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ASBESTOS AND CHROMITE DEPOSITS OF WYOMING

BY

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ABSTRACT.

Serpentine occurs as lenses from 50 feet to several miles across in the pre-Cambrian rocks forming the cores of the anticlinal mountain ranges of central and northwestern Wyoming. The serpentine is younger than metamorphosed sediments, is cut by metadiabase dikes, and both are cut by granite and pegmatites.

Chrysotile occurs in the serpentine both as cross fiber and slip fiber in veins elongated with the lens. Cross fiber up to 1½ inches long was found; most of it is short. A small tonnage has been produced from three deposits.

Microscopic examination of brittle chrysotile shows extensive replacement by quartz. Harsh chrysotile shows fine-grained quartz in rods or veinlets parallel to fiber length and in cross veinlets. Nearby pegmatites could have furnished the silica. The opinion is expressed that brittleness and harshness in chrysotile from the serpentine type of deposit is the result of introduction of silica with or without chemical reaction to form talc.

The chromite of Casper Mountain occurs disseminated, and in bands or lenses in tremolite-chlorite-talc schist, originally an ultrabasic rock. The best ore would require concentration to meet market requirements. Some laboratory concentrates contain sufficient Cr_2O_3 for the manufacture of ferrochrome; others contain an excessive amount of iron.

CONTENTS.

INTRODUCTION.

CHRYSOTILE asbestos and chromite have been reported from various localities in Wyoming and attempts at commercial production have been made, particularly between 1905 and 1921. Detailed geologic information on the deposits has not been available. Field examination of the reported occurrences was undertaken by the Geological Survey of Wyoming, and the writer spent two months in the field during the summers of 1934 and 1935. Plane table maps of five deposits and the surrounding territory were made and four other deposits were examined. The mapping of the largest area, Casper Mountain, was carried out on a scale of 1 inch = 1,000 feet; for smaller areas scales of 500 and 300 feet to the inch were used.

All of the deposits have certain features in common. The host rock is serpentine, or a derivative of serpentine. There are younger granites in the immediate vicinity. The deposits are of pre-Cambrian age. They occur only a few hundred feet or less stratigraphically below the base of the Cambrian sediments. The probable reason for this is that pre-Cambrian rocks now close to the Cambrian beds have been protected from erosion until comparatively recent time but, in places where the pre-Cambrian rocks were exposed early in the Laramide folding, the metamorphic rocks of the roof have been extensively removed, exposing large areas of the subjacent granites. All of the deposits except those on Casper Mountain are many miles from a railroad and are not easily accessible.

The writer wishes to thank Dr. W. D. Johnston, Jr., of the United States Geological Survey for reading and criticism of the manuscript, Mr. H. F. Eppson of the staff of the Agricultural Experiment Station of the University of Wyoming for analyses of samples of chromite ore, and R. C. Shoemaker and H. H. Olinger for their able assistance in the field.

BROWN BEAR ASBESTOS DEPOSIT.

The deposit (Fig. 1) is near the head of Berry Creek approximately a mile east of the watershed of the Teton Range and 7 miles south of Yellowstone Park. The area has not been surveyed but, according to the U. S. Forest Service map of the Teton National Forest, the claims would fall in sec. 19 or 20, T. 47 N., R. 116 W. The nearest rail point is Lamont Siding, Idaho, 25 miles to the west.

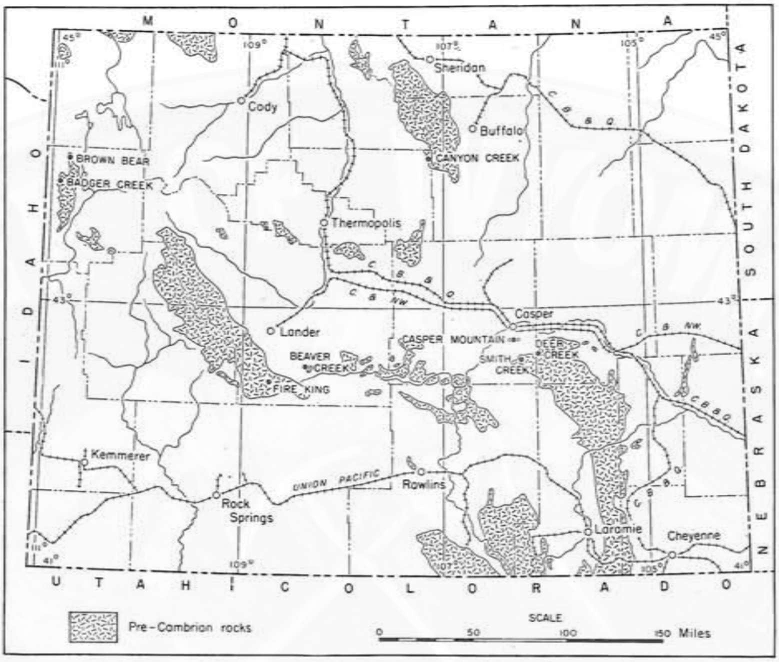

FIG. 1. Index map of Wyoming.

The west flank of the range consists of Paleozoic limestones and shales, and Tertiary eruptives. A few thousand feet east of the crest of the range, Berry Creek has cut through the basal Cambrian quartzite into granite, granite-gneiss, and pegmatites. A mile east of the watershed and a few hundred feet south of the creek a lens-shaped body of massive greenish-black rock is exposed in the wall of the valley. Under the microscope it consists almost entirely of chlorite, but the disposition of areas of finely divided magnetite suggests that seen in massive serpentine. The rock was probably originally an olivine-bearing ultrabasic rock and the body a dike, or a sill, which was folded during the time of granite intrusion. The mass strikes north and stands vertically, and reaches a maximum width of 50 feet. Near the middle, the east contact parallels the banding of granite gneiss, and the west contact is bounded by a zone of talc schist 20 feet wide, which grades westward into an injection gneiss. Southward the outcrop narrows, the number of granite dikelets penetrating the ultrabasic rock increases, and the body grades into an injection gneiss. The exposed length is approximately 400 feet.

A trench near the middle of the mass exposes vertical faces of the ultrabasic rock 20 feet high, and displays numerous fractures with slickensided walls. Greenish-yellow slip-fiber chrysotile and gray coarse slip-fiber amphibole occur along some of the fractures, predominantly those parallel to the lateral contacts. Most of the veinlets are less than ¼ inch wide. In the 50 feet of trench there are two veins varying from 6 inches to a foot in width containing both varieties in different places. Both of the larger veins have been invaded by granite-pegmatite, and much of the chrysotile has been partially or completely replaced by coarse-grained quartz. The unaltered chrysotile fiber is fine and pliable. Its length varies up to two inches, but most of it is less than one inch long. Much of the fiber is broken by cross fractures. The best exposures, those along the trench, indicate that the rock as a whole contains less than 5 per cent of chrysotile. The dumps of several short caved tunnels give no indication of a higher percentage.

It is reported[1] that the property was acquired in 1917 by the American Asbestos Milling & Mining Co., of Idaho Falls, Idaho. In 1920 thirteen miles of road had been built and the property was being developed. In 1921 it was said that the property required a mill for successful exploitation and the company had not yet reached this stage of development. At the time of the writer's visit in 1934 the property had been abandoned for some years.

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[1] Sampson, Edward: U. S. Geol. Surv., Mineral Resources U. S., 1920, Part II—Nonmetals, p. 317. Sampson, Edward: U. S. Geol. Surv., Mineral Resources U. S., 1921, Part II—Nonmetals, pp. 139–140.

BADGER CREEK DEPOSIT.

A reported occurrence of asbestos in sec. 5, T. 6 N., R. 117 W., on the west side of the Teton Range proved to be a small deposit of massive soapstone and fibrous talc in olivine diabase, which is cut by granites and quartz stringers.

FIRE KING ASBESTOS DEPOSIT.

The deposit is situated in sec. 26, T. 30 N., R. 100 W., in the northern part of the Atlantic gold district near the crest of the southeast part of the Wind River Range at an elevation of about 8,000 feet. It is 29 miles from Lander (Fig. 1).

The geology of the Atlantic gold district is well known from the work of Spencer,[2] who visited the Fire King group of claims in 1914 and describes other serpentine masses in the region. A brief description of the deposit is given by Diller.[3]

Along the southeast side of the serpentine bodies (Fig. 2) is a bed of pink quartzite, up to 50 feet thick, that stands vertically and strikes parallel to the serpentine contact. To the southwest the quartzite thins and grades into sericite schist. Southeast of the quartzite are alternating sericite and magnetite schists that strike generally parallel to the serpentine contact and dip steeply southeast. In the area of outcrop of the schists there are black bands many feet across. These grade across the strike into schists showing alternating bands of black and light gray material from 1/16 inch to several inches thick. The intimately banded schist grades into light gray sericite schist of uniform color. Thin sections of the black schist (Fig. 5) show that the dark bands consist principally of magnetite, but contain small amounts of quartz and green hornblende, alternating with lighter bands consisting predominantly of quartz and hornblende with a few grains of magnetite. A thin section of sericite schist shows abundant quartz, sericite, and a few grains of magnetite. The banded character of the rocks, the gradations of magnetite schist

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[2] Spencer, A. C.: Atlantic gold district and the North Laramie Mountains. U. S. Geol. Surv., Bull. 626, 1916.

[3] Diller, J. S.: U. S. Geol. Surv., Mineral Resources U. S., 1917, Part II—Non-metals, p. 201.

into sericite schist and sericite schist into quartzite, and the mineralogical composition indicate that the schists and quartzites were originally argillaceous sandstones, sandstones, and ferruginous siliceous sediments. Within the succession of sericite and magnetite schists there are accordant tabular bodies of metadiabase up to 100 feet thick.

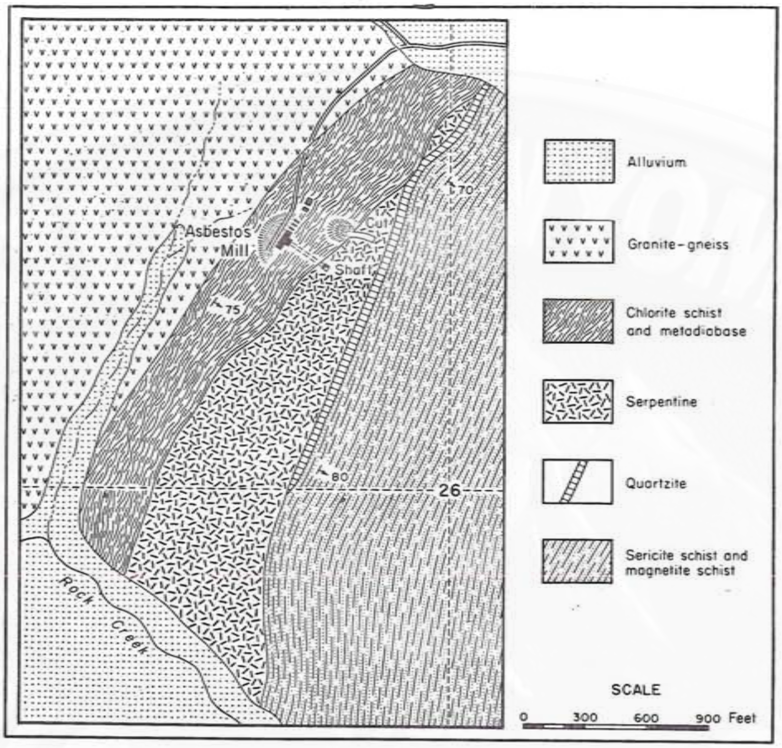

FIG. 2. Geologic map of the vicinity of the Fire King asbestos deposit.

Spencer[4] discusses the possibility of use of the magnetite schists for iron ore and shows that chip samples of 5 to 7 pounds across the ledges at intervals of about 2 feet for distances from 150 to 250 feet contain from 37 to 42 per cent of iron. His samples were unselected and he states there may be bodies of schist con-

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[4] *Op. cit.*, pp. 17–18.

taining more than 50 per cent of iron, which are large enough to be separately mined.

The two masses of serpentine form a ridge standing several hundred feet above the floor of Rock Creek. The smaller is 350 feet long and 80 feet wide. The larger has a maximum width of 700 feet, and is exposed for a length of 2,500 feet. It apparently wedges out to the south, as it is not seen beyond Rock Creek. The serpentine is generally dark green to black in color and massive, except where it has been converted to a talcose schist. A thin section of the black massive material shows that it consists almost entirely of serpentine. Magnetite occurs as a fine powder dispersed through the rock, in irregular rounded masses, and in elongated streaks. There are a few irregular patches of carbonate material replacing the serpentine. Although there are no remnants of primary minerals or replacement structures that would serve to identify them, it is probable that the present serpentine bodies were originally intrusives of an ultrabasic rock such as peridotite or dunite.

Northwest of the serpentine is a belt of lenticular chlorite schists and metadiabases up to 400 feet wide. The schistosity generally parallels the northwest contact of the serpentine. The chlorite schist contains, in addition to chlorite, remnants of brown basaltic hornblende, and a fine aggregate of chlorite intergrown with what is probably quartz. A thin section of a metadiabase shows green hornblende derived from a pyroxene, labradorite, and chlorite occurring along fractures in the hornblende. The evidence indicates that the chlorite schists and metadiabases were originally basalt flows and diabase sills.

All of the rocks described are cut by granites. Dikes and dikelets of granite are particularly abundant in the belt of the chlorite schist and metadiabase. To the northwest, dikelets penetrating between the leaves of the schist increase in number, and there is a transition from rocks consisting predominantly of basic schistose material to granite-gneisses containing uninjected remnants of metadiabase.

Certain conclusions as to the pre-Cambrian history can be drawn. The granites cut all other rocks and are the youngest. The ultrabasic rock now represented by the serpentine is probably the next older, as no diabase dikes were observed cutting it. The lenticular shape of the serpentine bodies and their accordant relation to the quartzite and to the chlorite schists and metadiabases suggest that the serpentine was originally an ultrabasic sill. It is possible, however, that the basic and ultrabasic rocks were both formed during the same period of igneous activity and that the sill was intruded in the later part of the period. Assuming that the area was affected by only one period of basic igneous activity, an assumption contrary to which Spencer gives no evidence after study of a much larger area, the sericite schists, magnetite schists, and quartzites are the oldest rocks, as they act as host for accordant sill-like bodies of metadiabase.

Chrysotile occurs in the small serpentine lens, and in the northern part of the large one in a zone some 150 feet wide and 900 feet long lying along the northwest contact. The serpentine is here cut by roughly parallel veinlets of cross fiber lying generally parallel to the serpentine contact. The serpentine bordering each veinlet is altered to a light-green, massive variety, whose width is generally proportional to the width of the chrysotile veinlet. Where veinlets are closely spaced all of the intervening serpentine is altered.

In the smaller serpentine lens, shallow pits and trenches show fiber less than ¼ inch in length. The veinlets are mostly spaced some inches apart. Judging from the trench and surface exposures, it is doubtful that any considerable tonnage of rock containing 5 per cent of this short fiber could be obtained. In the large serpentine body the best surface showing is in the cut indicated on Fig. 2. This cut is 125 feet long, 25 feet wide, and 20 feet deep at the east end. In the north wall, 20 feet from the east end, is a vein 6 inches to one foot wide, which branches upward into two narrower veins. There is little massive serpentine in the vein, but the cross fiber is cut by fractures parallel to the walls, so that the length of a large part of the fiber is less than ½ inch. On the south side of the cut the vein shows approximately the same width and character of fiber, but does not branch. It is exposed in a tunnel extending south from the bottom of the cut and in a trench parallel to the strike for a distance of 30 feet. A trench 75 feet southwest along the strike encountered no fiber. The proved length of the vein is 50 feet. In the walls of the remainder of the cut there are a few veinlets of cross fiber less than ¼ inch long and spaced some inches or feet apart. It is unlikely that this material could be profitably mined.

In the walls of the shaft (Fig. 2) is a vein 6 inches to a foot wide dipping steeply southeast. The lower part of the shaft and the mouth of the tunnel leading to the mill were caved in at the time of examination. James Carpenter of Atlantic City provided the following information: The shaft is 72 feet deep. From the bottom of the shaft a drift extends 400 feet northeast. For 300 feet the asbestos has been stoped out nearly to the surface and has been worked out for 12 feet below the level of the tunnel to the mill. From the bottom of the shaft a drift extends 50 feet southwest along the strike and another extends 150 feet southeast to the southeast contact of the serpentine.

Southwest of the shaft for a distance of 300 feet there are shallow pits and trenches, some of which show a few widely spaced veinlets of short fiber. Several trenches near the south end of the body disclosed barren rock. Since most of the exposure of the serpentine is bare rock, it is improbable that prospecting has missed any considerable amounts of chrysotile at or near the surface.

The chrysotile is light greenish-yellow in color. Fiber up to 1½ inches long was collected by the writer. The material in place in the large cut is mostly less than ½ inch long and crude material left in the mill is of this length or shorter. The fiber is fine and flexible and has been spun into yarn of good quality.

The property was prospected in 1914 by William Brice of Lander.[5] In 1917 it had passed into the hands of the American Fireproofing & Mining Co. of Denver.[6] In 1918 or 1919 several

[5] Spencer, A. C.: *Op. cit.*, p. 19.

[6] Diller, J. S.: U. S. Geol. Surv. Mineral Resources U. S., 1917, Part II—Nonmetals, p. 201.

cars of No. 1 and No. 2 crude fiber were shipped from Lander. The mill was built in 1919[7] and was operated for a short time. No production has been reported since 1920.

BEAVER CREEK ASBESTOS DEPOSIT.

The deposit (Fig. 3) is located in the southern border of the Wind River Basin in sec. 19, T. 30 N., R. 96 W., some 38 miles from Lander, and 5 miles south of Beaver Hill on the highway to Rawlins.

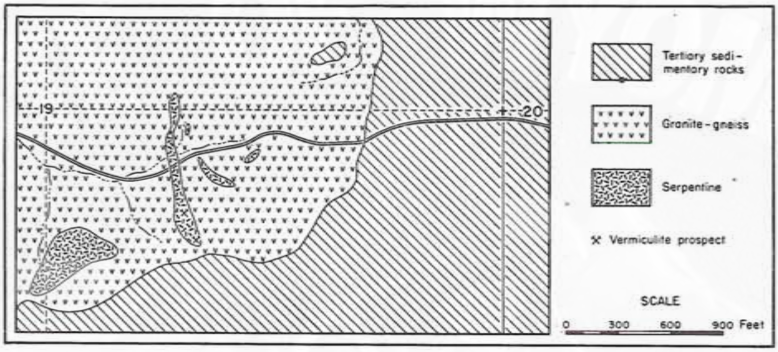

FIG. 3. Geologic map of the vicinity of the Beaver Creek asbestos deposit.

To the south and east of the claims is a gently rolling upland underlain by buff and white stratified volcanic ashes, which are probably the southern continuation of the beds of the White River group in the upper part of Beaver Hill. The Tertiary sediments in the mapped area are only a few feet thick, and in places contain boulders of pre-Cambrian granites and metamorphics up to a foot in diameter. The pre-Cambrian rocks are predominantly granite-gneisses and pegmatites. Within the granites are five lenticular bodies of massive serpentine, which are apparently roof-pendants or uninjected remnants left after stoping and injection by granitic magma of a variety of schists including some of ultrabasic composition. A few blocks and tabular remnants of metadiabase are also enclosed in the granites.

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[7] Diller, J. S.: U. S. Geol. Surv., Mineral Resources U. S., 1919, Part II—Nonmetals, p. 304.

The serpentine masses are well exposed, and are readily detected by the age. The western lens, which is 600 feet long and 250 feet wide, has been irregularly fractured in places, but the fractures are filled with massive serpentine. The central lens, which is 900 feet long and has a maximum width of 130 feet, is generally similar. In the gulch 50 feet north of the road, however, a zone of steeply dipping cross-fiber chrysotile veinlets striking generally parallel to the lateral contacts of the serpentine mass has been exposed by shallow trenching. The longest fiber seen by the writer was ¼ inch in length. Fred Abernathy, the claim owner, reports finding fiber up to 1¼ inches long. Although the fiber is fine and flexible, the shortness of most of it and the small amount shown in the trenches indicate that successful commercial production is unlikely. No asbestos was seen in the three smallest lenses.

In two places in the southern part of the central lens the serpentine is cut by pegmatite dikes along the borders of which vermiculite has developed. Prospect pits twelve feet deep show that the vermiculite extends several feet from the dikes and may extend farther. Surface cover prevented observations on the lateral extent of the vermiculite zones parallel to strike of the dikes.

CASPER MOUNTAIN.

Casper Mountain is the westernmost part of the Laramie Range (Fig. 1) in which pre-Cambrian rocks are exposed. The top of the mountain in T. 32 N., R. 79 W., (Fig. 4) is a rolling upland at elevations of 7,500 to 8,000 feet dissected by a few shallow valleys. The area can be easily reached by a good road, 8 miles out from Casper.

Casper Mountain was visited by Diller, who gives a brief description of the general geology, asbestos, and chromite deposits of the region including Smith Creek and Deer Creek.[8]

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[8] Diller, J. S.: Types, modes of occurrence, and important deposits of asbestos in the United States. U. S. Geol. Surv. Bull. 470: 512–516, 1911, and Occurrence of asbestos in Wyoming. Min. Sci., 63: 447–448, 1911.

General Geology.

Casper Mountain is a strongly unsymmetric westward-trending anticline, of Paleozoic beds, with a gently dipping south flank,

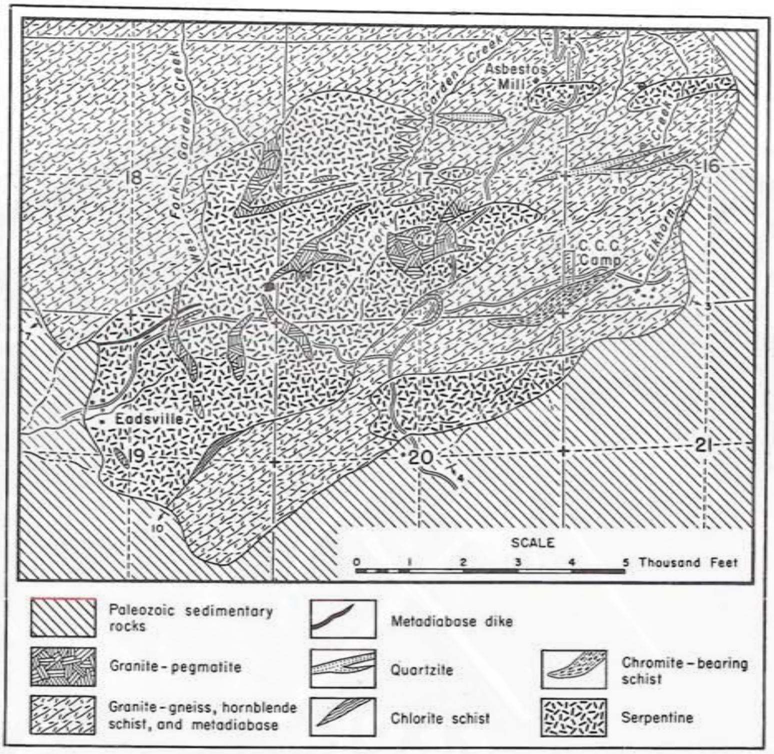

FIG. 4. Geologic map of part of Casper Mountain.

and a steeply dipping north flank. At the north base of the mountain pre-Cambrian and Paleozoic rocks lie on Upper Cretaceous beds along a southward-dipping thrust fault. In mapping the area no attempt was made to differentiate the Paleozoic rocks, but Pennsylvanian, Mississippian Madison limestone, and Cambrian Deadwood sandstone formations are present. In the NE¼ sec. 20 and in sec. 19 serpentine has been partially replaced by fine-grained silica showing colloform structures and has been oxidized to a reddish color to a depth of at least 20 feet below the base of the Deadwood. Near the abandoned mining camp of Eadsville, prospect pits in the red weathered zone show green copper stain.

Several square miles are underlain by serpentine. Most of the material is black on fresh fracture and weathers light gray, but near pegmatites may be yellowish-green in color. A thin section of a specimen from the small mass in secs. 16 and 17 shows unaltered remnants of olivine, indicating that the serpentine was originally an ultrabasic intrusive. In a number of places, particularly around the edges of the masses, the serpentine has been converted to schist. The zone of chlorite schist in E½ sec. 19 along the contact with granite-gneiss is a schistose phase of the serpentine. Tremolite was developed first and then was partially replaced by chlorite. A specimen from the west end of the serpentine body in secs. 20 and 21 consists predominantly of nonfibrous anthophyllite. Evidence is presented below indicating that the chromite-bearing schist in secs. 16, 17 and 20 was originally an ultrabasic rock.

The serpentine is cut by metadiabase dikes. One from sec. 19 contains labradorite laths surrounded by a yellowish-brown pyroxene, which has been partially converted to green amphibole. Others have been so strongly metamorphosed that the original diabasic structure is no longer visible. Most of the dikes are too small to map; one up to 50 feet in width and half a mile long is shown on the map in secs. 18 and 19.

There are numerous remnants of hornblende schist and amphibolite within the granite-gneisses. One from northeast of the asbestos mill shows basic andesine and brown biotite; the rock was originally an andesite. It is probable that the original material now represented by the metadiabases and hornblende schists was formed during a single period of igneous activity.

The quartzites are intruded by granitic dikes, but were not observed to be cut by metadiabase dikes; the age of the quartzite, therefore, is not clear. Remnants of hornblende schist and metadiabase parallel the curved, quartzite outcrop. Lenses of green amphibolitic material up to several inches thick occur within the quartzite, but none could be found crossing the bedding. This material consists mostly of green pleochroic hornblende.

The granites are the youngest pre-Cambrian rocks; it is probable that their gneissic structure is inherited from schists. They have so obscured relations in the older rocks that the original form of the serpentine bodies and their structural relations to the basic rocks, quartzites and any previously existing host rocks are largely matters of conjecture.

The serpentine is cut by numerous pegmatite dikes up to several hundred feet across, containing microcline, quartz and some schorl variety of tourmaline. They merit further investigation as a possible source of commercial feldspar.

Asbestos.

The areas of asbestos-bearing serpentine are confined to sec. 16 and the E½ sec. 17. Trenches and pits in the serpentine to the south and west show no chrysotile. The lens crossed by Elkhorn Creek in sec. 16 is locally traversed by steeply dipping veinlets of cross fiber. Surface workings in the hillside indicate that most of the fiber is less than ⅜ inch in length. Judging from the surface exposures and prospects it is not likely that there are extensive areas in which the rock contains more than 5 per cent of fiber.

A large part of the asbestos mined has come from a lens 1,400 feet long and 500 feet wide southeast of the mill. Several shallow pits east of the road show small amounts of fiber under ¼ inch in length. Near the center of the lens, west and north of the road, a pit 100 feet across and 40 feet deep exposes a tabular zone of cross fiber up to 18 inches in width standing vertically and striking east. The zone consists of closely spaced veinlets of chrysotile and thinner intervening bands of massive serpentine. Locally more than 50 per cent of the material is asbestos. Fiber up to 1 inch in length is present. Most of it is from 1/16 to ½ inch long. In the north and south walls of the pit there are more widely spaced veinlets of short fiber. A cut in the edge of the serpentine adjacent to the mill shows some short fiber. Several trenches east of the road in the northern part of the serpentine in SE¼ sec. 17 show small amounts of short fiber.

The Casper Mountain chrysotile varies in color from yellowish-green to amber. Some of it is harsh and brittle. Other material seems to be of good quality. Samples of brittle material from the lens in secs. 16 and 17 show unusual values for refractive index and birefringence. Determinations in oils of a number of fibers from each sample, used to insure different positions of rotation on the long axes of the fibers, are as follows:

Sample No.	n, horiz. hair parallel	n, vert. hair parallel	Birefringence
599	1.465–1.469	1.501–1.505	.032–.040
598	1.482–1.490	1.508–1.514	.018–.032
666	1.494–1.501	1.524–1.533	.023–.039

The samples are all notable for their brittleness, low refractive index and high birefringence. No. 666 is comparable in optical properties with the chrysotile of lowest refractive index and highest birefringence for which Larsen and Berman[9] give data, as follows: $\alpha = 1.493, \beta = 1.504, \gamma = 1.517$. No. 598 and No. 599 are of still lower refractive index and higher birefringence.

A thin section of No. 599 from the cut near the mill shows massive serpentine with partly altered crystals of olivine, and containing cross-fiber chrysotile veinlets. In a section of normal thickness, the chrysotile shows colors up to second order green. On the basis of this color the birefringence is around .035, a result consistent with that obtained by the immersion method. The olivine, massive serpentine, and chrysotile are cut by quartz veinlets (Fig. 7) some of which parallel the chrysotile veinlets and then turn parallel to the fiber, indicating that the quartz was deposited during or after a period of deformation that pulled the chrysotile away from the walls and fractured it along the fiber. Carbonate, possibly magnesite, is present in veinlets cutting across all minerals except quartz. Compound veinlets with quartz borders and carbonate interiors (Fig. 8) indicate that quartz

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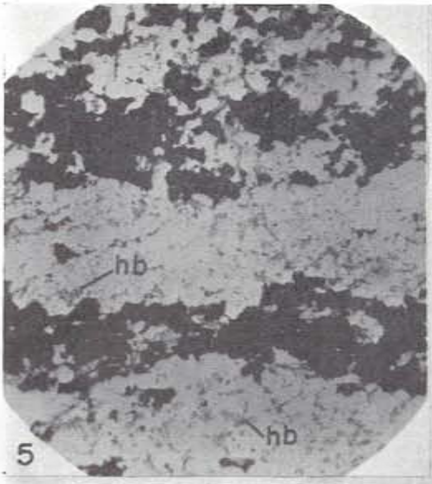
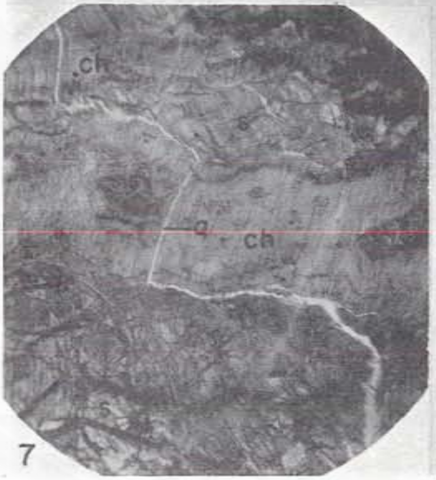
[9] Larsen, E. S., and Berman, Harry: Microscopic determination of the nonopaque minerals. U. S. Geol. Surv. Bull. 848: 99, 1934.





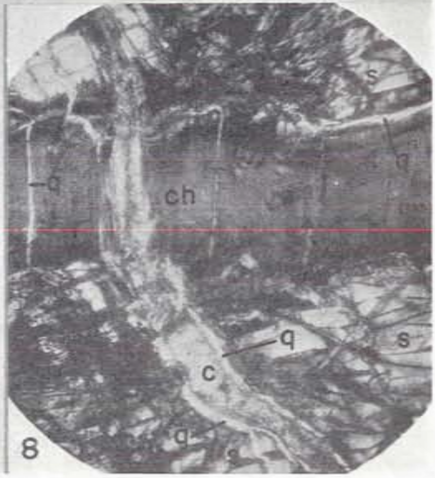


FIG. 5. Schist from the Fire King area showing alternating bands of magnetite (black) and quartz (light) with fine hornblende (hb). Ordinary light. × 75.

FIG. 6. Chromite (black) in chlorite and tremolite matrix (light). Casper Mountain. Crossed nicols. × 75.

FIG. 7. Quartz veinlet (q) cutting serpentine (s) and chrysotile (ch). Casper Mountain. Ordinary light. × 75.

FIG. 8. Compound veinlet of carbonate (c) bordered by quartz (q) cutting serpentine (s) and chrysotile (ch). Crossed nicols. × 75.

began to be deposited first. There was also a period of simultaneous quartz and carbonate deposition.

The serpentine lens from which the brittle chrysotile was collected is bordered on the north by a pegmatite. The most likely source for the quartz and carbonate veinlets is the granite. The writer suggests that there is a relation between introduction of quartz and carbonate and brittleness. It is probable that refractive index and birefringence are not related to brittleness. This subject is separately treated below.

Asbestos deposits in the vicinity of Casper and nearby were worked in 1901.[10] In 1905 Smith wrote,[11]

> Asbestos from the Casper Mountains has been known for some years, and samples recently submitted to asbestos manufacturers have been pronounced of excellent quality. The asbestos is of the chrysotile variety, and the fine silky fiber in the specimens exhibited is of good length. As reported, the chrysotile occurs in a large serpentine dike which has been traced and prospected for several miles.

Some of the later history of development is given in the following quotations:

> With the erection of a mill on Smith Creek and another on Casper Mountain, . . . a production during 1911 was to have been expected if asbestos production was the object in view.[12]
>
> In the Casper region of Wyoming, while the officers of several companies were being prosecuted for their methods of promotion, other companies have extended their prospects and have produced a small quantity of asbestos . . . but the developments are very meager.[13]
>
> The asbestos deposits of Wyoming are largely chrysotile, but they contain only a trace here and there of fair spinning fiber. They have attracted much attention . . . but have not yielded a production. The possibilities of the region are not yet fully known. They should be tested and developed by experienced manufacturers of asbestos who need raw material. There is no doubt that a large quantity of mill fiber of good grade occurs in that part of the country, including the Laramie, Wind River, and Big Horn mountains.[14]
>
> Fred Patee, of Casper, mined from his asbestos property near that city

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[10] Pratt, J. H.: U. S. Geol. Surv., Mineral Resources U. S., 1901, p. 891.

[11] Smith, G. O.: U. S. Geol. Surv., Mineral Resources U. S., 1905, p. 1157.

[12] Diller, J. S.: U. S. Geol. Surv., Mineral Resources U. S., 1911, Part II—Nonmetals, p. 998.

[13] Diller, J. S.: U. S. Geol. Surv., Mineral Resources U. S., 1912, Part II—Nonmetals, p. 994.

[14] Diller, J. S.: U. S. Geol. Surv., Mineral Resources U. S., 1916, Part II—Nonmetals, pp. 21–22.

a considerable quantity of serpentine, which was used in making sectional blocks for chimneys.[15]

The writer has not been able to obtain any record of production of asbestos from Casper Mountain in recent years. In 1935 a small tonnage of massive serpentine for concrete aggregate in chimney blocks was quarried from shallow pits a few feet west of the road in the SE ¼ sec. 17.

CHROMITE.

An elongated lenticular mass of chromite-bearing schist, with the foliation parallel to the contacts, crops out in secs. 16, 17, and 20. Boundaries were mapped mainly on the basis of rock fragments in the soil, and consequently are subject to revision. The length as mapped is 2,500 feet and the maximum width 350 feet. The central, northeastern, and other parts of the lens disclose barren schist or a few disseminated grains of chromite up to 1/16 inch across. In the western part of the lens in sec. 20, several trenches cross-cut the schist. One 800 feet west of the section corner shows some thin bands of chromite alternating with schist containing a small amount of disseminated chromite. The banding is somewhat contorted but generally parallels the contacts of the lens. There are also some parallel flattened nodules and pod-shaped masses of rock that appear to be mainly black and dark brown chromite. The pods vary up to two feet in width and a few feet in length. The rock as a whole has the general appearance of a banded gneiss with large flattened augen.

A thin section of disseminated chromite (Fig. 6) shows anhedral chromite in a groundmass of prismatic tremolite and chlorite. Fine-grained chlorite along the tremolite cleavages indicates that the chlorite is younger and was produced, at least in part, by alteration of tremolite. Within the chlorite are areas of fine-grained talc; the age relations of the two are not clear, but the irregular patchy distribution of the talc suggests that it is younger. The mineralogical similarity to other schists in the area that are border phases of the serpentine near contacts with

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[15] Sampson, Edward: U. S. Geol. Surv., Mineral Resources U. S., 1920, Part II—Nonmetals, p. 317.

younger granites, provides evidence that the chromite rock was once serpentine. In addition, the succession tremolite—chlorite—talc is well known in the steatization of ultrabasic igneous rocks and serpentine by younger acid intrusives.[16]

The distribution of the chromite, described above, is characteristic of deposits believed to have been formed by early crystallization of chromite from magma.[17] Other features, such as nearby younger granites, and pegmatites that cut ore and schistosity, show that the original ultrabasic rock has been subjected to processes connected with folding and igneous activity later than and unrelated to those of original ore deposition. Considerable attention has been given by Sampson,[18] Ross [19] and Fisher [20] to hydrothermal deposition of chromite. They do not discuss the regional history of the areas around the deposits considered and apparently assume that the hydrothermal solutions originated in the ultrabasic magma. Hess [21] later made a strong distinction between serpentinization produced by solutions originating within ultrabasic magma and steatitization by solutions from later acid intrusions. In the case of the Casper Mountain chromite, there is abundant evidence of steatitization and, judging from the nearby serpentine bodies, there has also been an earlier serpentinization. It is, therefore, possible that further studies of the deposit may provide valuable data on hydrothermal processes in chromite deposits.

The writer collected samples of the chromite ore, but made no attempt at systematic sampling. Nos. 585 and 588 were judged in the field to be representative of the richest material available. No. 587 is schist containing disseminated chromite. Nos. 585A and 588A are concentrates obtained by crushing Nos. 585 and 588

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[16] Hess, H. H.: The problem of serpentinization and the origin of certain chrysotile asbestos, talc and soapstone deposits. ECON. GEOL., 28: 634–657, 1933.

[17] Diller, J. S.: Recent studies of domestic chromite deposits. A. I. M. E. Trans., 63: 105–149, 1919.

[18] Sampson, Edward: May chromite crystallize late? ECON. GEOL., 24: 632–641, 1929.

[19] Ross, C. S.: Is chromite always a magmatic segregation product? ECON. GEOL., 24: 641–645, 1929.

[20] Fisher, L. W.: Origin of chromite deposits. ECON. GEOL., 24: 691–721, 1929.

[21] *Op. cit.*

and treating the fraction between 115-mesh and 250-mesh with Thoulet solution of specific gravity 3.2. Microscopic examination of the concentrates showed that they contain less than 5 per cent of tremolite and chlorite. In the analyses by H. F. Eppson below, the total iron was calculated as FeO.

Sample No.	588A	588	585A	585	587
Cr_2O_3	46.6%	26.7%	26.6%	13.7%	3.6%
FeO	36.0		63.0		
MgO	4.9				
Al_2O_3	11.0				

The following conclusions can be drawn from the analyses:

1. The Cr_2O_3 content of laboratory concentrate No. 588A is high enough to meet present requirements for the manufacture of ferrochrome.

2. The Cr_2O_3 content of laboratory concentrate No. 585A is too low for this purpose and the high iron content would make it unsuitable for use in chromite brick. The fact that the material is strongly magnetic indicates the presence of a considerable proportion of magnetite.

3. Removal of minerals of specific gravity less than 3.2 from the best appearing hand-picked samples, Nos. 588 and 585, increased the Cr_2O_3 content to an extent showing that silicate gangue minerals constitute 40 to 50 per cent of the rock. Even the best ore would have to be concentrated to meet present market requirements.

4. Some of the schist containing disseminated chromite, as represented by No. 587, is not worth considering for concentration.

Conclusions as to present commercial possibilities of the deposit and its value as a reserve in case chromite should no longer be available from outside the United States can be reached only after much more information is obtained. Quantitative data are needed on, (1) near-surface and depth distribution of materials of high enough Cr_2O_3 content to be suitable for concentration, (2) distribution of magnetite in the deposit, and (3) concentration processes for removal of silicates and possibly also magnetite.

SMITH CREEK ASBESTOS DEPOSIT.

South of Casper Mountain, Paleozoic and Mesozoic beds are involved in a syncline some ten miles wide. The eroded edges of the Deadwood quartzite in the south flank of the syncline form the northwestern boundary of the part of the Laramie Range known locally as the Deer Creek Mountains. The mapped area (Fig. 9) in T. 31 N., R. 78 W., is 27 miles by road from Casper, the nearest rail point.

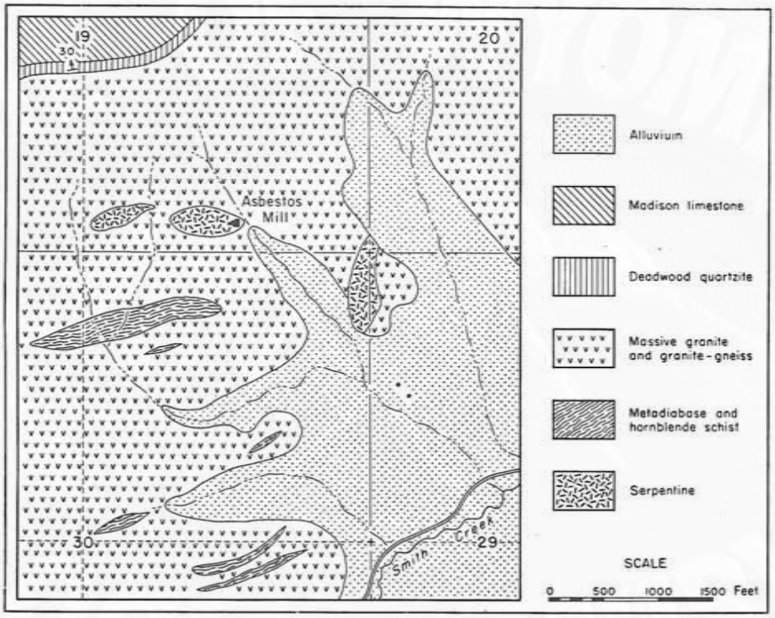

FIG. 9. Geologic map of the vicinity of the Smith Creek asbestos deposit.

The oldest rocks in the area are the serpentines. They are cut by metadiabase dikes of the same period of basic igneous activity disclosed in the southwestern part of the area. The serpentine and basic schists occur as lenses enclosed in granite-gneisses and massive pink granites, and are cut by dikes of granite and pegmatite. It is probable that the lenses are remnants that survived magmatic stoping and granitic injection.

The serpentine masses stand out as low hills above the rolling surface that descends from the base of the Deadwood toward Smith Creek. The serpentine is yellowish-green to black on fresh fracture and weathers light gray. The eastern lens, which is 900 feet long and 350 feet wide, shows no indication of asbestos. The central lens is 650 feet long and 300 feet wide. Near the center is a cut 25 feet wide, 50 feet long, and up to 20 feet deep. The serpentine here is greenish-black in color, and is cut by roughly parallel, vertical veins of cross-fiber chrysotile, which is yellowish-green in color and rather harsh. One band 6 inches wide consists largely of cross fiber. Partings of light green serpentine lie parallel to the walls and reduce the effective fiber length. The longest seen was ¾ inch; most of it is under ½ inch. There is little fiber west of the end of the cut. Apparently the best of the material above the floor level has been mined. A few shallow shafts and trenches farther west show small amounts of short, harsh fiber.

In the side wall of the pit a fracture one inch wide contains a light green, very brittle, columnar and blade-like mineral probably of a variety called metaxite or picrolite. The flat surfaces of the blades lie nearly parallel to the walls in a position similar to that of slip-fiber chrysotile. Because of the general parallelism of the fracture to the system of cross-fiber veins, it is probable that the material was formed at the same time as the cross-fiber and has been sheared, rotated, flattened, and altered, probably during the time of intrusion of the pegmatite dikes in the western end of the serpentine lens. The green material, although fibrous, consists largely of quartz (Fig. 13).

In the western serpentine lens, surface workings expose small amounts of cross-fiber, mostly less than ¼ inch in length in a zone 75 feet wide and 150 feet long. In the immediate vicinity of the fiber, the serpentine is pistachio-green in color and grains of magnetite are visible. Black bands of finely disseminated magnetite, up to ¾ inch wide, form a peculiar interlacing pattern and within each band there are longitudinal veinlets of cross-fiber up to 1/16 inch wide. On several of the dumps in this area there is short slip-fiber chrysotile and metaxite or picrolite similar to that previously mentioned.

The amount of asbestos mined and milled from the western lens was apparently small, judging from the size of the mill tailing pile, a mound 15 feet high and 30 feet in diameter. As the deposit was worked at the same time as the Casper Mountain asbestos and the two properties were controlled by the same company, the history of the Casper Mountain asbestos development, previously given, covers that of Smith Creek.

DEER CREEK DEPOSITS.

Green Hill Asbestos Deposit.

The deposit is located in sec. 23, T. 31 N., R. 78 W., Natrona County, three miles east of the Smith Creek mill; the Casper-Deer Creek Park road passes just west of the mapped area (Fig. 10).

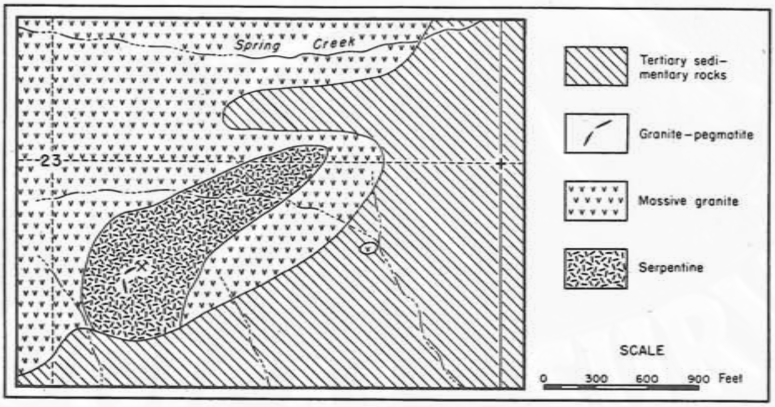

FIG. 10. Geologic map of the vicinity of the Green Hill asbestos deposit.

The deposit is on the rolling upland between Spring Creek, a tributary of Smith Creek, and the West Fork of Deer Creek, which is one-half mile south of the mapped area. A lens of serpentine 1,700 feet long and 500 feet wide forms a hill several hundred feet high and is surrounded by pink granite containing a few xenoliths of hornblende schist. The serpentine is cut by granite-pegmatite dikes.

Northeast of the E¼ cor. sec. 23 a 20-foot diabase dike cuts the granite. It shows a finer-textured border and sends an offshoot into the granite. A thin section shows fresh labradorite and a light yellowish pyroxene. The structure is typically diabasic; there is no evidence of schistosity. This dike is the only evidence seen by the writer near any of the asbestos deposits indicating igneous activity later than the intrusion of the granites. Fine-textured, white, volcanic ash beds of Tertiary age lie unconformably on the granites, but do not extend to the diabase dike. It is probable that the dike is not of Tertiary age, as the Tertiary ashes of this part of Wyoming are andesitic and dacitic in composition, but is instead of pre-Cambrian age and represents the same period of basic activity as the diabase dikes that cut granite near the Pathfinder Dam and the Devil's Gate on the highway between Casper and Rawlins.

Over most of the area of serpentine there is no indication of asbestos. A few feet east of the pegmatite shown on the map, a trench 50 feet long and up to 20 feet deep exposes a veinlet one inch wide, consisting of harsh chrysotile lying at about 45° to the wall. On the dump of a caved shaft a few feet away there are small amounts of harsh slip-fiber chrysotile.

On the same dump there are pieces of brown and black woody material, which show black bands of fibrous magnetite up to half an inch wide, and a few fibers of harsh chrysotile. A thin section shows that the rock consists predominantly of fine-grained quartz and irregular areas of talc. One field in the section shows coarse quartz lying parallel to the fibrous structure. The magnetite occurs concentrated in a few solid opaque areas, and also in finely disseminated form in lines identical in pattern with those of the fibers in a bent and distorted bundle of chrysotile. The writer believes that the woody material is slip-fiber chrysotile that has been silicified, and partly changed to talc and magnetite. Similar material from cross-fiber chrysotile of Casper Mountain has been previously described.[22]

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[22] Perry, E. L.: Fibrous magnetite after chrysotile. Am. Jour. Sci., 5th ser., 20: 177–179, 1930.

Koch Asbestos Deposit.

The deposit is located in sec. 15, T. 31 N., R. 77 W., Converse County, on the north side of the West Fork of Deer Creek, near the Casper-Deer Creek Park road.

A lens of serpentine approximately 1,500 feet by 500 feet trending northeast is surrounded by granite. Several smaller lenses 50 to 100 feet wide lie northwest of it. Surface exposures show no asbestos. A 250-foot tunnel that penetrates the large lens discloses a small amount of amphibole asbestos and one vienlet of chrysotile ¼ inch wide. In the first 100 feet of the tunnel, the serpentine is cut by several granite-pegmatite dikes up to two feet wide, bordered by zones of vermiculite up to 8 inches wide.

Deer Creek Canyon Chromite Deposit.

The deposit is located in sec. 11, T. 31 N., R. 77 W., Converse County, in a steep-sided valley draining eastward into Deer Creek, which here flows in a canyon about 1,000 feet deep in the northwest flank of the Laramie Range. The deposit can be reached from the Casper-Deer Creek Park road. It could not be mapped in detail because of deep talus.

Paleozoic beds that cap the uplands are cut by the tributary valley. Along its bottom is a belt of black, strongly sheared rock with a greasy luster, originally an ultrabasic intrusive, that trends N. 75° E. for approximately 1,000 feet to Deer Creek and extends several hundred feet beyond. The width is mostly less than 50 feet. The ultrabasic rock is cut by granite. Near the western end are a number of pits from which chromite has been mined, but at the time of the writer's visit caved walls restricted observations. Spencer [23] reported that there was a layer of fine-grained dense ore 2 to 5 feet thick apparently continuous for 150 feet along the wall of the serpentine. Analyses of ore show 35 to 45 per cent of Cr_2O_3. Carload lots carried 35 per cent of Cr_2O_3. Diller [24] reports that the first ore was mined in 1908 and

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[23] Spencer, A. C.: Atlantic gold district and the North Laramie Mountains. U. S. Geol. Surv. Bull. 626: 78, 1916.

[24] Diller, J. S.: Recent studies of domestic chromite deposits. A. I. M. E. Trans., 63: 145, 1920.

that possibly as much as 700 tons had been taken out by 1920. Since then there has been no production.

CANYON CREEK TALC DEPOSIT.

The deposit is located near the crest of the Bighorn Range (Fig. 1) in sec. 25, T. 48 N., R. 86 W., in Washakie County, 48 miles from Buffalo.

In the western part of sec. 25 there are granite-gneisses. In the central and eastern part a folded and schistose succession of greenstones, hornblende schists and olivine metadiabases strikes N. 15° E. and passes beneath the Deadwood quartzite in the next section to the south. Locally, there are very small amounts of brittle amphibole asbestos and talc in the schists. No chrysotile was seen. In the summer of 1934 the Wyoming Asbestos Mining Co. was employing 10 to 12 men in prospecting in the SE ¼ sec. 24. Prospect pits and a 25-foot shaft show only talc schist and fibrous talc.

CAUSE OF BRITTLENESS AND HARSHNESS IN CHRYSOTILE.

Soboleff and Tatarinoff state in their summary of conclusions on the cause of brittleness and harshness in asbestos: [25]

> 1. On the basis of the field investigations of the Rhodesian and Iltchirsk occurrences of chrysotile-asbestos it may be conclusively stated that brittle asbestos is a transition stage not between serpentine and normal asbestos, but between the latter and talc.
> 2. In most cases normal asbestos contains an excess of water.
> 3. Brittle chrysotile-asbestos (*a*) is characterized by an excess of SiO_2 and occasionally MgO; (*b*) it may be regarded as a product of metamorphism of normal chysotile-asbestos; (*c*) the explanation of the brittleness by the presence of CaO in the chemical composition of asbestos, *i.e.* by the isomorphous replacement of the MgO, is inconclusive.

With respect to the work of Keep [26] they say: [27]

> Keep seems to have shown rather conclusively from his field investigations that brittle asbestos is but a transition stage between normal asbestos

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[25] Soboleff, N. D., and Tatarinoff, M. V.: The cause of brittleness in chrysotile asbestos. ECON. GEOL., 28: 175–176, 1933.

[26] Keep, F. E.: The geology of the Shabani mineral belt, Belingiwe District. Geol. Surv. S. Rhodesia, Bull. 12, 1929.

[27] *Op. cit.*, p. 172.

and talc. In the latter there are veins consisting of pseudomorphs of talc after asbestos. Keep has made numerous chemical analyses of both types of chrysotile-asbestos, and has attempted to interpret them. However, his method of calculating these analyses into the mineralogical composition has not given positive results, although he remarks [28] that "with a decrease of the serpentine constituent and an increase of talc, corresponding to a decrease in silica, the fibers become brittle."

In connection with harshness in chrysotile occurring in limestones Bateman says: [29]

> The extremely harsh material cannot be utilized; the slightly harsh grade can be spun but yields a splintery yarn; the intermediate material, which constitutes the greatest amount of the harsh asbestos, can be used for spinning fiber only after a preliminary acid wash.

Of the Arizona chrysotile deposits occurring in limestones Diller says: [30]

> A. B. Shutts, general manager of the American Ores & Asbestos Co.'s mine, has given much attention to harsh and soft fiber; both are said to occur in the same vein, and he reports them as grading into each other. He called the writer's attention to veins of fibrous calcite in which the asbestos appears to have been so completely replaced by fibrous calcite that the calcite is pseudomorphous and preserves the fibrous structure of the chrysotile. Mr. Sampson suggests that the fibrous calcite may be a parallel growth instead of a replacement of chrysotile. The degree of harshness varies and appears to be proportionate to the degree of replacement of the asbestos by the calcite. These facts seem to furnish strong and convincing evidence that calcite causes the harshness of the fiber.

The writer believes that the apparent inconsistencies in the quotations above are the result of assuming that brittle and harsh chrysotile in the serpentine type of deposit and in the limestone type are formed by identical processes and that undue emphasis has been given to conclusions based on chemical analyses of materials which had not been subjected to detailed microscopic examination at high magnifications. Harshness and brittleness of chrysotile in the deposits examined by the writer are explicable by silicification of chrysotile in varying degrees and with or without chemical reaction between silica and chrysotile, by solutions from the granites found in the immediate vicinity. This process explains, as set forth below, some of the apparent inconsistencies

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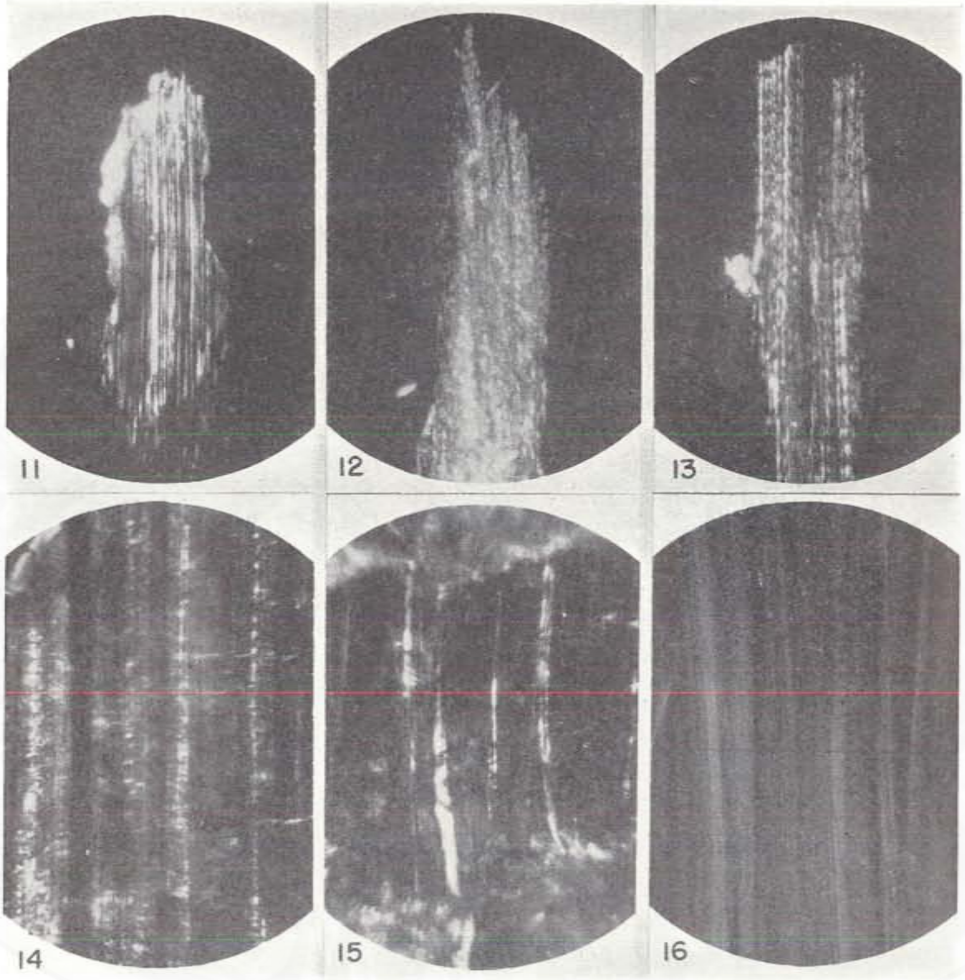
[28] *Op. cit.*, p. 111.

[29] Bateman, A. M.: An Arizona asbestos deposit. ECON. GEOL., 18: 669, 1923.

[30] Diller, J. S.: U. S. Geol. Surv., Mineral Resources U. S., 1919, Part II—Nonmetals, p. 303.



Figs. 11–16. Photomicrographs with crossed nicols and at extinction position. Fig. 11. Tiger-eye, South Africa. × 70; Fig. 12. Brittle chrysotile, Brown Bear. × 70; Fig. 13. Picrolite or metaxite, Smith Creek. × 70; Fig. 14. Harsh chrysotile, Brown Bear. × 210; Fig. 15. Harsh chrysotile, Casper Mountain. × 210; Fig. 16. Spinning-fiber chrysotile, Quebec. × 210.

encountered in interpretations of chemical analyses of samples from the serpentine type of deposit and also strongly suggests that brittleness and harshness in chrysotile from the limestone type of deposit is the result of varying degrees of replacement of chrysotile by calcite.

Figures 11 to 16, all of which were taken with crossed nicols at extinction position, are arranged in order from almost pure quartz to the finest grade of spinning fiber. The hand specimen of yellowish tiger-eye from South Africa, from which Fig. 11 was prepared, has the usual extreme brittleness of quartz and a subconchoidal fracture. The material has such poor fibrous structure that many of the fragments obtained by crushing are elongated across the fiber length. The photomicrograph shows that the quartz is coarse, but fails to give an adequate picture of the amount of quartz, as the red interference colors registered as black in the print, because of the use of orthochromatic film.

One of the slip-fiber veins of the Brown Bear deposit has been invaded by a granite-pegmatite and much of the fiber has been replaced by quartz. The fragment in Fig. 12 is from approximately one inch out from the wall of the original ultrabasic rock. Between one end of the fiber, which is approximately ½ inch long, and the wall is a quartz veinlet; at the other end is a dikelet of quartz and orthoclase. The green fibrous material is so tough and brittle that considerable force is needed to drive a knife blade into the specimen holding the flat surface of the blade parallel to fiber length. The material flies into small bits when struck with a hammer. The photomicrograph shows the mosaic of introduced quartz and gives a suggestion of the " ladder " structure shown prominently in Fig. 13.

The fragment in Fig. 13 is from near the middle of the central serpentine lens at Smith Creek. The long axis was originally nearly parallel to the walls of the enclosing massive serpentine. The hand specimens are blades and columns several inches long and up to an inch thick. When one attempts to bend a blade it breaks with a snap. The mineral is a variety to which the name picrolite or metaxite has been applied. The photomicrograph shows veinlets or rods of quartz parallel to fiber length and, between them, fairly evenly spaced elliptical spots of quartz. The structure suggests a number of parallel ladders.

The fiber in Fig. 14 is from the same hand specimen as the fregment in Fig. 12, but lies in contact with the wall rock at one end and is separated from the material of Fig. 12 by a quartz veinlet about 1/10 inch wide. The fiber is very harsh. After working it in the fingers splinters remain in the skin. The quartz mosaic shown is finer than that in the preceding figures, as the magnification is greater. The structural arrangement of quartz is similar to that in Fig. 13. In addition, some bands show no quartz mosaic even when turned slightly away from extinction position, and quartz also cuts across normal to fiber length.

Fig. 15 is a field of a thin section from hand specimen No. 599, greenish-yellow serpentine containing interlacing veinlets of harsh chrysotile up to ⅛ inch in length. The chrysotile has a very low refractive index and high birefringence, properties which are probably not genetically related to harshness. Other fields in the same thin section are shown in Figs. 7 and 8. As explained in connection with the description of the Casper Mountain asbestos, the thin section shows the history: (1) Fracturing of serpentine and chrysotile. (2) Deposition of quartz in veinlets, which cut across massive serpentine, extend up to the boundary of a chrysotile veinlet, spread along the contact between massive serpentine and chrysotile, and then cut across the chrysotile parallel to fiber length (Fig. 7). (3) Deposition of carbonate material (Fig. 8). The specimen was collected in the cut near the Casper Mountain mill. The serpentine is here bordered on the north by a granite-pegmatite, an obvious source for the quartz. The photomicrograph (Fig. 15) shows a number of streaks of quartz lying parallel to fiber length. Some are undoubtedly tabular veinlets. Others may be rod-shaped. The narrowest prominent quartz streak near the center of the field is 6 to 7 microns wide. In addition to obvious quartz streaks there is a strong suggestion of "ladder" structure. The dark bands along the borders of chrysotile veinlets (Figs. 7 and 8) indicate that silicification proceeded inward parallel to fiber length from the quartz separating the fiber ends from massive serpentine.

Fig. 16, given for comparison, is an excellent grade of spinning fiber from Quebec. The failure to show complete extinction is the result of a slight crossing of the fibers produced during cutting the bundle with scissors. Soft flexible fiber from Wyoming deposits shows the same lack of visible " ladder " structure at the same magnification.

The microscopic evidence is entirely in accord with the findings of Soboleff and Tatarinoff and with those of Keep. Introduced quartz in brittle chrysotile would appear in a chemical analysis as an excess of SiO_2 over the amount necessary for the composition of chrysotile. In the preparation of material for chemical analysis, the presence of a few very fine carbonate veinlets is likely to be overlooked. If the carbonate material is magnesite the analysis would show an excess of MgO. If the carbonate material contains calcite or dolomite or both the analysis would show CaO, which, on the assumption that the material analyzed was pure, would lead to the conclusion that CaO occurs as an isomorphous replacement of MgO. Low water and high SiO_2 content would necessarily appear in a chemical analysis of impure material in which chrysotile has been partially replaced by anhydrous silica. Keep's observation that brittle chrysotile is but a transition stage between normal chrysotile ($2H_2O \cdot 3MgO \cdot 2SiO_2$) and talc ($H_2O \cdot 3MgO \cdot 4SiO_2$) implies that the conversion process involves both loss of water and addition of SiO_2. The difficulties encountered in calculating Keep's chemical analyses into mineralogical compositions expressed in terms of chrysotile and talc strongly suggest to the writer that the difficulties are not in the method of calculation, but that the analyzed material contained free quartz or magnesite, which Hess [31] has shown is one of the end stage products of the steatitization of serpentine masses by granites.

The observations of Bateman on the effect of an acid wash on

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[31] Hess, H. H.: The problem of serpentinization and the origin of certain chrysotile asbestos, talc and soapstone deposits. ECON. GEOL., 28: 634–657, 1933.

slightly harsh chrysotile from the limestone type of deposit and Diller's description of the continuous transition from fibrous calcite through harsh and brittle varieties to the best grade of chrysotile suggest that, in this type of deposit, brittleness and harshness are the result of the presence of replacing calcite arranged in a pattern similar to that of the quartz in brittle chrysotile from the serpentine type of deposit.

University of Wyoming,
Laramie, Wyoming,
June 1, 1939.

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