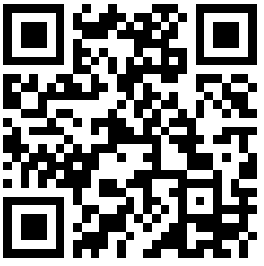
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AUGUST 1947

UNITED STATES
DEPARTMENT OF THE INTERIOR
J. A. KRUG, SECRETARY

BUREAU OF MINES
THOS. H. MILLER, ACTING DIRECTOR

REPORT OF INVESTIGATIONS

ARIZONA ASBESTOS DEPOSITS, GILA COUNTY, ARIZ.

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REPORT OF INVESTIGATIONS

UNITED STATES DEPARTMENT OF THE INTERIOR - BUREAU OF MINES

ARIZONA ASBESTOS DEPOSITS, GILA COUNTY, ARIZ.[1]

By Lincoln A. Stewart[2] and P. S. Haury[2]

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2/ Mining engineers, Bureau of Mines.

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INTRODUCTION AND RESUMÉ

Arizona asbestos mines are the only sources on the American continents of iron-free chrysotile spinning fiber that meets the Navy specifications for asbestos fiber for use in covering electrical cables. Rhodesia normally supplies the bulk of this grade of asbestos at about half the price of Arizona spinning fiber. The acute submarine menace in 1942 focused attention on the danger that imports might be cut off and that a sudden demand for greatly expanded production might fall on the Arizona mines to supply the tonnage of this essential material needed for war production.

A joint preliminary investigation of Arizona asbestos deposits was made in August 1941 by J. R. Thoenen, senior mining engineer of the Bureau of Mines and A. E. Granger, a geologist of the United States Geological Survey. A more extended investigation of the numerous asbestos mines and prospects, which are scattered over 25 townships of difficult terrain in Gila County, was begun by the senior author in August 1942.

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The Geological Survey assigned two geologists (Newton Chute and A. F. Shride) a few weeks later to study the geology as an aid in selecting the mines for the Bureau's exploration projects. Six mines were selected for exploratory work because it was desired to prove reserves of ore where production could be started quickly if urgent demand should arise. Acceleration of production is normally slow because of adverse operating conditions. First, the mines are at distances of 35 to 100 miles from Globe, the shipping and supply point, and the roads are few and poor. The mine openings start in steep canyon walls, so that mining supplies usually have to be packed in and the product packed out over 0.5 to 5 miles of burro trail. Second, most of the ore deposits are small, and the ratio of rock broken to spinning fiber recovered is very high, usually exceeding 200.

Plans were made to run three projects concurrently. Difficulties in obtaining priorities and delivery of the necessary mining equipment delayed the start of development work until January 1943, when snow, ice, and mud hampered transportation over the poor access roads. Project 2302 on the Grandview No. 4 claim of the Phillips Asbestos Co., 42 miles by road from the headquarters at Globe, was started early in January. The equipment could not be moved in to Project 2305, Enders White Tail No. 2, 51 miles from Globe, until a month later. It was mid-March before the equipment could be moved over the access road to Project 2304, Kyle's Sloan Creek group, which is 98 miles from Globe. Insufficient and inadequate labor also retarded progress, so that no other projects could be started before the end of the fiscal year. A small appropriation to continue the work in the fiscal year 1944 was sufficient for a little more than a month of work at Project 2303, the Reynolds Falls group, 53 miles from Globe. A crew of men selected from the three crews formerly employed supplied adequate labor, and progress at this project was satisfactory.

A total of 1,494 linear feet of drifting was done on the four projects; three open cuts were made and 609 linear feet of channel samples were cut. Minable ore was developed at the Phillips Grandview and Reynolds Falls projects. Neither of these was explored to the limits of the ore bodies. No commercial ore was found at the other two projects, although small, discontinuous lenses of good fiber were found at one of them.

ACKNOWLEDGMENTS

In its program of investigation of mineral deposits, the Bureau of Mines has as its primary object the more effective utilization of our mineral resources to the end that they make the greatest possible contribution to national security and economy. It is the policy of the Bureau to publish the facts developed by each project as soon as practical after its completion. The Mining Branch, Lowell B. Moon, chief, conducts preliminary examinations, performs the actual investigative work, and prepares the final report. The Metallurgical Branch, O. C. Ralston, chief, analyzes samples and performs beneficiation tests.

Special acknowledgment of advice and general direction is made to J. H. Hedges, district engineer for Arizona, and S. R. Zimmerley, regional engineer of the Western Region, and to Newton Chute and Andrew F. Shride, of the

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United States Geological Survey, for their mapping and interpretation of the geology of the area. Acknowledgment is likewise made to Guy Phillips, John E. Wells, Roger Q. Kyle, and Arthur Enders for their assistance and courteous treatment to Bureau personnel engaged in project work on their properties.

LOCATION AND ACCESSIBILITY

The asbestos field covers an area of some 25 townships in the Salt River and Cherry Creek basins, on parts of the Fort Apache and San Carlos Indian Reservations and portions of the Tonto and Crook National Forests (fig. 1).

The country is extremely rugged, and the roads are few and poorly developed. The shipping point is Globe, a town of about 7,000 population.

Paved highway U. S. 60 connects the eastern part of the district with Globe. Access roads lead from this highway to several of the mines.

The Phillips Asbestos Co.'s Grandview No. 4 claim is reached by 4 miles of good dirt road that branches off highway U. S. 60, 5 miles south of the Salt River bridge, or 36 miles from Globe. The working site was on a cliff face 300 feet below the road and at the end of a narrow 2,500-foot trail.

Enders' White Tail No. 2 claim is about 1 mile north of the Salt River bridge and within the Fort Apache Indian Reservation. It is reached by a road that branches off highway U. S. 60, 5 miles northeast of the bridge. This 5-mile access road is narrow and rocky and has stretches of mountainside cuts with steep grades. The road passes the camp site and winds around the rim of the canyon to a small flat area at the top of the limestone cliffs. The tunnel entrance is in the cliff face 75 feet below (fig. 3).

The Sierra Ancha district, on the western edge of the asbestos region, which includes the deposits on Cherry Creek and on the divide between Cherry Creek and Canyon Creek, is reached by poor access roads off an improved road that serves Young and Holbrook. This improved road connects with State highway 88 (Apache Trail) about 21 miles northwest of Globe. The Apache Trail branches off highway U. S. 60, 3.8 miles northwest of Globe.

Kyle's Sloan Creek group is on the drainage divide east of Cherry Creek and is reached by driving to Bottle Spring, 81 miles north of Globe on the Globe-Young-Holbrook road, thence 15 miles south to the camp. The last 5 miles of this road is unimproved. The working places on the Cowboy claim were 1 mile beyond the camp site at the end of a poor road. The Last Chance workings were about half this distance on the same road.

At 50 miles from Globe, on the Globe-Young highway, a poor access road leads to the Reynolds Falls group in the Sierra Ancha Mountains. The road winds along the steep-sided Reynolds Creek Canyon for 4 miles to the camp site and continues 1/4 mile farther up the canyon to the tunnel entrances.

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INDEX OF MINES

1. JOHNS MANVILLE	6. GLADDING-MC BEAN	11. BEAR CANYON	16. LUCKY STRIKE
2. REGAL	7. HORSESHOE (ENDERS)	12. APACHE	17. PUEBLO
3. PHILLIPS ASBESTOS CO.	8. FIBER KING	13. AMERICAN ORES CO.	18. TRIANGLE
4. EMSCO	9. MC INTYRE	14. MIAMI	19. SLOAN CREEK GROUP
5. PINE TOP	10. LOEY & LENA	15. REYNOLDS FALLS	20. ROCKHOUSE

O BUREAU OF MINES PROJECT X-OTHER ASBESTOS MINES

BASE MAP FROM TOPOGRAPHIC MAP OF ARIZONA BY U.S.G.S. & ARIZ. BUREAU OF MINES, 1923

CONTOUR INTERVAL 100 METERS (328 FT.)

0 5 10 15 20

MILES

Figure 1. - Location map, Gila County asbestos mines, 1944.

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OWNERSHIP

The claims on which exploration work was undertaken were owned as follows:

Project No.	Claim	Owner	Address
2302	Grandview No. 4	Phillips Asbestos Co.	Box 662, Globe, Ariz.
2303	Reynolds Falls No. 3	John E. Wells	National Bank of Tulsa Bldg., Tulsa, Okla.
2304	Cowboy Last Chance (Sloan Creek Group)	Roger Q. Kyle	Box 302 Globe, Ariz.
2305	White Tail No. 2	Fort Apache Indian Tribe, Arthur Enders, lessee.	Box 362 Globe, Ariz.

HISTORY

According to Melhase,3/ asbestos was first discovered in the Gila County district by Charlie Newton in 1872 after a battle with Indians at the "72" Springs, but no interest was taken in this deposit for a number of years. This location is on the property of the Phillips Asbestos Co.

In 1913, asbestos was discovered on Ash Creek, and a number of claims were staked near the present site of Chrysotile village. The following year, the Johns-Manville Co. acquired these claims and immediately began mining operations. The successful development of these claims led to intensive prospecting, and hundreds of locations were made along Salt River, Cherry Creek, and in the Sierra Anchas in the years immediately following.

Mining was begun in 1916 at an important deposit, later acquired by the American Ores & Asbestos Co., near the south end of the crest of the Sierra Ancha Mountains. Control was acquired by the Raybestos Co. in 1919. The limit of the known ore was reached in 1920, and the plant was dismantled in 1922. Melhase3/ reported total production from this mine of 1,300 tons of No. 1 crude and 300 tons of No. 2 crude. A large tonnage of shorter fiber remains in the mine dumps and stope fills. Of all the asbestos claims recorded in the district, only 22 in the Johns-Manville group have been patented.

Until recent years, most of the asbestos marketed was hand-cobbed. This limited production to the two higher grades - No. 1, 3/4-inch or longer fiber, and No. 2, having fiber 5/16 to 3/4 inch long.

In 1915, the first attempt to produce crude fiber by mechanical means was made by the Johns-Manville Co. on its property at Chrysotile. A small

3/ Melhase, John, Asbestos Deposits of Arizona: Eng. and Min. Jour. Press, vol. 120, No. 21, 1925.

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mill was built to handle about 12 tons of mill feed per shift. Apparently the markets were not ready for mechanically cobbed crudes. Milling was stopped in 1921, and the mine reverted to hand-cobbing methods.

A number of small mills were erected after 1923, most of which had a short span of life. Gradually there evolved a more or less standardized simple mill, consisting of a crusher, one or two sets of rolls, and a sizing screen.

A market finally developed for the crude milled grades, and, in addition to the standard No. 1 and No. 2 grades, Arizona grades of No. 3 (5/16 to 1/8 inch long) and No. 4 (less than 1/8 inch long) were established. In 1928, fiberizing equipment was installed at one mill; at present four mills produce fiberized products. The Johns-Manville Co. completed a modern fiberizing mill at Chrysotile in 1942. This treated a large amount of material from old dumps and mine fills, and also newly mined ore, until the mine was exhausted in 1945. The mill and mine plant were dismantled then, and all but the 22 patented claims were relinquished.

Several of the most productive deposits have been virtually exhausted.

Erection of a mill at Globe, financed through the Defense Plant Corporation, was begun in 1943. This mill was not completed with Government financing. It was taken over in 1945 by the Globe Asbestos Co., 170 California St., Pasadena, Calif. This company took over the Fiber King mine and began milling ore from it on January 31, 1946. The Globe Asbestos Co. is a subsidiary of Rheem Research Products, Inc.

PHYSICAL FEATURES

Broadly considered, the region is a plateau of nearly horizontal, hard strata, capped in places by remnants of lava and intruded by sills of diabase. Faulting has affected the area only to a minor degree.

Salt River, the master stream of the area, with Cherry Creek and its other tributaries, has dissected the region into innumerable steep-sided canyons, so that the terrain resembles that of the Grand Canyon, but with lower relief (fig. 2).

The general asbestos area is physically divided into two districts by the deeply eroded canyons of Salt River and Cherry Creek, which are accessible by two different road systems. Locally, these two divisions are known as the Salt River district and the Sierra Ancha district.

In the Salt River district the surface of the plateau varies in altitude from 4,500 to 6,800 feet, whereas in the Sierra Ancha district the variation is 5,000 to 7,400 feet. Some of the streams have cut into this plateau down to an altitude of 3,000 feet.

The asbestos outcrops usually are on the canyon walls, and the tunnel sites are reached by trail (fig. 3). Road and trail building in this area

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Looking across Salt River Canyon toward Project No. 2305



Along access road to Project No. 2305



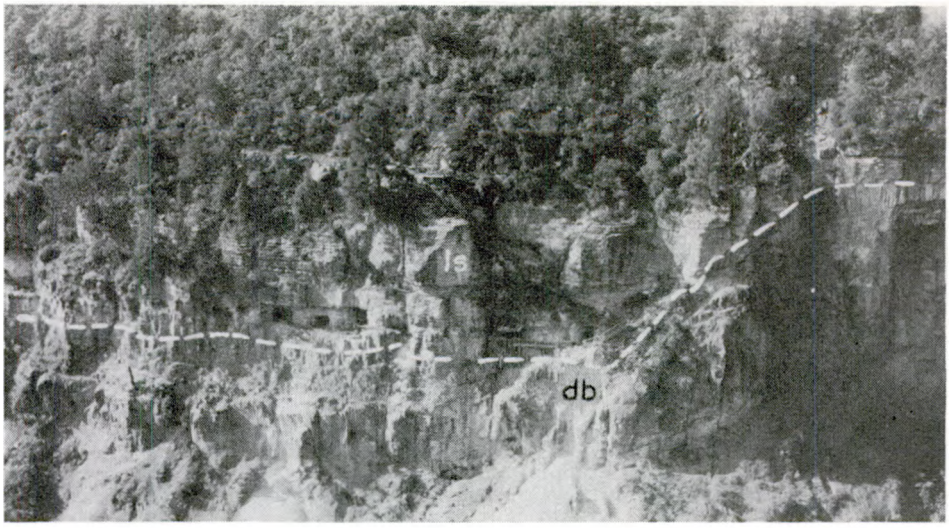
South end of Sierra Ancha Mountains showing white dumps of American Ores Asbestos Mine

Figure 2. - Typical views in asbestos country.

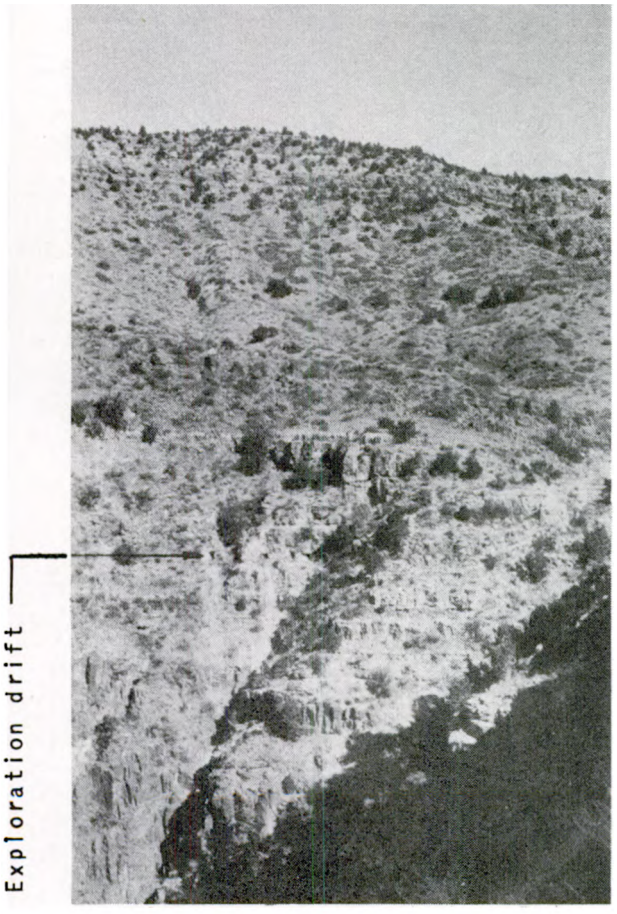
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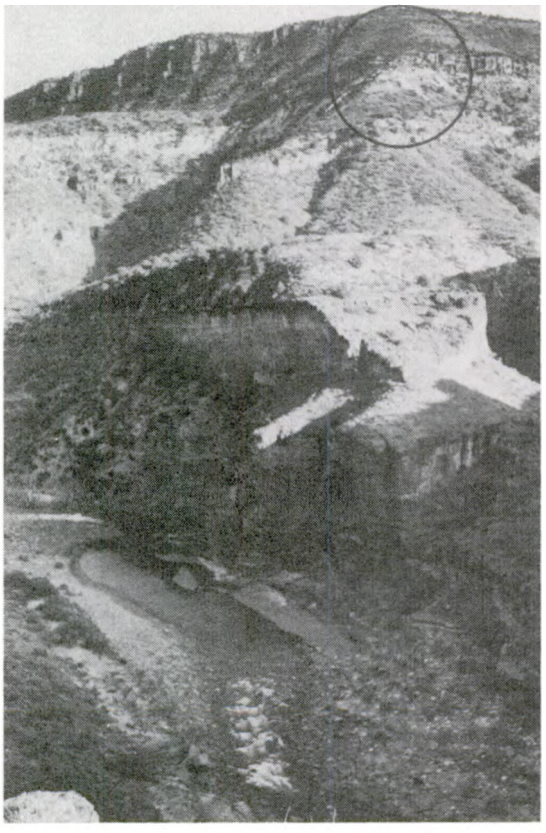
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Ladder Mine. Phillips Asbestos Company



Bureau of Mines Project 2305



Regal Mine from across Salt River

Figure 3. - Typical locations of mine openings.

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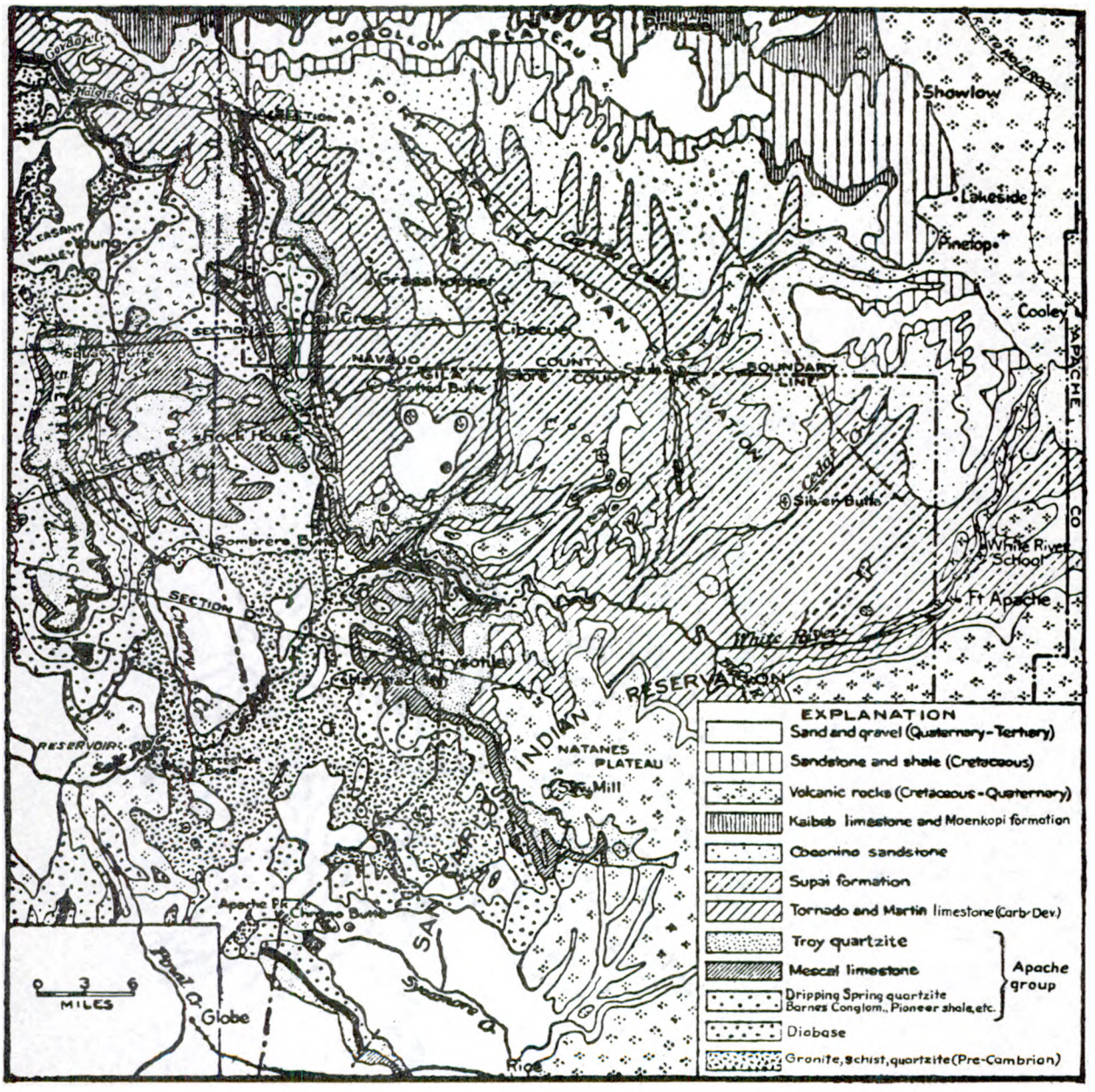


Figure 4. - Geologic map of upper part of Salt River Basin.
By H. N. Darton, Arizona Bureau of Mines Bulletin 119, p. 199,

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is extremely costly and difficult. For example, projects 2302 and 2303, on opposite sides of Salt River, were 2 miles apart. The road distance between them is 20 miles. The cost of a proposed access road from the Cherry Creek road to Young, via the Q ranch, involving construction of 12 miles of road and improvement of 6 miles of an old road, was estimated at $120,000.

No exact climatological data are available for the region. However, each year has its wet summer and winter seasons, with dry months between. Torrential rains, accompanied by considerable lightning, fall nearly every afternoon in July and August. These rains sometimes result in violent flash floods in even normally dry creek beds. From December to March, inclusive, the storms are less violent, but the snow that falls in the higher altitudes may block the access roads there for a month or more. At altitudes of a mile, the total yearly precipitation probably is about 20 inches, and the total average yearly snowfall is about 28 inches.4/ Seasonal temperatures, of course, are dependent on the altitude. At altitudes of approximately 5,000 feet, the temperature ranges from about 100° F. in the summer to 10° above zero in the winter; at 6,000 feet, the temperature is about 10° lower than at 5,000 feet.

GENERAL GEOLOGY

The asbestos-bearing strata are in the Mescal limestone formation of the Apache group, which was defined by Ransome5/ and tentatively determined as Cambrian. From bottom to top, the Apache group consists of the Scanlon conglomerate, Pioneer shale, Barnes conglomerate, Dripping Spring quartzite, Mescal limestone, and Troy quartzite. More recent work indicates that the Troy quartzite is definitely Cambrian and rests unconformably upon the Mescal limestone, which is now considered pre-Cambrian.6/

In the asbestos region, only the three upper formations of the Apache group have been extensively exposed by erosion (fig. 7). The areal distribution of their outcrops is shown on the regional geologic map by Darton (fig. 4).7/ The Mescal formation normally consists of about 300 feet or less of medium- to thin-bedded, hard, somewhat cherty, dolomitic limestone. The upper portion of most Mescal sections contains a massive algal member with a maximum thickness of about 100 feet. This algal member is composed almost entirely of spheroidal masses that have a concentric, shell-like structure with a maximum diameter of several inches. It generally forms cliffs and is the only definite horizon marker in the Mescal.

4/ Wilson, Eldred D., Asbestos Deposits of Arizona: Ariz. Bur. of Mines Bull. 126, 1928, p. 34.

5/ Ransome, F. L., Geology of the Globe Copper District, Arizona: Geol. Survey Prof. Paper 12, 1903; Some Paleozoic Sections in Arizona and Their Correlation: Geol. Survey Prof. Paper 98 (k), 1917, pp. 133-166.

6/ Stoyanow, A. A., Correlation of Arizona Paleozoic Formations: Geol. Soc. American Bull., vol. 47, 1936, pp. 459-540.

7/ Darton, N. H., A Résumé of Arizona Geology: Arizona Bureau of Mines Bull. 119, 1925, p. 199.

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The Apache group has been intruded by dikes and sills of diabase, usually along bedding planes. The beds are sometimes separated by hundreds of feet of diabase. Some sills have crosscutting relationships (figs. 5 and 6). The diabase generally weathers to smooth, steep slopes but contains many hard sheets with columnar cleavage that form great cliffs (fig. 8). These diabase intrusions are generally considered older than the Troy, but a few exposures show that some diabase was intruded into the Troy quartzite.

Structure

The regional structure is that of a broad, nearly horizontal plateau, gently downwarped toward the east, as shown in the three cross sections by Darton (fig. 9).7/ The greater part of this plateau area is only slightly affected by block faulting. Block faulting is more prominent toward the south in the vicinity of the Bear Canyon mine, toward Globe, and in the Sierra Ancha Mountains on the east.

Minor faulting was noted in all the asbestos mines and minor folding in some of them. Wilson8/ and Trischka9/ pointed out that the larger lenses of asbestos formed in selected beds of the limestone, spreading outward from groups of parallel crosscutting fissures or from two intersecting zones of such fissures. The long axes of the asbestos lenses lie in the fissure zones. At some mines there was minor warping of the beds into low arches or troughs along with the fracturing. These localities were especially favorable to the formation of commercial asbestos bodies. Shride reported that these fractured and warped areas have many small thrust faults that turn into bedding-plane faults and that these bedding-plane faults were important factors in localizing the bodies of asbestos. Wilson described the fracture patterns at many individual mines in his bulletin.

Regional Zones of Fracturing

The mines and prospects in the Salt River-Chrysotile area and those in the southern half of the Sierra Ancha Mountains lie in an east-west belt about 8 miles wide. This distribution suggests that this belt is a zone of the minor fracturing and folding that controlled the localization of the asbestos deposits. The Mescal limestone is missing in the middle part of the belt, between Cherry Creek and Canyon Creek, where the underlying Dripping Spring quartzite and the basal granite are exposed. In the downthrown fault block between this middle area and the Sierra Ancha (sec. C, fig. 9) the Mescal limestone outcrops in the steep walls of Cherry Creek canyon. This canyon is so extremely rugged as to discourage prospecting.

The broad exposure of the Mescal limestone farther north, between Cherry Creek and Canyon Creek, has many more prospects than are indicated on the map. Mapping of these does not indicate zoning. As has been noted, the asbestos-bearing limestone outcrops in the walls of rugged canyons. About half of the

8/ Wilson, Eldred D., Asbestos Deposits of Arizona: Arizona Bureau of Mines Bull. 126.

9/ Trischka, Carl, Asbestos and the Arizona Industry: E. & M. J., vol. 124, 1927.

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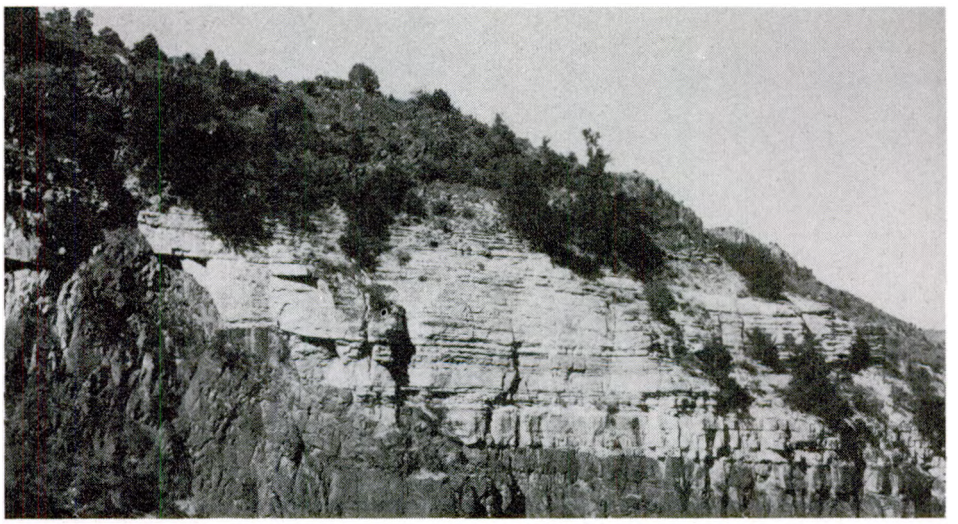


Figure 5. - A typical example of limestone-diabase contact. The contact is concordant at right and cross-cutting at left. At extreme left concordant relations are again shown.



Figure 6. - A complicated limestone-diabase contact.

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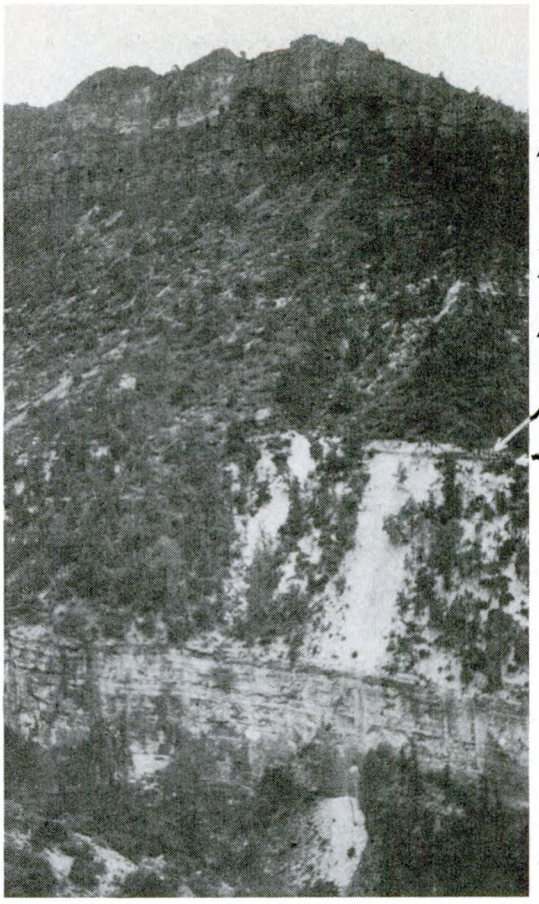


Figure 7. - McIntyre's Mine in Salt River Draw.

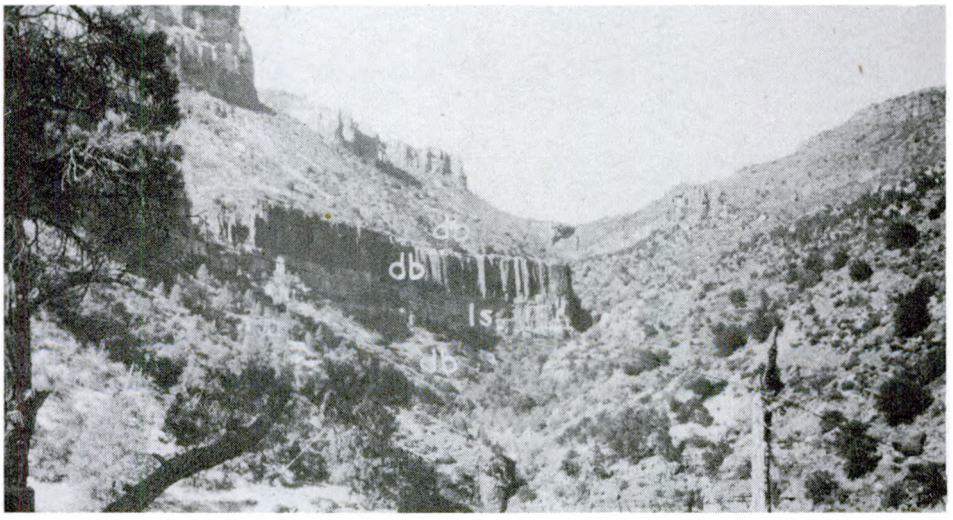


Figure 8. - View of Salt River Draw, showing columnar structure of diabase, as well as weathered diabase slopes.

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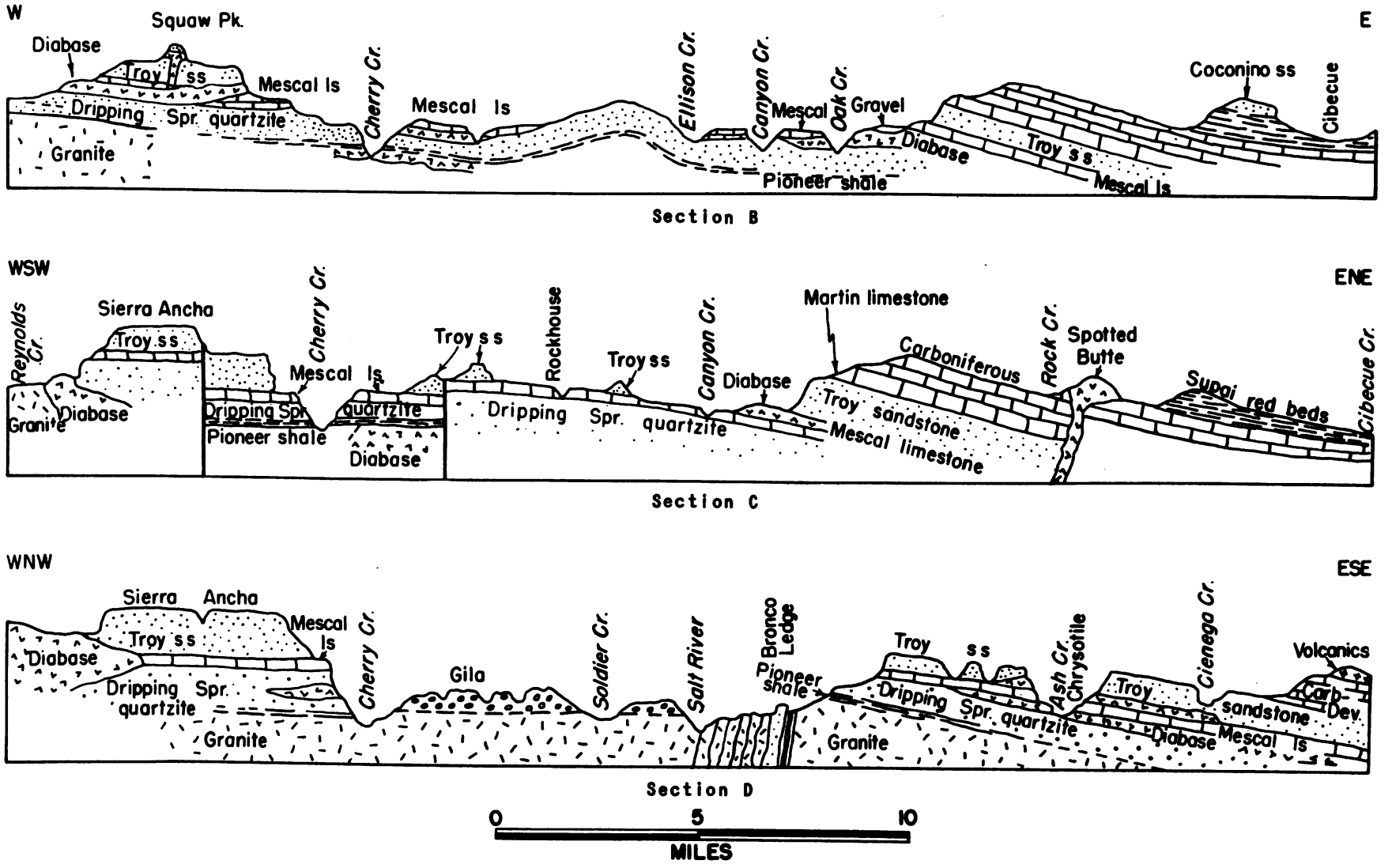


Figure 9. - Sections across the asbestos country.
By N. H. Darton, Arizona Bureau of Mines Bulletin 119, page 229.

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Mescal within the Salt River-Chrysotile area of asbestos mines has been eroded away. Erosion has removed much of the Mescal in Cherry Creek Canyon. It may be that drainage followed regional zones of minor fracturing. Field work to discover and delimit such zones of fracturing might be successful in outlining favorable areas for exploration.

Origin of the Asbestos

Wilson[10] states that

> The proximity of diabase to the asbestos deposits of Gila County suggests that the asbestos owes its origin to the diabase. The association of most of the best fiber-bearing bodies with transverse fissures indicates that the asbestos was deposited from mobile solutions which used those fissures as pathways of entry to such strata as were amenable to development of serpentine and asbestos.
>
> *** Microscopic examination of the diabase indicates that it has undergone hydrothermal alteration. Probably a final emanation from the diabase magma brought about this alteration and also the development of the serpentine and asbestos. Sufficient magnesium and silicon for these minerals may have been derived wholly from the olivine of the diabase, or part of the magnesium may have been supplied by the Mescal dolomitic limestone.

Shride[11] described the factors that controlled asbestos deposition as follows:

> The faulted bedding planes of massive limestones were major channelways for the mineralizing solutions, which replaced the limestone by serpentine. Most of the massive-limestone beds occur within the top 45 feet of the lower member of the Mescal formation; therefore, most of the asbestos deposits are within this stratigraphic interval. About half of the commercially important asbestos-serpentine zones are in the first 10 feet below the base of the algal member, and most of the other minable zones are in the limestones that are 25 to 40 feet below the base of the algal member. The deposits that are exceptions to this generalization are associated with other massive beds or are along major thrust faults.
>
> Chemical composition and initial porosity of the different limestone beds influenced the type and amount of metamorphism to a small degree, but do not appear to have been significant factors in the localization of asbestos-serpentine zones.

10/ Wilson, Eldred D., Asbestos Deposits of Arizona: Arizona Bureau of Mines Bull. 126.

11/ Shride, A. F., Results of the Geological Survey-Bureau of Mines Exploratory Program in the Asbestos Districts of Gila County, Arizona: Unpublished report, Jan. 1944.

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If diabase sills or dikes did cut across a favorable horizon or to a point near a favorable horizon in the limestone, a commercial deposit of asbestos was much more likely to have formed than if the intrusives were not emplaced near a favorable horizon. However, some commercial deposits are as much as 70 feet stratigraphically above diabase. The proximity of diabase seems to have been an important factor in the localization of asbestos deposits, not because the diabase was a near source or channelway for serpentine and asbestos-forming solutions, but because diabase intrusion fractured and folded the limestone. Post-intrusion bedding-plane and thrust faulting caused much fracturing of the limestone in beds that had been folded. Faulting began previous to diabase intrusion and continued until after mineralization ceased. Therefore, faulting, the effects of which were more intense in massive beds, was a factor in localizing diabase sills and dikes near the favorable horizons for asbestos formation. In many places, sills followed the same bedding planes that are mineralized in adjacent areas.

Bedding-plane faulting was the greatest single factor in the localization of the asbestos deposits. If bedding-plane faulting is not extensive, the asbestos deposits are likely to be limited to the limestone that was deformed by diabase intrusion. Most of the deposits in the district are limited to such folded limestones; in general, only a few tens of tons of asbestos can be mined from such deposits.

Asbestos deposits are also localized near shear zones or swarms of strike-slip faults. Such swarms or zones are rare in the district.

In a few areas, the intrusion of numerous dikes and cross-cutting sills caused many folds in the limestone. Any one of these folds was relatively unimportant in localizing a large deposit of asbestos. In an area containing many such structures, the possibilities for the formation of large asbestos deposits were good. Multistructural areas of this sort are rare; the Chrysotile area is an example.

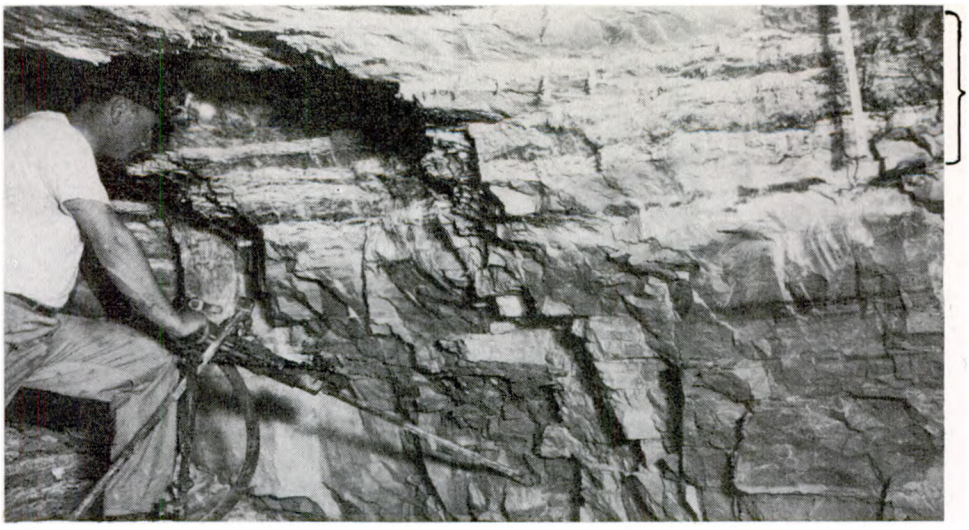
Mode of Occurrence

Arizona asbestos is invariably found in veins within bands of serpentine. The veins vary in thickness from a fraction of an inch to several inches and roughly parallel the borders of the enclosing serpentine. They are seldom continuous over long distances, but split into smaller veins or coalesce and form larger veins. The thicker veins frequently have longitudinal partings that reduce the apparent fiber length. Because of the tendency of asbestos veins to pinch or swell suddenly, their continuity and probable volume are difficult to predict.

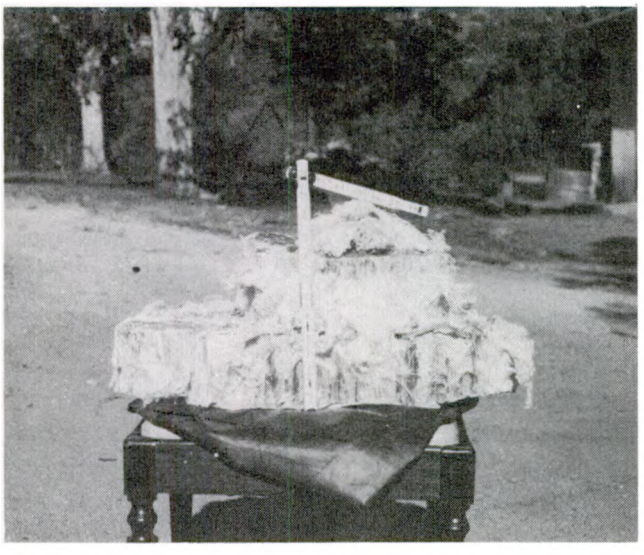
The serpentine bands vary in thickness from a few inches up to 2 feet or more and may contain 1 to 20 or more fiber seams. Local occurrences show

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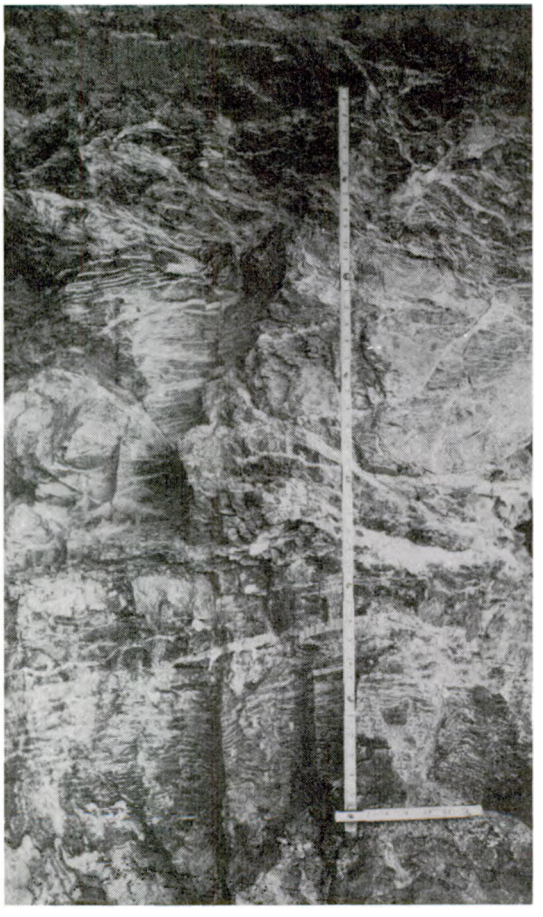
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A stope in an asbestos mine



A block of very long fiber



A 4-foot band of serpentine containing more than 100 asbestos veinlets. Enders White Tail No. 2.

Figure 10. - Typical asbestos occurrences.

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as much as 4 or 5 feet of serpentinized zone, containing over a hundred veinlets of asbestos (fig. 10). Often two or more asbestos zones are separated by a few feet of limestone, so that both can be mined in one heading. Elsewhere, multiple zones may be 10 to 30 feet apart.

The term "bone" is locally applied to a band or layer of serpentine in which the change to asbestos apparently was arrested in the initial stage. It may contain only minute traces of fiber or may have a considerable quantity of tufts of short fibers within the matrix of serpentine.

Almost invariably, little veins of fibrous calcite are in close association with asbestos seams. The only metallic mineral found in association with the asbestos is magnetite in small quantities. More commonly, magnetite is found in local concentrations, probably as replacement of limestone and associated serpentine, in areas above the asbestos zones.

NOTES ON ASBESTOS

Asbestos is not the name of a distinct mineral species, but is the commercial term applied to the fibrous varieties of several minerals, which differ widely in chemical composition. Among these are chrysotile, anthophyllite, tremolite, actinolite, amosite, and crocidolite.

Arizona asbestos is of the chrysotile variety, a hydrous magnesium silicate with the same chemical composition as serpentine. The fibers of chrysotile occur as "cross fiber"; that is, the fibers of which the material is composed and into which it may readily be separated lie approximately perpendicular to the walls of the vein.

There are two types of cross-fiber chrysotile - soft and harsh. Soft fiber feels smooth or soapy and can be twisted and bent between the fingers, and individual fibers are extremely flexible and strong. The longer fibers of this type represent the spinning grades. Harsh fiber is splintery, prickly, and somewhat brittle, so that a small bundle of it breaks if twisted a number of times.

There is a third type of chrysotile called "slip fiber," which is relatively rare in the Arizona deposits. Appreciable quantities are found in only one mine. This type occurs in slickensided fault planes, usually caused by thrust faulting, and is bedded on the fracture or slipping plane in a flat position. Owing to the manner of occurrence, these fibers may appear to have considerable length, but this is due to the overlapping of the fibers, which are all matted together, more or less in a parallel position. Slip fiber is less valuable than cross fiber because it is intimately mixed with finely crushed serpentine, which makes it difficult to mill out a clean fiber product.

All gradations between harsh, brittle fiber and silky, soft fiber can be found in the district. Probably two-thirds of the asbestos exposed in the various mines and prospects is soft fiber. A vein of soft fiber may lie close to a vein of harsh fiber in the same mine. At some places an asbestos vein changes from soft to harsh fiber, or vice versa, in a few feet. Some mines have only harsh fiber.

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When separated from the rock and all gritty particles, most of the chrysotile asbestos exhibits extreme delicacy and silkiness to the touch, with great adaptability for spinning. All fibers exhibit the grouping together of numerous fine threads within what appears to be a single fiber. The actual size of the fiber - that is, the diameter - is consequently indefinite, and although careful measurements have been made, which show that the smallest diameter so far determined is 0.00075 millimeter, it can be demonstrated that even the finest filament measured is composed of finer threads.12/

The Canadian Department of Mines built a special machine for the purpose of determining the breaking13/ strength of asbestos fibers, but the tests failed entirely, owing to the fact that the minute filaments of the fiber slipped past each other instead of breaking. In the asbestos industry, tensile-strength tests are made in the factories with asbestos rope or yarn.

MINING METHODS

The nearly flat asbestos zones usually outcrop in steep cliffs. The mines are opened by adits on the ore horizon, and mining is conducted either by modified room-and-pillar methods or by longwall stoping with backfill.

Development work in asbestos mines cannot be planned as definitely as in the mining of most other minerals, as the veins pinch and swell irregularly and are erratic in size and distribution.

Prospectors and some small mine operators usually strip the waste from above the ore zone and moil out the serpentine-fiber material from the floor. In the larger mines the serpentine-asbestos band is carried at the top of the drift, and the stopes are developed by progressively widening the opening. The barren limestone below the ore zone is removed by undercut drilling and blasting. When the cut holes are drilled, horizontal holes also are drilled at about 5-foot intervals immediately above the ore zone. The cut holes are shot first, and as much of the waste as possible is shoveled into the backfill, only working room at the face being maintained. The remainder of the waste is trammed to the dump. The material of the serpentine-asbestos zone is then dropped upon the clean floor by lightly blasting the top holes. This material is then hand-sorted. All the limestone and barren serpentine are rejected, and the serpentine-fiber material is trammed to the surface for removal to the mill.

Owing to the necessity for making the stopes high enough for men to work and also to the relative thinness of the asbestos streaks, the ratio of commercial fiber recovered to rock removed is about 1 ton to 75 or 100 tons. Experience in the district has shown that 40 to 45 percent of the waste can

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12/ Ross, James Gordon, Chrysotile Asbestos in Canada: Canadian Department of Mines Bull. 707, 1931.

13/ Cirkel, Fritz, Chrysotile-Asbestos: Its Occurrence, Exploration, Milling, and Uses: Canadian Department of Mines Report 69, 2d ed., 1910, p. 84.

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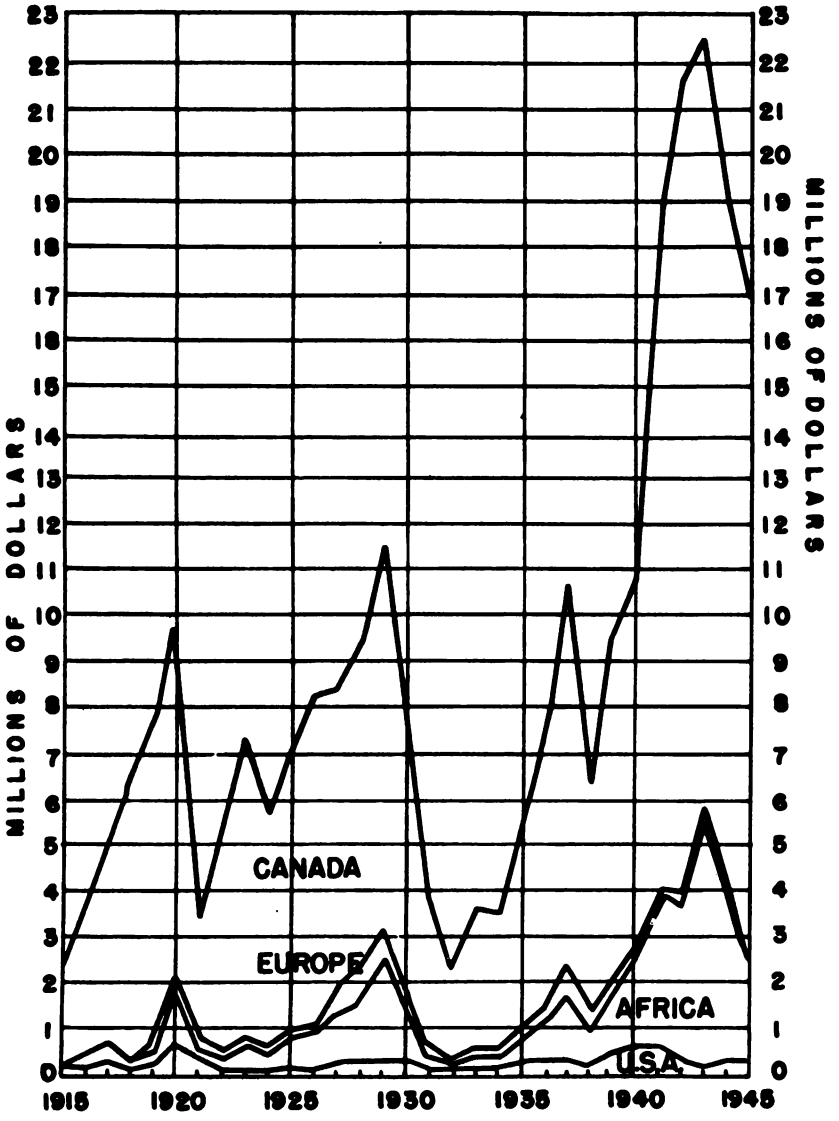


Figure 11. - Value of raw asbestos processed annually in the United States, 1915-1945, by sources.

From Minerals Yearbook, 1940-1943, and Mineral Market Report M.M.S. No. 1405

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be left in the mine by maintaining walled entries and by close gobbing. One property has a continuous stope 850 feet long by 200 feet wide in which the roof is supported mainly by the gob pile, as very few pillars were left.

Conditions are most favorable for mining when two or more asbestos zones of workable size are close enough to be worked in one operation. Where two zones are only a few feet apart, the intervening limestone is shot out by cut holes and mucked out. Then the upper zone is dropped by top holes, and the lower zone is shaken up by lifters at the same time.

Where the dip of the ore-bearing strata is too great to run near-level entries, it becomes necessary to extend haulageways below the advancing stopes. Raises are put up to the ore zone to open new faces and facilitate the removal of ore and waste.

PRODUCTION

Because of the small number of producers, publication of annual production figures for Arizona would reveal confidential data submitted to the Bureau of Mines by individual operators. As a consequence, the yearly production of asbestos in Arizona cannot be compiled from the published records of the government statistical services. The most complete record available (table 1) was compiled by Eldred D. Wilson of the Arizona Bureau of Mines.14/

The volume of production has varied widely with fluctuations in price. During periods of low prices, little asbestos was produced beyond that mined in doing the annual assessment work, and even less was marketed.

GRADING AND MARKETING

Although the United States uses more asbestos than any other country and consumed the greater part of the world's production in the earlier years, domestic production constitutes only a very small percentage of the raw material consumed. By far the greater part of raw asbestos is imported from Canada, but important amounts of the longer fiber are obtained from Rhodesia and British South Africa, and appreciable quantities came in from Russia during two periods (fig. 11). Arizona supplied the greater part of the domestic production up to about 1933, but Vermont now produces a much greater tonnage than Arizona. However, Arizona produces all the long-fiber chrysotile asbestos mined in this country.

The price for Arizona asbestos has necessarily followed the Canadian price because of the predominance of Canadian asbestos in the United States market. The early Arizona production was less in demand than Canadian asbestos because of poor grading in Arizona, where much of the asbestos was produced by small, inexperienced operators. Better grading was gradually established, and the Arizona product was standardized in four grades, as follows:

14/ Excerpt from a tabulation, "Production of Nonmetallics in Arizona," compiled and published by Arizona Bureau of Mines.

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Grade	Length of fiber
No. 1 spinning fiber	3/4 inch or longer
No. 2 spinning fiber	5/16 inch to 3/4 inch
No. 3	1/8 inch to 5/16 inch
No. 4	Less than 1/8 inch

TABLE 1. - Yearly production of asbestos in Arizona

Year	Tons	Value	Average value per short ton
1914	50	$17,500	$350
1915-18 (inc.)	1/1,900	1/467,000	1/246
1919	423	219,950	520
1920	1,200	625,822	522
1921	413	311,768	755
1922	93	1/27,000	1/290
1923	4	1,133	283
1924	1/132	1/30,551	1/231
1925	1/80	1/35,000	1/438
1926	100	1/40,000	1/400
1927	1/1,250	1/365,000	1/292
1928	1/1,500	1/435,000	1/290
1929	934	269,785	289
1930	683	177,912	260
1931	184	50,000	272
1932-34 (inc.)	1/34	1/9,000	1/265
1935	-	-	-
1936	464	41,780	90
1937	648	76,059	117
1938	942	31,063	33
1939	904	95,807	106
1940	1,197	149,290	125
1941	2,574	166,027	65
1942	1,742	101,061	58
1943	1,459	197,304	135
1944	696	158,272	227
	19,606	4,098,364	209

1/ Estimated.

The No. 1 and No. 2 grades correspond, respectively, to Canadian No. 1 crude and No. 2 crude. No. 3 is slightly higher-grade than Canadian shingle stock, and No. 4 corresponds roughly to Canadian cement stock. The Vermont product competes with the last two grades.

Figures 12-A and 12-B are price graphs of the principal grades of Canadian asbestos. The prices went very high during and immediately after World War I. No. 1 crude sold for more than $3,000 per short ton early in 1920. In 1921, Rhodesian and South African asbestos began to come into competition with Canadian asbestos and depressed the price to low levels by 1923. The

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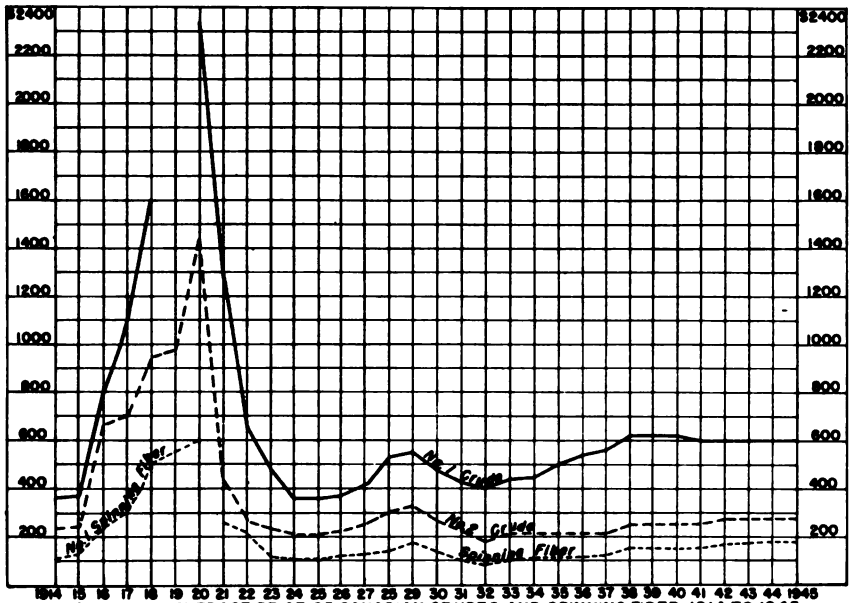


FIG. 12A-YEARLY AVERAGE PRICE OF CANADIAN CRUDES AND SPINNING FIBER, 1914 TO 1945

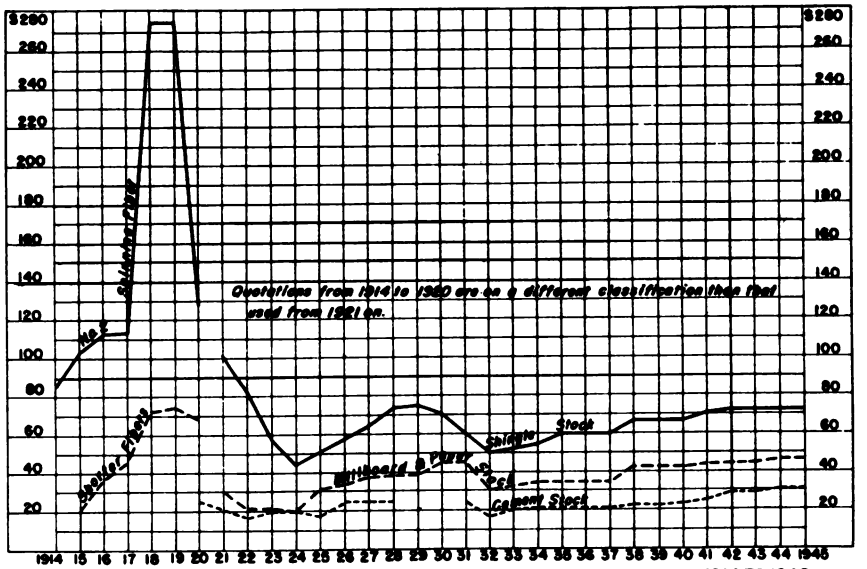


FIG. 12B-YEARLY AVERAGE PRICE OF LOWER GRADES OF CANADIAN ASBESTOS, 1914 TO 1945

From Mineral Resources of the United States, U.S. Geological Survey, 1914 to 1920; Cement Stock, 1920 to 1934. From U.S. Bureau of Mines I.C. 6869, for 1921 to 1934. From E. & M.J. Metal and Mineral Markets, 1935 to 1945

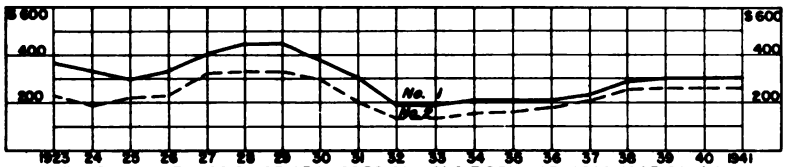


FIG. 13-YEARLY AVERAGE PRICE OF RHODESIAN LONG FIBER ASBESTOS, 1923 TO 1941

From U.S. Bureau of Mines I.C. 6869 and Minerals Yearbook, 1935 to 1941. Late quotations not available.



FIG. 14-YEARLY AVERAGE PRICES OF VERMONT ASBESTOS, 1931 TO 1945

From U.S. Bureau of Mines I.C. 6869 for 1931 to 1934. From Minerals Yearbook, 1935 to 1942
From E. & M.J. Metal and Mineral Markets, 1943 to 1945.

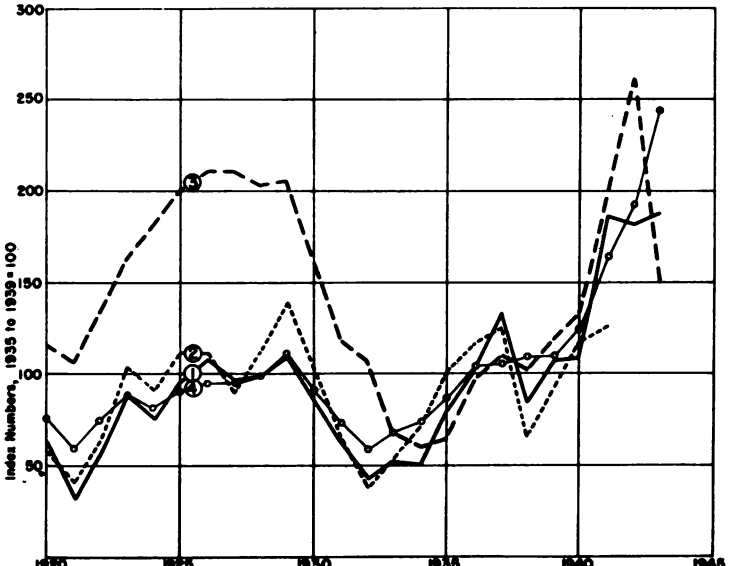


FIG. 15-CONSUMPTION OF ASBESTOS COMPARED WITH TOTAL PRINCIPAL CONSUMING ACTIVITIES

Units reduced to percentage of 1935-1939 average. After Minerals Yearbook, 1941 & 1943

①Asbestos Consumption, ②Automobile Production, ③Total New Construction, ④Industrial Production.

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mines of Rhodesia and South Africa produce a comparatively high percentage of long fiber. Equivalents of No. 1 and No. 2 crudes only are imported into this country and sell for about one-half the price of the Canadian crude (fig. 13).

Rhodesian and South African long-fiber chrysotile is in direct competition with the Nos. 1 and 2 grades of Arizona asbestos. Both are used for electrical-cable insulation. The Canadian asbestos contains too much iron to use it for this purpose. South African blue asbestos (crocidolite) and amosite are in strong competition with Canadian and Arizona spinning fibers for other purposes.

PRINCIPAL USES OF ASBESTOS

One of the leading uses of asbestos is for clutch and brake linings in automobiles and other power-driven machinery. Formerly, nearly all these linings were made of woven fabric. Now some 30 percent are molded and can use shorter grades of fiber. The most extensive use is in building construction. Large quantities are used for shingles and other roofing, also for heat insulation in house building and in industrial construction. Still another important use is for conduits for corrosive liquids and protective coatings against corrosive liquids and gases. The graphs in figure 15 show how the consumption of asbestos varies with building construction, automobile production, and general industrial activity.

PRESENT ACTIVITY AT ARIZONA MINES

Three operators were mining asbestos in July 1946 - the Phillips Asbestos Co., The Republic Filters Co. at the Regal mine, and the Globe Asbestos Co. at the Fiber King mine. All three operate mills. Enders is shipping some crude asbestos from stock along with crude obtained from dumps at various mines. Roger Q. Kyle's custom mill at Globe is operated intermittently on ore that he purchases. The crude asbestos is fiberized and blended to suit the demand of his market.

FUTURE OUTLOOK

Prices of crude asbestos in 1946 remained at the 1944-45 level. Demand increased during 1945 and tends to be higher. Building construction, the largest single consuming industry, is increasing. Increased automobile production and industrial installation also will support the uptrend. Reconstruction in war-devastated countries will increase the demand.15/

Arizona mines must compete with the much larger mines of Canada and Vermont, which are near the principal consuming centers in the East. This competition can be met by the longer grades of fiber and by specialized fiberized products but cannot be met by the shorter grades. However, markets for these latter grades are opening in the West. Increasing industrial production on the Pacific coast may make an outlet for Arizona asbestos there

15/ Bowles, Oliver, Asbestos Industry in 1945: Bureau of Mines Mineral Market Report MMS 1405, 1946, 5 pp.

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and reduce the freight differential against the Arizona product. One large manufacturer, who has a plant near Los Angeles, recently acquired a mine and a mill in Arizona. Thus, sales of Arizona asbestos will tend to a higher ratio of the shorter fibers than formerly.

BUREAU OF MINES WORK

The location and ownership of the four properties which the Bureau of mines explored are described on pages 4 and 5.

Standard mining practice was employed. At projects where new areas were to be opened, drifting began on the surface outcrop or at a predetermined elevation to cut the ore zone within the hill if the formation did not outcrop. Where extensions of known ore bodies were indicated, drifts were started at the ends of old stopes or adits. At each of the projects an explosives magazine was made by reconditioning an old prospect drift in the immediate vicinity and erecting a substantially built door designed according to specifications furnished by the Explosives Control Division of the Bureau of Mines.

SAMPLING

Asbestos veins have never been sampled by operators in this district. To determine the tonnage of fiber of various grades in reserves of ore developed by the Bureau, it was necessary to devise a sampling procedure.

The ideal sampling method would be to save and grade all the asbestos-bearing rock removed from the exploratory drifts, but several features of this method made it impractical.

In standard asbestos-mining operations, virtually all of the material of the serpentine-fiber band goes to the mill; therefore, to be representative, a sample should be taken by a continuous channel cut the full width of the serpentine-fiber vein for the entire length of the ore exposure in the exploration drift.

It was decided to cut the channel to a uniform depth of 3 inches along a variable vein width, and each sample was to represent 5 linear feet of drift at the center line. The ore zone along the side of the drift was first squared, so that it would present a relatively flat surface from which to measure the depth of the cut. A 5-foot interval marker had been constructed, the ends of which were capable of being extended at right angles to the base. A tape was stretched out along the center line of the drift, the base of the marker was laid on the tape, and each 5-foot interval was projected to the side of the drift. The samples were cut, sacked, moved to camp, and sun-dried.

The yield of the various grades of fiber from a given section of the serpentine vein was determined by actual milling of samples cut from that section.

If the value of the products recovered was sufficient to cover the estimated cost of mining, milling, and marketing, the material was considered

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commercial ore. On the basis of these results, the commercial limits of the ore body were determined.

The thickness of the serpentine-fiber streak is no criterion for judging ore, as the ratio of fiber to serpentine varies widely. Neither is it possible to judge the value of the ore by visual inspection and measurement of fiber length because, due to invisible partings, the fiber breaks up into shorter lengths in milling, resulting in a lower yield of the more valuable long fibers than would be anticipated.

Because of the obvious difficulties and expense of making a separate mill run for each 5-foot sample of 100 pounds or so, two to four samples were combined wherever the fiber was relatively uniform for a drift length of 10, 15, or 20 feet. Consequently, strict control of sample weights was necessary, as an over- or under-weight sample would introduce a magnified error in the calculated grade of the reserve blocks.

The theoretical weight of each 5-foot sample was calculated by using the specific gravity of the material (determined by tests to be 2.5) and the depth and average width of the cut. As the actual sample lengths were invariably more than 5 feet, owing to the irregularity of alinement of the drift walls, the samples were usually overweight.

The samples were reduced to the calculated weight by standard methods of mixing and quartering, or, as was occasionally necessary, the weight was increased by cutting additional material from the full channel length. This method of adjusting sample weights eliminated calculations involved in reducing results of irregularly alined samples to centerline measurements and automatically corrected weights of samples cut too deep or too shallow. The total weight of the samples milled was within one-quarter of one percent of the combined calculated weights.

This method of sampling asbestos veins is not considered entirely satisfactory. It was found that cutting the samples was much more difficult than had been anticipated. The serpentine matrix, although relatively soft, was found to be very tough. Instead of breaking out in chunks, only small chips or fragments could be moiled out. Therefore, some of the fibers were unavoidably cut or bruised, so that, in milling, more of the shorter lengths was indicated than originally existed in the vein.

Sampling by mining methods would have taken more time and money than was available. Saving all the vein material from each round of advance in a drift would involve small-scale stoping operations requiring at least double the time and cost per foot. The barren limestone would be undercut, blasted, and removed; the ore zone would then be shot down, partly hand-cobbed, and sorted to remove barren material, and the remaining asbestos-bearing material would be transported to the mill. A 6-inch serpentine-fiber band recovered from 4 feet of advance in a drift 5 feet wide would represent about 1,500 pounds of mill feed.

After a vein has been opened by a drift, it would be possible to mine out a sample by means of a narrow stope along the side of the drift. It is

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thought that it would be impractical to break a stope round less than 2 feet in width. Again assuming a 6-inch vein thickness, every 10 feet of sample would represent about 1,500 pounds of material.

Such large quantities of sample material would involve difficult transportation problems. At project 2302, the samples were packed on burros over a narrow, steep trail for half a mile to the road and then trucked a mile to the Phillips mill. From project 2303 the samples were trucked 94 miles to the mill. The usual custom milling charge is $15 per ton.

The mining work done at the four projects was as follows:

Project No.	Drifting, feet	Raising, feet	Open cuts, feet
2302	503		
2303	182		
2304	443		
2305	366	30	67
	1,494	30	67

Commercial asbestos was developed at projects 2302, Phillips Grandview No. 4, and 2303, Reynolds Falls Group, but not at the other two. Detailed descriptions of the four projects follow in chronological order.

PROJECT 2302, PHILLIPS ASBESTOS CO., GRANDVIEW NO. 4

The property of the Phillips Asbestos Co. covers approximately a 1-mile front along the precipitous ridges on the south side of Salt River, 2 miles southwest of the Salt River bridge on U. S. Highway 60. It is reached by 4 miles of graded dirt road branching off the highway 38 miles north of Globe. The area selected for exploratory work was on the north side of an eastward-trending ridge about 900 feet from its eastern end.

The mine is on the north side of a flat ridge between two of the many tributary canyons cut into the south wall of Salt River Canyon. The rim of the Salt River Canyon is at an altitude of about 5,000 feet, and the bed of the river is nearly 2,000 feet lower.

Description of the Ore Deposit

Around the ridge there is exposed a relatively flat-lying section of the lower Mescal limestone about 100 feet thick, which is in contact with thick diabase sills both above and below (fig. 16).

At the end of the ridge, where the asbestos-bearing zone outcrops near the bottom of the limestone, is a maze of small stopes and interconnecting drifts from which the better grades of asbestos had been mined several years ago. On the north side of the ridge, for 900 feet westerly from the end, the lower contact of the limestone with diabase is generally visible, but heavy talus obscures the formation for the next 1,000 feet west. This contact with the limestone is at a horizon above the asbestos zone, which is cut off some 40 feet within the hill by rapid thickening of the lower sill

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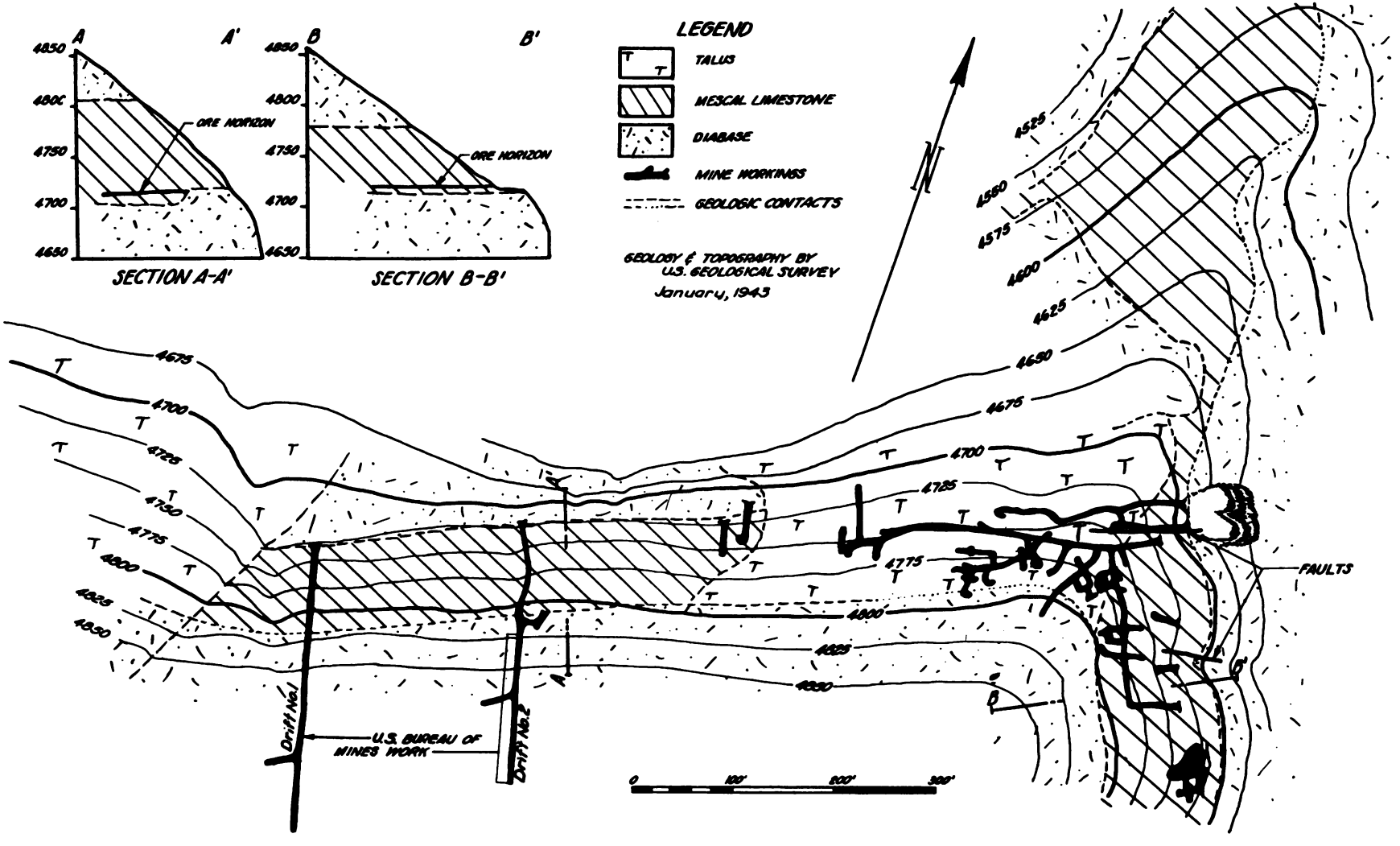


Figure 16. - Plan and sections - Grandview claims No. 4 and 5.

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Figure 17. - Plan and sections, Phillips Grandview No. 4 - Project 2302.

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along an axis roughly parallel to the face of the ridge. This cross-cutting feature was exposed by three existing tunnels, which had cut the asbestos zone at 100, 120, and 320 feet west of the end of the old mine workings.

The working site was chosen at the east edge of the talus slides 200 feet west of the most westerly of the old tunnels. The drift was to be started at a level which, as determined by geologic evidence, should cut the asbestos zone within the hill.

Bureau of Mines Exploratory Work

The work was begun in the first week of January 1943. A good camp was prepared by reconditioning several old buildings and repairing a quarter of a mile of truck trail to serve the campsite. The compressor was set up on the summit of the ridge near the road, and 1,000 feet of air line was laid down the hill to the site of the exploration drift. The ore zone was far below the road, and accessible only by a 2,500-foot trail, which was repaired and widened so that mining equipment, timbers, etc. could be packed down by burros.

Drift No. 1. - A bench was shot out on the cliff face to make working space, and drift 1 was started in the diabase about 8 feet below the level limestone contact. As this limestone was loose and blocky, heavy timber sets and spiling ahead were required to hold the ground. At 46 feet, the drift passed through the contact, here steeply dipping, and entered solid limestone. No further timbering was required. The drift was driven 289 feet into the hill on a bearing parallel to the next existing tunnel to the east (figs. 16 and 17).

The limestone against the crosscutting diabase contained three narrow serpentine-fiber bands, one at floor level, one at 4 feet, and another at 7 feet above the floor. The formations rose into the hill at about 1.50, so that the lower vein inclined gradually from floor level to 4 feet above track level at the end of the drift. Each of the two upper veins contained only a small amount of glassy, harsh fiber, did not improve in quality or size, and gradually pitched above roof level. These zones were occasionally checked by drill holes, but no change was indicated. Six-foot drill holes were also put down in the floor at intervals to determine the character of the formation below drift level. No fiber streaks were encountered, and there was no indication of proximity to the underlying diabase contact.

The lower, or main vein, which at the beginning contained very short fiber, showed gradual improvement in quality and quantity of fiber as the drift advanced. From the results of sample milling, the commercial limits of the ore body appear to be between 135 and 275 feet from the portal, with the best section at 215 to 225 feet. In the last 15 feet of drifting, the serpentine-fiber streak gradually thickened from 3 to 5 inches, but the fiber content was still below minable grade.

A crosscut was driven 30 feet west at 210 feet from the portal. The average grade of ore in this crosscut was better than that in the drift.

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Forty-seven 5-foot samples were cut in a continuous channel in the drift and crosscut.

Drift No. 2. - When enough men were available to drive two headings, work was begun in the old tunnel 200 feet east of drift 1. This tunnel had been driven as a "wheelbarrow" prospect and required reconditioning of width, height, curves, and grade before track could be installed and a mine car put into service. This location is hereafter called drift 2. The crosscutting diabase entered the floor at 45 feet from the portal, and the position of the drift was such that the lower serpentine-fiber band was carried at or near the roof. The limestone penetrated in the first 100 feet has numerous open cracks. These near-surface cracks had permitted ground water, probably charged with iron oxide and calcium salts, to filter through the asbestos seams, causing some discoloration and imparting a slight degree of harshness to the fiber for the first 50 feet of vein exposed.

This drift was extended an additional 147 feet, or a total of 270 feet into the hill. Toward the end, the drift was made 8 feet high to keep the updipping vein exposed. Although the vein persisted to the end of the drift with the quantity of fiber virtually undiminished, an increase in the number of partings reduced the fiber length to below No. 2 grade. From the results of sample milling, the commercial limit of the ore body is apparently between 75 and 215 feet from the portal.

A crosscut to the right was started at 180 feet from the portal and was driven 35 feet toward drift 1. An improvement in the grade of ore was indicated. Fifty-two 5-foot samples were cut in a continuous channel in the drift, crosscut, and an old stope that turns east from the drift 100 feet from the portal.

In the old prospect drift 200 feet east of drift 2, the two upper veins had been exposed, showing a small amount of harsh fiber similar to that in drift 1. Consequently, no attempt was made to explore these two veins from drift 2.

Sampling. - Channel samples were cut along 210 feet of drift 1 and along 215 feet of drift 2, also along the two short crosscuts from the drifts and the small stope east from drift 2, a total of 99 five-foot samples (fig. 18). Groups of the samples were combined, as shown on figure 18, and milled in the Phillips Asbestos Co. mill. Average width of the groups of samples and the mill yield of the several grades of fiber from each group are shown on figure 18.

The resultant grading is a little lower than it would be if the samples had been mined in the usual manner. During part of the work in drift 2, the owner furnished men to save the asbestos-bearing material. He reported that the recovery from 4 tons of this mill feed graded 0.5 percent No. 1 fiber, 20 percent No. 2 fiber, 20 percent No. 3, and 59 percent No. 4. The Bureau of Mines samples cut along this same section of the drift averaged 7.5 percent No. 2 fiber, 17 percent No. 3, and 76 percent No. 4. This comparison is indicative of the degradation of fiber by channel sampling but is not cited as a measure of such degradation.

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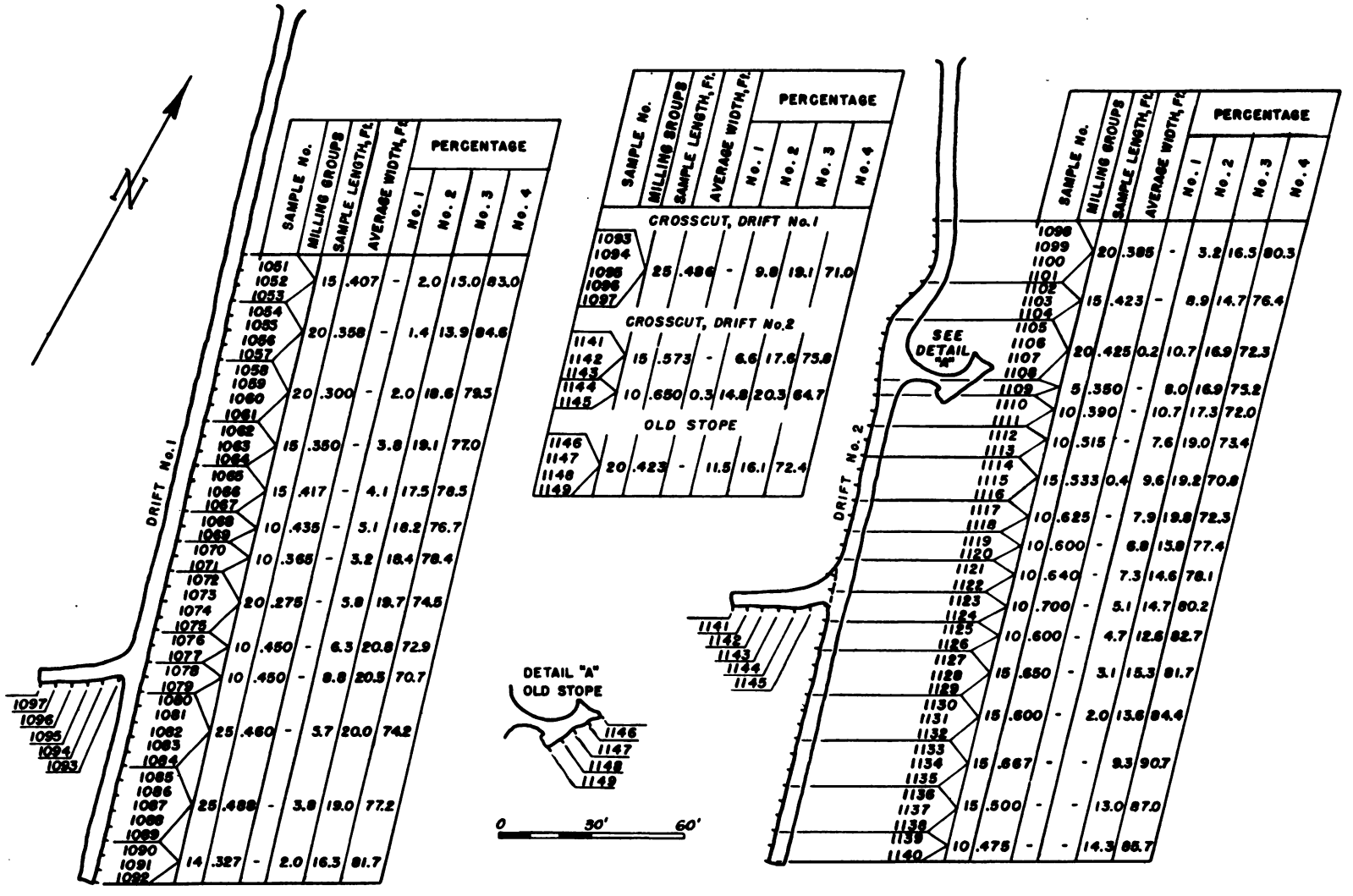


Figure 18. - Assay map, Phillips' Grandview No. 4, Project 2302.

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PROJECT 2305, ENDERS' WHITE TAIL NO. 2

Enders' White Tail No. 2 mine is in the Fort Apache Indian Reservation, on the north side of Salt River Canyon, about 1 mile north of the Salt River bridge on U. S. Highway 60. It is reached by a road that leaves the highway 5 miles northeast of the bridge. This road is narrow and rocky and has stretches of mountainside cuts with steep grades (fig. 2). It winds down around the canyon rim to a flat at the top of the limestone cliffs. The tunnel entrance is in the cliff face 75 feet below the flat.

The Salt River has here cut a canyon about 2,000 feet deep in a rolling plateau having altitudes of 5,000 to 6,000 feet. The sides of the canyon are dissected by tributary streams. The asbestos-bearing beds outcrop in the dissected walls of the canyon. The Phillips Grandview mine is 2 miles southwest of the Enders' White Tail, on the side of the ridge in the south wall of the canyon. The distance by road between the two mines is 20 miles. Precipitation is sufficient to support considerable vegetation. There is a good cover of pinon and juniper on the plateau. The lower limit of these trees is not far below the mine.

Geology and Ore Occurrence

At the White Tail, about 140 feet of the upper part of the Mescal formation lies between two thick sills of diabase. Of this outcropping limestone, the upper half represents the algal member. A northeast-trending, 6-foot, vertical, diabase dike crosscuts the limestone sheet and connects the two heavy diabase sills. Thin sills branch out from this dike and extend into the limestone for considerable distances. Minor thrust faults complicate the structure (figs. 19 and 20).

The asbestos-bearing strata outcrop under the algal formation about 80 feet below the top of the limestone cliffs. On the east side of the dike, a good grade of soft spinning fiber is exposed in an old tunnel and stope, which opened the ore zone for a length of 100 feet. The asbestos occurs in two zones about 3 feet apart, the upper zone immediately under the algal contact. This old work showed a concentration of asbestos in the area adjacent to the dike, which gradually decreases in quantity eastward and is noncommercial at about 60 feet from the dike.

This asbestos zone is 60 feet above the diabase. Very few commercial deposits occur at this distance above diabase, but because geologic conditions on the west side of the dike appeared to be similar to those on the east side it was thought that a body of asbestos might be found on that side. Consequently, it was decided to explore the area.

In November 1942, members of the Geological Survey made a geological map of the area in the vicinity of the proposed Bureau work. This mapping indicated that at about 900 feet back in the hill the limestone sheet was cut off by a low-angle, crosscutting diabase sill (figs. 19, 20, and 21); that this intrusive body had separated and raised this segment some 250 feet; that the northeast-trending, 6-foot, vertical dike likewise traverses this uplifted segment; that the contact between the algal and lower member of the formation

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was repeated at this higher elevation and could be exposed by trenching; and that there was a possibility that the same geological conditions that promoted ore deposition in the lower segment were present in this upper detached segment.

Bureau of Mines Exploration

Initiation of the project work was delayed a month by bad weather. The access road was improved, a camp was established, and a crew moved in about the middle of February 1943.

The Drift

A tunnel was driven roughly parallel to and about 20 feet west of the dike. At about 50 feet from the portal, an unexpected low-angle thrust fault was encountered, which had raised the ore zone above the drift level. It did not appear on the east side of the dike and was not visible on the surface. It was the first manifestation of the fact, later proved, that under compression the blocks on opposite sides of the dike acted as independent units, producing different patterns of deformation on the two sides.

The drift was continued for another 70 feet to reach a point from which to prospect the east side of the dike in advance of the old workings. No other fault was encountered, and the dip of the formation remained relatively level. Only small lenses of harsh fiber were occasionally cut in the bedding planes.

Two inclined raises were put up to reach the uplifted fiber zone, No. 1 at 120 feet and No. 2 at 60 feet from the portal. In both raises, the bottom of the algal limestone was found about 20 feet vertically above the track level.

Three fiber veins were cut in raise 1, approximately 1 foot apart, the topmost one against the algal contact. The upper vein was of a semi-harsh quality, but the other two showed soft, green asbestos of good quality. A small drift was extended a few feet toward the dike and also in the opposite direction, exposing 35 feet of ore zone. The veins pinched toward the dike and proved to be discontinuous in the opposite direction. As much as 3 to 5 inches of total fiber in two or three veins was exposed at some places, but pinched out within 10 feet or less. The asbestos occurrence was almost identical in 30 feet of drift from raise 2. Although good fiber was found in both these raise-drifts, it was in small lenses and the showing did not justify a connecting drift along the ore zone.

The main drift was continued when enough men were available to work two headings and was turned east to explore the area on the other side of the dike. The dike was found to be sheared and serpentinized on both borders, and the limestone beds are upturned against it. Thirty feet east of the dike, the base of the algal limestone dips down to the back of the drift. A narrow, serpentinized zone immediately under the contact contains small veins of fiber. Two discontinuous seams of asbestos were cut in the bedding planes several feet below the contact. The drift was continued 30 feet farther, but the serpentine zone decreased to 2 inches and the fiber seams pinched out, showing that the limit of mineralization had been reached (figs. 21 and 22).

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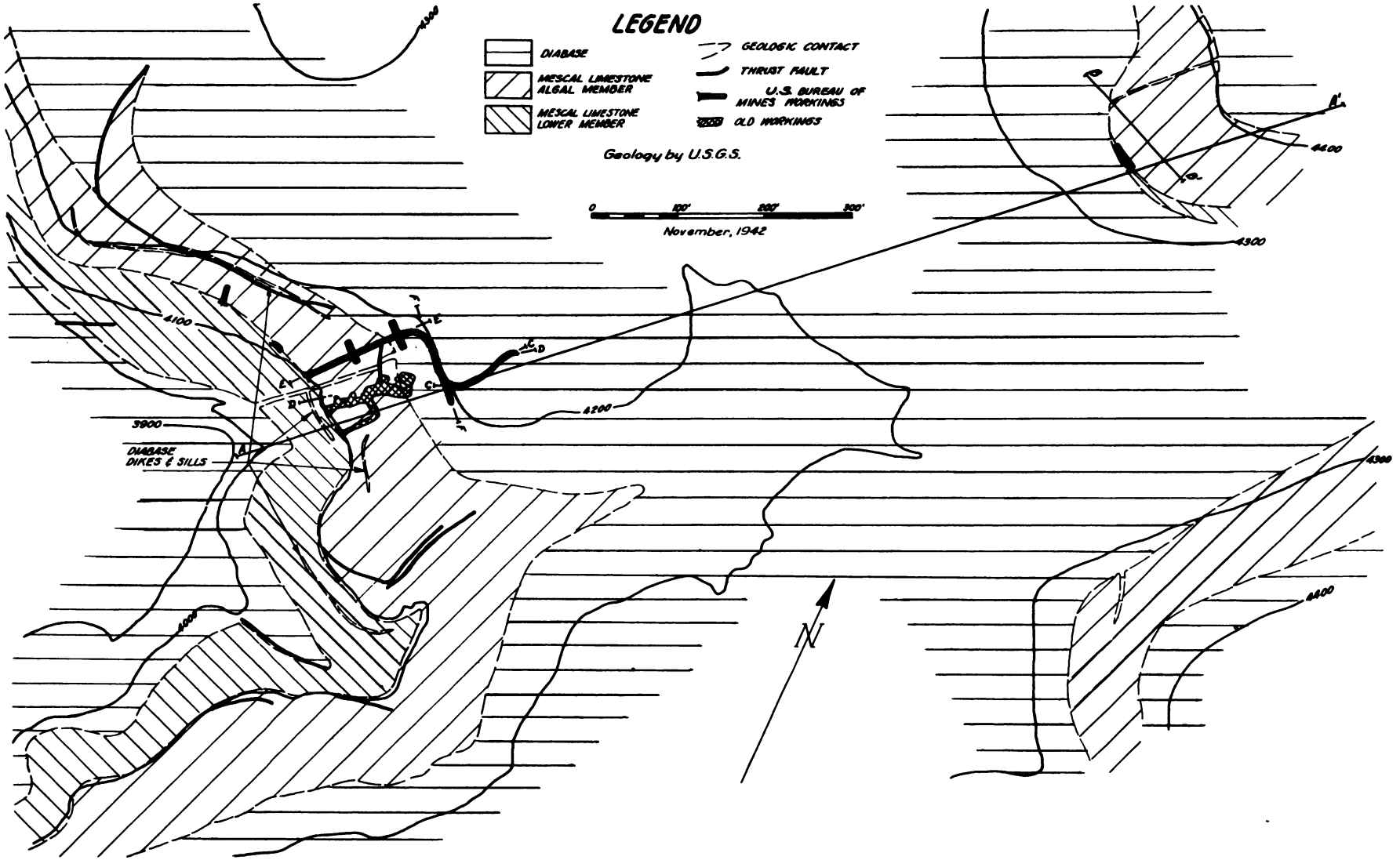


Figure 19. - Map of Enders' Whitetail No. 2 - Asbestos Project No. 2305.

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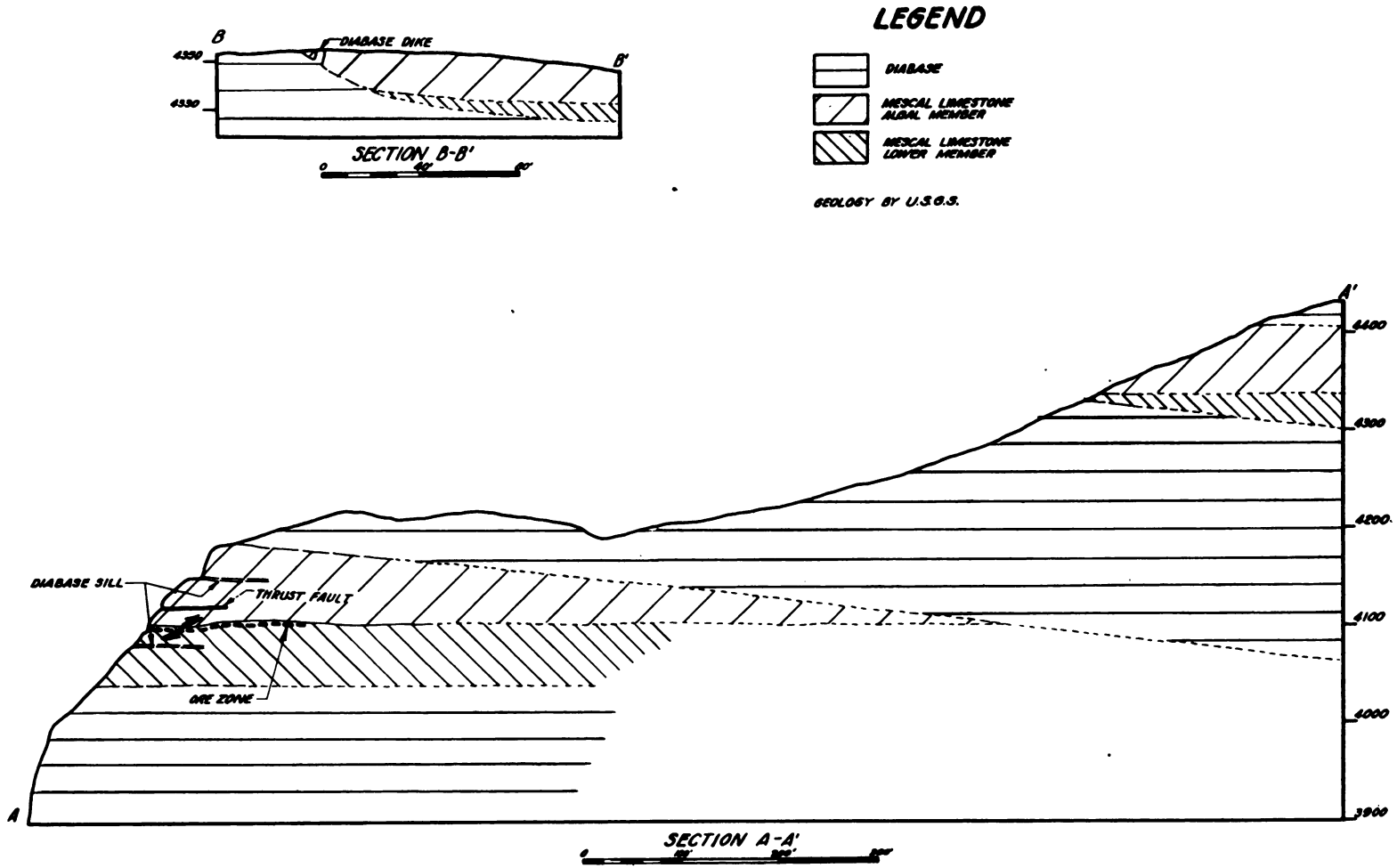


Figure 20. - Sections of A-A' and B-B'-Enders' Whitetail No. 2.

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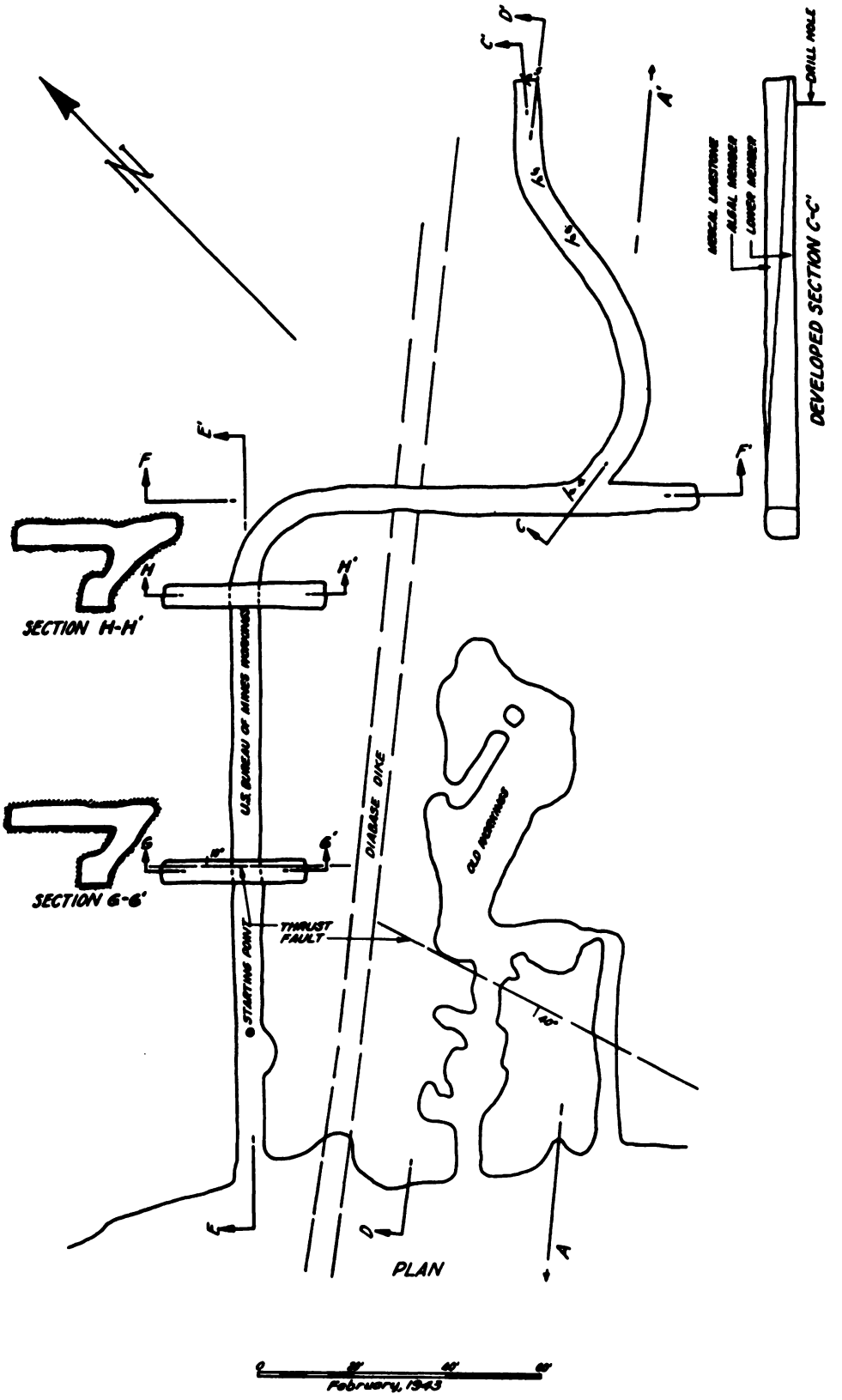


Figure 21. - Plan and sections - Enders Whitetail No. 2.

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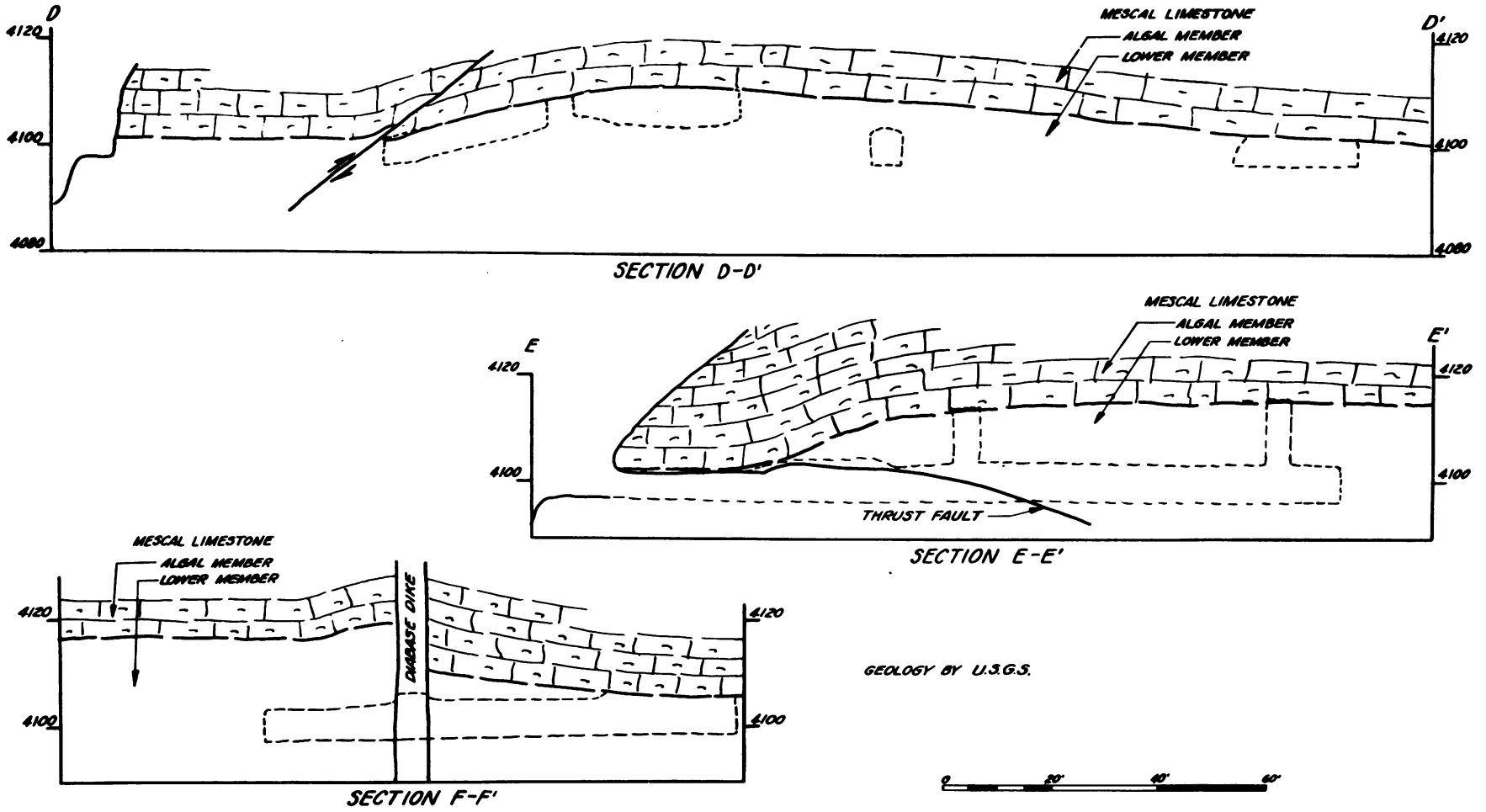


Figure 22. - Sections D-D', E-E' and F-F' - Enders' Whitetail No. 2.

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It was then decided to explore the area northeast, parallel to, and about 30 feet from the dike. The first round opened up a pocket of fiber 4 inches in total length, much of which was in strands of 1 to 2 inches. This proved to be a lens that decreased to a vein of 1/2-inch fiber within 10 feet.

In this area the formation was arched on an axis that trends north toward the dike (sec. D-D', fig. 22). The drift was turned along the strike of the formation to keep the ore zone near the top of the drift. To avoid cutting into the dike, the drift then had to be turned northeast, paralleling the course of the dike. The dip of the formation carried the base of the algal member down to within 18 inches of floor level, and as the last 30 feet of drifting had shown serpentine with only traces of fiber, the work was stopped after drilling a 6-foot test hole in the floor near the face of the drift. No fiber was found in the test hole.

Open Cuts

To check the possibility of an asbestos deposit in the upper detached segment, an excavation was made 40 feet east of the dike. This open cut exposed 3 to 5 feet of the strata immediately below the base of the algal member for a length of 32 feet (fig. 19). Serpentine was found to be poorly developed, and only one discontinuous asbestos vein was shown. It contained 1/16 to 1/2 inch of jointed, semi-harsh fiber of poor grade. Before abandoning this prospect, 6-foot drill holes were put down at the middle and at each end of the cut to test for possible lower veins. Little serpentine and no fiber was indicated by these holes.

Prospecting was done at two places west of the exploratory tunnel. Fifty feet west of the tunnel portal, a cut 15 feet long was made, exposing and undercutting the base of the algal member. A 6-inch serpentine-fiber zone was uncovered, showing 2 to 3 inches of "bone" but virtually no good fiber.

A second cut, 135 feet west of the tunnel portal, was opened for 20 feet into the hill. The stratum immediately below the algal contact, which normally represents the ore zone, was here found to be crushed and sheared by a bedding fault. In the solid formation below this shear zone was a vein of 1.5-inch glassy, harsh fiber, which pinched out within the length of the cut.

The small lenses of asbestos found were not sampled.

PROJECT 2304, ROGER Q. KYLE'S SLOAN CREEK GROUP

Exploration work was done on the Cowboy and Last Chance claims of Kyle's Sloan Creek group. The work could not be begun until mid-March, because snow and mud made the access road impassable for heavy equipment during the late winter. A camp was established within a mile of the project by reconditioning three old frame buildings.

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The mine is on the northeast edge of the Sierra Ancha District about 15 miles southeast of Young. It is reached by 15 miles of poor road that goes south from Bottle Spring, which is 83 miles north of Globe on the Young-Holbrook highway.

Sloan Creek and its tributaries have eroded this area into relatively shallow, V-shaped canyons, which are flanked by intervening mesas. The average altitude is about 5,400 feet, and the precipitation is sufficient to support a fair forest cover of pine, pinon, and juniper.

Geology and Ore Deposits

The Cowboy claim covers the south and east ends of one of the mesas, which is capped by Mescal limestone. The limestone is underlain by a thick diabase sill, which shows slightly upturned edges along its southeastern outcrop. A short distance above this outcrop, a narrow bench cut 350 feet long and several short adits exposed two asbestos-serpentine zones at 2 and 7 feet below the base of the algal limestone. The best ore had been found along the northern end of the cut.

Study by the Survey geologists indicated the possible presence of a relatively large-scale crosscutting feature of the underlying diabase sill, which strikes east nearly parallel to and about 500 feet back from the south edge of the mesa. The strata immediately under the base of the algal member are believed to be favorable beds for deposition of asbestos when diabase has crosscut them or when the diabase is relatively near, if fracturing or even slight folding of the strata resulted from the intrusion (figs. 23 and 24).

Bureau of Mines Exploration Work

In view of the seemingly favorable geological conditions on the Cowboy claim, it was decided to explore the asbestos-bearing horizon over the east end of the crosscutting axis (figs. 23 and 24). Drift 1 was driven 100 feet into the hill and exposed two serpentine zones about 5 feet apart immediately under the base of the algal limestone. The serpentine had a dull, grayish appearance and at no place in either zone was it found to be fiber-bearing.

Several tons of good fiber, much of it 2 and 3 inches in length had been taken from the northern end of the bench cut 450 feet south of drift 1. A 10-foot adit had been driven near the center of this "bonanza" lens, which showed the vein almost pinching out, except for a pocket of 1-inch jointed fiber in the face. To determine the limits of this deposit more certainly, it was decided to advance this heading.

The adit was extended an additional 27 feet (drift 2). Mineralization became weaker, and the drift was turned westward to keep the remaining serpentine and traces of fiber in sight. Work was stopped 37 feet from the portal, as it was evident that the limit of the mineralized area was being outlined.

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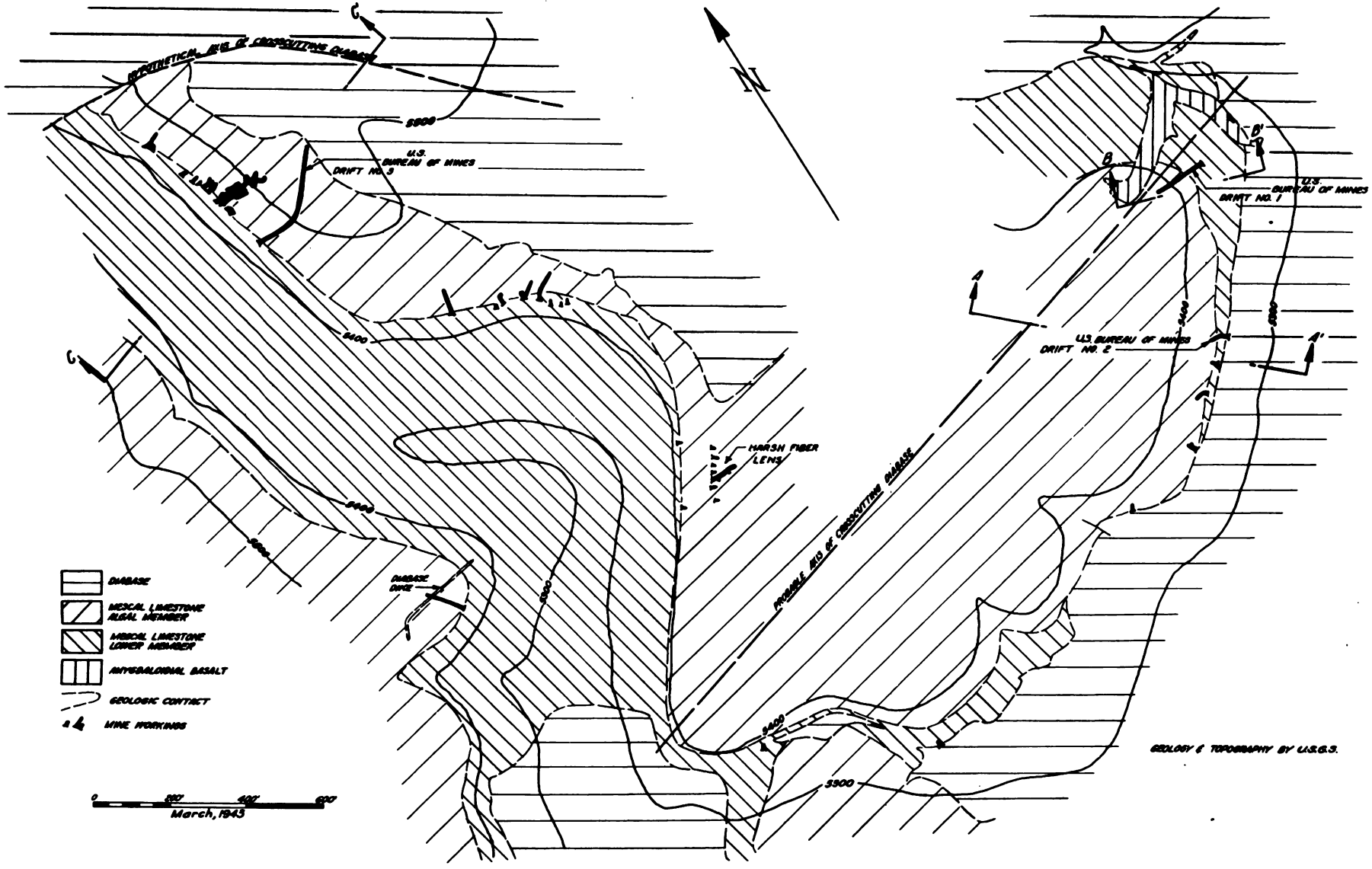


Figure 23. - Cowboy and Last Chance claims - Kyle's Sloan Creek group - Project No. 2304.

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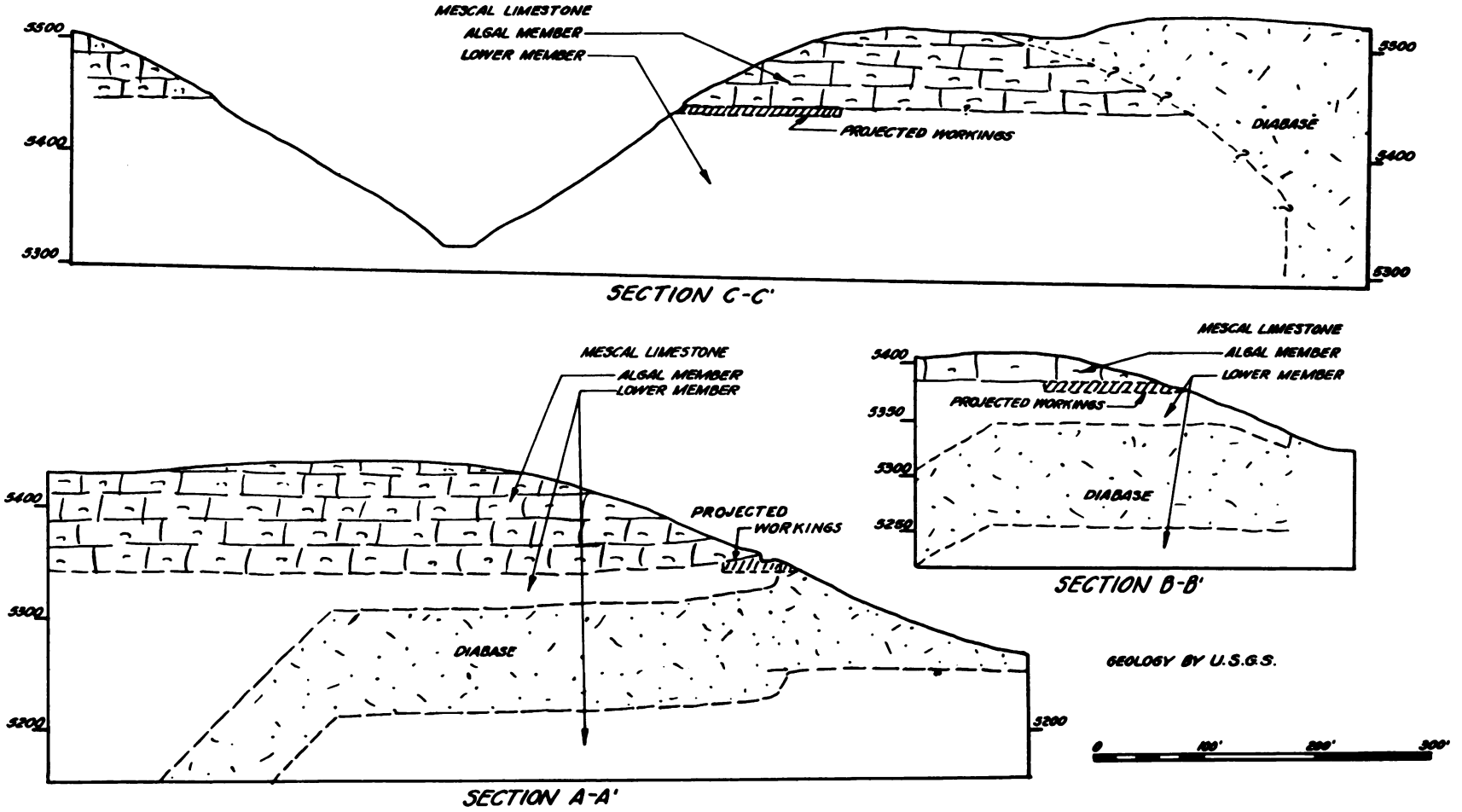


Figure 24. - Sections A-A', B-B' and C-C' - Cowboy and Last Chance claims.

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In the meantime, geologic mapping of the other fiber-bearing areas of the property suggested that a body of asbestos might be found on the Last Chance claim. The ore zone outcropped in several places along a nearly level horizon halfway down the side of the canyon and had been prospected in a number of places. The major work on this outcrop had opened the ore zone for 150 feet into the hill, with side stopes up to 40 feet wide. The serpentine-fiber zone was immediately under the algal limestone and averaged 24 inches in thickness. This zone contained up to 1.5 inches of fiber distributed in several asbestos veins. Most of the fiber was less than 1/2 inch in length, but all of it was soft and of very good quality. The possibility of an extension of the ore body appeared best to the south.

Drift 3 was started 150 feet south of the old work. Fifty feet of full-timbered entry was necessary to reach solid formation. As it was apparent that the formation was dipping into the hill, haulage by mine car was not attempted, and all muck was removed by wheelbarrow. Small veins of asbestos appeared at 70 feet from the portal, becoming more numerous for the next hundred feet and reaching a maximum of about 20 veinlets in 3.5 feet of serpentine at a flexure in the structure. Unlike many other deposits, the veins did not coalesce to form longer fiber.

As the ore zone developed a dip of 6° to the east, it was necessary to turn the drift northeastward to maintain a grade up which a loaded wheelbarrow could be pushed. The drift was driven 289 feet into the hill, prospecting the area to the south and east of the old workings. In the last 100 feet, the formation became level, and although the full face of the drift became serpentine or serpentinized limestone, the asbestos veinlets decreased in number and gradually pinched out. There was no evidence of asbestos in the last 65 feet.

The only diabase in the immediate vicinity appears as a sheet over part of the hill connecting with a major crosscutting feature back in the hill and parallel to the canyon. But the asbestos deposition decreased and disappeared as this diabase body was approached. Contrary to the common habit of asbestos deposits, the best fiber appears at the greatest distance from the crosscutting diabase.

The asbestos exposed in the drift was not sufficiently abundant or long to be minable; consequently, no samples were taken.

PROJECT 2303, REYNOLDS FALLS GROUP

The Reynolds Falls group of claims is in the Sierra Ancha Mountains at the junction of Reynolds Creek and its tributary, the South Fork. The area is reached by an ungraded, 4-mile dirt road, which branches off from the Globe-Young highway 49 miles north of Globe.

This region is in steep, mountainous terrain covered with pine forest. Except for the high Troy quartzite cliffs and bedrock exposed in the drainage channels, there are very few rock exposures, as the steep slopes are heavily covered with overburden.

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Description of the Ore Deposit

The ore zone is in the Mescal limestone about 65 feet above the relatively level contact with a thick diabase sill of great areal extent (fig. 25). The asbestos veins were originally found in the canyon bottom of the South Fork, and prospecting was confined to the immediate vicinity. As outcrops are few, the Survey geologists were unable to determine the stratigraphic position of the fiber-bearing zone within the Mescal formation. The algal member was not seen and may not be present in this section. The structural control that influenced the deposition of asbestos at this extreme distance from diabase was not definitely determined, as no dikes or crosscutting features are indicated. There are numerous more or less parallel, east-west premineral fractures showing slight horizontal movement, which may be related to the ore deposition.

The mine workings on the west side of the canyon had attained a maximum depth of 200 feet and a maximum stope or exploration width of 270 feet. A 66-foot adit was driven in the ore horizon on the opposite side of the canyon. The formation is obscured by overburden for 1,000 feet around the hill to the north, at which point several open cuts expose bedrock. One of these cuts is thought to be on the same stratigraphic horizon as the ore zone but shows only "bone" serpentine. The formations on the east side of the canyon likewise are heavily covered with overburden.

The Ore Zone

The ore zones exposed in the old workings are along bedding planes in the limestone about 65 feet above the diabase contact. These zones appear at several definite horizons within a vertical distance of 9 to 11 feet. The upper zone, which is carried at the top of the drifts and stopes, is 2 to 4 feet thick and is irregularly serpentinized in a wavy pattern with nodular serpentine common. Fiber occurs at any part of the zone in one to several veins. Previous operators state that they disregarded this zone as too erratic in attitude to be mined. The middle zone lies 2 to 3 feet below the bottom of the upper zone and consists of three serpentinized bands about 9 inches apart. The upper band is very persistent and has yielded most of the asbestos mined from this deposit. The middle band is less important but has produced some soft asbestos in places. The third band, not always present, is narrow and contains only small amounts of harsh fiber.

At the portal of the main mine workings, where bottom was taken up by a previous operator for drainage and track installation, a lower zone of harsh, brittle fiber 3 to 4 inches thick was encountered at 6 feet below the middle zone but was not mined.

Bureau of Mines Work

Lacking knowledge of the geology and being limited in project working time, it was not feasible to attempt exploration of the ore horizon from the surface, where much overburden would have to be removed and a timbered portal made. Therefore, it was decided to concentrate the work within areas already opened and to start an exploratory drift from the back of the old mine.

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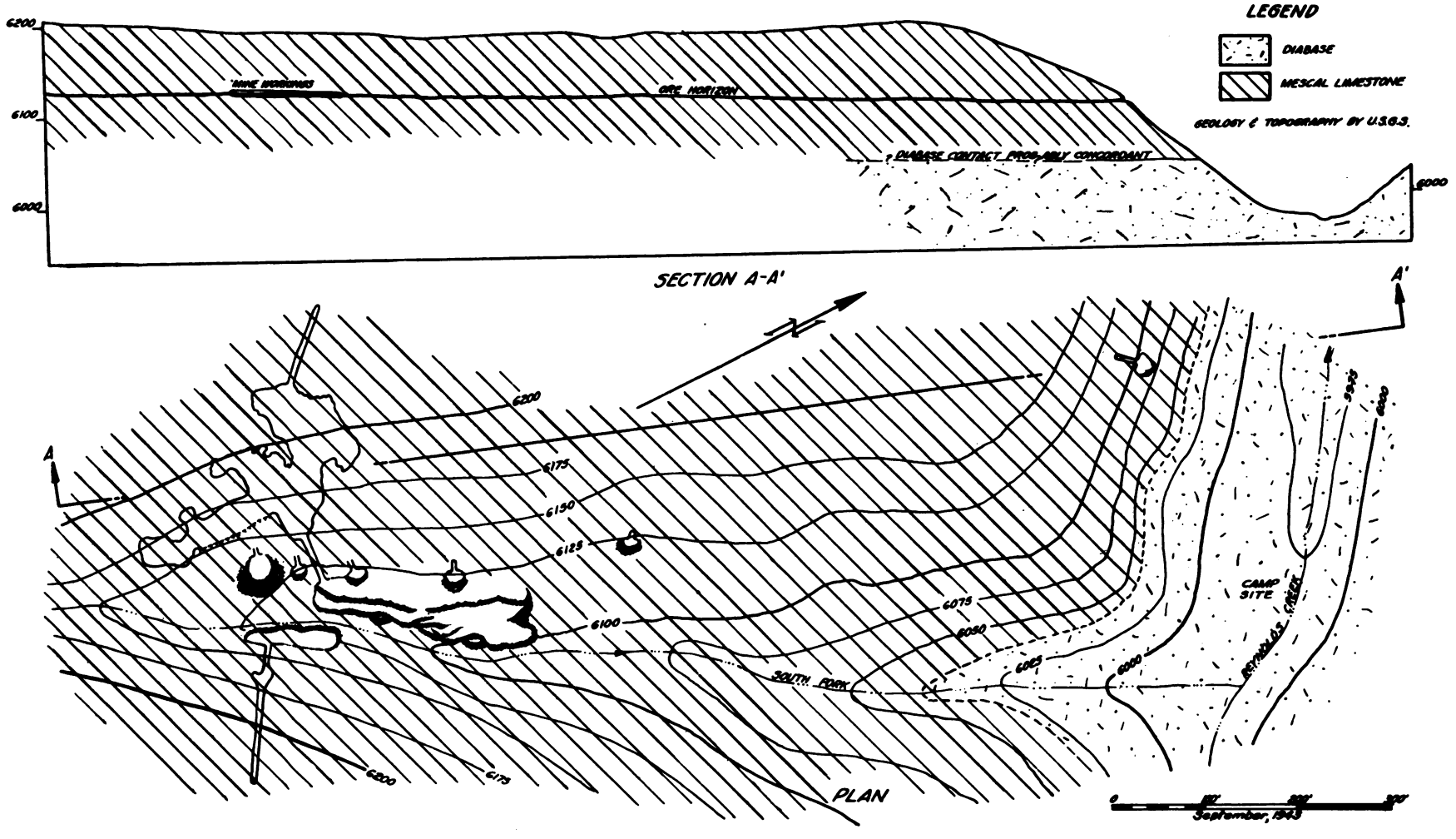


Figure 25. - Plan and section - Reynolds Falls area - Project No. 2303.

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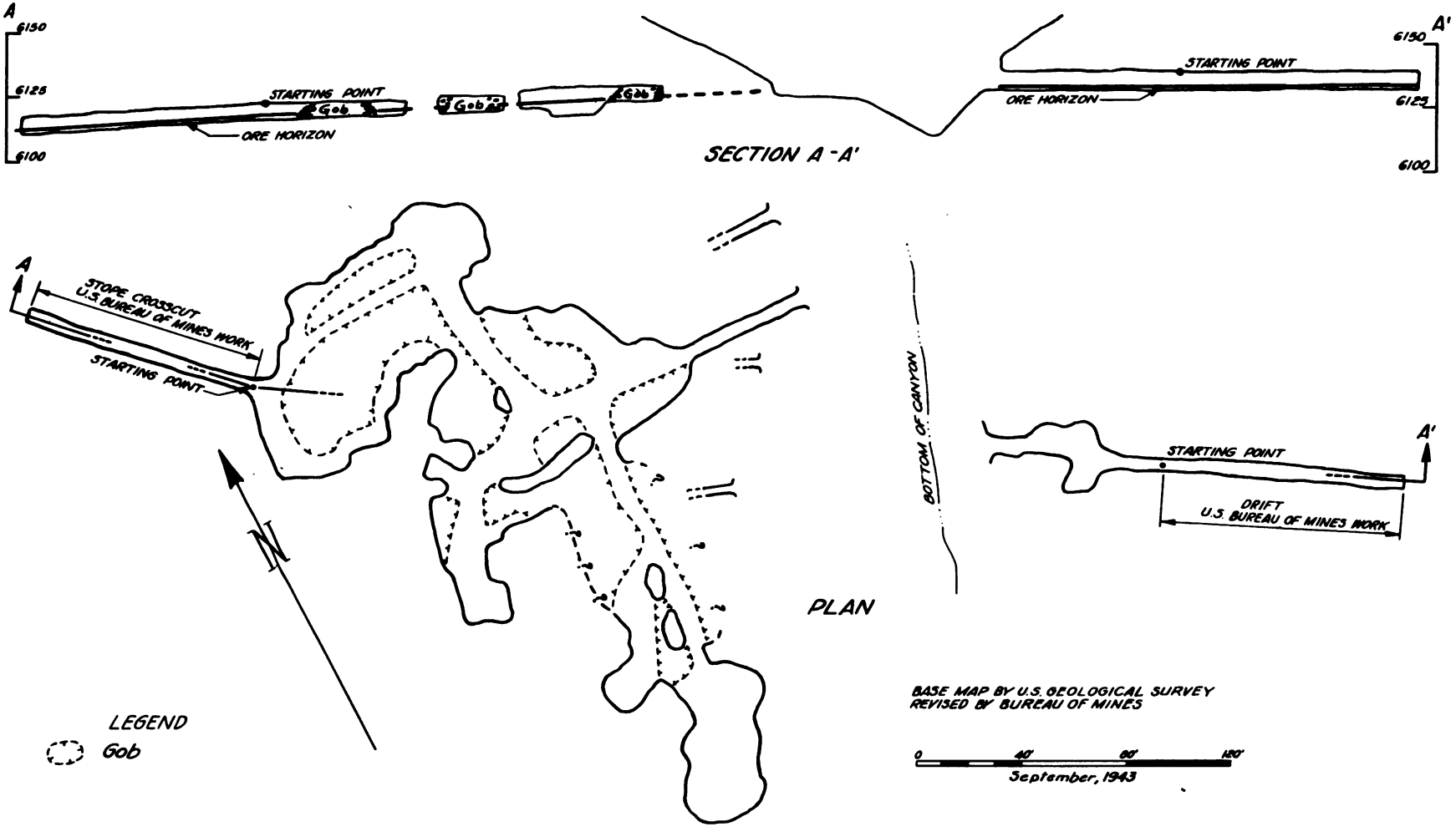


Figure 26. - Plan and section of Reynolds Falls mine - Project No. 2303.

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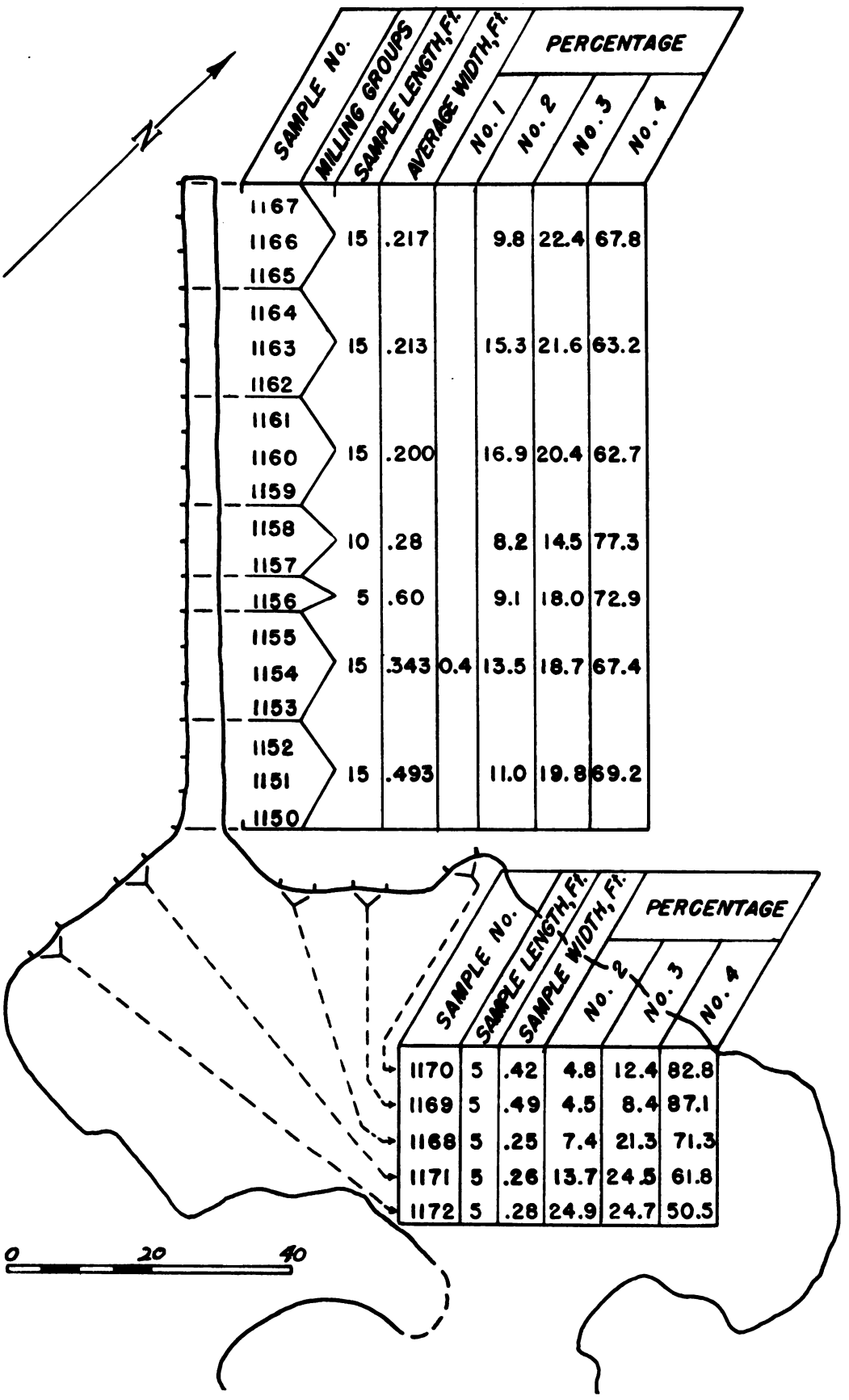


Figure 27. - Assay map, Reynolds Falls mine - Project 2303.

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A crew was moved in the second week of August 1943, a camp was prepared, and the water was siphoned out of the mine workings, which slope inward from the portal.

After a study of the stoped area, it was decided to drift northwest from the innermost corner, as this direction was between the bearings of the dip and the strike of the formations and would not be too steep for the use of wheelbarrows. It had been planned to push this exploration by using two shifts, but dampness and lack of ventilating currents left the mine too gassy for a night shift, so it was decided to explore the ore horizon on the other side of the canyon by extending the old 66-foot drift. The work in the mine stope was called the "stope crosscut," and that across the canyon was designated the "drift" (fig. 26).

There was no trouble with labor shortage or incompetent workers at this project, as the crew was selected from the three crews employed at former projects. The stope crosscut and the drift were each advanced 91 feet in less than a month of actual mining time when the work was stopped in mid-September 1943.

The Stope Crosscut

In the stope crosscut the upper zone varied from 2 to 4 feet in thickness and showed considerable fiber in discontinuous veins of erratic pattern at some places. More than half of the fiber was rather harsh and could not be mined profitably. The middle zone was about 2 feet above the floor. The upper serpentine-fiber band in this zone was 3 to 7 inches thick and contained 1 to 2.5 inches of total fiber. The fiber was not silky soft. There are occasional short lenses in which the fiber seems to be mixed with strands of the semi-harsh variety. However, previous operators state that the shipments have always been accepted as spinning grade. The lower band of this zone showed up to 2 inches of serpentine in which one-half to three-quarters inch of fiber occurred, but much of this was fairly harsh and it was not sampled.

The Drift

The upper and middle zones were exposed in the drift on the east side of the canyon. The upper zone was unimportant, as elsewhere, and near the portal each of the two bands of the middle zone showed one-half to three-quarters inch of fiber, usually with partings. The exploration work showed these veins decreasing in size, so no samples were cut.

Sampling

Only the upper band of the middle zone was sampled in the stope crosscut. Eighteen channel samples were cut in continuous 5-foot intervals along the left side of the crosscut from the starting point to the face, and five additional samples were cut at intervals along the stope face adjacent to the crosscut (fig. 27). The samples were combined as shown and milled at the Phillips Asbestos Co. mill.

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The following is not intended as a direct comparison but merely indicates the trend of milling results from the two methods of obtaining the mill rock. Records of custom-mill grading of the last 53 tons of mill rock extracted from the stope adjacent to the Bureau work show 0.6 percent No. 1, 40 percent No. 2, 18 percent No. 3, and 41 percent No. 4; the Bureau samples averaged 12 percent No. 2, 20 percent No. 3, and 68 percent No. 4.

The proportion of fiber to serpentine is much higher in this deposit than at any mine observed elsewhere in the district. By the visual analysis of the Survey geologist, the band from which these samples were cut contains 46 percent fiber in the total width of the serpentine. At another mine where the same method of analysis was applied the ratio of fiber to serpentine is 26 percent.

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