.38
Lime (CaO)	1.34
Magnesia (MgO)	45.86
Carbon dioxide (CO_2)	51.80
	99.74

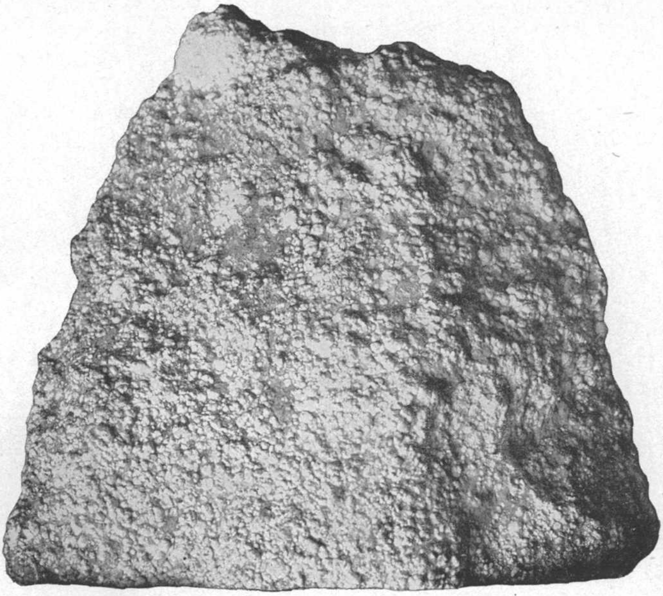
The magnesite seems to be suitable for brick, gas making, and paper making, but probably has too much lime to make good oxychloride cement.

As is usually the case, the serpentine is much more decayed near the vein than in other places. On the west wall of the vein the serpentine is so much impregnated with magnesite that it has a gray appearance for a thickness of several feet. In other places it has a glassy aspect over small areas, but the quantity is too small and the serpentine is too much cracked to permit its utilization as an ornamental stone. Many small veins of cryptocrystalline quartz cut the serpentine in various directions. In some of the veins are small vugs showing crystallized quartz.

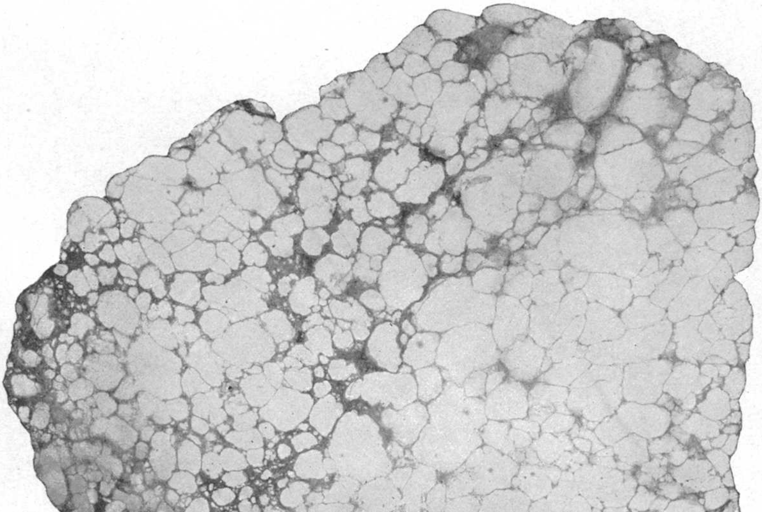
Bay Cities Water Company's land.—A couple of miles northeast of Morgan Hill station Coyote Creek turns abruptly to the west from a northward course and flows through a serpentine ridge into the Santa Clara Valley by way of a narrow cut, on the north side of which are several veins of magnesite. The serpentine in which they occur is similar to that east of Coyote station, and may be a part of the same dike. The lowest vein is perhaps 250 yards west of San Felipe Creek, which joins Coyote Creek at its westward bend. The outcrop of the vein strikes N. 85° E., is about 10 feet wide and 50 feet long, and forms the point of a small hill.

The magnesite is made up of rounded irregular particles ranging from half an inch downward in diameter (see Pl. VII, *B*), cemented by siliceous magnesite, which for an inch or more from the surface is stained red by iron. Many chunks of iron-stained quartz 2 feet or more in diameter lie on the ground near the outcrop. No work has been done on this vein.

About 100 feet farther up the hill is a larger deposit of rather impure magnesite, which does not carry so much silica, but has much serpentine mixed through it. A number of extremely irregular veins interlace through an area 200 feet long by 50 to 100 feet wide. In places the magnesite has an oolitic structure, analogous to the structure of the vein lower down the hill, but the particles are all small,



A



B

STRUCTURE OF MAGNESITE ON BAY CITIES WATER COMPANY'S LAND ON COYOTE CREEK.

A, Specimen from the upper deposit, showing a natural surface; *B*, Specimen from the lower deposit, showing a smoothly ground surface. Both natural size.

only a few grains reaching one-eighth inch in longer diameter. (See Pl. VII, *A*.) At the outer part the fragments are separated by talcose matter, but the mass becomes gradually more compact until the particles coalesce and form dense, solid magnesite. The principal vein runs almost parallel with the course of the hill, and a face 10 to 20 feet high has been exposed by a cut. In places segregations of clear-white magnesite reach 2 to 3 feet in thickness, but other portions of the vein are but a few inches thick. The material could be hand picked and a fair to good quality obtained.

An old sheet-iron furnace is in ruins on the ground, and it is said that an attempt was made to calcine the magnesite some years ago. Several carloads of the raw material are reported to have been shipped.

Mrs. A. F. Cochrane's land.—About 1½ miles south of the junction of Coyote and San Felipe creeks and about 3½ miles from Morgan Hill station, on the land of Mrs. A. F. Cochrane, is a rather bold outcrop, several feet wide, of a fine-grained buff-colored magnesite, which can be followed for more than 200 feet up the hill.

The serpentine shows much silicification and iron staining. In places blocks 8 or 10 feet thick are almost wholly replaced by iron-stained quartz. Elsewhere the cracks in the serpentine have been filled with quartz, very much as at other deposits the cracks have been filled with magnesite. The serpentine between the quartz veins is much decayed and in places drops out, leaving an irregular skeleton of silica much stained with yellow and red iron oxides. The great amount of iron present in this locality is very noticeable, and to it the magnesite probably owes its buff color, although the analysis shows but 0.18 per cent of ferric oxide. Silica makes nearly half of the rock. A partial analysis by A. J. Peters is as follows:

Partial analysis of magnesite from Mrs. A. F. Cochrane's land, near Morgan Hill.

[Solution of air-dried material.]

Silica (SiO_2)	49.85
Alumina (Al_2O_3)	3.45
Ferric oxide (Fe_2O_3)	.18
Lime (CaO)	.48
Magnesia (MgO)	21.53
Carbon dioxide (CO_2)	23.96
	99.45

In places small fragments of dull-yellow magnesite are included in the quartz. It is reported that some work was done on the deposit in 1897 and that several carloads of magnesite were shipped to San Francisco.

Red Mountain deposits.—Near Livermore, a town 48 miles southeast of San Francisco, there are a number of magnesite deposits, of which the only one now being worked is that of the American Magnesite Company, 32 miles southeast of Livermore on Red Mountain, in the northeast corner of Santa Clara County, along the Stanislaus County line. A number of the company's claims are located in the latter county. From Livermore an excellent road follows up the Arroyo Mocho, crossing into and running down the Arroyo Colorado. The maximum grade for the haul from the mine is said to be 3 per cent. At the mines the company has erected good buildings and roads, and an aerial tram 2,500 feet long, with a capacity of 100 tons per ten-hour day, delivers the magnesite to bunkers, from which it is loaded into wagons for hauling to Livermore. An attempt was made to haul the magnesite with oil-burning traction engines drawing two iron wagons carrying 17½ tons each, and two such trains were put into operation, but are reported to have been unsuccessful. The haul to the railroad is very long for a product of no greater value than magnesite, and can scarcely be profitable. The magnesite is shipped to Oakland, where the company's factories for brick, carbon dioxide, and other products are situated. The mine offices and other buildings are located near springs that give sufficient water for the engines, the mine, and other purposes. The country rock is lherzolite and peridotite, in some places much serpentinized and in others remarkably fresh. The magnesite occurs in the more altered portions.

Although these deposits have been known for a long time, they were not worked until 1905, owing to their distance from a railroad. They occur in a number of veins in a group around a small valley, so arranged as to be excellently located for working by adits and an aerial tram. Just how many veins there are can not be stated, as the brief time at the writer's disposal did not allow examination of the smaller ones. Owing to débris and faulting it is not possible to tell whether many of the outcrops belong to the same veins as neighboring ones or whether they are separate deposits. In the immediate vicinity there are, however, probably 10 or 12 veins, and possibly more, 2 feet or over in thickness, all of which could be well worked with but slight changes in the plant installed.

The veins stand out prominently in the bright sunshine of the valley and are almost dazzlingly white, so that they can be seen from the higher hills miles away. One of the veins, called the "Mammoth," stands fully 10 feet above the hillside.

The magnesite shows a number of peculiarities in weathering. Some of the surfaces weather into a pattern that looks like sun cracks in mud (see Pl. IV, *B*), with flatly oval surfaces from one-eighth to three-fourths of an inch wide between the cracks. In places there are fluted surfaces, such as occur on exposed limestones, but in narrower lines (see Pl. III, *A*), and locally the weathered surface is thickly studded with sharp points. Many exposed surfaces are covered with a white powder which has been supposed to be magnesium oxide or hydromagnesite, but which has been determined to be another form of magnesite. Underground also nodules or portions of veins of magnesite in places have turned to this powder, leaving a core of solid material. Mr. C. H. Spinks, the superintendent of the mines, told the writer that certain other veins a few miles distant, belonging to the company, carried very much more of this powder. Powdery magnesite has been described as occurring also in South Africa. (See p. 60.) Why it should take this form, breaking down from the solid state without apparent chemical change, is unknown.

Only one vein on the Alameda claim, near the top of the ridge, was being worked in November, 1905, when the claims were visited, and the first magnesite was shipped in that month. This vein has a strike of N. 30° W. (magnetic), with a steep southwesterly dip. It ranges in thickness from 15 to 40 feet, and could be definitely followed for about 300 feet S. 30° E. from faults against which it ends at the north. Whether the vein has been faulted off or whether its termination was originally fixed by the fault was not clear. Although the fault mud and breccia contains some crushed magnesite, this may come from other sources. Veins of rosiny opal and an aluminous siliceous material, 1 inch to 3 feet thick, occur along the fault. The magnesite is also badly cut and crushed by faults and contains in places much serpentine and some of the aluminous siliceous veins.

On approaching the vein through the tunnel one sees that the serpentine is greatly decayed and is cut in every direction by innumerable small veins of magnesite, crossing each other at all angles. Here and there, in veins which do not exceed 2 or 3 inches in thickness, sudden enlargements occur, which may be 3 feet in diameter and almost equidimensional. These are referred to as "bowlders," but they have nothing in common with bowlders beyond size and shape. Some of the smaller nodules are partly composed, mostly in the outer portion, of aluminous and siliceous material, the inner portion appearing to be comparatively pure magnesite. This material seems to be a replacement of the magnesite similar to the replacement of calcite by silica. The small veins grow in number and in thickness until by steady gradation the mass of comparatively pure magnesite is reached. At other points the vein's walls are abrupt and are probably delimited by faults. The vein was pierced by several adits on different levels, and a crosscut at one place entered the vein for 35 feet without going through it. A drill hole 8 feet long at the end of the crosscut was said not to have reached the other side. The magnesite is pure white, the crosscut looking as if freshly whitewashed. As is to be expected in a serpentine area, faults have cut the vein in a number of places, and through at least a portion of their length both hanging and foot walls are fault planes.

At several places pipes or nearly vertical channels, 6 inches and upward in diameter, now largely filled with clay, have been cut through the magnesite by water. The walls of these channels are much smoother than those of most similar channels cut in limestone, owing probably to the homogeneous composition of the magnesite. At two places the watercourses were large enough to use as chutes.

Mining is carried on by means of an open cut, in which the magnesite is quarried and allowed to fall through an upraise to an adit below, whence it is moved in cars to the aerial tram. The tramway drops 600 feet in the 2,500 feet to the bunkers. The skips are placed 500 feet apart and each carries 1,000 pounds of magnesite.

On the Canada claim, several hundred feet down the hill from the worked vein, is a large irregular outcrop of magnesite, between 40 and 50 feet across, which had not been prospected at the time the claim was visited. Later it was reported that a prospect tunnel run under this outcrop had shown the magnesite to contain much included serpentine.

Just across the ridge from the point at which mining was being carried on is the outcrop of the "Mammoth" vein, already referred to, which stands more than 10 feet above the hill slope on its lower side. It is about 4 feet thick and apparently is of excellent quality. It had not been prospected, so that nothing could be told of it beyond its outcrop.

A number of other veins in the group are up to 10 feet wide and at least one can be followed for 200 yards. They are not all equally pure, and several contain a considerable amount of included serpentine.

Extravagant estimates of the amount of magnesite in sight have been made, but though the amount exposed is large, the development at the time the deposits were visited was not extensive, and from the outcrops alone but two dimensions can be known, so that estimates of the total amount available are but little better than guesswork. Ravines cutting across the strike of the veins do not expose them and show that they are continuous for long distances.

The following are partial analyses of magnesite from the Alameda claim:

Partial analyses of magnesite from Alameda claim, Santa Clara County.

	1.	2.
Silica (SiO_2)	0.73	3.93
Alumina (Al_2O_3)	.14	.20 (with ferric oxide)
Ferric oxide (Fe_2O_3)	.21	
Lime (CaO)	.40	1.16
Magnesia (MgO)	46.61	......
Carbon dioxide (CO_2)	51.52	......
	99.61	5.29

Analysis No. 1 was made by A. J. Peters, of the United States Geological Survey. No. 2 was made by E. T. Allen, of the Carnegie Institution geophysical laboratory, to determine the amount of impurities present, preparatory to using the magnesite in his experimental work. Both specimens were collected by the writer, and the second was picked out for its whiteness under the supposition that it would be especially pure. F. E. Wright determined microscopically that the silica was present as quartz, and not as combined silica.

Close to the magnesite veins, about 250 yards southeast of the present workings, are small impregnation veins of chromite. The chromite occurs in grains from the size of a pea downward, and can be clearly seen to spread from joints in a serpentinized peridotite. It is accompanied by a pale lilac-colored chlorite, probably either kotschubeite or kammererite. A small amount of work has been done on the veins, but the prospects do not seem to have been encouraging. A little cinnabar is said to have been found in the neighborhood, and two mercury mines are being developed within a radius of 4 or 5 miles.

On Cedar Mountain, in Alameda County, the company had also located eight magnesite claims which, however, were not being worked and were not visited.

Other Santa Clara County deposits.—There were said to be other deposits in the neighborhood of Coyote, but the locations given were so indefinite that they could not be found. Small deposits are said to occur in Alum Rock Park, near San Jose, and in the vicinity of the mercury mines at New Almaden, but they are without commercial importance. From the amount of serpentine in the county it is rather to be expected that there should be other occurrences of magnesite.

ALAMEDA COUNTY.[a]

King claim.—Two miles from the Arroyo Mocho road and 22 miles southeast of Livermore, on the King claim, several small veins of magnesite are exposed in a cut. There has been no production.

Banta's camp deposit.—In sec. 16, T. 5 S., R. 4 E., on a narrow ridge southwest of Banta's cabin in the Arroyo Mocho canyon, 24 miles southeast of Livermore, is a small outcrop of magnesite. There has been no development.

STANISLAUS COUNTY.

Some of the American Magnesite Company's deposits (see p. 34) are in Stanislaus County, adjoining the Santa Clara County line. It is probable that other deposits occur along the western edge of the county, where the brushy, sterile hills of the serpentine area are but seldom traversed.

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[a] Data furnished by Chester Naramore.

SAN BENITO COUNTY.

Extensive areas of serpentine occur in San Benito County, in which are located the New Idria mercury mines, now the largest producers in California. No magnesite has been reported, but it is probable that it may yet be found. At present transportation facilities are poor, and in wet weather the roads are very bad.

SAN LUIS OBISPO COUNTY.

Magnesite in small veins is reported to occur on the Kiser place, 8 to 9 miles northwest of Cambria. The country is rough and the deposits are a long way from railroad transportation. San Simeon, a port of call for coastwise vessels, is the nearest shipping point.

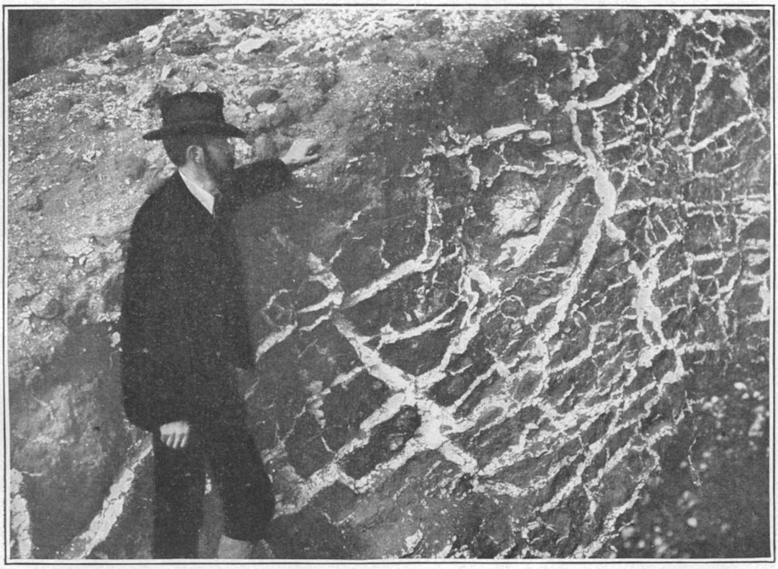
SANTA BARBARA COUNTY.

Specimens of magnesite seen at Santa Barbara were said to come from a deposit about 20 miles back in the mountains. No details could be obtained, but the specimens seemed to indicate that they had come from rather small veins. As a guide could not be obtained and there were no trails, the deposit was not visited.

RIVERSIDE COUNTY.

About 3½ miles south of Winchester, in a hill rising about 650 feet above the surrounding valley, intrusives, now changed largely to serpentine, have been thrust into biotite schist standing on edge and having a general northwesterly strike. The limits of the serpentinous bodies are rather vague, but the masses are probably several hundred feet thick. Pegmatite dikes, carrying tourmaline, cut both schist and serpentine. The dikes range in thickness from 4 inches to a number of feet, and where they cut the serpentine chlorite is developed for a distance of 2 to 6 inches on each side. At several places along the schist-serpentine contact radial asbestos of a poor quality has been formed through a thickness of 6 to 8 feet. Narrow veins of fibrous asbestos are developed along a vein of magnesite a few inches thick in a tunnel about 70 feet long, which was run into the hill in search of gold.

At a number of places in the serpentine trenches have been dug exposing magnesite stockworks with veins ranging in thickness from 2½ inches down to those too small to be readily noticeable. (See Pl. VIII, *A*.) From the best exposure, near the top of the hill, a piece of magnesite 6 inches thick, 18 inches wide, and 3 feet long was said to have been taken out, and was the largest piece found. In general the veins at this point are from one-half inch to 2 inches thick, with local enlargements. The distance between veins ranges from 3 to 10 inches. The magnesite itself is spongy and porous.



A. STOCKWORK OF MAGNESITE VEINS 3½ MILES SOUTH OF WINCHESTER.

B. SHEETED SERPENTINE CONTAINING THIN VEINS OF MAGNESITE, NEAR DEER CREEK, TULARE COUNTY.

A partial analysis of the magnesite by P. H. Bates, of the United States Geological Survey, is as follows:

Partial analysis of magnesite from hill near Winchester.

Silica (SiO_2)	4.73
Alumina (Al_2O_3)	.12
Ferric oxide (Fe_2O_3)	.08
Lime (CaO)	.43
Magnesia (MgO)	44.77
Carbon dioxide (CO_2)	49.40
	99.53

The lime is fairly low and there is little iron, but the silica is high. A company has been formed to work the magnesite, but that these deposits can compete with larger ones turning out as good or better rock in other parts of the State seems doubtful.

In a well bored in the valley about a mile northwest of this deposit a magnesite vein 20 inches thick is said to have been struck. It was supposed by some that there must be a connection between this vein and the other deposits, but there is no ground for this belief, and such a connection is altogether unlikely.

THE SIERRA NEVADA OCCURRENCES.

KERN COUNTY.

Magnesite is said to exist in Walkers Pass, in the Sierra Nevada, east of Bakersfield, but the deposits are so far from railway transportation that they are not now of economic importance. A specimen seen at Bakersfield was solid and of good white color.

TULARE COUNTY.

White River deposits.—Veins reaching 6 inches in thickness are reported to occur along White River, 4 or 5 miles west of Tailholt, but none of workable size are known.

Deer Creek deposits.—On and near the top of a serpentine hill about 1 mile south of the schoolhouse at Simmon's ranch, about 8 miles southeast of Porterville, there are a great number of comparatively thin veins of magnesite. The hill is a portion of the outside range of foothills, in front of which lie two or three smaller hills, also of serpentinized rock. In one, directly in front of the magnesite deposits and about 1 mile west, chrysoprase veins are being mined. A similar occurrence of chrysoprase veins in serpentine containing magnesite has been noted at Frankenstein, Silesia.[a] Veins of chalcedony up to 3 inches thick, showing greenish tints, occur near the magnesite veins. The country rock is a dull brown serpentinized peridotite

[a] Squire, Lovell, Some observations on the magnesite of Silesia: Trans. Royal Geol. Soc. Cornwall, vol. 9, pt. 1, 1875, pp. 59-70.

similar to that near Porterville. (See below.) As in the Porterville area, the rock is sheeted in places and contains great numbers of perpendicular thin parallel veins of magnesite, not over an inch thick and about an inch apart. Crossing the perpendicular veins at a small angle are a second series of veins, and a third series crosses at right angles. (See Pl. VIII, *B*.) The veins are probably due to shearing, which produced cracks. These cracks then formed channels for surface waters, and were filled by magnesite derived from the decomposition of the inclosing rock and brought by the waters from a distance and precipitated. Some, but not many, of these veins reach 2 feet in thickness for short distances; generally they are discontinuous and irregular.

A small amount of magnesite of excellent quality has been mined on the west side of the hill from a nearly vertical vein running parallel to the course of the hill and ranging from 10 to 18 inches in thickness.

A specimen obtained on the top of the hill was partly analyzed by P. H. Bates, of the United States Geological Survey, with the following result:

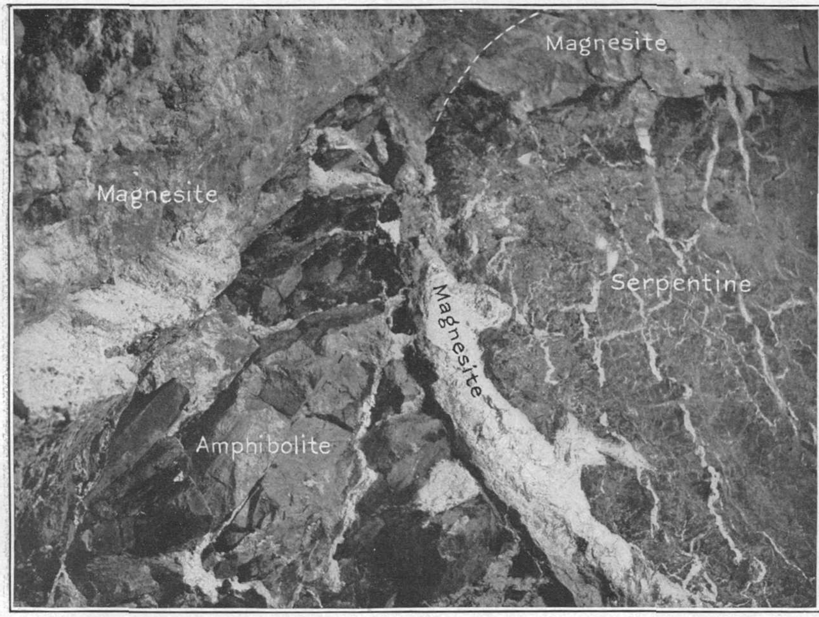
Partial analysis of magnesite from Deer Creek, Tulare County.

Silica (SiO_2)	0.31
Alumina (Al_2O_3)	.11
Ferric oxide (Fe_2O_3)	.08
Lime (CaO)	.24
Magnesia (MgO)	47.22
Carbon dioxide (CO_2)	51.64
	99.60

This is an excellent magnesite, the total impurities amounting to less than 1¼ per cent, but on the other hand the veins are small. The deposit is not more than 3 or 4 miles from the railroad, and may at some time pay to work.

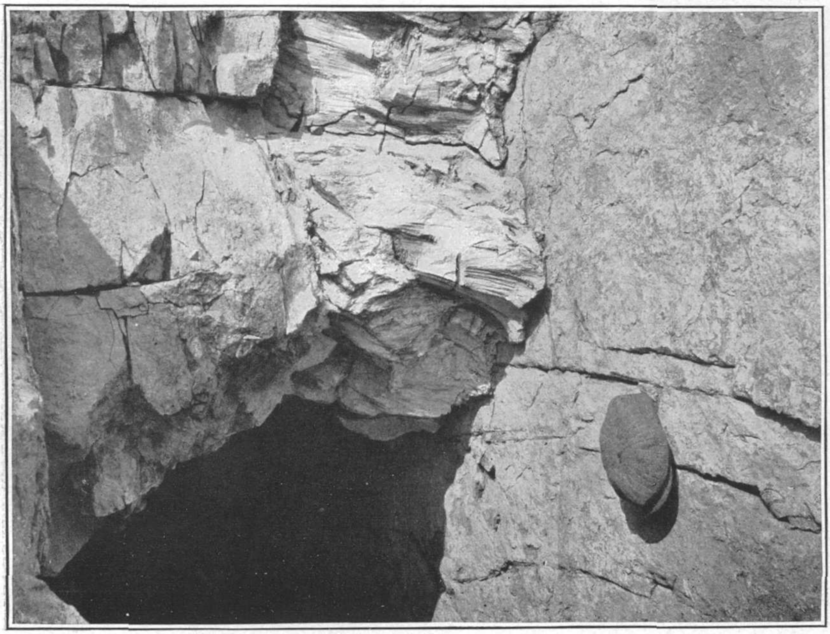
On the east side, near the top of a somewhat higher hill adjoining this one on the south, other small deposits of magnesite occur. Several short veins up to 2 feet thick were seen. Another 30 inches thick is said to be located not far from the saddle between the hills.

Porterville deposits.—In the outer range of foothills, about 4 miles northeast of Porterville, magnesite veins stand out prominently on two rounded hills at the top of smooth, steep slopes, rising about 1,000 feet above the town. One of the hills, which will be referred to as the northern hill, runs a little east of north, and the other, which will be referred to as the eastern hill, about N. 60° E. At their junction is a saddle about 300 feet below the summits. The hills are free from brush or trees, and the broad San Joaquin Valley flattens smoothly away, so that the white veins standing above the surrounding rocks attract attention from considerable distances. W. P. Blake,



A. AMPHIBOLITE DIKE CUTTING THROUGH FLAT VEIN OF MAGNESITE, 4 MILES NORTHEAST OF PORTERVILLE.

Small magnesite veins have formed in the amphibolite.



B. CRUSHED MAGNESITE VEIN, 2 FEET WIDE, NEAR FURNACE 4 MILES NORTHEAST OF PORTERVILLE.

who passed through this region with the United States expeditions making explorations and surveys for a railroad in 1853, briefly described the deposits in his report.[a] Mining did not begin, however, until 1901, since when it has been carried on continuously. From 1902 up to the present time the mining has been done by the Willamette Pulp and Paper Company, which controls under lease the northern hill and the west end of the eastern hill. Charles S. Harker is the owner of both hills and still retains control of the larger part of the eastern hill. The veins occur in a brown serpentinized peridotite, having an apparent bedded structure. The serpentine forms part of a metamorphic complex consisting of a small amount of fine-grained quartzite, amphibolite schist, serpentine, and other magnesian rocks, some of which are talcose and mica bearing. The rocks have a general northerly strike, with a rather high (60°) easterly dip. They are cut off by a granitic mass on the south, a few hundred feet from the deposits. (See fig. 21.) Several granitic dikes cut the serpentine and other rocks, but do not cut the magnesite veins, though basic dikes (amphibolites) of several varieties cut both the country rock and the veins and are here and there squeezed to schist.

Faulting is common, but does not divide the serpentine into the small irregular blocks which result, in the serpentines of the Coast Range and many others, from the swelling of the rock as it changes its chemical and mineralogical form. However, movement is evident, and the magnesite is invariably crushed in the larger veins. In one vertical 2-foot vein a couple of hundred feet southeast of the kiln (Pl. IX, *B*) the magnesite has been so squeezed that it is left in irregular fragments whose sides are covered with abrasion lines, the whole looking as if at the time of crushing it had been in a semi-plastic state. In other veins the planes along which the magnesite has moved on itself are smooth and shaped so as to somewhat resemble the curve of a highly arched shell. Along many of these planes is a bright red stain of iron oxide, although the surrounding magnesite is pure white. In other places the magnesite has evidently been crushed almost to a powder and recemented.

It seems probable that the movements which have caused so much crushing and distortion have been due to other causes than the serpentinization of the peridotite, for, as stated, it is not badly shattered, nor does it show the great number of smooth faces, due to small internal movements, that are common under such circumstances. The movements here may have been due to the stresses occasioned by the raising of the Sierra Nevada, to the intrusion of the granite or the amphibolites, or to all of these causes.

[a] Blake, W. P., Itinerary, or notes and general observations upon the geology, mineralogy, and agricultural capabilities of the route: Report of explorations in California, for railroad routes to connect with the routes near the 35th and 32d parallels of north latitude, Washington, 1856, p. 28.

Thin, nearly parallel veins of magnesite, mostly but a small fraction of an inch thick and but little farther apart, occupy zones in the serpentinized rock in which the sheeting due to shearing and crushing is especially prominent. These zones are practically vertical. The rocks have been fissured by faulting in many directions, and in the fissures magnesite veins have been deposited. Two of the largest veins occupying such spaces are practically flat. The veins range in thickness from threadlike seams to 8 feet, and the principal vein, which occurs in the northern hill (Pl. X, *A*), has been exploited through the hill, a distance of 785 feet, and can probably be followed through the valley between the hills and into the eastern hill. On the

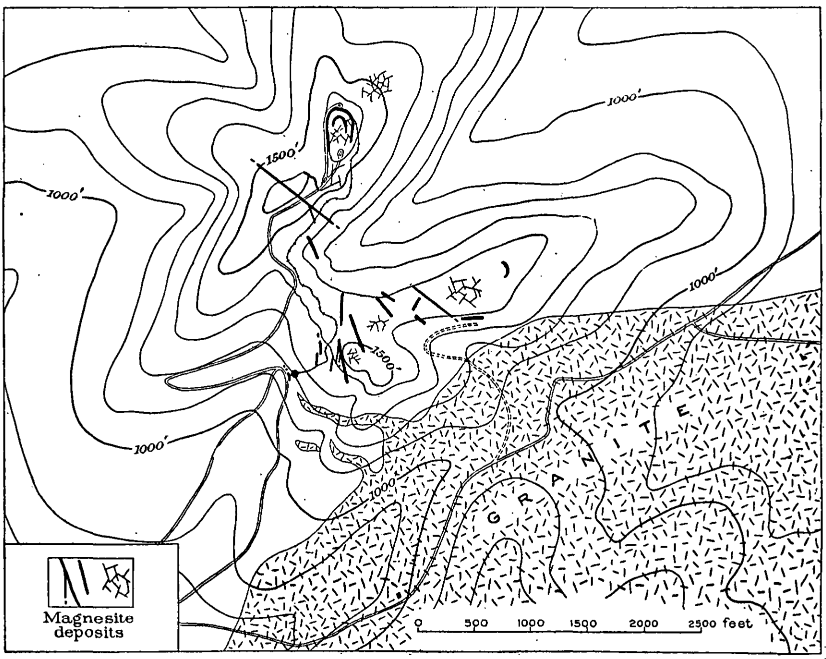
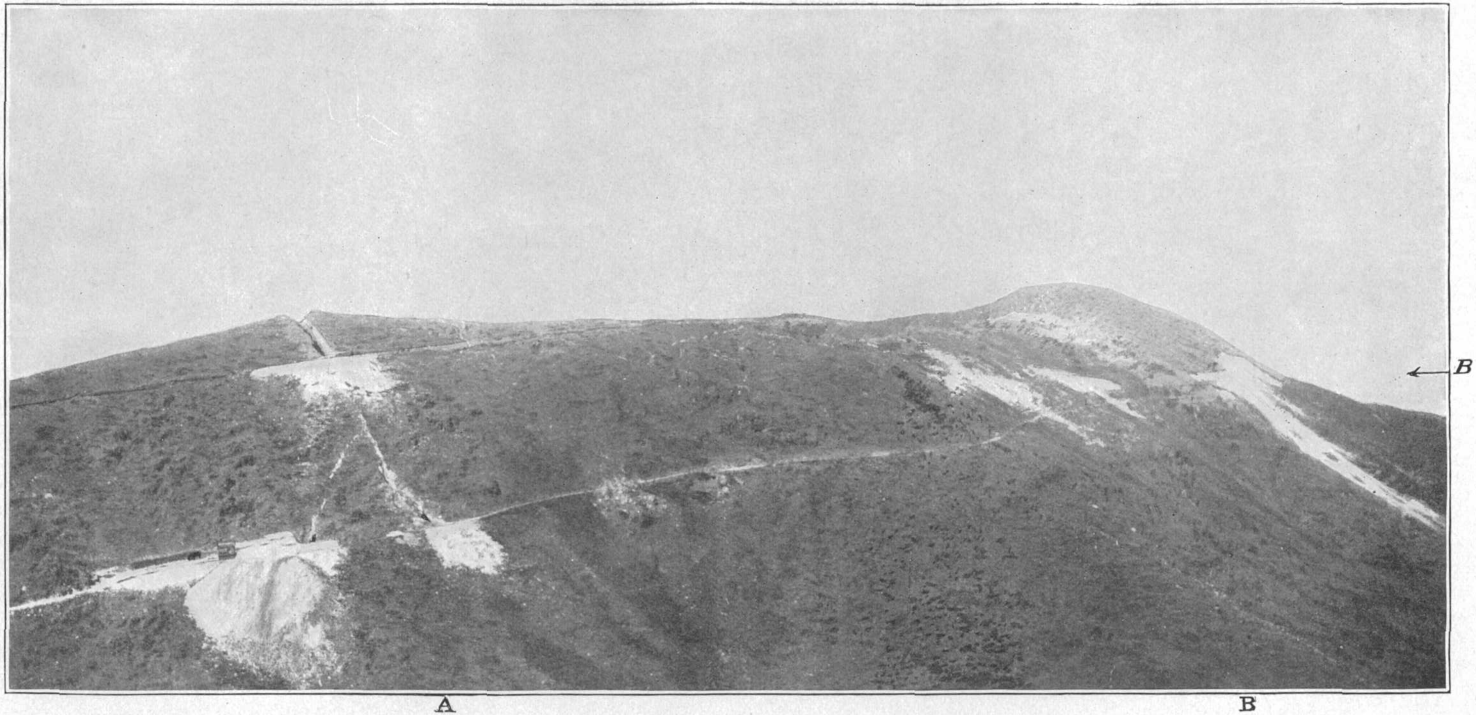


FIG. 2.—Plan of magnesite veins and workings 4 miles northeast of Porterville, Cal.

northern hill this vein ranges in thickness from 2 to 8 feet; it cuts the hill near the south end (see Pl. X, *A*, and fig. 2), strikes northwest, and dips steeply to the northeast. An amphibolite dike 2 to 3 feet thick has been intruded into the serpentine near the vein and follows it for a short distance. Along this stretch the vein has been squeezed to a schist; at other places it is comparatively fresh. About 100 feet from the southeastern outcrop of the vein it is joined by another vein of about the same thickness, having a strike of N. 10° W., which has also been mined.

At the north end of the hill are two "blanket" or flat veins. The largest one (Pl. X, *B*) is practically horizontal in the middle part and



NORTHERN HILL AT WILLAMETTE PULP AND PAPER COMPANY'S MAGNESITE MINE NEAR PORTERVILLE, LOOKING NEARLY NORTH.

A, Nearly vertical vein; *B*, Lower "blanket" vein. The lower line ascending toward the right is a tramway; the upper one is a wagon road.

somewhat uplifted at both ends—north and south. It extends through the hill, a distance of 362 feet, and is probably longer than broad, and from 2 to 4 feet or more thick. A basic dike flattens and spreads under a large part of the vein in a thin sheet 1 to 2 feet thick; then, breaking through (Pl. IX, *A*), it overlies the remainder of the vein. Thin magnesite veins fill cracks in the dike, but the mass of the vein is cut by it. It is probable that small veins, similar to those in the dike, are being formed all through the hill at the present time. There is nothing to show that the vein has been tilted from a more upright position to its present place, and it was evidently formed as it lies, flat and cutting across the vertical structure of the serpentine. This is accounted for by supposing that there was a slow movement in the rocks along this plane at the time of the vein's deposition, the magnesite filling uneven open spaces along the horizontal fault, and that when there was another movement these deposits held the mass apart and made room for contiguous deposits. The crushed condition of the whole mass and the presence of inclusions of serpentine in lines approximately parallel to the sides of the vein give this hypothesis some color.

The other "blanket" vein lies above the north end of the vein just described. It dips at a rather low angle and will probably be found to run into the lower one.

Adjacent to all the larger veins are many small reticulated veins ranging up to 3 or 4 inches in thickness. At the north end of the deposits is a stockwork of small veins 2 to 6 inches thick (Pl. XI, *A*), and it is thought that it may pay to blast the whole mass and hand pick it. Between the blanket veins and the large vertical vein are a number of smaller veins, from the outcrops of which some hundreds of tons of magnesite can probably be broken. At the north end of the hill, below the blanket veins, there is also a considerable stockwork of veins which can probably be worked by blasting and hand picking.

On the west end of the eastern hill there are several veins of magnesite reaching a thickness of somewhat more than 3 feet, from which a small amount of magnesite has been mined.

W. P. Bartlett, the superintendent for the Willamette Pulp and Paper Company, has developed an excellent system of stoping the vein standing at a high angle. He first ran a tunnel through the hill, along the vein, somewhat less than 100 feet below the top. He then began to break down the magnesite from the roof at the farther end of the tunnel, allowing the waste to accumulate, so that the face of magnesite, which constantly retreats toward the portal of the tunnel, could be reached from the débris slope, down which the magnesite was rolled and removed in cars from the foot. This process is shown diagrammatically in fig. 3. The magnesite was entirely removed from above this level, and the same system is being worked on the level below, which is even with the tramway, and when this is worked out probably a still lower level may be worked on the same vein. Either underhand or overhand stoping, whichever is at the time more advantageous, can be carried on by this system.

The blanket veins require the removal of some waste rock, as the veins are not thick enough (from 2 to 4 feet) to permit economical working by mining out the magnesite alone. The waste is piled in the spaces already mined and forms a partial support for the roof. The roof is good and almost no timbering is required. A small amount of work has been done on some of the smaller veins, both on the northern hill and on the west end of the eastern hill. Practically all of the magnesite mined is calcined, and a tramroad, laid on such a grade that the cars run down by gravity, is built along the

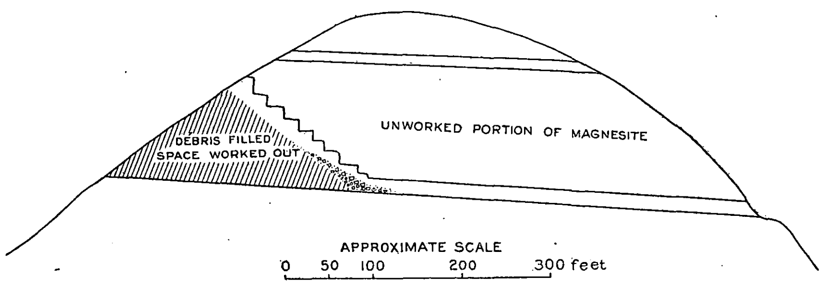
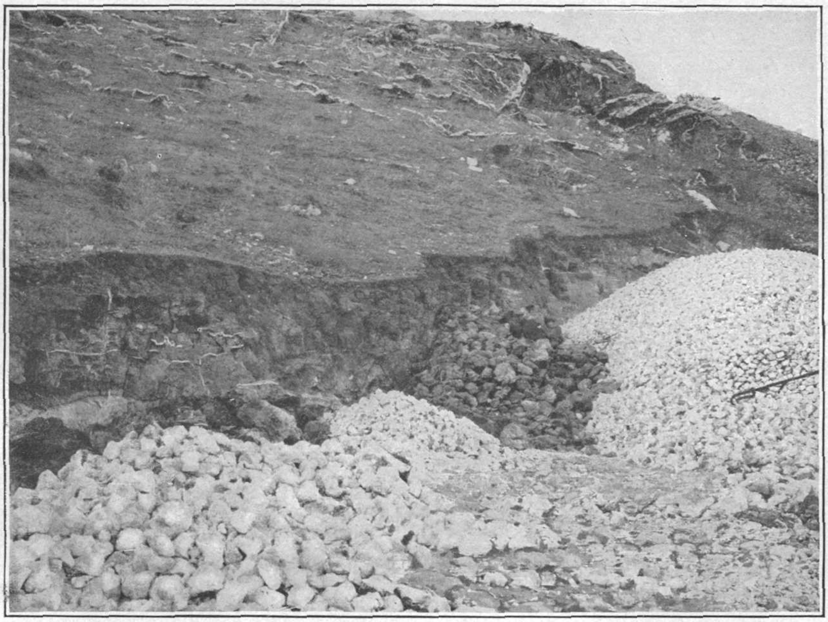


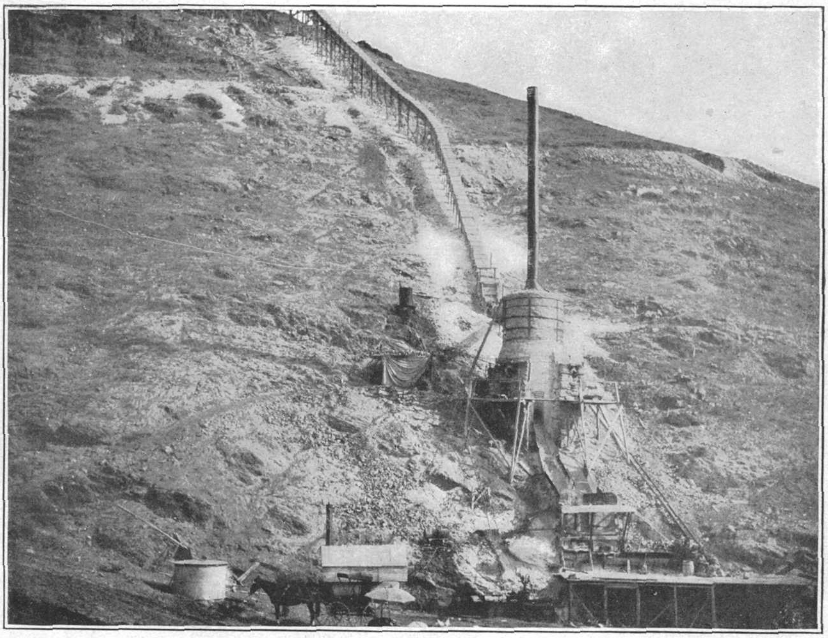
FIG. 3.—Diagram showing mode of working a highly inclined magnesite vein at Willamette Pulp and Paper Company's mine near Porterville, Cal.

east side of the northern hill, through the saddle, to the kiln, which is located near the west base of the eastern hill. The veins are fortunately so situated that the tramway runs just under the blanket veins while maintaining its grade through the saddle. The kiln is located below the tramroad, so that the magnesite is dumped into a long chute through which it slides into the top of the kiln. (See Pl. XI, *B*, and fig. 4.) The magnesite is broken by hand at the tunnels to lumps 4 inches or less in diameter. Crude oil is used for fuel, and the magnesite gradually rises in temperature as it moves from the top downward through the kiln, until it reaches the flame from the burners. It is then raised to a white heat, and kept there for twenty to twenty-five minutes, when it is withdrawn from below. It is said that after this treatment 3 to 5 per cent of carbon dioxide still remains in the material. The air for the burners passes through the withdrawn material and is thus considerably heated.



A. OUTCROP OF STOCKWORK OF VEINS AT NORTH END OF WILLAMETTE PULP AND PAPER COMPANY'S DEPOSITS NEAR PORTERVILLE.

Broken magnesite ready for calcining in foreground.



B. FURNACE FOR CALCINING MAGNESITE AT WILLAMETTE PULP AND PAPER COMPANY'S MAGNESITE MINE NEAR PORTERVILLE.

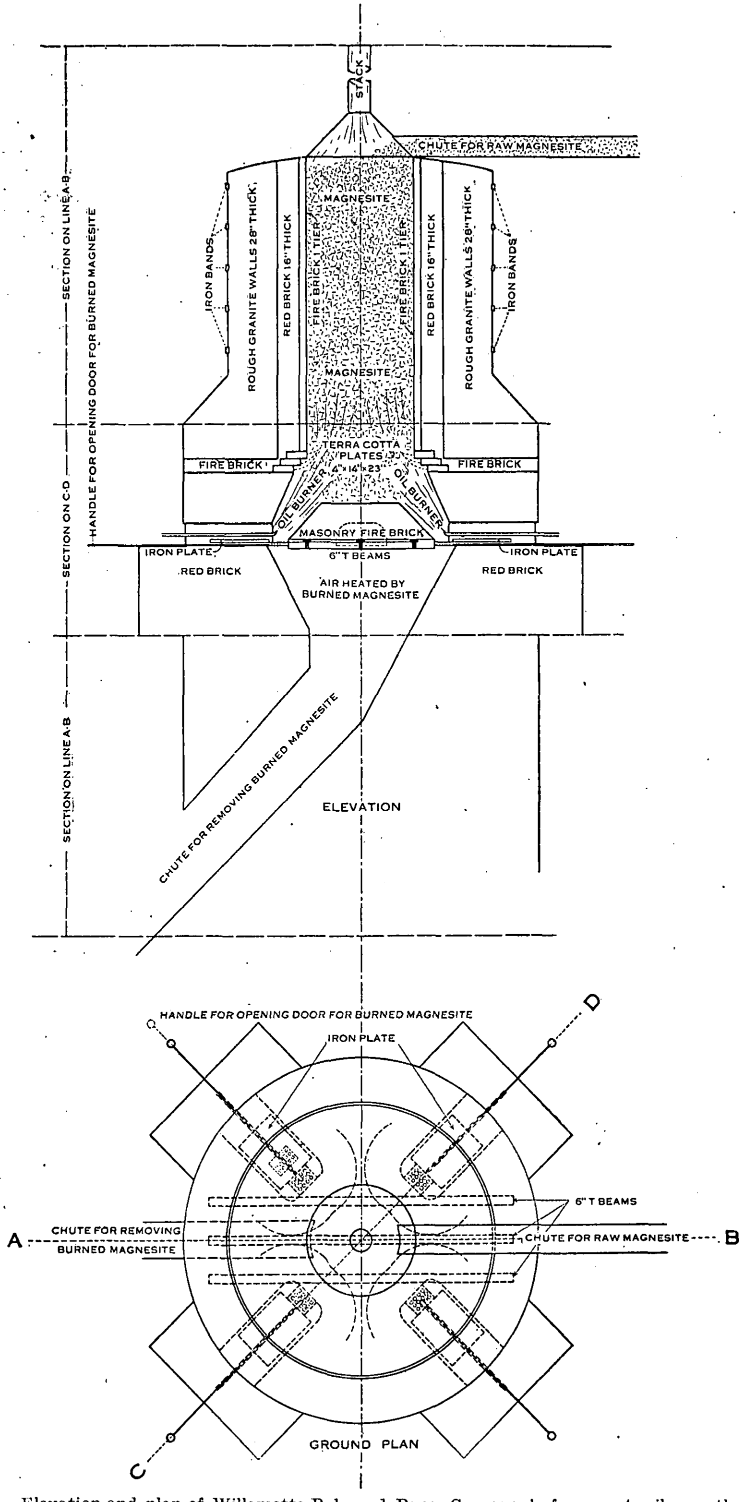


FIG. 4.—Elevation and plan of Willamette Pulp and Paper Company's furnace, 4 miles northeast of Porterville, Cal.

The following analyses of magnesite from this hill are at hand:

Analyses of magnesite from hill 4 miles northeast of Porterville.

	1.	2.
Silica (SiO_2)	2.28	0.90
Alumina (Al_2O_3)	.03	.49
Ferric oxide (Fe_2O_3)	.26	
Lime (CaO)	1.32	1.49
Magnesia (MgO)	45.17	44.39
Carbon dioxide (CO_2)	50.74	50.06
Water and undetermined	....	2.57
	99.80	99.90

1. Collected by the writer from tunnel No. 1 (in the large, highly inclined vein), and analyzed by A. J. Peters, of the United States Geological Survey.
2. Collected by W. P. Bartlett and analyzed by Abbot A. Hanks, of San Francisco, Cal.

The lime in these samples is probably too high to allow a good cement to be made, but as the operating company uses practically the entire product in wood-pulp whitening and digestion at its Oregon mills, this impurity is not particularly obnoxious.

In general the magnesite is white, but here and there it contains films of chlorite or serpentine where crushed. At other places there is a red stain of iron oxide on the surface of faces that have slipped on each other. Certain faces have been thinly coated with quartz, and one such face in which shrinkage cracks affect the quartz also is shown in Pl. VI, *B*.

The capacity of the furnace is from 27 to 29 tons of magnesite per day, giving 13 to 14 tons of magnesia. All shipments are made from Hilo spur, 1 mile north of the Porterville station.

On the eastern hill there are a large number of magnesite veins of dimensions similar (except in length, in which they are probably deficient) to those on the northern hill. The total amount of magnesite is probably considerably less; as already stated, one vein may be the extension of the main vein cutting the northern hill. No such flat veins as those described on the northern hill are to be seen here. In places the veins contain a considerable amount of serpentine in fine particles, and elsewhere the serpentine contains sufficient magnesite to give it a gray appearance.

A small amount of magnesite has been removed by open excavations and shipped by Charles S. Harker, the owner, to Oakland for the manufacture of carbon dioxide.

Deposits on South Fork of Tule River.—In a high hill on the southwest side of South Fork of Tule River are a large number ot magnesite veins with outcrops ranging in thickness up to 20 feet. The magnesite veins seen are on the north side of the hill in secs. 30 and 31, T. 22 S., R. 29 E. They are less than a mile south of Success schoolhouse and about 9 miles from the railroad at Porterville. Should active work be undertaken, the road could probably be somewhat shortened. The haul is almost entirely down hill. An electric road from Porterville to Springville, which has been under contemplation for some time, if built, would pass within 3 miles of the deposits.

As Success schoolhouse is the most readily identifiable object in the landscape, the directions used in this description will be given with reference to it.

The portions of the hill containing the magnesite are composed of a rock much more completely serpentinized than that nearer Porterville. In the sections examined there are only scattered fragments of original minerals, probably pyroxenes, locally in radial crystals, which, in the hand specimen, reach 2 inches in length.

At the foot of the hill S. 26° W. (magnetic) from Success schoolhouse, a magnesite vein outcrops along the edge of the narrow flood plain of the river. The outcrop is from 3 to 10 feet thick, and is exposed prominently for a distance of about 500 feet, running northwestward, parallel to the river. In this distance it rises from the level of the flood plain to 60 feet above it at the southeast end. What is apparently the end of the outcrop, however, may be only the point to which it has been covered by débris from the hill slope, and at the other end it may run for some distance beneath the covering of soil. At each end, however, is a small watercourse, and in serpentine areas such channels very commonly mark fault lines. The magnesite is generally of a good white color, but is here and there grayish. In places the vein contains horses of serpentine, and at one place it is cut by a fine-grained basic dike, which is composed mainly of light-green amphibole and a fresh plagioclase feldspar with much magnetite, and which for most of the distance that it is visible runs approximately parallel to the vein.

On the assumptions that 5 feet is the average thickness of the vein and that it extends for 100 feet into the hill—both of which premises seem wholly reasonable—the vein would contain 500 (length) $\times$ 5 (thickness) $\times$100 (depth) = 250,000 cubic feet, which, on the basis of 11 cubic feet per short ton, is equivalent to about 22,700 tons.

A partial analysis of magnesite from this vein, made by A. J. Peters, gave the following result:

Analysis of magnesite from hill south of Success schoolhouse, Tulare County.

Silica (SiO_2)	0.80
Alumina (Al_2O_3)	.42
Ferric oxide (Fe_2O_3)	.20
Lime (CaO)	1.02
Magnesia (MgO)	45.94
Carbon dioxide (CO_2)	51.30
	99.68

The total impurities here amount to nearly 2.5 per cent, of which about 1 per cent is lime. There is probably enough lime to make it undesirable for the manufacture of cement, but it is a good material for use in paper, gas, or brick making.

The serpentine is in places full of thin parallel veins of magnesite, similar to those at the deposits near Porterville and Deer Creek. A couple of hundred feet above and west of the northwest end of the large vein just described are a large number of irregular magnesite nodules and masses, from which probably several hundred tons could be blasted at small cost. In the same neighborhood there are a number of smaller veins. About 200 feet (barometric measurement) above the flat vein is a fairly continuous outcrop reaching possibly 20 feet in thickness and 200 feet in length, in which the magnesite is of a beautiful pure-white color, but there are many inclusions of serpentine.

At a point S. 17° W. (magnetic) of Success schoolhouse and about 800 feet (barometric) above the river is a vein from 2 to 6 feet wide, which may be followed for about 200 feet. The strike is northwestward, with a high northeasterly dip.

On the top of the hill, at an altitude of over 1,000 feet above the river, are a number of veins ranging up to 6 feet in thickness, but most of them can not be traced far. One vein, averaging between 2 and 3 feet in thickness, was followed for 250 feet, and with greater care it may be possible to trace it farther. These veins are nearly a mile south of the flat vein first described, and in the intervening space are hundreds of irregular veins, which measure up to a foot or even more in thickness and which, in places near the river, form stockworks that could be blasted and hand picked at small expense.

The belt of serpentine carrying the magnesite has been crushed and sheeted in a northwesterly direction, and probably owes this structure to the forces that acted similarly on the magnesite-bearing serpentines nearer Porterville, which lie about 6 miles northwest. No development work has been done on these deposits.[a]

Round Valley deposits.—On the east side of the mouth of Round Valley, between 3 and 4 miles east of Lindsay, a number of magnesite veins ranging up to 2 feet in thickness crop out on the southwestern face of the hill, between 150 and 450 feet (barometric) above the floor of the valley. The country rock is serpentine, similar in macroscopic appearance to that at Porterville. The belt in which the veins occur has a northwestern trend similar to that of the deposits on South Fork of the Tule and of those near Porterville. The lower veins are of poor quality, as they contain a considerable amount of serpentine. The upper veins appear to be of good quality, but all are thin and too far

[a] Since this paper went to press word has been received from Mr. W. P. Bartlett that he is now shipping magnesite from these deposits.

apart to be worked economically from the same opening. Hauling to the Southern Pacific Railroad at Lindsay would be easy and on down grade all the way.

Deposits near Exeter.—Magnesite had been reported to the writer as occurring in a number of the orange orchards east of Exeter, where it was said to be killing the trees, but in each case the substance was found to be carbonate of lime. However, on the southwest spur of Rocky Hill, 2 miles east of Exeter, there are a few small veins of magnesite about 500 feet above the valley. The largest vein is not more than a foot wide, and most of them are only from 1 to 3 inches wide. The area over which the veins occur is very small and the deposits are without economic value.

A vein of californite, a variety of vesuvianite, occurs alongside the magnesite. It is said to have been worked under the supposition that it was impure chrysoprase. From the matter thrown out the vein appears to be from 2 to 4 inches wide. The rock in the shaft was so much shattered and coated with calcareous material that the vein could be but imperfectly made out. The color of the californite is rather irregular; the ground color is a light green, carrying a hint of yellow, but through this are sprinkled small spots of buff or white, and spots about one sixty-fourth of an inch across of dark green.

Deposits of magnesite were reported in the Yokohl Valley, a few miles east or southeast of Exeter, but they could not be definitely located.

Naranjo deposits.—George D. Ward, of Oakland, is interested in some small deposits of magnesite about 7 miles northwest of Lemon Cove and 1 mile northwest of Naranjo post-office. The deposits are situated in a serpentine hill containing many intrusions of greenstone and granite. Most of the veins are from 2 to 5 inches thick and are exposed for only a few feet. They are in general of rather pure-looking but spongy material though some have considerable serpentine mixed with them. The largest vein is situated on the north side of the hill and is but 16 inches thick. A small excavation has been made, and this affords the only exposure. The vein is much crushed and the magnesite appears to be of only fair quality. At a number of places on the hill are veins, 1 to 2 inches thick, of translucent white nonprecious opal.

Other Tulare County deposits.—Small veins of magnesite are reported to occur near Auckland, but they are probably of little importance. There are undoubtedly other veins, which may or may not be of value, in the great areas of serpentine that lie along the foothills of the Sierra Nevada through the entire length of the county.

FRESNO COUNTY.

Nine miles east of Sanger George D. Ward has located magnesite claims on both sides of Kings River, near what is known as Red Hill. The country is one of rather high, smooth, nearly treeless hills, rising perhaps somewhat over 1,000 feet above the river. The rocks are metamorphic and include some serpentine and partially serpentinized tuff. They are all in comparatively narrow bands, and, except the serpentine, are gneissoid. Much of the rock was originally granite or diorite. All the rocks have a structure much resembling bedding. The amount of magnesite in sight seems, at first glance, remarkably large for the amount of serpentine present.

On the north side of the river the principal vein is on what is known as the Snow Cap claim. The vein outcrops about half a mile from the river, in a small embayment in the hills. A face has been exposed showing the magnesite to be at least 8 feet thick. (See Pl. XII, *B*.) It has a strike of N. 24° W. (magnetic) and an easterly dip of about 75°, which probably agree with the strike and dip of the country rocks. On the foot wall is a considerable amount of soft, friable magnesite, which is very much like calcareous tufa and which is, in fact, a magnesian tufa. This deposit is more than a foot thick. About 3 feet from the foot wall is an irregular vein of magnesite, from 6 inches to 3 feet thick, which probably joins the main vein a short distance below, and which could be economically mined with it. The vein can be definitely followed for about 600 feet to the north, across a low hill, and seems to get thinner toward the farther end. The magnesite is a clear white, containing serpentine only here and there.

A partial analysis of a specimen of fine-grained pure-white magnesite from the body of the vein, collected by the writer and analyzed by A. J. Peters, was as follows:

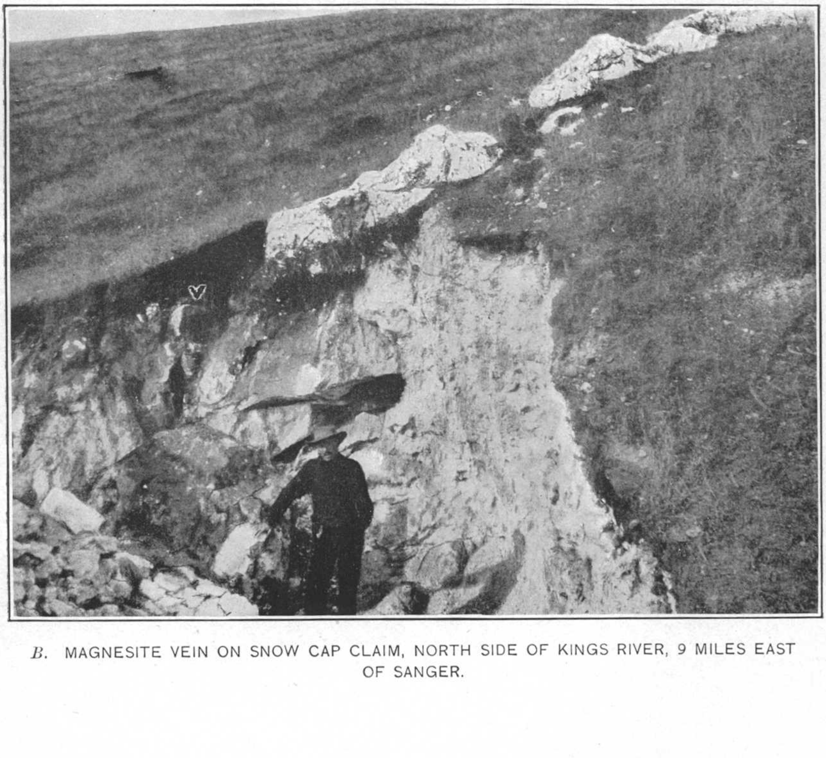
Analysis of magnesite from large vein, Snow Cap claim, Kings River.

Silica (SiO_2)	0.20
Alumina (Al_2O_3)	.04
Ferric oxide (Fe_2O_3)	.12
Lime (CaO)	.96
Magnesia (MgO)	46.48
Carbon dioxide (CO_2)	51.80
	99.60

It will be noticed that there is nearly 1 per cent of lime in the specimen, although a commercial analysis made for Mr. Ward was said to show none.

A quarter of a mile north from the end of the vein, along the same strike, is a vein of rather impure magnesite. The dip is shallower and it is not likely that the two veins are connected.

A. MAGNESITE VEIN ON SOUTH SIDE OF KINGS RIVER, 9 MILES EAST OF SANGER.



B. MAGNESITE VEIN ON SNOW CAP CLAIM, NORTH SIDE OF KINGS RIVER, 9 MILES EAST OF SANGER.

A couple of hundred feet up the ridge, west from the main outcrop of the Snow Cap, is a magnesite vein of good quality from 10 to 21 inches wide, which may be followed for 100 to 150 feet. It is on the Snow Cap claim. On the same claim, in the gulch on the south, 200 feet from the main outcrop of the Snow Cap and just below an old wagon road, a mass of fine white magnesite showing a surface of 8 by 13 feet has been uncovered. At the time of visit not enough work had been done to show whether the occurrence was a vein or a large nodule.

On the Governor claim, a quarter of a mile S. 16° W. from the main Snow Cap outcrop, across a gulch and about 100 feet (barometric measurement) above the Snow Cap, is a small outcrop of a magnesite vein of good quality, dipping highly S. 60° E. It is probably 2 feet thick and has been exposed for a length of 10 feet. Magnesite float, which has been found 300 feet or more to the southwest, has been supposed to come from the extension of this vein, but there is nothing at present shown to prove it.

Besides the vein mentioned there are at a number of places smaller veins, largely of noncompact magnesite. The surfaces of the spongy magnesite are colored a fine pink. Small red lichens grow upon the magnesian rocks of this vicinity, and if treated with an alkali (sodium hydrate or ammonia) they give the same pink hue, so that the color may be derived from these lichens, or it may be due to some iron compound. No other coloring material, such as cobalt or manganese, which would account for it could be detected in the specimens.

On the south side of Kings River, about half a mile from and 650 feet above the stream, is a fine large vein of magnesite, which runs east and west across a northward-projecting hill. (See Pl. XII, *A*.) The vein as exposed at the time it was visited was at least 8 feet wide and may have been somewhat wider. It could be readily traced for about 200 feet, but no attempt had been made to show its length by excavations, so that it may prove to extend farther. The magnesite seemed to be of good quality, with but few inclusions of serpentine.

The deposit is reached by a fairly easy grade and could be very economically worked. The haul from the deposits on both sides of the river to the railroad at Sanger is all downhill except for trifling grades, and in general the roads are excellent. The magnesite from the two sides would, however, have to go by different roads, owing to the difficulty of fording the river.

MARIPOSA AND TUOLUMNE COUNTIES.

Large bodies of magnesite containing green mica and pyrite have occasionally been reported from Mariposa and Tuolumne counties, but probably most if not all of the deposits referred to are dolomite containing large amounts of mariposite, a chrome mica. There are in these counties, however, belts of serpentine in which it would not be surprising to find magnesite, though the writer's inquiries have so far located none.

PLACER COUNTY.

Damascus deposits.—Many statements have been published from time to time heralding the deposits near Damascus as "the largest in the State," possibly because they are among the least convenient to reach. The writer did not visit the locality, as at the time he was in this portion of the State the deposits were reported to be covered with snow. The magnesite is in the S. ½ sec. 18, T. 15 N., R. 11 E., 3 or 4 miles from Damascus and Michigan Bluff and probably not more than 10 miles in a direct line from Colfax. The following information was kindly furnished by Mr. Harold T. Power, of Bullion, Cal., and Mr. H. W. Turner, formerly of the United States Geological Survey, but now of Portland, Oreg.

In the southwest quarter of the section the deposits are located just below the Morning Star ditch, in a serpentine country rock. Besides a number of small veins an inch or so in width, there are several lenses of magnesite forming practically one body about 30 feet in width and 100 feet long, which contains some serpentine. A specimen sent in by Mr. Power is of good appearance, though not very compact. As no analysis has been made, its composition can not be given. A small exposure of a 2-foot vein is said to occur in the southeast quarter of the section.

The country is so rough that under present conditions the magnesite can not be mined at a profit. A lumber railroad has been surveyed to run close to the deposits, and should such a road be built they might be worked.

W. P. Bartlett, of Porterville, reports a 2-foot vein of magnesite in the canyon of American River, near this place, but on account of its unfavorable location it is valueless. Other small veins also have been reported, but so far nothing of value has been found.

MAGNESITE DEPOSITS IN OTHER COUNTRIES.

It is always desirable to know something of mineral deposits which may be possible or certain competitors in any mining or quarrying enterprise. California's commercial isolation from the eastern portion of the United States, caused by the long railroad hauls, precludes railroad shipment of products that sell as cheaply as magnesite. Owing, however, to the possibility of shipping by water with a fair margin of profit, the following notes on competing foreign deposits are given.

NORTH AMERICA.

CANADA.

Quebec.—Magnesite occurs at a number of places in the Dominion of Canada, but the deposits known seem to be remarkably different from those of California. In eastern Canada magnesite has been found in the township of Grenville, Argenteuil County, Quebec,[a] in place and in loose bowlders, some of the latter weighing many tons. In appearance this magnesite is granular and much like clear, rather coarse grained marble, and it is supposed to be of sedimentary origin. One outcrop is about 100 feet wide and a quarter of a mile long. If it is a sedimentary deposit it is unique, so far as has come to the attention of the writer, as nowhere else are magnesian sediments known in which the percentage of magnesium carbonate present exceeds to any appreciable degree the theoretical amount contained in dolomite (45.65 per cent). Although limestones carrying any percentage of magnesium carbonate up to 45.65 may be found, the remainder of the series between 45.65 and 100 per cent have had no representatives until the discovery of these deposits. Analyses by the Geological Survey of Canada of various specimens showed magnesium carbonate, 49.71 to 95.50 per cent; calcium carbonate from a "very small amount" to 30.14 per cent; and magnesia other than carbonate (probably nearly all serpentine), 3.08 to 9.17 per cent.

An average of 57 samples from another locality gave—

Average composition of magnesite from Quebec.

Magnesium carbonate	81.27
Calcium carbonate	13.64
Magnesia other than that present as carbonate	3.66
	98.57

British Columbia.—In the Atlin district of British Columbia, at the town of Atlin,[b] deposits of hydromagnesite ($3MgCO_3.Mg(HO)_2+3H_2O$) occur in Pine Creek valley as a fine white powder covering several acres and known to be as much as 5 feet deep. The deposits are evidently derived from springs, the waters from which carry 1.834 parts of magnesia in 1,000. Hydromagnesite when pure carries 43.9 per cent of magnesia, 36.3 per cent of carbon dioxide, and 19.8 per cent of water.

Similar deposits[c] occur at the 108-mile House on the Cariboo road

[a] Hoffman, G. C., Report of the section of chemistry and mineralogy: Ann. Rept. Geol. Survey Canada, vol. 13 (for 1900), pt. R, 1903, pp. 14–19.

[b] Gwillim, J. C., Report on the Atlin mining district, British Columbia: Ann. Rept. Geol. Survey Canada, vol. 12, pt. B, 1899, pp. 47–48.

[c] Hoffman, G. C., Report of section of chemistry and mineralogy: Ann. Rept. Geol. Survey Canada, vol. 11, 1900, pp. 10–11.

93 miles north of Ashcroft, Lillooet district, British Columbia, where they are scattered over 50 acres or more of ground. At three or four places patches of the material 50 to 100 feet wide stand a foot or more above the general surface. At one point a shaft showed the deposit to be over 30 feet thick.

At Atlin an exceedingly impure magnesite occurs with serpentine and dunite,[a] and is said to be over 1,000 feet wide on the Anaconda group of claims. It is impregnated with iron pyrites, and is cut by apple-green quartz carrying 1 pennyweight of gold per long ton and 15 per cent of nickel. A partial analysis of the magnesite is as follows:

Partial analysis of magnesite from Atlin, British Columbia.

Magnesia (MgO)	21.70
Protoxide of iron (Fe_2O_3)	5.10
Carbonic acid (CO_2)	27.00
Silica (SiO_2)	45.68
Combined water and loss	0.52
	100.00

Under present conditions these British Columbia deposits are probably without economic value.

MEXICO.

Lower California.—On the island of Santa Margarita, in Magdalena Bay, extensive deposits of magnesite have recently been examined by Julius Koebig, of Los Angeles, for a firm of that city. The country rocks are said to be sandstone, quartzite, and syenite. No mention is made of more magnesian rocks, though it seems highly probable from the amount of magnesite described that such rocks are present. The island is mountainous and is 25 miles long by 4 or 5 miles broad. Doctor Koebig says in his report:

> Practically every canyon of the Sienite Mountains, by decomposition of the eruptive rocks, shows larger or smaller deposits covering in some instances the entire surface of hills and mountain sides. The banks of the canyons, where the rocks have been cut by the streams during the rainy season, show magnesite strata several feet thick, and for a distance of a few hundred feet to over a mile the arroyo itself contains large quantities of magnesite in the shape of bowlders, weighing from a few pounds to 3 to 5 tons apiece. * * * Estimated in the most conservative way, I have seen actually in sight on the surface, and in no case more than 1½ miles from shore, 300,000 to 500,000 tons ready to be picked up and packed to the beach without the use of any tools other than a sledge hammer. * * * For labor there are plenty of Mexicans to be had at not to exceed \$1.50 Mexican per day. * * * As means of transportation to the wharf there are 300 or more donkeys on the island. * * * There is plenty of water for a crew of Mexicans and the pack animals.

[a] Gwillim, J. C., op. cit., pp. 21-22.

The following analyses are given in the report:

Analyses of magnesite from Santa Margarita Island, Lower California.

	1.	2.
Insoluble, sand and clay	Trace.	0.06
Ferric oxide (Fe_2O_3)	0.21	.10
Alumina (Al_2O_3)		
Carbonate of lime ($CaCO_3$)	.43	....
Lime (CaO)	....	Trace.
Carbonate of magnesia ($MgCO_3$)	99.36	....
Magnesia (MgO)	....	99.05

1. Raw magnesite; analyst unknown.
2. Calcined magnesite; analysts, Baverstock & Staples, Los Angeles, September 13, 1907.

The company offers to furnish the magnesite for $3.50 f. o. b. vessel at Santa Margarita.

Other deposits of magnesite are reported from various parts of Mexico, but little is known of them.

SOUTH AMERICA.

VENEZUELA.

The Venezuelan Government has recently granted for twenty-five years the exclusive privilege[a] of exporting magnesite found on private lands on the island of Margarita, to a company which expects to ship from 12,000 to 15,000 tons annually. Nothing further is known of the deposits.

Dana[b] quotes N. S. Manross as stating that magnesite occurs near Mission Pastora, in Canton Upata.

EUROPE.

AUSTRIA.

Styria in Austria has very large deposits of magnesite which are actively worked. The largest company is the Veitscher Magnesitwerke Actiengesellschaft,[c] with mines at Veitsch, 5 miles from the Mittersdorf Murzthal railway station. During 1903 this company produced 71,016 tons of magnesite and shipped to the United States 35,000 tons of the calcined product.

This company and the Magnesite Company, Limited, of Hungary, have a working agreement.[d]

[a] Moffat, T. P., Daily Consular and Trade Repts., No. 3108, Washington, February 25, 1908, p. 8.
[b] Dana, E. S., Descriptive mineralogy, 6th ed., New York, p. 275.
[c] Rublee, W. A., Daily Consular Repts., No. 2276, Washington, June 6, 1905, p. 2.
[d] Private letter.

HUNGARY.

The Magnesite Company, Limited,[a] with headquarters at Nyustya, Gomor County, is the largest company operating in Hungary. The veins worked are very large, ranging from 150 to 300 feet in width, and are worked as open quarries, with stages from 40 to 60 feet high. The magnesite is yellowish or bluish white, in some places fine grained and in others of very coarse crystalline structure. The following analyses of the magnesite, of which No. 2 is calcined, are given as representative:

Analyses of Nyustya magnesite.

	1.	2.
Silica (SiO_2)	0.74- 0.76	1.67
Alumina (Al_2O_3)	.39- .27	3.47
Ferric oxide (Fe_2O_3)	3.27- 3.43	4.68
Lime (CaO)	1.20- .90	2.94
Magnesia (MgO)	44.80-45.00	86.90
Carbon dioxide (CO_2)	50.10-50.20	....

The output of dead-burned magnesite of the company in 1904 (1905?) was 22,000 to 23,000 tons from Nyustya and 11,000 to 12,000 tons from Jolsva and Ochtina. The company was at that time making 750,000 magnesite brick per year.

The production of magnesite in Hungary during 1907 was as follows:[b]

Production of magnesite in Hungary, 1907.

	Quantity.	Value.
	Quintals.	*Crowns.*
United Magnesite Company, Nyustya	98,000	519,000
Company of Magnesite-Industry:		
Nyustya (Gomor)	1,090	} 10,877
Jolsva (Gomor)	1,126	
Martonhaza	437	
General Magnesite Company, Hizsnyo (Gomor)	78,000	330,000
	178,653	859,877

The product is equivalent to 19,693 short tons, valued at $174,554. The whole output was made into brick.

Besides brick and calcined magnesite, the Hungarian companies ordinarily make "caustic" or partly calcined magnesite for use as a mortar, with which magnesite brick are set.

GERMANY.

Deposits of magnesite were worked for many years in the neighborhood of Frankenstein, Silesia.[c] The magnesite is said to occur in

[a] Private letter.

[b] Letter from director substitute, Mining Dept., Royal Hungarian Géol. Inst., April 24, 1908.

[c] Squire, Lovell, jr., Some observations on the magnesite of Silesia: Trans. Royal Geol. Soc. of Cornwall, vol. 9, pt. 1, 1875, pp. 59-70.

"nests," probably similar to what are called "bowlders" in California; that is, in large nodules. The deposits are covered with soil, and the peasants dig at random for it. The analysis was given as follows:

Analysis of magnesite from Frankenstein, Silesia.

Silica (SiO_2)	5.60
Alumina (Al_2O_3)	.85
Calcium carbonate ($CaCO_3$)	.40
Magnesium carbonate ($MgCO_3$)	93.00
	99.85

As would be expected from the lack of iron or other coloring matter, the magnesite is said to have been very white. It is not known whether the deposits are still worked. Some chrysoprase was found in veins close by.

GREECE.

The principal magnesite deposits of Greece are located on the island of Eubœa.[a] The Anglo-Greek Magnesite Company, Limited, operates magnesite quarries belonging to the Galataki monastery, 10 miles from the port of Limni, whence the magnesite is shipped. The output of this company during 1902 and 1903 was as follows:

Magnesite output of Galataki quarries and exports to the United States, 1902 and 1903.

[Short tons.]

	Raw magnesite.		Caustic calcined magnesite.		Dead-burned magnesite.
	Output.	Exported to the United States.	Output.	Exported to the United States.	
1902	14,600	6,647	3,500	578	....
1903	26,300	3,200	3,550	125	1,200

The Society of Public Works of Athens is exploiting magnesite deposits by underground workings at Mantudi and Limni. During 1902 it shipped to the United States 7,390 metric tons of magnesite and 92 tons of fire brick; in 1903, 2,335 tons of magnesite; in 1905, 22,747 tons of magnesite; and in 1906, 32,194 tons of magnesite, which was produced at Mantudi.[b] The total output for Greece in 1905[c] was 47,849 short tons, and in 1906, 71,015 short tons, valued at $168,376 and $283,333, respectively. Magnesite is also found at Xirochori, on the island of Eubœa; near Mariki, close to Thebes (Bœotia); and at Hermioni, in Argolis.

[a] McGinley, Daniel E., Daily Consular Reports, No. 2276, Washington, June 6, 1905, pp. 3, 4.
[b] Bergbau in Griechenland: Zeitschr. angew. Chemie, vol. 21, January 31, 1908, p. 225.
[c] Quoted "from a Government report" in Min. Jour. (London), vol. 82, 1907, p. 633.

Analyses of fused Grecian magnesite from unknown mines gave Fitzgerald & Bennie [a] the following figures:

Analyses of Grecian magnesite (mines unknown).

	1.	2.	3.	4.	5.
Silica (SiO_2)	0.69	1.82	2.50	2.24	2.21
Alumina (Al_2O_3) / Ferric oxide (Fe_2O_3)	1.79	1.76	3.45	2.05	3.20
Lime (CaO)	3.29	1.74	1.10	2.48	1.85
Magnesia (MgO)	93.68	94.37	92.80	93.63	93.27
	99.45	99.69	99.85	100.40	100.53

ITALY.

Magnesite occurs at Casellette, in the Val di Susa, and at several other places in the Turin district, and on the island of Elba. None of the deposits seem to be of very large size. During 1906 the Turin district produced 1,463 short tons of raw magnesite,[b] valued at $3,958, and 220 tons of calcined magnesite,[c] valued at $2,180.

The Casellette deposits[d] consist of great numbers of roughly parallel small veins up to a few inches thick, in a serpentinized lherzolite. They are close enough together so that the rock can be broken down and hand picked.

No production was reported from the island of Elba, though the deposits have been worked in former years. The deposits are stockworks of small veins[e] in a serpentinized lherzolite and are apparently similar to those at Winchester, Cal. (See p. 38.) The following analyses of the Elba magnesite are given by D'Achiardi:

Analyses of magnesite from the island of Elba.[f]

Water (H_2O) at 110° C	1.82	2.28
Water (H_2O) above 110° C	1.68	2.08
Carbon dioxide (CO_2)	44.70	43.86
Silica (SiO_2)	8.15	8.65
Alumina (Al_2O_3) / Ferric oxide (Fe_2O_3)	Trace.	.10
Lime (CaO)	3.50	.99
Magnesia (MgO)	40.84	42.05
	100.69	100.01

MACEDONIA.

Magnesite is found in large quantities[g] in Macedonia near the coast, not far from the Greek border. Some of the veins stand out

[a] Physical properties of fused magnesium oxide: Trans. Am. Electrochem. Soc., vol. 9, 1906, p. 102.
[b] Rivista del Servizio Minerario, 1906, Roma, 1907, p. xlix.
[c] Op. cit., p. liii.
[d] Piolti, Giuseppe, Sull' origine della magnesite di Casellette (Val di Susa): Mem. della Accad. sci. Torino, 2d ser., vol. 47, pp. 126–142.
[e] D'Achiardi, G., La formazione della magnesite all' Isola d' Elba: Atti (Mem.) Soc. toscana sci. nat., Pisa, vol. 20, 1904, pp. 86–134.
[f] D'Achiardi, G., op. cit., pp. 123, 129.
[g] Der Bergbau in Mazedonien: Montan Zeitung (Graz, Austria), vol. 15, January 1, 1908, p. 10.

like walls and may be seen from the sea. Little work has been done on them, but in 1906 a new mine on the Chalkidike Peninsula began operations, and a furnace was put up.[a]

NORWAY.

Magnesite is being mined from deposits in Norway at Snarum,[b] in the Modums division of Buskerud bailiwick, on the Kroder line, a spur of the Drammen Randsfjord line, 56 kilometers (35 miles) from Drammen, the nearest city and port. The magnesite is found in serpentinized olivine rocks which occur with schists and quartzites. Some of it is crystallized in rhombohedra, but such deposits are generally small. The main deposits are ordinarily granular. In both forms the magnesite is nearly pure white, though the granular magnesite contains some serpentine, which occurs in more or less distinctly marked bands or in grains up to the size of a bean, rather evenly distributed through the mass. The included serpentine is used to sinter the material in burning the brick.

There are two principal fields—the Dybingdals, 3 miles north of Snarum station, and the Langerud field, 1⅓ miles west of Snarum station. In the former the magnesite area covers about 1,200 square meters. The veins average about 13 feet in width, and dip 30° and upward. They are worked by underhand stoping. In the Langerud field magnesite is exposed for 135 feet along Snarum or Halling River, and also 100 yards farther southwest. There are also smaller deposits in the neighborhood of these fields. A factory, which has a capacity of about 2,500 tons of brick per year, is operated near Snarum.

The magnesite is sold calcined or as brick. An analysis of the brick is as follows:

Analysis of magnesite brick made at Snarum, Norway.

Silica (SiO_2)	9.3
Manganous oxide (MnO)	.05
Aluminum sulphate ($AlSO_4$)	2.00
Iron oxide (Fe_2O_3)	4.60
Phosphoric anhydride (P_2O_5)	.046
Sulphur (S)	.003
Lime (CaO)	.00
Magnesia (MgO)	83.600
Loss by heating	.50
	100.099

The magnesite is remarkable in that it shows no lime. According to tests quoted in the article referred to, brick from the Snarum factory are more heat resistant than the Austrian Veitsch brick.

[a] The mineral wealth of Macedonia: Mining Jour. (London), vol. 83, 1908, p. 251.

[b] Daumann, E., Magnesit fran Snarum: Bihang till Jern-Kontorets Annaler for 1905, Stockholm, 1905, pp. 222-235.

During 1907 [a] the output of the works was 900 tons of calcined magnesite, valued at $12,060, and 125 tons of brick, valued at $3,685.

RUSSIA.

Magnesite occurs in Russia in the Uphim Mountain district of the Urals, and during 1906 one firm, the Magnesite Company, produced 26,320 tons of magnesite. [b]

AFRICA.

TRANSVAAL.

Extensive deposits of magnesite occur between Kaapmuiden and Malelane, 2 miles south of the Pretoria-Delagoa Bay Railway, 87 miles from Lourenço Marquez and 300 miles from Johannesburg. The magnesite is found in a great number of veins, ranging up to 4 feet in thickness, and has been exploited to a depth of 95 feet.[c] Most of the veins are much thinner than the limit of width given, but there seems to be a large area of serpentine carrying them. The serpentine is here 3 miles wide. Some of the magnesite is soft and powdery, like that at Red Mountain, Santa Clara County, Cal. (p. 35).

One 4 to 6 inch vein [d] is described as "entirely of pure, glassy-looking magnesite." Hall gives the following analysis of a picked specimen from these deposits:

Analysis of magnesite from Malelane, Transvaal.

Magnesia (MgO)	45.272
Carbon dioxide (CO_2)	49.80
Silica (SiO_2)	2.30
Lime (CaO)	......
Ferric oxide (Fe_2O_3)	.80
Moisture at 110° C.	.16
	98.332

Quartz forming thin coatings on the magnesite is found at various places.

The rock is used for making carbon dioxide, and much of it is calcined by producer gas at about 1,100° C. and mixed, either in lump or ground, with magnesium chloride imported from Germany to make oxychloride cement. Most of the output goes into this product, for which its freedom from lime makes the material particularly well suited.

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[a] Letter from Dr. Johan H. L. Vogt, professor of metallurgy at the University of Kristiania, February 15, 1908.

[b] Magnesite and chrome iron ore in the Urals: Mining Jour. (London), vol. 82, December 14, 1907, paragraph on p. 721.

[c] Hall, A. L., The magnesite deposits of Malelane: Rept. Geol. Survey, Transvaal Mines Dept., for 1906, Pretoria, 1907, pp. 127–132.

[d] Hall, A. L., op. cit., pp. 128–129. For further reference to the Malelane deposits see Hollis, W. S., Magnesite deposits in South Africa: Daily Consular Repts., No. 2276, Washington, June 6, 1905, pp. 7–8; Praagh, L. V., The Transvaal and its mines, London and Johannesburg, 1906, pp. 633–634.

OTHER AFRICAN DEPOSITS.

Henry W. Nevinson [a] speaks of "the volcanic district of North Bihé, with its boiling springs and great deposits of magnesia." The Bihé region is a couple of hundred miles east of Benguela, in Portuguese West Africa. No further details are given, but the association with boiling springs suggests that such a magnesian deposit would probably be hydromagnesite, similar to the deposits in British Columbia. (See p. 53.)

"Magnesia," [b] by which magnesite is probably meant, is reported to occur in Mashonaland, near the western side of Africa, notably at Umtali and at the great Zimbabwe ruins—at the latter place in steatite.

ASIA.

INDIA.

Madras.—Magnesite is found at a number of places in India, the most important of which seems to be in the Chalk Hills, 4 miles northwest of Salem, Madras Presidency, in the southern part of the Indian Peninsula. The magnesite here occurs in interlacing veins, some of which stand several feet above the surrounding talcose, serpentinized, and other magnesian rocks. From the whiteness of the outcropping magnesite the name "Chalk Hills" has been given to the range. The main magnesite deposits occur over an area of 10 square miles,[c] and there are various outlying deposits. During 1905 the production was 2,035 tons of magnesite, valued at $2,750, and during 1906 1,832 tons, valued at $2,440.[d]

Mysore.—Magnesite deposits occur at a number of points near Mavinhalli and Kadakola, in Mysore,[e] in the south-central part of the Indian Peninsula. The deposits do not seem to be of commercial importance at present, though the magnesite has been used locally as a substitute for lime.[f] There are also reported to be many deposits of magnesite in the neighborhood of Yelwal,[g] but their extent is unknown.

Ceylon.—"Hydromagnesite does not occur in commercial quantities so far as known, but has some local use." [h]

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[a] The slave trade in Africa: Harper's Magazine, vol. 112, December, 1905, p. 116.

[b] Swan, Robert M. W., Notes on the geography and meteorology of Mashonaland, in Bent, J. T. Ruined cities of Mashonaland, London, 1892, p. 347.

[c] King, W., jr., and Foote, R. B., On the geological structure of the districts of Trichinopoly, Salem, and South Arcot included on sheet 79 of the Indian atlas: Mem. Geol. Survey India, 1865, pp. 312-327.

[d] Dennison, E. Haldeman, Daily Consular Repts., No. 3138, Washington, March 31, 1908, pp. 1-2.

[e] Primrose, A., Notes on magnesite in the Mysore district: Rec. Mysore Geol. Dept., vol. 4 (1904?), pp. 147-157.

[f] Op. cit., p. 151.

[g] Ram, B. Jaya, Summary of the work done during the year 1904-5: Rec. Mysore Geol. Dept., vol. 6 (1906?), p. 52.

[h] Parsons, James, principal mineral surveyor for Ceylon, letter, March 5, 1908.

AUSTRALIA.

QUEENSLAND.

In Queensland [a] magnesite occurs in the Normanton district in the Gulf country; in the Rockhampton district on Dinner, Sawpit and Stewarts creeks; at Stanwell, Islapot, Moonmera, and the Pointer, near Yamba. In other districts it occurs at Clermont, Toorwomba, Ipswich, Kilkivan, and Newellton. The deposit at Kilkivan is thought to be the largest, though all the deposits are so small that it is improbable that any of them can be worked commercially.

NEW SOUTH WALES.

Small deposits are known in New South Wales [b] in the diamond fields at Bingera, county of Murchison, and near Mudgee. At Two-mile Flats, near Mudgee, pebbles in waste heaps were cemented together by it. On Cudgebegong Creek it forms in peculiar vermicular or wormlike forms. Other localities in New South Wales are Lochlan River, Mooly Gully, and Scone, county of Brisbane; Louisa and Lewis Pond creeks, county of Wellington; and Barraba, county of Darling. None of these deposits are of commercial value, but recently magnesite has been discovered in what appears to be considerable quantity [c] 3½ miles northwest of Fifield. Over an area of 100 acres it crops out through red clay as large rounded blocks of pure-white material. It is said to be capable of yielding many thousand tons of magnesite at a cost not exceeding 38 cents per ton, on drays. A partial analysis of this magnesite is as follows:

Partial analysis of magnesite from Fifield, New South Wales.

Magnesium carbonate ($MgCO_3$)	99.01
Lime (CaO)	Absent.
Ferric oxide (Fe_2O_3), Alumina (Al_2O_3)	.54
Gangue (sand)	.42
	99.97

SOUTH AUSTRALIA.

Large deposits are reported in South Australia, but so far no work has been done on them.

TASMANIA.

In Tasmania magnesite "occurs in serpentine, Parson's Hood Mountain; in veins, Trial Harbor; Meredith Range; Dundas; Hazlewood."[d]

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[a] Dunstan, B., Magnesite in Queensland, quoted in Queensland Gov. Min. Jour. (Brisbane), vol. 8, August, 1907, p. 405.

[b] Liversidge, Archibald, The minerals of New South Wales, 2d ed., Sydney, 1882, p. 176.

[c] Jaquet, J. B., Magnesite at Fifield: Australian Min. Standard, vol. 38, 1907, p. 172.

[d] Petterd, W. F., Minerals of Tasmania: Papers and Proc. Royal Soc. Tasmania, 1893, Hobart, 1894, p. 45.

OCEANICA.

NEW CALEDONIA.

Extensive deposits of magnesite occur on the north end of the west coast of New Caledonia,[a] at the contact of black schists with serpentine, particularly between Koumac and Voh. A specimen obtained near Koumac gave the following analysis:

Analysis of magnesite from vicinity of Koumac, New Caledonia.

Silica and insoluble (SiO_2, etc.)	0.8
Ferric oxide (Fe_2O_3)	.8
Lime (CaO)	3.3
Magnesia (MgO)	42.4
Carbonic anhydride (CO_2)	51.5
Moisture	.4
	99.2

It will at once be noticed that the lime content is too great to permit the use of the material in oxychloride cement. The freight is high from New Caledonia to Europe or America, so that the only exports have been a trial shipment of 42 tons in 1907.[b]

[a] Glasser, Ed. M., Report à M. le ministre des colonies sur les richesses minérales de la Nouvelle-Calédonie: Ann. des mines, 10th ser., vol. 5, pt. 5, 1904, pp. 548-549.

[b] Eng. and Min. Jour., vol. 85, February 1, 1908, p. 283, quoting from Bulletin du Commerce, Noumea, New Caledonia.

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