MISCELLANEOUS NONMETALLIC PRODUCTS.

THE TYPES, MODES OF OCCURRENCE, AND IMPORTANT DEPOSITS OF ASBESTOS IN THE UNITED STATES.

By J. S. DILLER.

INTRODUCTION.

The United States has for many years led all other countries in the manufacture of asbestos goods, but in the mining of asbestos it has not until recently attained any importance, and even now it produces only about one-twentieth as much as Canada. The production of Canada forms so large a part of the world's total annual output, however, that even 5 per cent of it is well worthy of mention.

Asbestos is reported to have been mined in the United States as early as 1880. It was of the amphibole variety and the mining of this variety has continued with variable annual production ever since, but it was not until 1908, when the production of chrysotile began, that a more important phase of the industry was initiated. The annual production has been increased to over 3,000 tons and the outlook for the future is promising.

At present there are in the United States six asbestos localities of more or less interest either to the asbestos industry or to science. They are in the vicinity of Lowell, Vt.; Casper, Wyo.; Grand Canyon, Ariz.; Sall Mountain, Ga.; Kamiah, Idaho; and Bedford, Va. At the localities in Vermont, Wyoming, and Arizona the asbestos is chrysotile, and at those in Georgia, Idaho, and Virginia it is amphibole.[1] Practically all of the asbestos produced in the United States in 1909 came from Vermont and Georgia.

All these localities have been visited by the writer for the special purpose of noting production, but the stay of only a few hours or days at each locality gave no opportunity for detailed study. However, the great interest in asbestos is a sufficient justification for the

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[1] The term "amphibole" is used here in its broad sense to include anthophyllite.

submission of a general view of the field, noting especially its types and modes of occurrence in the United States.

TYPES OF ASBESTOS.

There are three types of asbestos fiber—cross fiber, slip fiber, and mass fiber. Cross-fiber asbestos occurs in veins, and the fibers, if not disturbed, run directly across the veins from wall to wall. Slip fiber occurs in slipping planes, and the direction of the parallel fibers in the plane indicates the direction of the slipping. It is in many places associated with slickensides and may be widely distributed throughout the rock in the planes of readjustment to changing stress. Here and there the slipping is extensive and the shear zone or fault plane has a mass of slip fiber a foot or more in thickness and many feet in length and breadth, forming a definite vein deposit of considerable size. Mass fiber occurs in fibrous bundles or groups and the fiber may be parallel or divergent, in places radial. It is strongly contrasted with the cross-fiber and slip-fiber types in that it does not occur in veins, but forms the whole mass of the rock in which it is developed.

Asbestos of the cross-fiber type is almost invariably chrysotile, but rarely it is anthophyllite. Some asbestos of the slip-fiber type is chrysotile, but more is amphibole. Asbestos of the mass-fiber type, so far as known is always anthophyllite.

MODES OF OCCURRENCE.

By the term "modes of occurrence" is meant the environment of the asbestos deposit, referring especially to its relation to the rocks with which it is genetically associated. There are four modes of occurrence of asbestos in the United States.

The first mode is as cross-fiber veins of chrysotile in serpentine derived from peridotite, a deep-seated igneous rock, as near Lowell, Vt., and Casper, Wyo. So far as known, it is much the most important mode of occurrence and is well illustrated at the Thetford mines, in Canada.

A second mode is as cross-fiber veins of chrysotile with serpentine in limestone. Its most important illustration is in the Grand Canyon of the Colorado in Arizona.

The third mode of occurrence is as mass-fiber amphibole (anthophyllite), composing stocks and dikes of fibrous amphibolite, and is well illustrated in the deposits worked for many years at Sall Mountain, Ga. Asbestos of this mode has recently been opened and has attained some importance at Kamiah, Idaho.

The fourth mode is as slip-fiber veins in rocks which for the most part are cortlandite and pyroxenite, but which locally pass into peridotite, as at Bedford and Rockymount, Va. An example of each of these modes of occurrence in the United States will be briefly described.

Commercial asbestos has been found in the first and third modes of occurrence only. Attempts have been made, but not yet successfully, to mine asbestos of the second and fourth modes of occurrence.

FIRST MODE OF OCCURRENCE.

ASBESTOS OF THE LOWELL REGION, VERMONT.

INTRODUCTION.

The asbestos of the Lowell region of Vermont illustrates the first mode of occurrence. It is so far as known one of the most important deposits in the United States, and much of its interest arises from the fact that, as shown by the accompanying map (fig. 59), it is in the same belt and associated with the same rocks that occur in the large asbestos mines of Thetford and Black Lake, Canada.

Asbestos was discovered in the Lowell region by Zodock Thompson, who stated[1] in 1824 that—

> a range of serpentine passes through the township (formerly Kellyvale, now Lowell) in a northeasterly direction and through the corner of Westfield to Troy. The serpentine is accompanied with beautiful precious serpentine and an abundance of very fine asbestos and amianthus. * * * Near the center of the township where the serpentine forms another bluff, Serpentine Hill, asbestos is plenty.

Asbestos was practically rediscovered and brought to public attention in 1899 by a French Canadian lumberman of Thetford, in the employ of Judge M. E. Tucker, who recognized its economic importance and developed a prospect near the foot of a prominent bluff of peridotite largely altered to serpentine at the east base of Belvidere Mountain, where, at Chrysotile, the Lowell Lumber & Asbestos Co. is now mining and milling asbestos.

In 1900 B. B. Blake called attention to asbestos on the western border of the same mass of serpentine nearly 2 miles from the Tucker property, and the following year the New England Asbestos Mining & Milling Co. erected a large mill fully equipped with modern machinery for winning the asbestos from the serpentine. The mill began operations on the Blake property in May, 1902. It ran only about six months and has since been closed.

DISTRIBUTION.

There are four important localities of asbestos in Vermont connected with the serpentine in the Lowell region. These localities

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[1] A gazetteer of the State of Vermont, 1824, pp. 164–165. My attention was called to this interesting work by Mr. W. G. Gallager.

were outlined and described from a petrographic point of view by V. F. Marsters,[1] and have lately been considered more fully in their economic aspect by C. H. Richardson,[2] of the Geological Survey of Vermont, under the direction of G. H. Perkins, State geologist. The first locality, as indicated on the map (fig. 59), is 2 miles northeast of Lowell village. The second is northwest of Lowell, in the vicinity of Westfield, and the third and fourth are southwest of Lowell, near Mount Belvidere—one at the old mill of the New England Asbestos Co. and the other, by far the most important, at Chrysotile.

All these localities except the second have been examined by the writer, but in less detail than by either Marsters or Richardson, whose valuable reports give full information.

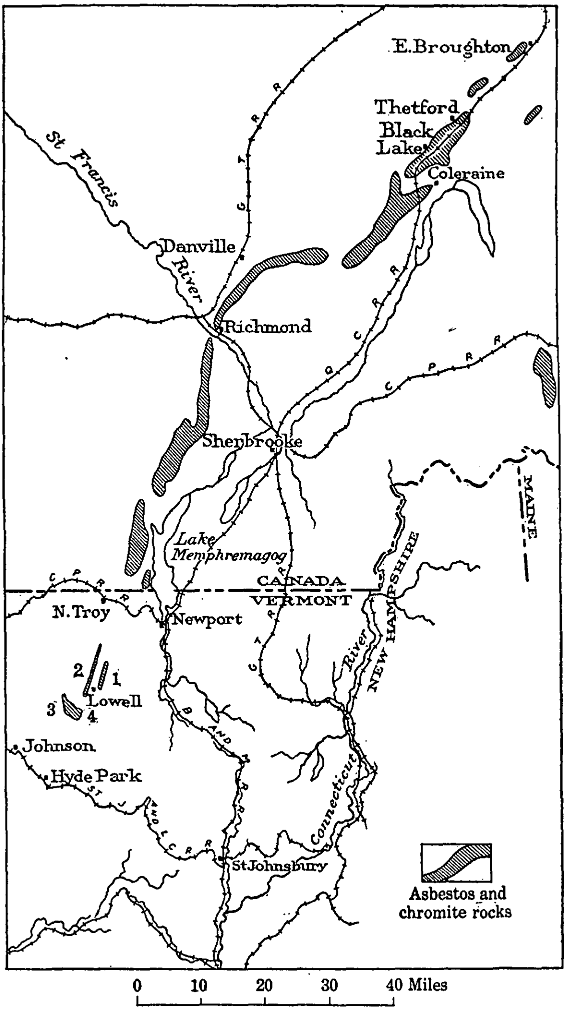

FIGURE 59.—Map showing location of asbestos deposits in northern Vermont and adjoining portion of Canada. 1, 2 miles northeast of Lowell; 2, northwest of Lowell; 3, New England Co.'s mill; 4, mine and mill of Lowell Lumber & Asbestos Co., Chrysotile. The lines in Canada are taken from a map by J. A. Dresser, of the Geological Survey of Canada.

The locality 2 miles northeast of Lowell is on the farm of C. F. Kelley. It was prospected in a number of pits some years ago by M. E. Tucker, of Hyde Park, who owns the mineral right. The rock locally contains numerous small cross-fiber veins and some of slip fiber in serpentine derived from olivine.

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[1] Bull. Geol. Soc. America, vol. 16, 1905, pp. 419–446; Fourth Ann. Rept. State Geologist of Vermont for 1903–4, pp. 86–102.

[2] Seventh Rept. Vermont Geol. Survey, pp. 315–330.

Richardson, who examined this locality recently, regards it as sufficiently encouraging to warrant the erection of an asbestos mill and the development of the property.

The second locality is described by Richardson as situated on the northeast side of the Round Mountain area in Lowell and Westfield. The belt is several miles in length and a mile in width. Locally it contains a considerable quantity of slip-fiber and cross-fiber asbestos, which in certain specimens amounts to as much as 25 per cent of the mass. The topographic situation of this outcrop is especially favorable to development. The property is owned by Thomas Gilbert, of Westfield, and is under an option which soon expires.

A locality on the southwest side of Belvidere Mountain containing 90 acres was leased for 198 years by the New England Asbestos Mining & Milling Co. It was deeply prospected at the time the mill was operated. The serpentine contains much slip fiber, but as yet comparatively little cross fiber is exposed, though it is said to occur in the shaft at a depth of 40 feet. The rocks are soft, and the mill is situated nearby below the quarry so as to make handling economical. A sample weighing 2,150 pounds from this quarry was milled at Chrysotile in the improved mill of the Lowell Lumber & Asbestos Co., and the yield, according to Richardson, was over 15 per cent of the mass milled, as follows:

	Pounds.
No. 1 fiber	7.5
No. 2 fiber	30
No. 3 fiber	50
No. 4 fiber	254
	341.5

At the same time (June, 1908) 1,752 pounds of tailings from the old mill of the New England Co. were put through the mill at Chrysotile and found to contain 237 pounds of usable fiber. With the loss of so much fiber in the tailings, it is not surprising that the mill closed. There is great reason to believe that proper management may yet make that mine a successful producer.

The fourth and most active asbestos locality of the Lowell region is at Chrysotile, where the Lowell Lumber & Asbestos Co., of which W. G. Gallager is president, has had a mine and mill in successful operation for several years. It is the locality originally known as the Tucker property, and has from the first attracted attention on account of the quantity and quality of the asbestos fiber, as well as the character of the serpentine and the favorable situation of the outcrop for mining.

The peridotite at Chrysotile is greatly fractured close to its junction with the amphibolite, and much of it is completely altered to serpentine. Slip fiber is the most conspicuous and abundant variety of asbestos. It forms sheets between the sheared blocks of serpentine and some of the fiber is very tough. Here and there the rock is traversed by groups of parallel cross-fiber veins commonly one-half to three-fourths and rarely an inch in thickness. The light-colored dikes of granitic rocks seen in the Thetford mines are so far as known absent in Vermont, but otherwise the rocks mined at Chrysotile are very like those of the principal mines in Canada.

In the south quarry of the mine now being worked there is a 4-foot belt containing more than 20 parallel veins of cross-fiber asbestos, which forms nearly 19 per cent of the whole mass of serpentine rock within the belt. Under the superintendence of skilled workmen from the Canadian mines a considerable portion of the asbestos in this belt is being cobbed as No. 2 crude, and thus has recently been initiated the production of a higher grade.

As the development of the mine advances and its production increases it is of special interest to note the testimony of manufacturers who use the fiber. The president of one of the largest manufacturing companies writes:

> We have used many carloads of the two or three grades produced by Mr. Gallager. Of course this property has not yet produced any grades such as No. 1 or 2 crude, but what they do produce in the way of paper stock and long fiber is perfectly satisfactory and compares very favorably with similar grades from Canada.[1]

The mine is being developed on the eastern edge of the serpentine, in a bluff facing eastward, and the mill is near by on the gentler slope below the mine, so that gravity can be utilized to great advantage in moving the material from the mine through the mill.

The slope of serpentine rises steeply westward in a prominent bluff toward Mount Belvidere, and the width of the belt is nearly 2 miles. The face of the mine is now about 40 feet high and will rapidly increase as the mine advances into the steep slope, so that the amount of easily available serpentine above the level of the mine is enormous. It is not to be expected that all of this large mass of serpentine is sufficiently rich in asbestos to be worth milling. Further exploitation must determine the proper course of development. If the richest rock is limited to the eastern edge of the serpentine and its richness increases with the depth, the development should be limited to that portion; but if the body of the peridotite (serpentine) instead of being a sheet or sill is a thick mass, a batholith, its richest portion, as shown by Dresser,[2] who has made a special study of the Canadian mines, may be expected to be in the center—that is, under the big bluff west of the mine.

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[1] This was written before the introduction of skilled labor and the production of No. 2 crude.

[2] Dresser, J. A., Canadian Min. Jour., Aug. 1, 1910, p. 470.

In this connection it is interesting to note what has just been published[1] by Dr. Fritz Cirkel, the most prominent living authority on asbestos. Concerning the asbestos at Chrysotile he says:

> The productive belt is about 300 feet wide. The serpentine is of greenish, mottled color and in its outward appearance is entirely different from that of Black Lake and Thetford. It carries asbestos veins up to 1 inch thick, but the fiber as a rule is divided in the middle, parallel to the walls, by a seamy parting of serpentine, sometimes containing fine grains of magnetite and chrome iron ore. At the time of the writer's visit, in March, 1910, the main working pit, which represents an open cut, was 75 feet wide, with a rock face of 40 feet. These veins ramify through the rock in irregular fashion, and some rich rock is occasionally met with. About one-half of the serpentine goes to the dump, and the balance is a milling material of good quality. No "crude" is obtained. The mill is capable of treating about 200 tons per day, and the fiber produced compares favorably with that found in Canadian mines.

IMPROVEMENTS.

The present mill of the Lowell Lumber & Asbestos Co. was erected in 1908. It is about 100 feet in length, 40 feet in width, and two stories in height. Under the new management from Canada the machinery is being changed, enlarged, and improved. A 100-horsepower oil engine is already installed to run the fiberizer screens and pneumatic machinery of the mill and two 50-horsepower oil engines are in course of erection to operate the rock crushers, conveyors, and dryers.

The output of chrysotile in 1909, including all grades, is said to have been about 2,100 tons, an amount which was surpassed in 1910.

A traction engine and several trucks capable of hauling 20 tons at a load from the mine 12 miles to the St. Johnsbury & Champlain Railroad at Hyde Park returns with fuel oil for the engine that furnishes power for the mill and mine.

Mr. Gallager states that the company proposes to erect a much larger mill, capable of yielding 100 tons of asbestos daily, and then to engage in manufacturing asbestos objects for the utilization of the lower grades.

OUTLOOK.

The fact that the asbestos prospects of the Lowell district are in the same belt and associated with the same rocks that occur in the great asbestos mines of Canada, about 130 miles to the northeast, is in itself a strongly suggestive feature, but when to this are added the results of the encouraging test of quantity and quality afforded by the two years' run of the Lowell Lumber & Asbestos Co.'s mill at Chrysotile there is good reason to believe that Vermont will soon become a still more important producer of asbestos.

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[1] Cirkel, Fritz, Chrysotile asbestos, its occurrence, exploitation, milling, and uses, Mines Branch Canada Dept. Mines, Ottawa, 2d ed., 1910.

In the development of this industry the railroads should play an important part and connect by an easy route directly from North Troy to Hyde Park by way of Chrysotile, so as to furnish convenient transportation. An accurate topographic map of the region should be made.

ASBESTOS OF CASPER REGION, WYOMING.

DISTRIBUTION.

In the front range of the Rocky Mountains near Casper, Wyo., there are two distinct localities of asbestos—one on Casper Mountain, 8 miles directly south of Casper, and the other on Smith Creek, about 20 miles southeast of Casper. (See fig. 60.) The Casper Mountain area embraces approximately 4½ square miles and the Smith Creek area nearly 7 square miles. Both areas have their greatest extent

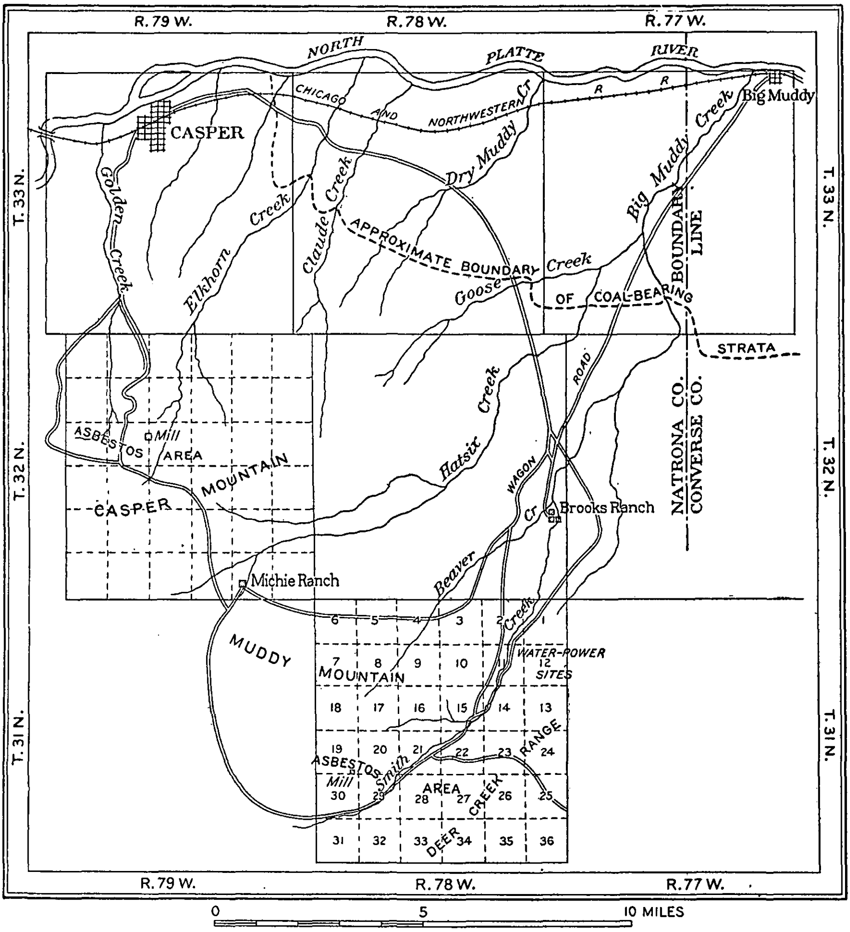

FIGURE 60.—Map of vicinity of Casper, Wyo., showing Casper Mountain and Smith Creek asbestos areas.

in a line running a few degrees north of east and are characterized by the same rocks, among which serpentine, diorite, and granite are perhaps the most important.

STRUCTURE.

The rocks of the asbestos areas, so far as observed, are wholly igneous. They lie unconformably beneath the Cambrian sandstone and belong to the Archean. The Smith Creek and Casper Mountain areas are due to anticlines which bring the deep-seated altered rocks to the surface. The two areas are separated by a broad syncline which contains a great thickness of Paleozoic and Mesozoic sediments. These sediments have all been deposited since the asbestos was formed. The general geologic features of the region have been worked out and described by N. H. Darton.[1]

ROCKS OF THE ASBESTOS AREAS.

The rocks of the asbestos areas are hornblende schist, diorite, granite, and serpentine. The black hornblende schist is a well-defined, medium-grained schist in which hornblende is somewhat more abundant than the altered feldspar and quartz. The diorite differs from the hornblende schist generally in being finer grained and without definite schistose structure. Much of it is compact with the habit of greenstone.

Granite is perhaps the most distinctive rock of these areas. It is medium to coarse grained and generally red, owing to the color of the abundant feldspar. Much of it is composed of quartz and feldspar, with only a trace of hornblende or other ferromagnesian silicates. The structure, though generally even granular, is in places graphic, and here and there the rock passes into pegmatite and appears in the form of more or less distinct dikes. The granite is generally regarded as one of the important rocks in the great Archean mass of the Laramie Range and as older than the diorite and serpentine. This may well be true for the main body, but in the asbestos areas, especially in the divide between Smith Creek and Deer Creek, the granite locally appears as large dikes and sends tongues into the adjacent serpentine.

Serpentine being the source of the asbestos it is by far the most important rock of the area. It occurs in belts which, at least in the Smith Creek area, where their distribution has been noted most fully, extend northwest and southeast. This is true both of the mass which is now being worked at the west end of the area and of the one farther east running through the property of the International Asbestos Mills & Power Co. The western belt is about 1,500 feet long

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[1] Prof. Paper U. S. Geol. Survey No. 32, 1905, Pl. XXXV.

and from 150 to 300 feet wide. In general the trend of these belts is toward the asbestos area of Casper Mountain and suggests the connection of the two areas beneath the syncline of sedimentary rocks that lies between them.

The most common type of serpentine in this region is bluish and impure, but the more typical form is that which is associated with asbestos. It is generally very much crushed and sheared. The serpentine where examined contained no remnants of the rock from which it was derived. Its microscopic structure, however, clearly indicates that the original rock was composed almost wholly of olivine. It was not only a peridotite but practically a dunite.

The rocks of the asbestos areas, ranging from granite to peridoite, with a number of intermediate forms, have resulted apparently from the differentiation of a single magma, of which the asbestos is one of the final products.

THE ASBESTOS.

Cross-fiber veins.—The asbestos of the Casper Mountain region is almost wholly chrysotile. In color it varies from pale green to colorless on the one hand and to yellowish bronze on the other. It occurs in the form of cross-fiber veins in serpentine. Veins were observed at a number of places with fiber over an inch in length. In the same vicinity there are usually found great numbers of small parallel cross-fiber veins ranging in thickness from that of paper up to three-fourths of an inch. Veins from one-fourth to one-eighth of an inch in thickness are most common. Some of the veins cut others, indicating that all the veins of chrysotile were not formed at the same time. In these parallel groups the larger the veins the greater the distance between them. The waxy-lustered serpentine between the veins varies in color from greenish yellow to gray. Grains of magnetite are common in the serpentine, and here and there magnetite with a little asbestos forms dark lustrous veins up to one-fourth of an inch in thickness, but in general the asbestos veins of the Casper region are free from magnetite, and in that respect appear to have an advantage over the asbestos veins of Vermont and Canada. The belts of such parallel veins may be from 4 to 10 feet wide. A number of such belts rich in asbestos veins occur within the serpentine. Between these belts the serpentine is either barren or contains only a few small veins of asbestos.

As in other asbestos fields, the veins of cross fiber are traversed by partings parallel to the vein walls, which cut the fiber to shorter lengths and greatly reduce its grade, but such partings are not more abundant in the cross-fiber veins of the Casper region than elsewhere.

Slip fiber.—There is considerable slip fiber in the sheared portions of the serpentine, and although some of it is brittle and lacks tensile strength most of it is of good quality. The asbestos veins in places are not only puckered and crumpled but crushed and sheared, so that the cross fiber appears to pass into slip fiber, as at East Broughton, Canada. These rocks evidently have been much disturbed and sheared since some of the earlier asbestos veins were formed. Much of the slip fiber may be younger than the cross fiber.

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

Relation of asbestos to granite.—Although the cross-fiber veins of chrysotile are always in serpentine the localities in which they are most abundant are generally near the contact between serpentine and granite. This is especially true at the McConnel shaft and the Rainbow opening in the Casper Mountain area, as well as at several points in the International and the Wyoming Consolidated properties on Smith Creek, and the larger veins are for the most part approximately parallel to the contact, as if the granite were a factor in their development.

IMPROVEMENTS.

The Smith Creek area has a mill which began operations in October, 1910, on the Wyoming Consolidated property. It is provided with jaw crushers, Jeffrey pulverizers, Parker Asbestos Jumbo fiberizers, and various screens and other accessories, and has a daily capacity apparently of not over 50 tons of rock as it comes from the mine. There is an ore chute from the mine direct to the mill, where the machinery is so arranged as to make the greatest use of gravity.

A mill of similar design and probably of about equal capacity has been erected in the Casper Mountain area, but has not yet been reported in operation. C. H. Parker, formerly of the Thetford mines, Canada, is general manager of both the International and the Northwestern properties.

SOURCE OF POWER.

The timber of the region is sufficient to produce only a moderate supply of power. If the timber is preserved Smith Creek and other streams that have steep grades and good mill sites would, though small, afford a more enduring power supply.

Another important supply of power lies in the Glenrock coal field, which contains an abundance of coal of sufficiently high calorific value to be used to advantage in a gas producer engine to generate electricity at the coal mine for transmission to the asbestos mills and mines of the Smith Creek and Casper Mountain areas.

The Lander oil field is only a short distance to the west and may yet become an important source of power for this region.

RELATION TO MARKET.

The principal shipping point for the asbestos of the region will be Casper, on the Chicago & North Western Railway, 1,103 miles west of Chicago and 328 miles north of Denver. The Smith Creek area is 30 miles from Casper by a good wagon road which is roughly estimated to descend about 600 feet. The Casper Mountain area is 8 miles south of Casper and nearly 1,000 feet above the town, and there is a good road to the foot of the mountain. For transportation from the mill over the steep slope of the mountain to the wagon road it is proposed to construct a 6,000-foot tramway.

OUTLOOK.

In consideration of the quantity and quality of the fiber, its relation to the markets of the West, and the mining and milling improvements already installed, the asbestos of the Casper region seems destined to become a factor in the asbestos industry of the United States, but how important it may become, and when, can not be told without further development and investigation. The developments are not yet sufficient to warrant any definite opinion as to the future of the region, and in the meantime much depends on those who control the claims.

SECOND MODE OF OCCURRENCE—ASBESTOS OF THE GRAND CANYON, ARIZONA.

PREFACE.

The asbestos of the Grand Canyon of Arizona illustrates the second mode of occurrence of asbestos—that is, its occurrence with serpentine in limestone.[1] The serpentine, like the limestone in which it occurs, is derived from material of sedimentary origin, and as to its original source is therefore in strong contrast with the serpentine derived from peridotite.

DISTRIBUTION.

The asbestos belt of Arizona is a long, narrow strip lying at a definite geologic horizon among the Algonkian strata in the depths of the Grand Canyon of the Colorado, about 4,000 feet below its rim

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[1] A somewhat similar case is described by Merrill (Proc. U. S. Nat. Mus., 1888, p. 105) as occurring at Montville, N. J.

and in places over a thousand feet above the river. It has been studied at two localities in the canyon—one beneath Grand View,[1] where the serpentine-asbestos belt is exposed for nearly 2 miles with a width of only a few feet, and the other 30 miles farther west, in the canyon beneath Bass's camp,[2] where the same belt has a length of about three-fourths of a mile. According to Noble, the same asbestos belt outcrops for several miles in the canyon west of Powells Plateau, but owing to its inaccessibility the locality has not yet been examined.

STRUCTURE.

The structure of the asbestos belt is monoclinal. The strata in it are part of a thick series of Algonkian rocks which dip generally to the north or northeast at angles of 10° to 20°, and are traversed here and there by normal faults, generally of small displacement. These rocks form part of the north wall of the great gorge of the Colorado, where they are separated from both the overlying Cambrian and the underlying Archean by conspicuous unconformities. The strata, although deep-seated and of great age, are as a body not crushed, fractured, or metamorphosed as are those in which asbestos of the first mode occurs, and this fact has an important significance concerning the origin of the asbestos veins.

THE ROCKS AND THEIR RELATIONS.

The rocks with which the asbestos is associated are given in the following section[3] below the great sill of diabase in Asbestos (Hakataia) Canyon.

Section of asbestos-bearing rocks in Asbestos Canyon.

	Feet.
Diabase.	
Layer of green serpentine	2
Pure white crystalline limestone	1½
White crystalline limestone with bands and nodules of serpentine	2
Serpentinous nodular and banded layer carrying veins of asbestos	1
Banded crystalline limestone with bands and nodules of serpentine	10
Nodular cherty limestone	4
Soft blue slate	5

The asbestos below the diabase is not absolutely constant in horizon but may lie, according to Noble, anywhere from 3 to 15 feet below the contact.

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[1] Pratt, J. H., Mineral Resources U. S. for 1904, U. S. Geol. Survey, 1905, p. 17.

[2] Noble, L. F., Am. Jour. Sci., 4th ser., vol. 29, 1910, pp. 520–522; personal letter dated June 21, 1910.

[3] Noble, L. F., op. cit., p. 520.

The limestone above the diabase contains some serpentine and small veins of asbestos rather widely distributed, but on the whole this material appears to be much less abundant and persistent than that below the diabase.

The serpentine and asbestos occur in the limestones only where these strata are invaded by the diabase sill; where the diabase lies between shales there is no development of these minerals within the invaded strata. In no place in the area are they developed within the diabase itself. It is, therefore, clear that they are a contact-metamorphic phenomenon conditioned by the invasion of the limestones by the diabase. It seems probable, as suggested by Diller, that the serpentine which incloses the veins of asbestos is derived from some mineral in the limestones and not from the diabase. The limestones themselves are magnesian and locally siliceous in the form of chert bands and nodules. In another part of the area the conversion of the shales to jaspers where they are in contact with the diabase is evidence that the fumarolic action accompanying the injection of diabasic magma was manifested by aqueous and probably siliceous emanations and was fairly intense. It seems possible that the operation of the fumarolic action upon the elements already present in the magnesian limestones might have been sufficient to convert the more siliceous portions into serpentine. The occurrence of the asbestos in veins that cut both the nodules of serpentine and the limestones is evidence that the formation of the cross-fiber asbestos was itself a somewhat later phenomenon.[1]

ASBESTOS.

The serpentinous layer that carries the asbestos is usually from 12 to 14 inches in thickness and the general trend of the asbestos veins within it is parallel to the bedding of the limestone. Locally the asbestos fiber is 4 inches in length from side to side of the vein, but generally the veins do not exceed 2½ inches and in many places they appear as a series of small parallel veins. The larger veins are remarkable for their continuity. According to Pratt,[2] below Grand View, where the outcrop of the serpentine-asbestos layer is in places as much as 18 or even 24 inches in thickness, there may be in it two or three large parallel veins of asbestos that continue for 150 feet. Within this thin layer containing the asbestos cross-fiber veins over an inch in width are common. The width of the veins at this horizon varies greatly from place to place, so that a 3-inch vein in one locality may be represented by a zone of innumerable small veins in another, but the actual continuity of the zone that carries the asbestos, according to Noble, is rarely broken.

The asbestos veins have but few partings and these are generally of chalcedonic quartz with rough borders instead of the smooth, sharp lines like those which generally mark the sides of the veins. Very little, if any, magnetite is present in the veins. The asbestos

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[1] Noble, L. F., op. cit., pp. 521–522.

[2] Pratt, J. H., Mineral Resources U. S. for 1904, U. S. Geol. Survey, 1905, pp. 1138–1139.

is generally of a beautiful golden-yellow color, though in places shading to pale green. It is finely fibrous, smooth, silky, and of great tensile strength, so that it compares favorably with the crude asbestos from any other country.

Locally as much as 40 per cent of the 12-inch layer may be Nos. 1 and 2 crude, with 10 per cent of lower grades, but in general the thin layer would probably not average more than 15 per cent of all grades.

The eastern area under Grand View has been most extensively prospected. A few years ago the Hance Asbestos Co. opened a number of cuts along the outcrops and ran tunnels down the dip, some of them for 75 feet.

The large proportion of crude to other grades in this Grand Canyon deposit is remarkable. Ordinarily such a deposit could be profitably mined, but the narrow limits of the asbestos belt, taken in connection with its attitude and the difficulties of getting the asbestos across the river and out of the canyon to the railroad, appear to render successful mining very problematical, except in a small way with donkeys for transportation. In any case the development of this deposit would have to be on a small scale only and for high-grade material. A shipment of about 1,500 pounds of crude asbestos from the Grand Canyon was sent by E. B. Pike, 151 Chambers Street, New York City, to Germany for testing and proved to be of entirely satisfactory quality.

Whatever part the asbestos of the Grand Canyon may play in the asbestos industry of the country, it will ever be recognized as one of the most exceptional and interesting deposits of asbestos yet discovered. The entire absence of rock crushing and the remarkable continuity of the asbestos veins approximately in the plane of stratification clearly indicate that the veins were not deposited in open fissures but by the replacement of serpentine in the planes of weakness somewhat later than the development of the serpentine itself. Here, too, we have convincing evidence of the development of asbestos by igneous intrusion. We may therefore the more readily accord to the granite dikes in Canada and elsewhere a decided influence in the formation of the asbestos near their contacts.

THIRD MODE OF OCCURRENCE—ASBESTOS OF KAMIAH, IDAHO.

The third mode of occurrence of asbestos is as mass fiber in dikes or lenticular bodies of amphibolite, and good examples of this mode occur near Kamiah, Idaho, and Sall Mountain, Ga.

The Idaho locality is about 14 miles southeast of Kamiah, where the amphibolite forms about half a dozen ledges within a few square miles. The largest of these ledges has a lenticular shape and is about

200 feet in length, 40 feet in width, and 35 feet in height above the ground. Apparently they are intruded in mica schist, but deep prospecting has discovered the bottom of some of these masses and they must not be expected to extend down great distances. Some of them, at least, probably pinch out before reaching a depth as great as the length of the outcrop on the surface. But as there are a number of openings and probably other masses not yet discovered, a large amount of material is available.

The term " mass fiber " is used to indicate that the whole mass is fibrous and that the fiber is neither cross fiber nor slip fiber, both of which are essentially vein deposits. The fibrous mineral, acording to Merrill,[1] who studied the Sall Mountain rocks, is anthophyllite. The fibers are arranged in small bundles one-fourth to three-fourths of an inch in length. The bundles generally lie in all directions through the rock, but are locally arranged in radial groups so as to form rosettes on cross fractures. Some of the rosettes are 4 inches in diameter, with radial fibers of dull to vitreous luster and many cross fractures. The fibers are brittle and readily break into short lengths and split into fine threads that are polygonal in cross section. None of the material is of spinning grade, and its short mill fiber of low tensile strength renders it much less valuable than all but the lowest grades of chrysotile.

At present all the rock quarried is hauled in wagons to Kamiah and shipped by rail to Spokane, where the Spokane Asbestos Firebrick Co. is sawing and grinding it for various purposes.

FOURTH MODE OF OCCURRENCE—ASBESTOS OF BEDFORD, VIRGINIA.

The fourth mode of occurrence of asbestos is as slip-fiber veins in rocks of variant composition though perhaps generally hornblendic. The best illustration of this mode yet observed by the writer in the United States is 12 miles south of Bedford, Va., where there are two outcrops of a few acres each. The asbestos is of the amphibole variety. The prevailing rock of the area is composed of hornblende and olivine. In some places it is pyroxene and olivine and in others almost wholly olivine. For the most part the rock is closely related to cortlandite, but in some places it is peridotite and locally may be pyroxenite. These rocks all appear to be differentiation products from one magma. In nearly all of them the rock has numerous acicular crystals and fibrous bundles of anthophyllite. The same mineral rarely forms cross-fiber veins.

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[1] A brief account, including chemical analyses, of the asbestos of Sall Mountain and other localities in Georgia was given by George P. Merrill in Proc. U. S. Nat. Mus., vol. 18, 1895, pp. 282–291.

This rock complex is cut here and there by planes of shearing along which have been developed veinlike masses of slip fiber that lie in the plane parallel to the direction of slipping. These masses of slip fiber attracted the attention of prospectors for asbestos and are the parts that have been mined out. The veins, of which there are several in the same vicinity, strike approximately northwest and southeast and dip to the southwest. A vein 18 inches thick has been followed along the strike for 30 feet and down the dip by two inclines for perhaps 50 feet. These masses of slip fiber are very irregular and so far as known are of so small extent as to furnish a very unreliable basis for mining operations such as were undertaken a few years ago and failed, not only on account of the low grade of the fiber but on account of the small quantity available.

SUMMARY.

Aside from the minerals serpentine, amphibole, anthophyllite, and crocidolite, all of which have asbestiform varieties, there are three types of asbestos fiber distinguished by the manner of grouping as cross fiber, slip fiber, and mass fiber, and all are of commercial importance but of different degrees, decreasing in the order named.

Cross fiber forms veins, and the fibers, though parallel to one another when first formed, are approximately perpendicular to the plane of the vein and run directly across it from wall to wall. Chrysotile generally appears in this type and anthophyllite rarely.

Slip fiber forms veins on slip planes and the fibers are parallel not only to one another but to the direction of slipping. Chrysotile, amphibole, and anthophyllite appear in this type.

Mass fiber is strongly contrasted with cross fiber and slip fiber in that it is not a vein formation but constitutes large bodies of rocks. The fibers are grouped in bundles or bunches and may be parallel or divergent. The groups of fibers lay in all directions in the rock, but in some localities they are arranged parallel by earth movements and the rock becomes schistose. Anthophyllite only is known in this type, and although of much lower grade than chrysotile the yield is large, for ordinarily 90 per cent of all that is removed from the quarry is bagged in the mill.

The phrase "mode of occurrence" being employed to refer especially to the genetic relation of the deposit to its environment, there are four modes of occurrence of asbestos in the United States. The first mode is as cross-fiber veins in serpentine derived from peridotite. It is the mode of the deposits near Lowell, Vt., and Casper, Wyo., as well as in the productive mines at Thetford, Canada.

The serpentine of the Casper Mountain region where purest is clearly derived from olivine, and the asbestos where most abundant is associated with the purest serpentine.

Asbestos veins are in general most abundant in the vicinity of masses of granite, suggesting that the intrusion of the granite was a factor in the development of the asbestos.

The occurrence of considerable bodies of chromic iron ore at both Casper Mountain and Smith Creek, in Wyoming, on the border of the serpentine containing the asbestos, is suggestive in being analogous to that of the Thetford and Black Lake region of Canada.

The second mode of occurrence of asbestos is as cross-fiber veins developed in limestone by the contact metamorphism of an adjacent intrusive rock. A striking example of this mode is exposed in the Grand Canyon of the Colorado wherever a certain magnesian limestone of Algonkian age comes into contact with a thick sill of diabase. Certain portions of the limestone were converted into serpentine, and somewhat later the serpentine became traversed by veins of asbestos approximately parallel to the bedding of the limestone. Although the asbestos belt is very narrow the quantitative proportion of Nos. 1 and 2 crude asbestos of excellent quality to that of the lower grades is very large. Nevertheless, the serpentine-asbestos belt is so narrow and the difficulties of deep mining and transportation in the canyon are so great that the successful exploitation of this asbestos is very problematical, unless in a small way by the removal of the high-grade material from along the outcrops.

The third mode of occurrence is as lenticular masses or dikes of mass-fiber amphibolite, such as has been mined for a number of years at Sall Mountain, Ga., and has lately been opened at Kamiah, Idaho. This material, especially when weathered, is easily mined and pulverized. Being brittle, it breaks into short lengths and yields but one grade. However, so large a proportion of the whole mass (90 per cent) turns out as fiber that, though the material is of low grade only, mining operations continue.

The fourth mode of occurrence of asbestos is in veins of slip fiber traversing rocks closely related to cortlandite, pyroxenite, and peridotite, and is illustrated by deposits near Bedford, Va. The rocks are much sheared and are locally converted into amphibolite schist. The asbestos is developed most prominently on the fault planes where masses of amphibole slip fiber of considerable size have attracted the attention of miners but have not yet yielded profitable mines.

Some slip fiber is found in nearly all masses of serpentine. In places it is soft and strong and appears to be chrysotile, but much of it, being amphibole, is harsh and brittle and of much lower grade than chrysotile.

PROSPECTING FOR ASBESTOS.

Asbestos occurs only in ancient crystalline rocks of Paleozoic or earlier age, and the rocks in which it is found are almost invariably of igneous origin, peridotite altered to serpentine being by far the most important.

The asbestos region of Canada, which has been so successfully worked for many years, is now so well exposed in mines, prospects, and glaciated hills as to afford an excellent opportunity for investigation, and we may well profit by the researches of the Canadian Geological Survey,[1] which has recently studied the Canadian field in detail and pointed out that the conditions most important to observe in prospecting for asbestos (chrysotile) are purity of the serpentine, its fractures, and the presence of granite.

The purity of the serpentine depends on the degree of differentiation of the magma and is regarded as the most important. The purer the serpentine the more likely it is to form asbestos.

A scarcely less important condition is the abundance of fractures. The more abundant they are, especially if the serpentine is intruded by granite, the more likely it is that the circulating magmatic waters will form asbestos.

In the United States the exploitation of chrysotile asbestos is not yet so far advanced that definite conclusions can be formulated concerning its development, but as far as it goes in similar deposits the important conditions fully agree with those noted above.

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[1] Dresser, J. A., Summary report on the serpentine belt of southern Quebec, Geol. Survey Canada, 1909.

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The volumes for 1901 to 1904 contain reports by J. H. Pratt, for 1905 by George Otis Smith, and for 1906 to 1910 by J. S. Diller.

DOLOMITE FOR FLUX IN THE VICINITY OF MONTEVALLO, SHELBY COUNTY, ALABAMA.

By CHARLES BUTTS.

The Ketona dolomite member of the Knox dolomite has been described in several publications of the United States Geological Survey.[1] The name applies to the basal, chert-free part of the Knox, which is some 600 feet thick in the vicinity of Birmingham. It is economically important as the source of most of the flux rock used in the Birmingham smelting furnaces and its occurrence in other parts of the Birmingham district will be of interest to quarrymen and to those connected with the iron-smelting industries.

In a recent survey of the Bessemer quadrangle, south of Birmingham, the presence of this dolomite in a remarkably pure condition has been determined. Samples were collected on Shoal Creek, between Montevallo and Maylene, in the SW. ¼ NE. ¼ sec. 33, T. 21 S., R. 3 W., about half a mile a little south of east of Ryan station on the Southern Railway, on property belonging to a Mr. Freeman. They were taken from an outcrop of the dolomite in a branch of Shoal Creek on the west, a sample being taken every 100 feet westward across the outcrop for 600 feet, beginning at the mouth of the branch. The dip at this point is 20° E., so that the total thickness of rock sampled is about 200 feet, each sample representing a thickness of 40 feet. The samples were examined in the laboratory of the United States Geological Survey for the determination of lime carbonate, magnesium carbonate, and insoluble matter, with the results shown in the following table, arranged in stratigraphic order of the samples from the top downward:

Analyses of dolomite from the Freeman farm, in the SW. ¼ NE. ¼ sec. 33, T. 21 S., R. 3 W., half a mile southwest of Ryan station, 5 miles north of Montevallo, Ala.

	1	2	3	4	5	6	Average.
Lime carbonate ($CaCO_3$)	54.73	54.04	53.70	54.02	54.57	54.71	54.295
Magnesium carbonate ($MgCO_3$)	44.02	43.76	43.51	43.85	43.77	44.01	43.82
Insoluble	.61	.68	.96	.49	.64	.44	.64
	99.36	98.48	98.17	98.36	98.98	99.16	98.755

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[1] Bull. 315, 1907; Bull. 400, 1910; Birmingham folio (No. 175), Geol. Atlas U. S., 1911.

These analyses show a very pure carbonate rock. The amount necessary to make up 100 per cent in the analyses is supposed to consist of a number of minor constituents, of which iron oxide is probably the chief. The insoluble matter is supposed to be silica and alumina, probably mostly the former.

The ratio of lime and magnesium carbonates is nearly that of the mineral dolomite, which is composed of 45.6 per cent magnesium carbonate and 54.4 per cent lime carbonate.

Recalculating the average percentages of the carbonates in the seventh column of the table on the basis of 100 per cent carbonates, gives 44.65+ per cent of magnesium carbonate and 55.34+ per cent calcium carbonate, very nearly the dolomite ratio.

The rock here described is considerably purer than the Ketona of Birmingham Valley, as can be seen by comparison with the following analyses:

Analyses of dolomite from Ketona and North Birmingham quarries.[a]

	1	2
Silica (SiO_2)	1.31	.70
Alumina (Al_2O_3)	.96	.63
Lime carbonate ($CaCO_3$)	55.80	56.41
Magnesium carbonate ($MgCO_3$)	42.47	43.00

[a] Bull. U. S. Geol. Survey No. 400, 1910, p. 196.

1. Average of four analyses of average samples from Ketona quarry, Ketona, Ala., August to October, 1903. Analyses furnished by the Tennessee Coal, Iron & Railroad Co.

2. Average of ten analyses of carload lots from North Birmingham quarry, August, 1903, to June, 1905. Analyses furnished by the Sloss Co.

The magnesium and lime carbonate ratio is practically the same in the rock at these localities as in the rock described in this paper, but the insoluble matter is twice as great at North Birmingham and three and one-half times as great at Ketona.

The rock on Shaol Creek is rather thick bedded, very coarse grained, and soft. It is generally of a gray color, but in spots it is faintly mottled with pink.

The 200 feet of rock from which the samples analyzed were taken lies in a much thicker body of noncherty dolomite correlated with the Ketona. This dolomite outcrops in a band half a mile or so in width extending along Shoal and Beaver Dam Creeks and northward past Helena. It underlies the low ground between the coal measures on the west and the chert ridge on the east called Newhope Mountain east of Helena and Pine Ridge east of Maylene. Just what proportion of this mass is of the grade shown by the analyses is unknown. There is at least 200 feet of pure rock in the section studied, but whether such rock may not be much thicker or what its extent along the outcrop may be is undetermined.

Besides the area of Ketona along Shoal Creek and to the north there are, in the vicinity of Montevallo, other thin bands of dolomite of the Ketona type disconnected by faults. The outcrop is much narrower in these other bands because the dip is steeper and possibly because the stratum is thinner. One of these bands follows the course of Spring Creek from the northwest corner of sec. 7, T. 22 S., R. 2 W., to Montevallo and southwest to Wilton. The rock is well exposed along the byroad running north through the W. ½ sec. 12, T. 22 S., R. 3 W., in the southwest corner of the section, and also just east of Montevallo, on the Columbiana Road, on the east margin of Sprink Creek. The dip along this outcrop is 40° SE. It also shows well on Mahan Creek, three-quarters of a mile north of Brierfield, in the SE. ¼ NW. ¼ sec. 19, T. 24 N., R. 12 E. At this point there appears to be 200 feet or more of rock similar to that sampled on Shoal Creek—soft, coarse grained, light gray, and in places faintly mottled with pink. The dip at this point is 30° SE. Exposures along this band occur on the Centerville Road in secs. 22 and 27, T. 24 N., R. 11 E., and probably under the bridge across Sixmile Creek at Sixmile.

The outcrops of this rock in the region described are on low, flat ground, as in Birmingham Valley, and the quarrying conditions are practically the same in the two regions.

The principal areas of this dolomite are crossed by the Southern Railway, so that transportation could be provided for at small expense. The Brierfield and Shoal Creek localities are both easily accessible to the railroad, and the haul from Shoal Creek to the furnaces at Bessemer would be scarcely greater than from Ketona.

GRAPHITE NEAR DILLON, MONTANA.

By Alexander N. Winchell.

INTRODUCTION.

Imports of graphite into the United States regularly and largely exceed the domestic production, even when the total production of both natural and artificial graphite is included. It is evident, therefore, that a careful study and a wider knowledge of all natural supplies of graphite in this country are desirable.

In the southern part of the Dillon quadrangle, Montana, about 60 miles nearly due south of Butte, occur deposits of high-grade flake or crystalline graphite. These deposits are chiefly on the ridge between Van Camp Creek and Timber Gulch, on the property of the Crystal Graphite Co. They are reached from Dillon, which is on the Oregon Short Line Railroad, by a drive of about 15 miles to the southeast over a good mountain road. They are near the southwest end of the Ruby Range.

The rocks exposed in the Ruby Range are chiefly the thick limestone series of the Paleozoic of Montana. In the southwest end of the range these limestones have been repeatedly faulted, perhaps at the time when they were arched and folded into mountains. At the mouth of Van Camp Canyon limestone, apparently of lower Paleozoic age, dips to the northwest. In going east up the canyon it appears that this limestone is underlain by quartzite (the Flathead quartzite?), which overlies quartz schists and slates, apparently pre-Cambrian in age. By faulting this series is repeated so as to outcrop at least at three places within about 2 miles. Igneous rocks are uncommon, but one dike of a basic type was observed.

At the graphite property, at an elevation of 7,500 to 8,000 feet above sea level, or about 2,500 feet above Dillon, the average strike is about N. 70° E. and the average dip is about 45° NNW.

THE DEPOSITS.

The graphite presents the remarkable condition of occurring in several different ways in this single locality. The first mode of occurrence observed is as seams in sedimentary rocks. The seams are mostly narrow and rather persistent, but ordinarily they are not more than an inch or two in thickness. They are strictly parallel with the bedding. On the Faithful claim they occur in marbleized limestone. On the Lucky Boy claim they are in the underlying quartz schists, mica schist, and garnet schist. At another outcrop on this claim the graphite occurs in somewhat irregular seams on both sides of a graphic granite intrusion lying apparently as a sill in rather massive garnetiferous quartz schist. A basic dike, 30 to 40 feet wide, cuts across the formations a short distance to the west and faults all of them.

West of this dike the graphite is chiefly in veins and faults not parallel with the bedding. The bedding here strikes about north and the dip is about 50° W., while the graphite occurs in a fault vein striking N. 70° E. and dipping about 60° NNE. Graphite occurs also in veins and faults in several other positions, and some of the veins containing graphite are cut by faults. An adit tunnel opening some of this ground discloses graphite in irregular bunches, pockets, stringers, and veins having no relation to bedding, the occurrence being similar to the mode of deposition of vein material in zones where rocks have yielded to stresses, not by clean fracturing but by irregular shearing. In such places irregularly lenticular masses may reach 6 to 8 inches in thickness and 2 to 4 feet in diameter. At the time the property was visited, in 1910, the sheared area had only recently been penetrated. It has a thickness, at least locally, of 4 to 5 feet. Its continuity as a well-defined zone is not yet established.

At another outcrop the graphite occurs in intimate association with garnet. Locally it completely surrounds large crystals of garnet; more commonly a crystal of garnet is surrounded by quartz, which in turn is largely surrounded by graphite. Again, graphite occurs in seams in garnet, or garnet, quartz, and graphite are intimately mixed. Schists form the country rock of these deposits.

At another outcrop graphite is intimately intergrown with quartz, feldspar, and mica, making a sort of graphite gneiss. In places the mica disappears and the graphite becomes more abundant. In such places the graphite may constitute one-third of the rock, and it serves as a matrix in which lie the feldspar anhedra, with more or less associated quartz. Such graphitic gneiss is not known to be abundant on this property.

Near the east end of the property graphite occurs above a fault containing pegmatite in a decayed quartz-feldspar rock resembling a pegmatite. This rock lies in layers more or less parallel with the pegmatite, which intrudes the limestone in sills. The graphite separates the layers and cuts across some of them. The graphitic material here is usually narrow; it rarely exceeds an inch or two in thickness.

ORIGIN OF GRAPHITE.

It is probable that in nature graphite has originated in several different ways. Thus it may well be that the seams of graphite parallel with the bedding in marbleized limestone and in quartz schist are the result of metamorphism of carbonaceous layers in those rocks. But something more than the metamorphism of carbonaceous matter in place is required to explain the origin of graphite in quartz surrounding garnet crystals, and it is still more difficult to assume that the graphite found as a constituent of veins and pegmatites is due to metamorphism.

It must be recognized that the graphite of pegmatites is just as truly a primary constituent of the rocks as quartz or mica or feldspar. It is well known that the constituents of igneous rocks have crystallized at high temperatures from silicate solutions. Therefore the carbon which formed the graphite must have existed in some form in these solutions. A satisfactory theory of the origin of graphite in igneous rocks must therefore explain how the carbon existed in these silicate solutions at high temperatures, and how it formed graphite during the cooling of the solutions. The writer has discussed this problem more fully elsewhere;[1] it is sufficient here to state that, except in solid undissolved form, which could not, during cooling, produce graphite inclosing other minerals, carbon as such apparently can not exist in magmatic solutions on account of its infusibility and insolubility. The conclusion is reached that the carbon must have existed in the solutions in the form of some compound.

It appears that hydrocarbons are improbable sources of graphite, for they are wholly transformed[2] into hydrogen and carbon monoxide at 700° or 800° C. in the presence of water, which is probably never absent during the formation of pegmatites and veins. Carbides of the metals seem to be equally improbable as sources of graphite, for all the metallic carbides,[3] except those of iron, chromium, molybdenum, and tungsten, are unstable at magmatic temperatures in the presence of water; and iron, chromium, molybdenum, and tungsten are almost wholly absent from the rocks containing graphite near Dillon.

It seems probable that the carbon which crystallizes to form graphite in pegmatites existed in the silicate solutions in the form of the oxides CO and CO_2. This conclusion is supported by the following facts: First, carbon in any form uncombined and in very many compounds (except when already combined with oxygen) will unite with oxygen very readily to form CO or CO_2, or both. Second,

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[1] Econ. Geology, vol. 6, 1911, pp. 218–230.

[2] Coquillon, J., Compt. Rend., vol. 86, 1878, p. 1197 (cited by Hempel, W., Gas analysis, 1906, p. 302).

[3] Moissan, H., Traité de chimie minérale, vol. 2, 1905, pp. 259, 260.

carbon combines with water at temperatures above 500° C. to form hydrogen and CO or CO_2, or both, according to the reactions $C+2H_2O=CO_2+2H_2$ and $C+H_2O=CO+H_2$. Third, oxides of carbon certainly exist in magmatic solutions, at least to some extent, for both CO and CO_2 are important constituents of volcanic emanations[1] and are also known to be both mechanically inclosed and " adsorbed " or dissolved in igneous rocks.[2]

Finally, evidence that the oxides of carbon may be deoxidized in whole or in part during the cooling of magmatic solutions, with the resultant formation of free carbon, probably graphite, is furnished by the experiments of Boudouard,[3] who proved that with decreasing temperatures $2CO=CO_2+C$. Weigert[4] has shown further that with falling temperatures $CO_2+2H_2=2H_2O+C$ and $CO+H_2=H_2O+C$. These reactions begin slowly at temperatures above 1,000° C., are most effective between about 750° and 600° C., and continue at a decreasing rate to temperatures somewhat below 500° C.

As hydrogen and the oxides of carbon are present in magmatic solutions,[5] all the conditions necessary for the formation of graphite are present in the cooling of an ordinary magma. The amount of these gases present in most magmas is too small to produce any appreciable quantities of graphite; and in so far as they escape into the atmosphere without mutual reaction no deposits of graphite can form. But if any magma should contain, or obtain through assimilation in any way, abnormally large quantities of these gases, and should solidify at such depth that the gases could not freely escape, graphite deposits would probably be formed.

Any magma which contains sufficient water, on coming into contact with bituminous or carbonaceous shales or slates, may be expected to convert all that portion of the carbon which is heated above about 600° C. to the oxide state through the agency of the water. The resulting gaseous hydrogen and oxides of carbon, being soluble in water and silicate solutions under pressure, may be expected to move about with, and as freely as, the magmatic solutions themselves. Finally, when these solutions cool below about 600° C., graphite may be expected to crystallize out in much the same way as other minerals crystallize from a cooling magma.

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[1] Lincoln, F. C., Econ. Geology, vol. 2, 1907, p. 258. Chamberlin, T. C., and Salisbury, R. D., Geology, vol. 1, 1905, pp. 618, 619.

[2] Chamberlin, R. T., Gases in rocks: Pub. Carnegie Inst. No. 106, 1908, pp. 14–27, 49–52, 57–61.

[3] Boudouard, O., Annales chim. phys., vol. 24, 1901, p. 5. In Bulletin 7 of the United States Bureau of Mines, just issued, Clement, Adams, and Haskins confirm Boudouard's results in a general way but declare that given equilibrium conditions are reached at temperatures about 100° C. higher than those reported by him.

[4] Abegg's Handb. anorg. Chemie, vol. 3, pt. 2, 1909, p. 196.

[5] Lincoln, F. C., Econ. Geology, vol. 2, 1907, p. 258.

ECONOMIC CONSIDERATIONS.

At the present time development has not proceeded far enough to prove the existence of large deposits of graphite on the property of the Crystal Graphite Co. near Dillon, Mont.. But the prospecting done proves the existence of considerable graphite occurring in several different ways and of very high grade. A better understanding of the probable mode of origin of the graphite should be of much value in guiding further exploration, both at this locality and elsewhere. It is particularly desirable to recognize the probable importance of water (aqueous gas) in carrying the heat which metamorphoses carbonaceous shales and also in oxidizing the carbon and thus rendering it soluble and mobile. At the deposits near Dillon the importance of pegmatite dikes, as the probable source of at least a part of the water concerned, should also be recognized. In some places these dikes may serve as guides in exploration work. In other places veins and shear zones must be followed to find the graphite. Where it occurs in seams in bedded deposits, there should be no difficulty in following it. But in such places it is important that prospecting be confined to the region in which the activity of the water was sufficient to produce the change without being sufficient to carry the graphite away.

FLUORSPAR NEAR DEMING, NEW MEXICO.

By N. H. Darton and E. F. Burchard.

INTRODUCTION.

The occurrence of fluorspar in southern New Mexico has been known for some time, several specimens of the mineral having been sent from Silver City to the mineralogical museum of the New Mexico School of Mines, at Socorro, within the last 10 years. Only recently, however, has fluorspar been found in sufficient quantities for exploitation. The American Fireman's Mining Co., of Kansas City, Mo., in prospecting for metallic ores on property situated 10 miles northeast of Deming, Luna County, N. Mex., has opened a number of veins of fluorspar which give promise of containing nearly if not quite enough spar to supply the western market for several years.

In the summer of 1910 the general geology of the region was mapped by N. H. Darton in connection with the preparation of the Deming geologic folio and of a water-supply paper on the Mimbres Valley, and the fluorspar deposits were examined by E. F. Burchard. The present paper is the result of the independent observations of the two authors.

GEOLOGY OF FLUORITE RIDGE.

By N. H. Darton.

LOCATION AND TOPOGRAPHY.

Fluorite Ridge is an outlying portion of Cooks Range, 10 miles north of Deming. (See fig. 61.) It trends northwest and southeast and has a length of about 4 miles and a maximum width of 1½ miles. It rises from 500 to 1,500 feet above the surrounding desert and its highest central summit attains an altitude of slightly more than 5,700 feet. The surface is rough, rocky, and of very irregular configuration, with many deep draws separated by high ridges and knobs. It has no surface water and supports only a scanty desert vegetation.

GENERAL STRUCTURE.

The salient geologic features of Fluorite Ridge are shown in figures 62, 63, and 64. There is a thick central mass of monzonite porphyry, the intrusion of which caused an irregular dome-shaped uplift of the strata. This dome is elongated to the northwest and southeast, and while the strata on the south and east sides stand nearly vertical, those on the north and west sides present moderately low dips. The plane of intrusion is low in the Paleozoic rocks at the southeast end of the ridge, but it rises rapidly to the north and west into formations of earlier Cretaceous age. Along part of the southwest side of the ridge the porphyry slopes extend down to the edge of the desert and the structural relations are not exposed.

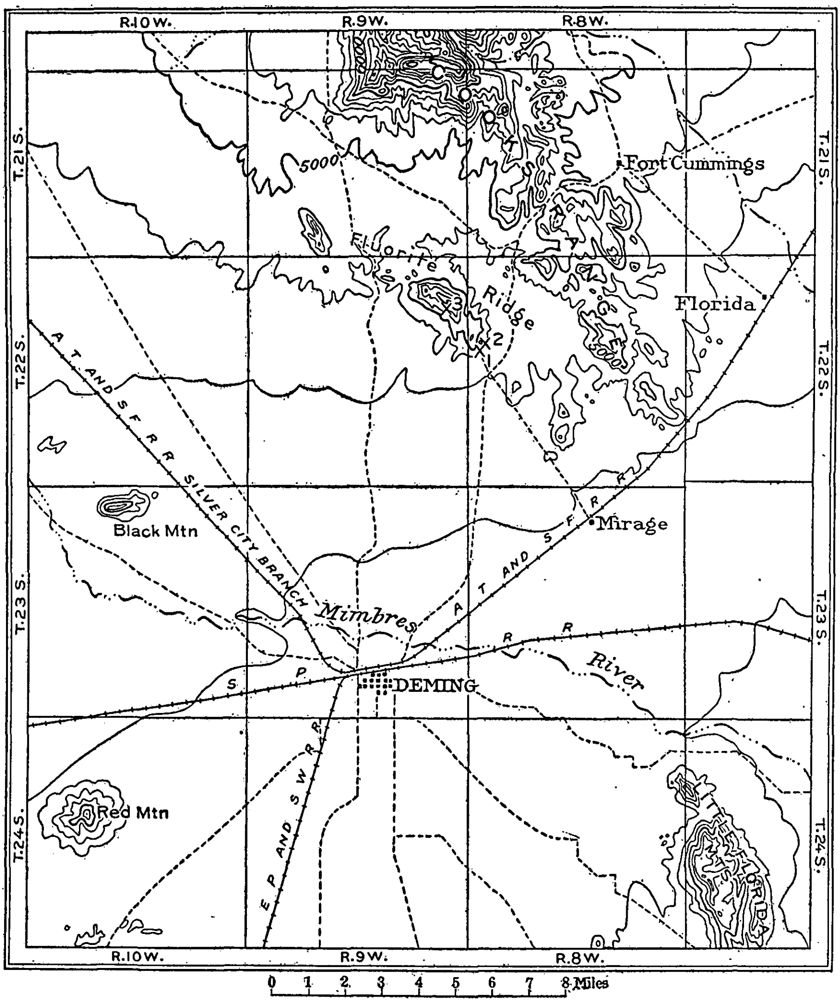

FIGURE 61.—Map of Fluorite Ridge and vicinity of Deming, N. Mex., showing location of fluorspar deposits. 1, 2, 3, Openings described in text.

ROCKS.

The sedimentary rocks appearing in Fluorite Ridge range from Cambrian to early Cretaceous in age and are intruded by granites, porphyry, and basalt.

Granite.—The lowest rocks exposed in the uplift are granites and diorites of various kinds, which outcrop for a short distance in the lower slopes southwest of the Fluorite camp. They underlie sandstones of supposed Cambrian age, but as a branching mass of the granite is intruded into the overlying strata the age of the crystalline rock is post-Cambrian. Probably pre-Cambrian crystalline rocks are present not far below the surface in this area, and they may outcrop southwest of the camp, but if so they appear to be indistinguishable from the intrusive rock.

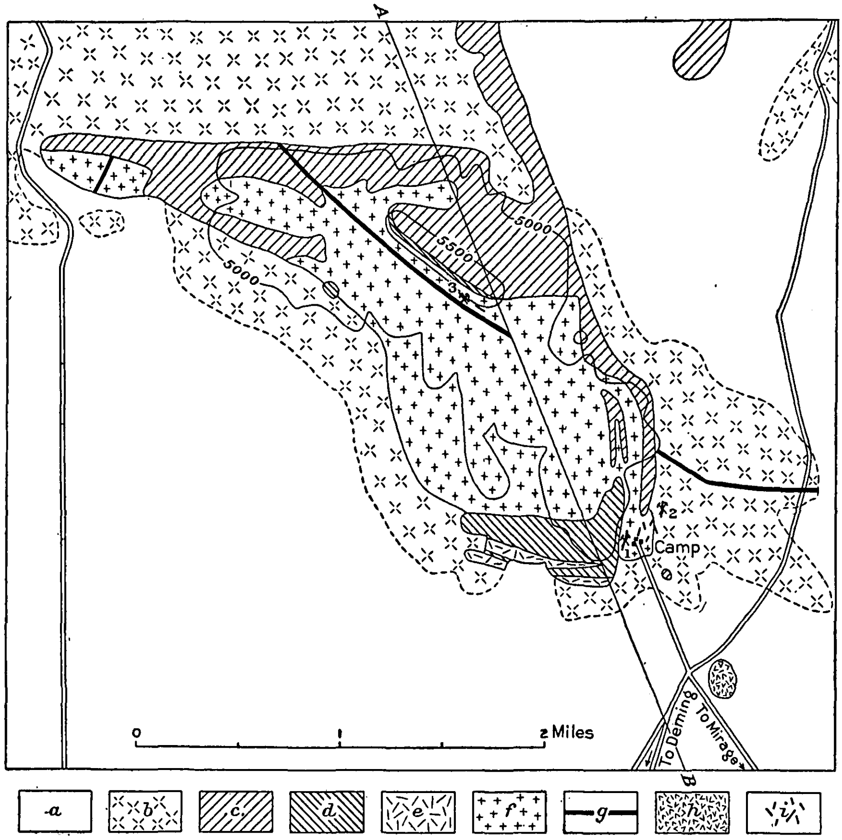

FIGURE 62.—Geologic map of Fluorite Ridge, 12 miles north of Deming, N. Mex. By N. H. Darton. *a*, Desert fill; *b*, andesitic agglomerate; *c*, sandstone (early Cretaceous); *d*, limestone, sandstone, and shale (Paleozoic); *e*, intrusive granite; *f*, monzonite porphyry; *g*, basalt dikes; *h*, rhyolite; *i*, fluorite veins; 1, 2, 3, openings described in text; *A–B*, line of section in figure 63.

Paleozoic sedimentary rocks.—The ridge rising west of the Fluorite camp consists largely of limestones and sandstones dipping steeply north and presenting a succession from probable Cambrian to Carboniferous, with a total thickness of nearly 2,400 feet. At the base are 150 feet of brown sandstones, massive and quartzitic at the bottom and top, and softer and thinner bedded in the middle. The lower medial beds contain much glauconite in bottle-green grains, a feature characteristic of sandstones of Cambrian age in many places. No fossils were found. The basal quartzite lies on granite, but apparently on a plane of intrusion. These sandstones are succeeded by gray limestones containing Ordovician fossils. About 150 feet above the base of the limestones is a thick member of quartzite, which gives rise to the prominent knob just west of the camp, and still farther north, or higher in the series, other quartzite and chert members are included in the limestone. This limestone is succeeded by black shale, believed to be the same as that known to be Devonian farther north in Cooks Range. The shale is about 100 feet thick, but its limits are not well exposed. Next above lies 250 feet of limestone containing fossils of the Mississippian series of the Carboniferous, comprising *Spirifer centronatus* and *Leptæna rhomboidalis*, identified by G. H. Girty.

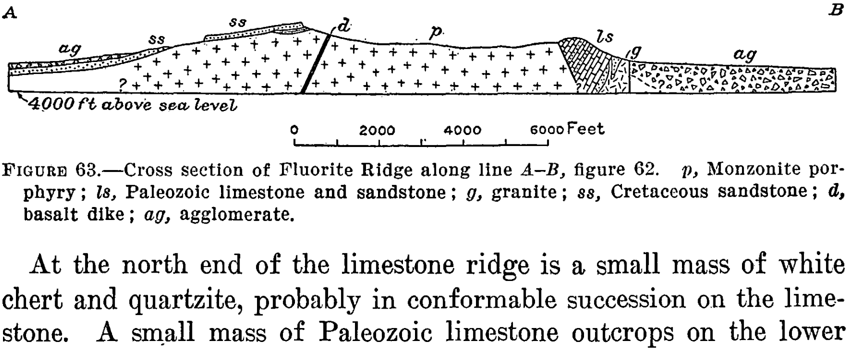

FIGURE 63.—Cross section of Fluorite Ridge along line *A–B*, figure 62. *p*, Monzonite porphyry; *ls*, Paleozoic limestone and sandstone; *g*, granite; *ss*, Cretaceous sandstone; *d*, basalt dike; *ag*, agglomerate.

At the north end of the limestone ridge is a small mass of white chert and quartzite, probably in conformable succession on the limestone. A small mass of Paleozoic limestone outcrops on the lower slope of the ridge 1,000 yards west of the Sadler mine (No. 3 on figs. 61 and 62), and there is another mass of limestone lying on the porphyry in the slope north of that mine.

Cretaceous sandstone.—The most extensive sedimentary formation in Fluorite Ridge is a massive gray to white sandstone, which is uplifted by the porphyry all along the northern and eastern sides of the ridge. It is about 200 feet thick. In places its base is a conglomeratic member containing fragments of chert and limestone, but this appears only in the central part of the uplift. Farther east and west the porphyry rises into higher beds. Fossils of the Washita group of the Comanche series were discovered in upper beds of the sandstones in the western part of the ridge.

Porphyry.—The main mass of Fluorite Ridge consists of monzonite porphyry, a gray massive rock with scattered crystals of light-colored feldspar. It cuts limestones and sandstones of Paleozoic and early

Mesozoic age and probably was intruded in Tertiary time. Doubtless it is considerably more than a thousand feet thick in the central part of the area.

Agglomerate.—The most extensive deposit in the area is the agglomerate which surrounds the base of the ridge. It rises gradually above the desert in low, irregular mounds and is exposed by erosion in many small draws. It consists of angular masses of andesite and other allied rocks embedded in a tuff of igneous material. Beds of volcanic ash and nearly pure tuff occur. All the deposit is sufficiently hard to be classed as a rock, but some of it is considerably rotted by weathering. A dull purple tint is most general, but some of the rock is gray and buff, and the finer-grained deposits are nearly white. It includes some irregular masses of rhyolite apparently in sheets and irregular stocks, one of which rises in a low mound half a mile southeast of the Fluorite camp. It is the youngest formation exposed except the desert fill and local wash and some narrow dikes of basalt which penetrate it.

LOCAL RELATIONS.

Opening No. 1.[1]—The principal fluorite mine, just west of the camp, is in an extension of the main monzonite porphyry mass through the east side of the ridge and along the eastern slope. Whether this porphyry extension cuts across the edges of the thick succession of nearly vertical Paleozoic limestones and quartzites or is separated from them by a fault is not clear. Separation by faulting, as shown in the cross-section figures, is suggested by the sharpness of the break and the presence of many polished surfaces along vertical joint planes. These are exhibited in the mine, which has been worked to a point within a few yards of the break. The sedimentary rocks rising in the high ridge just west of the mine are mainly limestones, with several interbedded members of quartzite and considerable chert. At the base are sandstones and quartzite lying on and penetrated by granite; at the top is a mass of quartzite sandstone cut off by the porphyry at the north end of the ridge.

The surface of the porphyry mass pitches down under the agglomerate to the south and east at the camp, and although no contact relations are visible there is apparently an unconformable overlap. A few hundred yards south of the camp a small mass of quartzite rises above the agglomerate, apparently being a summit on an underground extension of the Cretaceous quartzite in the knobs a short distance to the north.

Opening No. 2.—The second opening for fluorite, somewhat less than a quarter of a mile northwest of the camp, is in a low mound of agglomerate not far northwest of the porphyry margin and only a

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[1] Numbers correspond to those shown in figs. 61 and 62.

few rods east of a knob of Cretaceous quartzite. Some of the relations are shown in figure 64. The main vein here is along a fault trending N. 10° E., probably an extension of the great fault exhibited a few miles farther northeast. The rocks show many polished joint planes but no structural details. The nature of the rock on the west side of the fault is obscured by the covering of talus.

Opening No. 3.—At opening No. 3, or the Sadler prospect, the rock is monzonite porphyry similar to that at the camp and apparently a part of the same mass. The pit is on the south slope of the central summit ridge, about 150 feet below the top of the porphyry intrusion. The relations are shown in figure 63, a section just east of the mine. Just south of the openings there is a 2-foot dike of basalt which extends in a northwest-southeast course through the ridge, cutting porphyry, sandstone, and agglomerate. South of the Sadler mine the porphyry extends down to the desert, and on the north it extends up the slope to the sedimentary capping, which consists mainly of a thick sheet of sandstone dipping gently to the north and constituting the summit and north slope of the ridge. At its base in places are deposits of conglomerate and breccia containing a large amount of chert and numerous limestone pebbles, some of which carry carboniferous fossils. There is also an exposure of cherty limestone above the mine, lying between the sandstone and the porphyry. The igneous contact in this vicinity is largely covered by talus, but at a few points where it is exposed it is seen to be very irregular, the porphyry cutting across the sandstone, conglomerate, and limestone for several yards. Near the contact the limestone is altered to calcite and the porphyry becomes fine grained and shows close jointing.

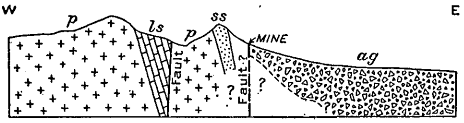

FIGURE 64.—Section through second opening at fluorite mines. *p*, Monzonite, porphyry; *ls*, limestone; *ss*, quartzite; *ag*, agglomerate.

THE FLUORSPAR DEPOSITS.

By ERNEST F. BURCHARD.

LOCATION.

The fluorspar occurs on the flanks of Fluorite Ridge, one of the foothills of Cooks Range that rises about 1,350 feet above the plain at Deming. The most promising prospects have been opened in two localities about 1¼ miles apart. One of the localities is at the extreme southwestern base of the mountain, on a gentle rise about 400 feet above the plain; the other well up the south slope of the mountain, about 900 feet above the plain. (See fig. 61.) Two railways pass through Deming, the Deming and Silver City branch of the Atchison, Topeka & Santa Fe Railway and the San Francisco and New Orleans line of the Southern Pacific Co. A third road, the El Paso & Southwestern, makes Deming a terminal point.

Wagon roads radiate in all directions from Deming, which has of late become an important business center, largely on account of the development of the underground waters of the Mimbres Valley and their utilization in agriculture. Deming lies in a nearly flat valley covered by desert deposits, with Cooks Range 10 to 15 miles northeast and the Florida Mountains 10 miles or more to the southeast. The fluorspar deposits are most easily reached by a 10-mile drive from Deming, but the product is shipped from Mirage, a siding on the Atchison, Topeka & Santa Fe Railway, 5½ miles southeast of the prospects.

OCCURRENCE AND CHARACTER OF THE FLUORSPAR.

The fluorspar occurs in veins cutting monzonite porphyry. Certain of the veins fill fracture planes in the rock along which there has been movement in both a vertical and a horizontal direction, but between the walls of other fissures there has not been noticeable displacement. The rock in localities Nos. 1 and 2, figures 61 and 62, is traversed by two or more sets of approximately parallel veins. As shown by the openings that have been made there appear to be at least five or six distinct veins in each set. One set of veins strikes N. 17° E. to N. 27° E., and the other set N. 6° E. to N. 18° W., while other veins were observed to strike at various angles between these limits. The veins are nearly vertical or dip steeply in a southeast or northeast direction. The vein material is mainly fluorite mixed with a little quartz. Where the veins are partly siliceous they resist weathering slightly better than the surrounding porphyry and therefore leave broken traces on the surface. At the surface the fluorspar is in places altered to calcium carbonate. The thickness of the veins, as shown by surface cuts and by prospect pits and shafts, ranges from a few inches up to 12 feet or more, but it is generally from 2 to 4 or 5 feet. The structure of the veins is in some places distinctly banded; in other places the vein may appear to consist merely of a mass of crystalline spar, showing no banding, but carrying pockets of quartz; and brecciation of the vein by which large fragments of the wall rock have been included is by no means uncommon. The walls of the veins where open to any considerable depth are found to be smooth in places, but are rarely smooth or regular for great distances, and the wall rock is generally much decomposed.

At locality No. 3, figures 61 and 62, only one set of veins, striking in a northwesterly direction, was observed. They stand nearly vertical or dip steeply toward the northeast. These veins had been opened in only two or three places at the time of visit, and the maximum width observed was only about 4 feet, not all of which was spar. The veins cut monzonite porphyry, as at locality No. 1, and were observed to occur in the direction of the strike at intervals for a distance of a quarter of a mile.

LOCAL DEVELOPMENTS.

At locality No. 1 the American Fireman's Mining Co. opened in 1909 a number of the veins by means of shallow cuts, and has sunk several test pits to depths of 6 to 12 feet, and two shafts to depths of about 80 feet. In all about 20 openings had been made up to August, 1910. A triangular area about a quarter of a mile wide at the base from northwest to southeast and about a third of a mile from northeast to southwest has been shown to carry productive veins of fluorspar. The surface of the area slopes gently to the southeast. At the main opening the vein strikes N. 17½° E. to N. 22½° E. and dips 65° to 70° SE. The vein had been opened to a depth of 75 or 80 feet in August, 1910, and had been worked underground for about 100 feet along the strike. The thickness between the walls of the vein measures 4 to 12½ feet, the irregularities being due to the pinching together of the walls in places. The strike of the vein is apparently slightly sinuous, according to the irregularities in the walls, but there are no evidences of movement between the walls. The rock inclosing the vein has acquired a reddish color by alteration, so far as observed, and although in some places the vein walls are smooth and clean, in others there is an interpenetration of the vein and wall material.

The fluorspar is principally of a light-green shade, but some purple spar is present, especially near the margins of the vein, and some quartz in pockets and thin stringers is scattered throughout the mass of spar. The spar was mined from several levels and milled down through chutes to the lowest level, from which it was hoisted in buckets up the shaft to the surface. A steam hoist was being installed at the time of visit. On the strike of the opening, less than 100 yards to the north of the shaft, an open cut and shallow burrow showed a promising vein of spar with a fork extending in a northwest direction. These veins and one other a few yards to the west are the nearest to the limestone mass, which lies 35 yards or more to the west. None of the veins were observed to extend into the limestone. The greater part of the spar that has been produced in this region has been taken from the shaft just mentioned.

All the other veins that have been opened lie 250 to 325 yards west of and at a lower level than the principal shaft. Eight or ten shallow trenches and one test pit about 30 feet deep have been dug here, exposing veins 6 inches to 4 feet thick, some containing good fluorspar and others running into barren or highly siliceous material.

Some of these veins strike a little west of north and others strike N. 30° W. to N. 42° W. Nothing sufficiently promising seems to have been found here except at a point about one-fourth mile north of the company's store. A considerable showing of spar has been developed by a series of trenches, pits, and a shaft. There appear to be two or three veins here nearly parallel and only a few yards apart. The main vein seems to follow a fault plane, as indicated by openings extending 100 yards or more. At the deepest place the workings are about 75 feet below the surface. The surface cuts are extensive and show the structure fairly well. The footwall of the vein is a cherty conglomerate, resembling the material capping the mountain three-fourths of a mile to the west. The hanging wall is so covered with spar that it is difficult to determine its nature. Where the spar has been removed the wall is shown to be surfaced by soft clay, so a thin layer of spar is generally left to prevent caving. The indications at the surface are, however, that the hanging wall is of agglomerate. In places west of the fault, or beyond the footwall, loose fragments of reddish granitic and porphyritic rock were noted on the surface. The fault hades toward the hanging wall, which is the upthrow side. Just to the north of the shaft the strike of the vein has been so bent that for 3 or 4 feet the fluorspar has been offset and cut out entirely. At this point the walls are much slickensided in a nearly horizontal direction. There is evidence of faulting here since the vein was deposited. The outcrop of the vein has been repeated, and a small section of it that had been shoved over to the west 10 feet or more was at first thought by the miners to be another vein, but it soon gave out at shallow depth. In the main vein here the opening showed from a foot to 7 or 8 feet of fluorspar of good quality. A considerable quantity has been mined and some shipments have been made.

At these prospects the fluorspar is not subjected to any mechanical concentration but is simply cobbed and stacked up in piles of lump and gravel spar from which shipments are made. It is hauled by wagons 5½ miles to Mirage, a station on the Atchison, Topeka & Santa Fe Railway, over a road that is generally down grade for a mile or more and then nearly flat. At the base of the grade is a platform scale on which all the shipments are weighed. For several miles the road is rather sandy, making the hauling of heavy loads rather difficult. In 1910 G. M. Sadler, of Deming, succeeded the American Fireman's Mining Co. in the operation of the prospects. The analyses on page 544 show the general excellence of the spar that has been mined from this district.

At locality No. 3, figures 61 and 62, about 1¼ miles northwest of locality No. 1, Mr. Sadler has opened by surface cuts a few veins of flourspar. The openings are within 200 to 250 feet of the summit of the mountain, and are on a rather steep southward-facing slope. The principal opening is on a nearly vertical vein that strikes north to northwest, bending toward the west as it is followed farther. In August, 1910, this opening extended about 100 feet and reached a depth of about 15 feet at the extreme end, where it was driven into the hillside. As opened the vein ranges in thickness from less than a foot to more than 4 feet, but the maximum thickness is not all fluorspar. The spar is streaked with silica and iron oxide and shows quartz druses and geodes and some reddish-brown quartzitic seams and pockets, but in places there are fairly pure masses of apple-green spar. The spar on the dump was a mixture of green and reddish-brown material, with a considerable scale of clay and ferruginous material. Another trench several hundred yards to the east at a slightly lower level has exposed for 200 feet or more a vein showing discontinuous fluorspar 12 to 18 inches thick, which is largely altered to calcium carbonate at the surface. The spar below the surface is rather clean looking, but this thickness is hardly sufficient for exploitation, except at very shallow depths.

No spar had been shipped from this locality at the time of visit, although preparations were being made to ship some material from the largest cut. A platform upon which spar is wheeled in barrows has been built above the wagon road to facilitate the loading of wagons.

ECONOMIC CONSIDERATIONS.

Composition, character, and distribution of fluorspar.—Fluorspar or fluorite, chemically calcium fluoride (CaF_2), consists of calcium and fluorine in the proportions of 51.1 to 48.9. The mineral is crystalline and is only slightly harder than calcite. It crystallizes in the isometric system and is found commonly in cubical crystals. In color the spar ranges, according to purity, from a clear, slightly bluish glasslike substance through various other brilliant colors to dark purple, although much of it is white and opaque. Fluorspar, associated with other minerals, has a broad distribution geographically and a wide range geologically. The deposits thus far exploited in the United States are, however, confined to Arizona, New Mexico, Colorado, Illinois, Kentucky, and Tennessee.

Value of fluorspar.—Fluorspar is a mineral of relatively low value as compared with the metallic ores mined under similar conditions in the West. Under the most favorable conditions, therefore, the margin of profit can never be expected to be large, and it requires exceptionally good management to conduct any spar-mining operations profitably in the Western States. In 1909 there were 50,742 short tons of domestic fluorspar, including gravel, lump, and ground varieties, marketed in the United States at an average value of $5.75 a short ton. Of this total 40,808 short tons were sold as gravel and lump spar, at an average value of $4.72 a ton at the mines. Spar produced in Colorado and New Mexico sold unground at about the average price for the whole production of spar in the United States, including the ground variety.

Uses and requirements of fluorspar.—Fluorspar is used in the manufacture of glass, enameled, and sanitary ware, in the electrolytic refining of antimony and lead, in the production of aluminum, in the manufacture of hydrofluoric acid, and in the iron and steel industries as a flux in blast furnaces and in basic open-hearth steel furnaces. It is estimated that about 80 per cent of the American fluorspar output, mainly in the form of gravel spar, is consumed in the manufacture of basic open-hearth steel. The use of fluorspar is increasing in practically all these industries. The western market for fluorspar is more limited than that of the Central and Eastern States, but it is nevertheless increasing. During 1910 new iron and steel works have been opened at Irondale, Wash.

Supplies of spar mined in the West have heretofore not been sufficient to supply the western market for more than a few months at a time. This has been due to several conditions, the most important of which is the fact that the western spar thus far produced has not been of so high a grade as that produced in the Illinois-Kentucky district. Fluorspar for iron and steel making should carry at least 85 per cent of calcium fluoride, and preferably it should be purer. For most other chemical uses it should contain from 95 to 98 per cent of calcium fluoride.

Grades of western fluorspar.—None of the spar that has been mined in Colorado and New Mexico has been cleaned in any way except by hand. Mechanical concentration would improve the grade of the Colorado spar greatly, but none of the fluorspar prospects in Colorado have proved of sufficient richness to warrant the installation of washing plants. In certain places water is available, but in others the problem of finding water would be difficult. The Colorado product as mined has therefore never averaged quite high enough in grade to fully satisfy purchasers or to command a price satisfactory to producers, and the production has consequently lagged behind the possibilities.[1] There is little necessity for washing the spar of the deposits near Deming, N. Mex., on account of the unusual purity of the vein material. Doubtless a considerable saving of spar might be accomplished by washing, but such a process would not be at all feasible on account of the scarcity of water. Supplies of water for men, teams, and hoisting engine have to be hauled from a well more than 4 miles distant on the road to Deming. There is little probability

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[1] Burchard, E. F., Fluorspar in Colorado: Mineral Resources U. S. for 1908, U. S. Geol. Survey, 1909, pp. 607–617.

that a well could be obtained by drilling anywhere near the fluorspar deposits, on account of the nature and structure of the underlying rocks.

ANALYSES.

The following table gives analyses of gravel fluorspar from Mirage, N. Mex., in carload lots, used in basic open-hearth steel furnaces, and, for comparison, analyses of spar from Colorado, Illinois, and Kentucky made on a similar basis:

Analyses of fluorspar.

From Mirage, N. Mex. (carload lots).

Locality.	CaF_2.	SiO_2.	Al_2O_3+ Fe_2O_3.	$CaCO_3$.	$MgCO_3$.	Authority.
Mirage, N. Mex	93.68	4.68	0.74	0.76	Trace.	Colorado Fuel & Iron Co.
Do	93.55	4.97	.80	.62	Trace.	Do.
Do	91.98	6.60	1.00	.67	Trace.	Do.
Do	88.80	9.83	1.10	.48	Trace.	Do.
Do	88.30	9.85	1.06	.98	Trace.	Do.
Do	89.52	8.62	.92	.79	Trace.	Do.
Do	91.32	6.60	.74	.74	Trace.	Do.
Do	90.13	7.86	.70	.74	Trace.	Do.
Do	92.19	6.05	.68	.83	Trace.	Do.
Do	90.90	6.96	.86	.88	Trace.	Do.
Do	90.22	7.60	1.04	.68	Trace.	Do.
Do	88.59	9.66	.96	.83	Trace.	Do.
Do	93.99	3.84	1.12	1.12	Trace.	Do.
Do	89.70	8.60	.92	.80	Trace.	Do.
From Colorado, Kentucky, and Illinois (generally carload lots).						
Rosita, Colo	86.75	9.3	4.2			Colorado Fuel & Iron Co.
Do	81.55	13.3	5.1			Do.
Do	82.25	12.6	5			Do.
Do	84.3	11.6	n. d.			Do.
Do	60.9	27	n. d.			Do.
Jamestown, Colo	76.05	19.8	4.2			Do.
Do	83.76	12.2	4			Do.
Do	85.9	10.5	3.75			Do.
Do	79.06	15.24	5.26			Do.
Do	86.75	8.60	4.46			Do.
Marion, Ky	84.25	2.98	1.28	10.28		Do.
Do	87.8	3.10	2.06			Do.
Do	90.02	4.72	1.5			Do.
Do	92.7	2.5	.64			Do.
Do	96.01	1.9	1.88			Do.
Do	94.72	1.22	.98	1.82	0.68	Lackawanna Steel Co.
Do	95.63	1.32	.93	.38	1.22	Do.
Fairview, Ill	88.85	3.4	1.45			Carnegie Steel Co.

From these analyses it will be seen that the spar shipped from Mirage is of exceptionally high grade, considering the fact that it has not been washed and cleaned as has the Illinois-Kentucky product.

COSTS OF PRODUCTION.

The fluorspar near Deming is mined almost wholly by contract. Mexican labor is employed and the miners earn about $1.50 a day. Mining the spar costs $1.75 a ton, plus 25 cents for incidental expenses, and haulage to the railroad costs $1.50, making a total cost of $3.50 a ton dumped into cars. In 1910 the spar was selling at $5.25 a ton on the cars, based on at least 90 per cent of calcium fluoride, and the freight from Mirage to Pueblo, paid by the purchasers, was $2 a ton. According to the contract a penalty of 20 cents a ton was deducted for each 1 per cent that the spar falls below 90 per cent of calcium fluoride, but no premium was paid except on spar that carries more than 95 per cent of calcium fluoride, for which each extra unit brought 20 cents more a ton. The equipment for mining the spar is simple, the largest single item of expense being a small steam hoist stationed at the deepest working. Several teams are necessary to haul the output. Small store buildings and machine shops have been located at both places where the spar was being developed. The laborers live in tents, and work can be carried on the year round. From the opening of these deposits in the summer of 1909 to the close of 1910 nearly 5,000 tons of fluorspar had been shipped, averaging 92 per cent of calcium fluoride.

CONCLUSIONS.

The exploration for and development of fluorspar deposits under present conditions in the Western States can not be said to offer attractive profits; nevertheless the western market for fluorspar is growing and the cost of transportation precludes the importation of foreign spar, so that where deposits are so situated that the freight rates do not hold down the price to a profitless level, and where the cost of haulage does not further wipe out all chances of gain, development should be encouraged.

SURVEY PUBLICATIONS ON MISCELLANEOUS NONMETALLIC PRODUCTS—ASBESTOS, BARITE, FELDSPAR, FLUORSPAR, GRAPHITE, MICA, QUARTZ, ETC.

The following list includes a number of papers, published by the United States Geological Survey or by members of its staff, dealing with various nonmetallic mineral products. The Government publications, except those to which a price is affixed, may be obtained free by applying to the Director, United States Geological Survey, Washington, D. C. The priced publications may be purchased from the Superintendent of Documents, Government Printing Office, Washington, D. C.

BAIN, H. F. Fluorspar deposits of southern Illinois. In Bulletin 225, pp. 505–511. 1904. 35c.

BALL, S. H. Mica in the Hartville uplift, Wyoming. In Bulletin 315, pp. 423–425. 1907.

——— Graphite in the Haystack Hills, Laramie County, Wyo. In Bulletin 315, pp. 426–428. 1907.

BASTIN, E. S. Feldspar and quartz deposits of southeastern New York. In Bulletin 315, pp. 394–399. 1907.

——— Economic geology of the feldspar deposits of the U. S. Bulletin 420, 85 pp. 1910.

——— Quartz and feldspar. In Mineral Resources U. S. for 1909, pt. 2, pp. 907–913. 1911.

——— Geology of the pegmatites and associated rocks of Maine, including feldspar, quartz, mica, and gem deposits. Bulletin 445. 152 pp. 1911.

——— Graphite. In Mineral Resources U. S. for 1909, pt. 2, pp. 809–840. 1911.

BREWER, W. M. Occurrences of graphite in the South. In Seventeenth Ann. Rept., pt. 3, pp. 1008–1010. 1896.

BURCHARD, E. F. Barytes and strontium. In Mineral Resources U. S. for 1909, pt. 2, pp. 697–700. 1911.

——— Fluorspar and cryolite. In Mineral Resources U. S. for 1909, pt. 2, pp. 633–638. 1911.

DILLER, J. S. Asbestos. In Mineral Resources U. S. for 1909, pt. 2, pp. 721–729. 1911.

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