Mineral Resources of the San Carlos Indian Reservation Arizona

By CALVIN S. BROMFIELD *and* ANDREW F. SHRIDE

A CONTRIBUTION TO ECONOMIC GEOLOGY

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By Calvin S. Bromfield and Andrew F. Shride

ABSTRACT

At the request of the Council of the San Carlos Apache Tribe the U. S. Geological Survey entered into a cooperative agreement calling for a brief reconnaissance study to determine, as far as practical, the mineral potential of the San Carlos Indian Reservation. Five months of field work was done during the winter and spring of 1952–53.

About 30 percent of the reservation is covered by alluvial deposits of late Tertiary, Pleistocene, and Recent age, and another 60 percent is covered by volcanic rocks of Tertiary and perhaps Pleistocene age. These rocks are younger than the major epochs of metallization in southeastern Arizona. The remainder of the area is underlain by pre-Cambrian and Paleozoic sedimentary rocks, pre-Cambrian granite, and pre-Devonian diabase.

The reservation is located in two physiographic provinces: the northern part is in the Colorado Plateaus province and the southern part is in the Basin and Range province. The boundary between the provinces generally follows the southern rim of the Natanes Plateau. The mountain ranges south of the Natanes Plateau are, in general, tilted fault-block mountains composed largely of southwestward-dipping pre-Cambrian and Paleozoic sedimentary rocks. The northern part of the reservation is dominated by the Natanes Plateau. West of Blue River, the plateau is composed of generally flat-lying pre-Cambrian and Paleozoic rocks overlain by Tertiary volcanic flows. East of Blue River, the older rocks disappear under the Tertiary volcanic rock and reappear at one place only—between Arsenic Tubs and Park Creek.

Asbestos is the most important mineral resource on the reservation and most of the prospecting has been for this mineral. Asbestos was the only material being mined in 1953 (five mines being active). Deposits of tufa stone, peridot, guano, copper, iron, gypsum, and diatomaceous earth also occur on the reservation; of these, only tufa stone, peridot, and guano have been mined commercially.

INTRODUCTION

LOCATION AND ACCESSIBILITY

The San Carlos Indian Reservation occupies 2,500 square miles in east-central Arizona (fig. 76). It extends from Mount Turnbull on

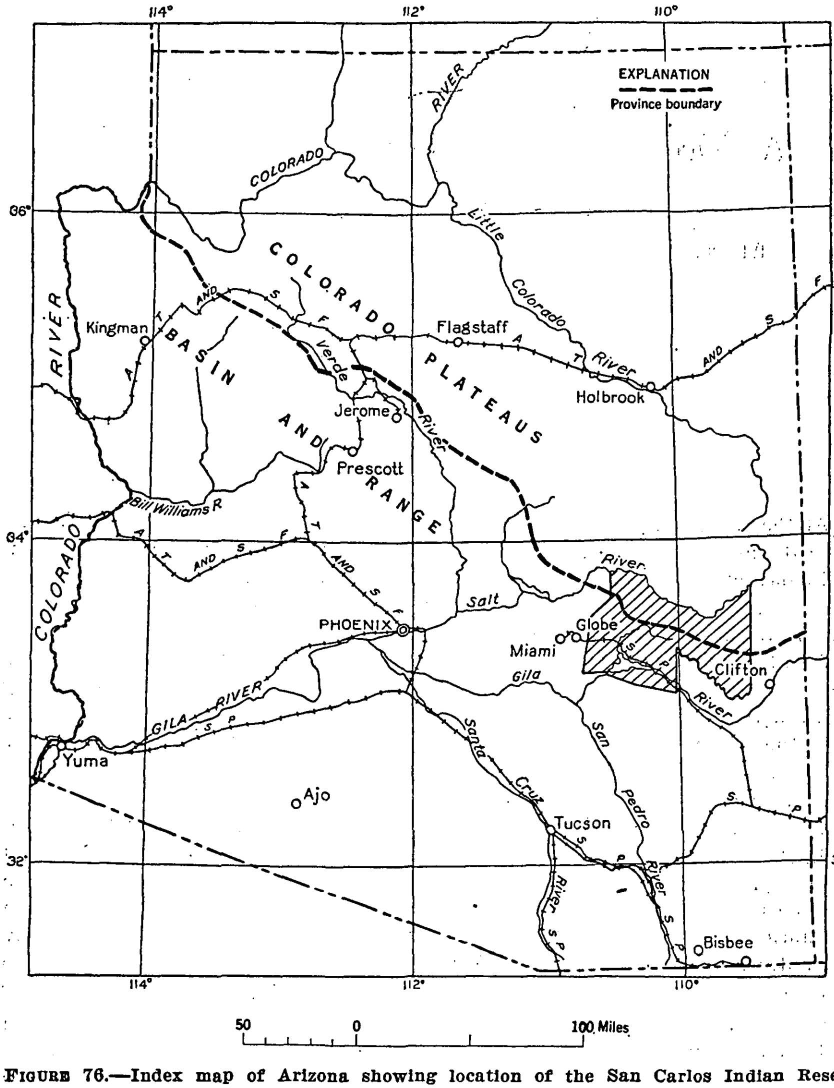


FIGURE 76.—Index map of Arizona showing location of the San Carlos Indian Reservation.

the south, to the Salt and Black Rivers on the north—maximum distance of 50 miles—and from near Globe on the west to the vicinity of Eagle Creek on the east—a distance of about 70 miles. It includes parts of Gila, Graham, and Pinal Counties.

Most of the inhabitants of the San Carlos Indian Reservation live in the towns of San Carlos and Bylas, although a few people live at Peridot and Calva. These settlements are joined by a branch line of the Southern Pacific Railroad, which has its terminus at Globe and connects with the main line at Bowie, Ariz. The only other permanent inhabitants are on a few ranches widely scattered over the reservation.

As of 1953, there were two paved highways in the area. U. S. Highway 70, which passes through Bylas, traverses the southern area of the reservation, and part of its route between Globe and Safford follows the Gila valley; and U. S. Highway 60 cuts across the extreme northwestern corner of the reservation. Two improved graded roads connect the Indian Agency headquarters at San Carlos with U. S. Highway 70 at two places. The remainder of the reservation is serviced by dirt roads of varying degrees of improvement. Much of the area is accessible only by trail. Winter snows and summer rains make many of the dirt roads impassable for short periods.

TOPOGRAPHY AND GENERAL SETTING

The San Carlos Indian Reservation lies on the boundary between the Colorado Plateaus and the Basin and Range province. Within the reservation the precise boundary between these two physiographic provinces cannot always be determined, because lavas of a great volcanic field cover much of the reservation and, in place, obscure the division. Roughly, however, a northwest-trending line following the southward-facing escarpment of the Natanes Plateau would approximate the south boundary of the Colorado Plateaus province (fig. 76 and pl. 52).

North of the south-facing escarpment of the Natanes Plateau, called the "Natanes Rim" in this report, is an area typical of the plateau province. The area is characterized by the general high level of its surface and by the approximate horizontal position of its rocks. The average altitude is about 6,000 feet; however, several prominent features, such as Hilltop and Chiricahua Butte, rise to over 7,000 feet. The drainage in this broad area is generally northward to the Salt and Black Rivers. These rivers, and their principal tributaries, have cut steep rugged canyons into the plateau surface. These canyons make parts of the area almost inaccessible.

South of the Natanes Rim is an area that is typical of the Basin and Range province. Broad intermontane alluvial-filled valleys and several northwest-trending mountain ranges characterize the area.

The mountain ranges are the Turnbull Mountains (on the south boundary of the reservation), the Mescal, Hayes, and Gila Mountains, and a southeastward extension of the Apache Mountains (called the "Apache Ridge" in this report). Mount Turnbull is the highest point on the reservation with an altitude of about 7,700 feet. Several peaks in the Mescal Mountains are over 6,000 feet, and altitudes of over 5,000 feet are not uncommon in the Hayes and Gila Mountains. The southeastward extension of the Apache Mountains is less rugged than the other mountains; here, altitudes range from 3,300 to 4,600 feet.

The broad alluvial-filled valleys are characterized by partly dissected sediments and alluvial slopes which incline gently inward to the Gila and San Carlos valleys, and by an extensive basalt-capped mesa extending several miles northeastward from San Carlos. Near San Carlos isolated basalt-capped mesas, remnants of a more extensive surface, project above the general level of the surrounding valley.

The drainage of the broad region lying south of the Natanes Plateau is controlled by the westward-flowing Gila River and its principal tributaries—the San Carlos River and Bonita Creek. The headwaters of Bonita Creek and the San Carlos River are on Ash Flat, a broad intermountain plain lying between the eastern part of the Natanes Rim and the Gila Mountains. Bonita Creek flows southeastward and drains the eastern portion of Ash Flat, whereas at the western end the drainage is northwestward to the San Carlos River.

The lowest altitude on the reservation, 2,290 feet, is in the Gila River at the southwest edge of the reservation.

HISTORY OF MINING AND PRODUCTION

The San Carlos Indian Reservation was established in 1872, and the area was closed to prospecting and mining at that time. In 1919, Congress authorized the opening of Indian reservations to location of mineral lands. Most of the prospecting on the reservation was done during the first few years following the opening of the Indian lands to location. The majority of the claims staked have been for asbestos. The Emsco, Bear Canyon, Apache, and Pinetop (known earlier as the Falls group) properties, which are the major asbestos mines, were discovered and located by 1922.

In 1936, under new authority granted by Congress,[1] the Apache Indians adopted a constitution, one of the provisions of which withheld to the Indians all rights in the granting of leases on mineral lands of the reservation.[2]

In monetary value, asbestos has been by far the most important resource on the reservation and most of the prospecting has been for this mineral. The total value of the asbestos production probably exceeds $500,000. The Emsco and Bear Canyon mines have been the largest producers. Second in value to asbestos has been tufa stone. The areas known to be underlain by tufa stone have been withdrawn from location and all quarrying has been by the Indian Service or by

[1] Act of June 18, 1934 (48 Stat. 984), as amended by Act of June 15, 1935 (49 Stat. 378).

[2] Sec. III Conservation of Assets, Art. V, Constitution and By-Laws of the San Carlos Apache Tribe of Arizona.

the Indians. Peridot, the gem quality variety of olivine, has been gathered in small amounts by the Indians since the turn of the century. A few tons of bat guano have also been produced.

MINING REGULATIONS OF THE SAN CARLOS INDIAN RESERVATION

The San Carlos Indian Reservation is unallotted land and claims may be located here; however, mineral leases are subject to certain regulations.[3]

Leases are made by the tribal council. Prospecting permits, usually covering a period of 90 days, are issued by the council for about $50.00. Locations are made and filed in the usual manner, and a lease application is filed with the tribal council. The application must also be processed through the office of the Bureau of Indian Affairs in Washington, D. C. Bond, which varies with the acreage involved, must be furnished and an annual acreage rental fee is required. Leases are generally issued for a period of 5 years, and royalty payment is usually 10 percent of the value at the mine site of all ores marketed. Appended to the lease are provisions regarding the employment of Indian labor and the grazing rights of the Indians.

PRESENT STATUS OF MINING AND PROSPECTING

Five mines were active on the San Carlos Reservation during 1953. These five, all asbestos mines, were the Apache, Pine Top, Bear Canyon, Salt River, and Great View mines. Late in the year, operations were stopped at the Bear Canyon and Salt River mines, and work was recessed at the Pine Top mine. Prospecting was in progress on the undeveloped Chiricahua and Mystery groups of asbestos claims. A lease was pending on the Peacock claims, which is a copper prospect.

PURPOSE AND SCOPE OF THIS REPORT AND METHODS OF STUDY

The U. S. Geological Survey, in cooperation with the Council of the San Carlos Apachee Tribe, undertook a reconnaissance study of the San Carlos Indian Reservation, to determine, as far as possible, the mineral potential of the reservation. The procedure followed was (1) to make a review of all existing data to determine areas that contain mineral deposits, followed (2) by spot examinations of these deposits, and (3) by reconnaissance of areas that are geologically favorable for the occurrence of such deposits. Many of the deposits visited were tested for radioactivity. The Dripping Spring quartzite was also

[3] For those interested in the legal details, Part 186 of Title 25, Code of Federal Regulations is followed in the granting of mineral leases on unallotted Indian lands.

tested for radioactivity. Field work occupied parts of 5 months during the winter and spring of 1952–53.

The geologic map of the reservation (pl. 52) is modified, by the addition of detail, from the geologic map of Arizona prepared by N. H. Darton (1924). Additions are the result, in part, of reconnaissance maping on aerial photographs and, in part, from interpretation of geology from aerial photographs. This geologic map is very much generalized, and small outcrops of the several geologic formations are not delineated.

ACKNOWLEDGMENTS

During January and February of 1953 Bromfield was assisted in the field by W. L. McIntosh, and during March and April he was assisted by J. A. Noel. Shride prepared descriptions of some of the larger asbestos deposits from data collected during earlier geologic examinations. R. B. Raup, Jr. and D. V. Haines of the Geological Survey did the work on radioactivity.

The writers acknowledge the information furnished by M. E. Linn, of the U. S. Bureau of Indian Affairs, concerning the location of several mineral occurrences, and the information on roads and trails from P. A. Buss, also of the Indian Bureau. D. E. Green, manager of the Bear Canyon asbestos mine, gave the location of several asbestos prospects in the Bear Canyon area and acted as guide to one prospect; Jeff Davis, of the Lakeside Trading Post, acted as the guide to the Tribal claims, and Howard Hale, of Globe, guided the writer to an occurrence of diatomaceous earth. Thanks are due to Clarence Wesley, chairman of the San Carlos Apache Tribal Council, and to Jesse Stevens, vice-chairman of the Council, for providing guides, horses, and information. Thanks are also due to the officials of the Bureau of Indian Affairs for making it possible to obtain pertinent records from their files.

PREVIOUS WORK IN THE AREA

In 1871, A. R. Marvine (1875, p. 218–225), a geologist with the Wheeler Expedition, crossed the region and obtained the first geologic information on a part of the area that now lies within the reservation. His route was southwestward from Fort Apache, across the Salt River and Natanes Plateau, into the San Carlos Valley, and over the Apache Mountains. In 1873, G. K. Gilbert traversed the Natanes Plateau, Bonita Creek, and Gila Mountains; he noted the extensive lava fields characteristic of this part of the area and gave the first description of the Gila conglomerate (Gilbert, 1875, p. 525–542). A. T. Schwennesen (1921) studied the geology and water resources of the Gila and San Carlos valleys in the San Carlos Indian Reservation. N. H.

Darton (1925, p. 242–243, 252–253) gives some geologic data on the Mescal and Hayes Mountains, and gives a description of the Natanes Plateau. Carl Lausen (1927) published a paper on the occurrence of peridot near San Carlos, and E. D. Wilson (1928), in a report on asbestos in Arizona, gives descriptions of several asbestos deposits on the San Carlos Indian Reservation.

The only published geologic map that includes the whole region is the geologic map of Arizona on a scale of 1 : 500,000. This part of the state map is based on reconnaissance work by Darton. A reconnaissance map of the Mescal and Hayes Mountains, which includes the southwestern corner of the reservations, is given in "Résumé of Arizona geology" (Darton, 1925, p. 267).

These reports, particularly those of Darton, are the chief sources of geologic information available concerning the reservation area. Other references to the geology of this area are included in the bibliography.

GENERAL GEOLOGY

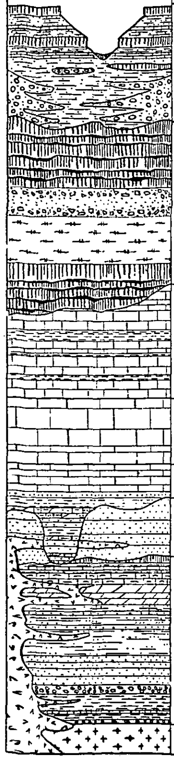
Late Tertiary, Pleistocene, and Recent deposits of lake and stream origin mask the underlying bedrock over more than 30 percent of the reservation area. Volcanic rocks, part of the great Datil lava field of Arizona-New Mexico, cover another 60 percent of the area. These volcanic rocks are in part contemporaneous with, and in part older than, the late Tertiary and Pleistocene valley-fill deposits. All of the volcanic rocks are later than the major epochs of metallization in southeastern Arizona. The remainder of the area is underlain by pre-Cambrian and Paleozoic sedimentary rocks, diabase, and pre-Cambrian granite. Figure 77 is a graphic representation of the stratigraphic column with brief descriptions of the formations. It also shows the industrial minerals and metals that occur in the several formations.

SEDIMENTARY ROCKS

The sedimentary rocks within the reservation range in age from pre-Cambrian to Recent; those of late Tertiary and Pleistocene age predominate.

PRE-CAMBRIAN ROCKS

Younger pre-Cambrian rocks are the oldest sedimentary rocks exposed in the reservation area. They are widespread in the western half of the reservation and crop out in the Mescal and Hayes Mountains, the Apache ridge, along the Natanes escarpment, and in the canyon of the Salt River. These rocks include, in ascending order, the Scanlan conglomerate, Pioneer shale, Barnes conglomerate, Dripping Spring quartzite, and Mescal limestone. Collectively, these formations



AGE	GROUP, FORMATION	CHARACTER	THICKNESS IN FEET	ECONOMIC VALUE
Recent, Pleistocene(?) and Tertiary (Pliocene)	Gila conglomerate	Recent sands and gravels in stream bottoms, Pleistocene (?) gravels, overlying the Gila conglomerate with erosional unconformity; Gila conglomerate which includes fanglomerates and lake beds consisting of limestone, mudstone, diatomaceous beds, and gypsum; the lake beds are interbedded with tuff and basalt flows. The basalt caps buttes and extensive mesas in the San Carlos valley	700+	Diatomaceous earth, gypsum, building stone (tuff), volcanic scoria found in crater on Peridot Mesa, peridot in flows
	UNCONFORMITY			
Older Tertiary	Volcanic rocks	A succession of rhyolitic, andesitic, and basaltic flows, breccias, and tuffs. Widespread in Gila Mountains, and on Natanes Plateau. Gravels under thin flows along Salt River in western part of Natanes Plateau not shown	1000+	
	UNCONFORMITY			
Pennsylvanian	Naco limestone	Thin- to medium-bedded light-gray limestones with interbedded shale. Forms slopes and benches above the Escabrosa limestone	1200	
Mississippian	Escabrosa limestone or Redwall limestone	Medium- to very thick-bedded gray limestones. Middle part massive and in many places forms cliffs	500	
Devonian	Martin formation	Consists of shales, sandstones, and medium-bedded, in part dolomitic, limestone. Forms slopes and benches between Troy quartzite and Escabrosa limestone	200-350	
	UNCONFORMITY			
Cambrian	Troy quartzite	Buff to pink and red, medium- to thick-bedded quartzite, pebbly beds common, cliff forming	0-400	
	UNCONFORMITY			
Younger pre-Cambrian	Apache group: Basalt			
	Apache group: Mescal limestone	Gray- to buff-colored cherty limestones and dolomitic limestones in lower member massive cliff-forming algal limestones in middle member, silty and siliceous beds, with some thin-bedded gray limestones in upper member; diabase intrusion widespread. Thin basalt flow found locally at top	0-350	Asbestos veins associated with intrusive diabase
	Apache group: Dripping Spring quartzite	Light-colored, thick-bedded quartzite in lower member, rusty to black and brown, thin- to medium-bedded siltstones and silty quartzites in upper member; alternate bands of red and black silty quartzites and siltstones common in lower portion of upper member; forms cliffs	300-500	Anomalous radioactivity prevalent in upper member of formation. Host to uranium deposits elsewhere in Gila County
	Apache group: Barnes cgl.	Conglomerate consisting of well-rounded pebbles and cobbles of quartzite and quartz; red arkosic matrix	0-50	No recognized mineral value
	Apache group: Pioneer shale	Red to purple shale with a few light-colored quartzite beds; forms slopes	0-150	No recognized mineral value
	Apache group: Scanlan cgl.	Thin conglomerate at base of Apache group consisting of pebbles and cobbles of quartz in arkosic matrix	0-15	No recognized mineral value
	UNCONFORMITY			
Older pre-Cambrian				

FIGURE 77.—Geologic column and associated mineral resources, San Carlos Indian Reservation.

are known as the Apache group. The section is as much as 1,000 feet thick.

The Apache group rests on a somewhat irregular erosion surface of an older pre-Cambrian granite. Locally, a pre-Cambrian basalt flow is at the top of the Apache group. In most other exposures, however, post-Apache erosion has removed the basalt, and the overlying Paleozoic rocks lie on the Mescal limestone; however, on the San Carlos-Sawmill road, near Hilltop, Cambrian Troy quartzite lies on the Dripping Spring quartzite and the Mescal limestone has been removed by erosion.

The lowest formation of the Apache group, the Scanlan conglomerate, is made up of quartz and quartzite pebbles and cobbles in a light-colored matrix made up largely of granitic debris. It rests on the pre-Cambrian granite. The conglomerate ranges from a thin layer including scattered pebbles to a bed 15 feet thick.

Overlying the Scanlan conglomerate is the Pioneer shale. The formation is composed of sandy shales and a few thin light-colored beds of quartzite, which are more common near the base. The formation, though well-indurated, is less resistant to erosion than the overlying Barnes conglomerate and Dripping Spring quartzite, and, as a result, it tends to crop out as slopes beneath the massive cliffs of the overlying rocks. The formation is as much as 150 feet thick.

The Barnes conglomerate, which rests on the Pioneer shale and which apparently is a basal conglomerate of the Dripping Spring quartzite, is readily distinguished from the Scanlan conglomerate. It is composed of abundant well-rounded quartzite and quartz pebbles and cobbles in a red quartzitic matrix. The conglomerate generally is less than 10 feet thick, but in places it is as much as 50 feet thick.

Next above the Barnes conglomerate is the Dripping Spring quartzite. This formation is prominent in all exposures of the Apache group, and many of the rugged cliffs of the southern escarpment of the Natanes Plateau, the Seven Mile Mountains, the northeast side of the Hayes Mountains, and the lower parts of the Salt River Canyon are composed of this quartzite. The formation can be separated into at least two rather distinct parts: a lower part of light-colored, medium- to thick-bedded quartzites of medium grain, which form the prominent cliffs characteristic of the formation; and an upper part of red to rusty-brown and black, thin- to medium-bedded siltstones and silty fine-grained quartzites. Some light-colored quartzites are interbedded in the upper part. A distinctive feature in this part of the formation is banding resulting from the alternation of black to purple siltstones and red to rusty-brown silty quartzites. The formation ranges in thickness from 300 to 500 feet over the reservation area.

The Mescal limestone is the uppermost formation of the Apache group over most of the reservation. Generally, it has been split and dilated by the intrusion of the widespread diabase sills; therefore continuous, complete sections of the formation are rarely observed. The Mescal limestone is economically significant because it is the only host rock in east-central Arizona for asbestos deposits.

The formation is divisible into three members: (1) a lower, thin- to medium-bedded, flat-bedded limestone member, (2) a middle, massive limestone member that includes structures interpreted as relicts of algae colonies, and (3) an upper, thin-bedded siltstone and shale member.

Along the Salt River Canyon, in the northwestern part of the reservation, the lower member is 150 to 200 feet thick and is composed dominantly of impure to moderately pure limestones intercalated with calcareous shales. The uppermost 10 to 12 feet of the member and two other units, 30 to 45 feet and about 100 to 110 feet, respectively, below the top of the member, are of relatively pure, gray, crystalline limestone, in beds 1 to 4 feet thick. The remainder of the lower member generally is composed of impure limestone beds, ½ to 4 inches thick, alternating with thin beds of calcareous shales or included shale partings. Chert occurs in the limestone in the Salt River section, but not in large quantities. Some of the carbonate beds are dolomites or are dolomitic, but such beds are uncommon.

Southward from the Salt River area the three limestone units thin, and individual beds throughout the section are progressively thinner to the south. The lowest limestone unit, 100 feet below the top of the member, has not been observed in the southern part of the reservation. Chert and dolomite are abundant in the lower member southward from the Natanes Plateau; in places, dolomite is more abundant than limestone. South of the Natanes Plateau, thin layers of chert characteristically stand out on weathered surfaces.

The middle, or algal, member is composed of thick, massive limestone beds totaling 10 to 140 feet in thickness. The fossil algae (which are wavelike in section and which are concentric and saucerlike in plan), the massive beds, and the tendency to form cliffs are characteristics of the middle member. In the Salt River area, this member is of limestone; to the south, the member becomes increasingly dolomitic, individual beds become thinner, and the algal structures become less readily discernible than in the Salt River area.

The contact between the algae-bearing middle member and the flat, slabby limestones of the lower member is sharp, and everywhere on the reservation it is easily recognized at the base of the cliff-forming portion of the formation. The uppermost 10 to 30 feet of the middle member is thinner bedded than the remainder of the member and in places includes shale.

The upper member is dominated by brown siltstones and gray to black shales, totaling as much as 110 feet in thickness. A chert bed, 2 to 4 feet thick, marks the base of the member. Thin chert bands are common; in a few places, thin marly limestone beds have been observed in the member. These chert bands, the limestones (where present), and the stratigraphic position serve to distinguish the upper member of the Mescal from the somewhat similar siltstone and shaly units of the upper half of the Dripping Spring formation.

Through the northern part of the reservation, the pre-Cambrian basalt and part, or (in places) all, of the upper member of the Mescal are missing due to erosion prior to deposition of the Troy quartzite. East of Highway 60, in the vicinity of Seneca, part of the algal member and all of the overlying Troy quartzite are missing due to erosion that pre-dated deposition of the Martin limestone of Devonian age. In many places east of the Salt River bridge on U. S. Route 60, the Martin limestone is in depositional contact with diabase sills that intruded the Mescal limestone can be found below the pre-Martin erosin surface. and Martin limestone rests on progressively lower stratigraphic units of the Mescal as the Salt River Canyon is traversed upstream from the bridge. At a point 7 miles east of the bridge, only the basal beds of the Mescal limestone can be found below the pre-Martin erosion surface. It is probable that in places within this 7-mile interval the Martin limestone rests on the Dripping Spring quartzite.

The Mescal limestone has not been observed along the Natanes Rim south and west of Hilltop to the west boundary of the reservation. The Mescal limestone may not be observable along this interval of the Natanes Rim, owing to the presence of talus cover or faulting, but in part it may be absent as a result of pre-Troy or pre-Devonian erosion. This condition apparently exists in the section that is exposed where the road ascends the Natanes Plateau a few miles south of Hilltop. Here, Troy quartzite overlies Dripping Spring quartzite, and the Mescal limestone is absent. Asbestos deposits cannot exist along this part of the escarpment if the Mescal is absent. Plate 52, which follows the interpretation of the state geologic map for this area, shows Mescal limestone along this portion of the Natanes Rim.

Southeastward from Red Whiskers Spring in the Hayes Mountains the entire Mescal limestone thins rapidly and changes from a section dominantly of limestone to one exclusively of siliceous beds. At Coolidge Dam, the formation is only 25 feet thick.

PALEOZOIC ROCKS

West of Blue River, Paleozoic sedimentary rocks overlie the pre-Cambrian Apache group. The Paleozoic formations crop out extensively in the Mescal and Hayes Mountains, in Apache Ridge, along the western part of the Natanes Rim, and along the rim of the Salt River Canyon.

The Paleozoic sedimentary rocks are represented by the Troy quartzite of Cambrian age, the Martin formation of Devonian age, the Escabrosa limestone or Redwall limestone of Mississippian age, and the Naco limestone of Pennsylvanian age.

East of Blue River, Tertiary volcanic flows cover the older formations and only three hitherto unreported outcrops expose the underlying rocks. These outcrops are along a part of the south front of the Gila Mountains, along the Natanes rim east and west of Park Creek, and in the vicinity of Rincon spring. The base of the Paleozoic section in the Gila Mountains is not exposed; the lowest formation is a quartzite similar to the Troy quartzite. Near Park Creek, a basal quartzite similar to the Troy rests directly on pre-Cambrian granite. Both of these quartzites are overlain by interbedded sandstones, shales, and limestones generally like those of the Paleozoic formations in the western part of the reservation.

The Troy quartzite of Middle and Upper Cambrian age is the basal formation of the Paleozoic rocks on the San Carlos Indian Reservation. It consists of medium- to thick-bedded quartzites usually of light color on a fresh face but usually of reddish cast in outcrop. Characteristically, the formation, especially toward the base, is coarse-grained and in places conglomeratic. Medium- to large-scale cross-bedding is also a common feature in the Troy quartzite. In most places, the relative paucity of feldspar grains, the generally coarser grain and larger-scale crossbedding distinguish the Troy quartzite from the thick-bedded quartzites of the lower part of the Dripping Spring formation. In common with the Dripping Spring quartzite, the Troy quartzite forms cliffs. In places, Troy quartzite forms the southwest-dipping rim-rocks of the Mescal and Hayes Mountains. The quartzite is as much as 400 feet thick.

Quartzites similar in appearance to the Troy are found in isolated exposures on the south slope of the Gila Mountains, and near Park Creek under the Natanes rim in the eastern part of the reservation. These quartzites are undoubtedly equivalent to the Troy quartzite but, considering their proximity to Morenci, it may be as proper to correlate them with the Cambrian Coronado quartzite of that district as it is to correlate them with the Troy.

The Martin limestone of Devonian age overlies the Troy quartzite. The formation consists of limestone, sandstone, and shale. A sandstone unit of variable thickness usually is found at the base. This unit is overlain by a section that includes yellow-brown magnesian limestones, sandy in places, interbedded with thin limy shales; medium- to coarse-grained crossbedded sandstones; gray to pink papery shales; and medium-bedded gray limestones. The Martin limestone ranges in thickness from 200 to 350 feet. The formation tends to form slopes and benches between the cliffs of the Troy quartzite (below) and the cliffs of the Escabrosa or Redwall limestone (above).

Above the Martin limestone is about 500 feet of medium-gray limestone of Mississippian age, in part containing nodules of chert. The most notable feature of this sequence of limestones is the presence of exceptionally massive gray limestones in the lower and middle portions of the formation. These massive beds form a conspicuous limestone cliff, which is a diagnostic feature for the formation in all of its outcrops. In the area south of the Natanes Plateau, the name most generally used for these rocks is the Escabrosa limestone; north of the Natanes Plateau, the name most generally used is Redwall limestone.

Next above the limestone of Mississippian age is the Pennsylvanian Naco limestone. In the Mescal and Hayes Mountains this sequence of generally medium-bedded gray limestones with some intercalated shales is as much as 1,200 feet thick.

TERTIARY SEDIMENTARY ROCKS

There are at least two distinct ages of Tertiary sedimentary rocks on the reservation. These rocks are separated in time by a marked period of orogeny. The older gravels underlie volcanic flows in the western part of the Natanes Plateau. Their age is not well known. The younger gravels occupy the major valleys south of the Natanes Plateau and are correlated with the Gila conglomerate of late Pliocene and Pleistocene age.

The older gravels overlie Paleozoic sedimentary rocks and underlie older Tertiary andesitic flows in the western part of the Natanes Plateau (pl. 52) along the Salt River. The older gravels contain coarse detritus among which rocks of the Apache group can be recognized. From this, it is inferred that their source was highlands to the south because the rocks of the Apache group are not exposed to the north.

The older gravels are part of a more widespread gravel deposit which is found to the north and west of the reservation along the Mogollon Rim. The gravels can be seen north of the reservation along the highway between the Salt River and Show Low where they underlie thin volcanic flows and overlie Paleozoic sedimentary rocks.

Similar gravels have been described by Price (1950) from the Sycamore Canyon area near Prescott, Ariz. where the gravels underlie a basalt flow of supposed Pliocene age.

The age of these older gravels is not well known. The older gravels, and the volcanic flows that overlie them, are separated from sedimentary rocks of probable late Pliocene age by a period of major orogeny that outlined the structural valleys of the Gila and San Carlos Rivers and Bonita Creek. Late Pliocene sediments have been deposited in these basins. It is presumed then that the older gravels are Pliocene and perhaps older.

The Tertiary sedimentary rocks that fill the Gila and San Carlos River valleys and Bonita Creek (pl. 52) to an unknown, but considerable, depth include coarse conglomerates, derived from the surrounding mountains, and lake beds deposits which include limestones, mudstones, diatomaceous sedimentary rocks, and gypsum. The conglomerates and lake beds interfinger. Usually, the conglomerates are marginal to the lake beds that, in general, were deposited in the center of the basins; however, at Blue River on the margin of the basin, thick fresh-water limestone laps up against the Natanes Plateau.

The conglomerates and lake beds are continuous with the Gila conglomerate at Safford, Ariz. Knechtel (1938, p. 198) has dated the Gila conglomerate in that area as late Pliocene in age.

PLEISTOCENE(?) AND RECENT ALLUVIUM

Coarse gravels of Pleistocene(?) age mantle the surface of the late Tertiary sedimentary rocks. An erosional unconformity separates the two formations. These relations are especially well exposed along the road from Coolidge Dam to Bylas.

Recent silts, sands, and gravels occupy the courses of the present-day drainage.

IGNEOUS ROCKS

Pre-Cambrian granite is the oldest igneous rock found within the reservation. The largest exposures of the granite are in the area between the Natanes Rim and Seven Mile Mountains and northeast from the Hayes Mountains to Bucket Mountain (pl. 52). The late pre-Cambrian Apache group lies upon the eroded surface of the granite in the Mescal Mountains, Hayes Mountains, the southeasterly extension of the Apache Mountains, and in places under the Natanes Rim.

A vesicular basalt flow is found locally at the top of the Apache group at several places along the Apache Ridge (pl. 52) and in Bear Canyon (not shown on pl. 52 because of the small scale of the map). Elsewhere on the reservation the basalt is generally absent, either because the flows did not reach these areas, or because the basalt was removed by pre-Troy erosion. The basalt is reddish to dark brownish in color and is commonly vesicular. Amygdules in the highly altered and decomposed rock contain calcite, chlorite, and epidote (?).

The basalt is overlain unconformably by the Troy quartzite of Middle and Upper Cambrian age. Near the west boundary of the reservation in the Apache Ridge the basalt is intruded by later diabase.

Pre-Devonian diabase sills, of great lateral extent and ranging in thickness from a knife-edge to several hundreds of feet, intrude the Apache group and Troy quartzite. In the Salt River Canyon these sills are well exposed along the canyon walls where several thick sills have intruded the Mescal limestone. Diabase has also intruded the Apache group in the Apache Ridge, the Hayes and Mescal Mountains, and in Bear Canyon. In the Hayes Mountains, near the Wylomene claims and near Red Whiskers Spring, the diabase intrudes the Troy quartzite and is unconformably overlain by the Martin limestone. The diabase varies from fine- to coarse-grained, and usually has a dark-green color, though it may weather to shades of brown and olive green. It is an important igneous rock in this region of Arizona because of its genetic relationship to asbestos mineralization where it intrudes the Mescal limestone.

On the flanks of Mount Turnbull granitic and rhyolitic rocks occur. These rocks appear gradational one to the other. Their age is uncertain, though Ross (1925, p. 32–33, 35) assigns similar rocks in the Aravaipa-Stanley district to the early Tertiary period.

Volcanic rocks are widespread within the reservation area. At least two periods of vulcanism, the rocks of which are separated by a structural unconformity, can be distinguished. Older Tertiary volcanic rocks, possibly of middle Tertiary age, are found in the Turnbull and Gila Mountains and in the northern and eastern parts of the reservation. Basalt flows found interbedded with, and overlying, the Gila conglomerate type of sedimentary rocks are younger and unconformable with these older Tertiary volcanic rocks. These younger flows are probably of Pliocene and Pleistocene (?) age.

The older Tertiary volcanic rocks present a greater lithologic variety than the younger Tertiary or Quaternary (?) or both, volcanic rocks. The older volcanic rocks include basalts, rhyolites, andesites, and rhyolitic tuffs and breccias. About 1,000 feet of these flows and pyroclastic rocks overlie the exposed Paleozoic rocks in the Gila Mountains. Along the Natanes escarpment on the north side of Ash Flat approximately 500 feet of white to pink rhyolitic tuffs are overlain by at least 500 feet of andesitic flows. These andesitic flows make up much of the surface in the western portion of the Natanes Plateau. Thick andesitic flows crop out also in the mountainous area in the southeast corner of the reservation, east of Bonita Creek.

The older Tertiary volcanic rocks have been involved in the faulting that resulted in the present distribution of the major physiographic features.

The younger Tertiary and Quaternary(?) volcanic rocks, probably of Pliocene and Pleistocene(?) age, are represented by basalt flows interbedded with, and overlying, the Gila conglomerate type sedimentary rocks. Typical exposures are found north and east of San Carlos, where several flows crop out along the mesa sides and a flow caps the extensive mesa extending northward and eastward from the Triplets. A similar flow forms the surface near Ash Creek Ranch on Ash Flat (pl. 52). Several isolated mesas southwest of San Carlos are also capped with these basalt flows.

The basalt flows and the interbedded sedimentary rocks, in contrast to the older Tertiary volcanic rocks, are generally flat-lying and have been little disturbed.

STRUCTURE

Parts of the two major structural provinces are included in the San Carlos Indian Reservation area. These structural provinces are the Colorado Plateau province and the Basin and Range province (fig. 76). The area of the Natanes Plateau (pl. 52), which dominates the northern part of the reservation, lies in the plateau province and the area to the south of the Natanes Plateau, which includes several northwest-trending mountain ranges and intervening valleys, lies in the Basin and Range province.

The structural boundary between the Colorado Plateau and Basin and Range structural provinces is arbitrarily shown on figure 76 as the south rim of the Natanes Plateau. Actually, it is probably a zone in which the plateau edge is successively down-faulted into the structural basins which face the Natanes Rim on the south. This is especially true in the general area from the reservation boundary west of Sawmill (pl. 52) and east to Blue River. Between Blue River and the area just north and west of Ash Creek Ranch the boundary between the two provinces is indistinct where late Pliocene basalts associated with the Gila conglomerate lap up against the older Tertiary volcanic flows. West of this point on the north side of Bonita Creek almost to Park Creek (fig. 76) the north side of the valley is linear and is probably a fault scarp. The fault or faults along which the valley block was lowered are not exposed, but they probably are covered under the Gila conglomerate which fills this valley to an unknown but no doubt considerable depth. East of Park Creek the boundary is not well marked.

The plateau area is characterized by the general horizontality of the exposed sedimentary rocks and by the scarcity of faults. In the western part of the reservation along the south-facing rim of the plateau the Apache group and Paleozoic rocks, which are overlain by thin Tertiary flows, dip gently northward or are flat-lying. The sedimentary rocks are exposed along the rim as far east as Blue River, beyond which they disappear under the Tertiary flows. Near Arsenic Tubs on the north side of Bonita Creek valley the Paleozoic rocks are again exposed under the volcanic flows (pl. 52), and the sedimentary rocks and Tertiary flows have a gentle northeasterly dip.

South of the Natanes Plateau in the Basin and Range province the bedded rocks are tilted at moderate to steep angles. Faults are common and they delineate several northwestward trending ranges separated by alluvial-filled structural basins. These ranges are the Gila, Turnbull, and Seven Mile Mountains, the Apache Ridge, and the Hayes and Mescal Mountains.

In the Gila and Seven Mile Mountains the rocks generally dip at moderate angles to the northeast. The Apache Ridge, Hayes, and Mescal Mountains are homoclinal fault blocks in which the rocks strike northwestward and dip at moderate to steep angles toward the southwest. They present, in part, relatively steep northeasterly facing scarps, and southwesterly dip slopes.

The mountains have been uplifted relative to the basins along northwest faults. These faults are now largely covered by fanglomerates along the valley sides. Northeast faults, such as those in the Apache Ridge, those north of Bylas in the Gila Mountains, and those in the Hayes Mountains are generally of relatively minor displacement and have little or no reflection in the topography.

A few faults cut the Pliocene lake beds. This can be seen in the area of the Iron Claims (fig. 79), where limestone and mudstone of the lake beds are faulted against Paleozoic sedimentary rocks. In general, however, the lakebeds are flat lying and little disturbed.

The valleys of the Gila River, Bonita Creek and San Carlos basins are thought to be structural basins formed by down-faulting between the adjacent and relatively upraised mountain blocks. In places, such as west of Peridot Mesa and south of Black Mesa, small isolated highs of the basin floors have been exhumed by erosion of the overlying cover of Pliocene and Pleistocene sediments, but in general the floors of the basins are probably covered to a considerable depth by the later sediments. The depth of this cover and the configuration of the basin floors are not known. At Geronimo, just off the reservation a few miles southeast of Bylas, and 810-foot well bottomed in valley fills. Near Safford, the thickness of the lake beds is considered to be at least 1,600 feet or more (Knechtel, 1938, p. 204).

The age of the major orogeny that uplifted the mountain blocks and formed the relatively down-faulted basins has not been closely dated. The older Tertiary volcanics are involved in the faulting, but the late Pliocene and Pleistocene Gila conglomerate, and its lake-bed facies and interbedded basalts generally are not. The Gila conglomerate fills the structural basins formed by the faulting. Therefore, the major faulting was prior to late Pliocene time.

MINERAL DEPOSITS

The mineral deposits of the reservation may be subdivided into metallic and nonmetallic classes. The metallic deposits have been of no importance, whereas the nonmetallic deposits have accounted for all production. Known metallic deposits include copper and iron minerals. Nonmetallic deposits that have yielded some production are asbestos, building stone ("tufa" stone), peridot, and guano. Nonmetallic deposits of unknown value include gypsum and diatomaceous earth.

In the following pages, the mineral commodities are considered in turn; a general discussion of the known occurrences and the geologic factors determining their localization is followed by detailed descriptions of the individual deposits. The individual deposits are indexed as to location on plate 53. Their geologic setting is shown in plate 52.

METALLIC DEPOSITS

COPPER

Only small and noncommercial quantities of copper are known on the reservation. These include the Copper King-Wylomene claims in the Hayes Mountains, the Peacock claims southwest of San Carlos, the Bitter Spring and Geronimo prospects on the flanks of Mount Turnbull, and the Tribal claims in the Gila Mountains.

At least three factors must be considered to explain why only minor copper deposits are known on the reservation: (1) the age of intrusive activity, (2) the position of the reservation with relation to the regional geologic structure, and (3) the widespread cover of Tertiary and Quaternary rocks.

Metallic mineral deposits and mining districts commonly are in areas of past igneous activity. The metallization is closely associated in space and time with this intrusive activity. The most important period of igneous activity and associated metallization in southeastern Arizona was during Laramide time (Late Cretaceous to early Tertiary). All of the large copper deposits in the adjacent areas, such as those near Globe-Miami, Morenci, Ray, and Christmas, are considered to be of this period. Intrusive rock of Laramide age is missing in general from the San Carlos Indian Reservation except, perhaps, in the part of the reservation around Mount Turnbull. Here are granitic and rhyolitic intrusives that may be a continuation of similar rocks of Laramide age (Ross, 1925, p. 33, 36–37) that crop out just south of the reservation boundary in the Stanley district. This part of the reservation may be considered to be on the fringes of the Stanley district, which produces only a small amount of copper. Only scattered and meager copper showings have been prospected in this part of the reservation.

In addition to igneous activity and associated metallization, the position of the reservation with relation to the regional geologic structure is of importance. As discussed in a previous section the reservation lies on the boundary between two structural provinces: a plateau province, characterized by little-disturbed, relatively flat-lying sedimentary rocks, and a mountain province characterized by more disturbed and faulted areas giving rise to individual fault-block mountains and more complex structures. All of the large copper or base-metal deposits are in this "mountain region" of Arizona, because it was in this region that structural deformation provided loci for igneous intrusion and associated metallization. The strongest metallization, however, seems to be concentrated in cross zones at intervals along this northwest-trending main belt. The deposits of the Globe-Miami district are confined to a northeast-trending zone about 6 miles wide. The northeastward continuation of this zone would pass just west of Chromo Butte and skirt the west boundary of the reservation. This might suggest the possibility of a few small outlying metalliferous deposits along the west boundary of the reservation. However, the metallization decreases in intensity southwest and northeast from the Schultze granite stock between Miami and Superior and appears to be dying out in the vicinity of McMillenville and Richmond Basin where the deposits are small and the principal metal is silver.

There is probably another northeast-trending belt of mineralization and igneous intrusions that takes in Lone Star Mountain (northeast of Safford), Morenci, and Metcalf. Thus, it is possible that base-metal deposits are present under the cover of lavas and alluvial deposits in the extreme southeastern part of the reservation; but the discovery of these will depend on methods of prospecting that are not yet developed and perfected.

COPPER KING OR WYLOMENE CLAIMS

These claims are in the southern part of the Hayes Mountains in sec. 9, T. 3 S., R. 17 E.,[4] on the east side of Dick Spring Canyon, about 3 miles south of Tincup Spring (pl. 53). The claims are in a rugged area at an altitude of 4,500 feet. They are accessible only by foot or

[4] The San Carlos Indian Reservation is unsurveyed and all section, township, and range descriptions given in this report are projected land locations as shown on Department of Interior, Bureau of Indian Affairs map of the reservation, edition of 1945.

horseback from the end of a road which branches from U. S. Highway 70 at the Lakeside Trading Post and ends in a canyon east of the claims.

The claims are accessible as follows:

Miles	*Directions*
0.0	At Lakeside Trading Post, take truck trail west.
0.2	Fork, turn right.
3.4	Fork, turn left. Right fork goes to Indian Spring.
9.2	Park vehicle in wash. Claims are about 1 mile westward. No. trail. Workings are near top of basalt-capped knob on south-trending ridge (pl. 54).

Claims known as the Copper King No. 1 and 2 were first located in this area in 1919 by Frank Cain, A. H. Gibson, and J. C. Gibson, and a lease was obtained in 1921. The lease became delinquent through nonpayment of rental fees. In 1927, the claims were relocated as a part of the Wylomene group by Pollard K. and Wylomene Pearson. A lease was obtained, and a small amount of work was done. This lease, in turn, ended in litigation through nonpayment of rental fees. The claims have since been inactive. The workings include a pit, two adits (one of which is caved), and two shallow shafts. No production is recorded.

In this area, the Apache group and Troy quartzite, both intruded by diabase, are overlain with apparent conformity by the Martin and Escabrosa limestones. These rocks strike from N. 25° W. to N. 50° W. and dip at angles from 25° to 30° SW. An erosion remnant of a Tertiary(?) basalt flow lies on the beveled surface of the tilted pre-Cambrian and Paleozoic rocks (pl. 54). Faults and fissures, trending east and northeast, cut the pre-Cambrian and Paleozoic rocks.

Copper minerals have been found in two northeast-striking fissures cutting the diabase. One of these two fissures is near the southeast margin of the Tertiary(?) basalt flow. This fissure strikes N. 70° E. and dips 80° to 85° NW. A pit exposes a weakly copper-mineralized vein which ranges in width from a knife-edge to a maximum of 8 inches. The diabase is stained by iron oxides for a few feet on either side of the stringer. Minerals include azurite, malachite, chalcocite, and specular hematite. A grab sample from a small pile of sorted ore assayed 0.02 ounce gold and 0.9 ounce silver to the ton, and 8.62 percent copper.

Several hundred feet north of this pit is a 60-foot adit and 20-foot shaft on a fault of nearly vertical attitude trending N. 60° E. The diabase is iron oxide stained for several feet away from the fault. Along fracture and minor slip surfaces, copper carbonates are erratically distributed. Minerals were malachite and chalcocite. None of this material was observed in place, and it evidently occurred in narrow stringers and pods along the fault.

PEACOCK CLAIMS

These claims are about 1 mile east of Bucket Mountain in sec. 30, T. 1 S., R. 18 E. (pl. 53), and they are easily accessible by a truck trail that turns southward from the new Cutter-Peridot highway at a point 5.7 miles west of Peridot. The claims are approximately ½ mile south of the highway.

William Stevens, James Stevens, and John Case located the Peacock claims in 1919. Shortly thereafter, T. Fink and H. J. Hagen obtained an option to purchase, but after doing a small amount of work the option was relinquished. No subsequent work was done, and the lease lapsed. Recently, H. J. Hagen applied for a lease on the property, and at the time of this writing, the lease was still pending. There has been no production from this property.

The area is one of low relief and is located on the gently sloping pediment area that borders the Hayes Mountains on the east. The claims are at an approximate altitude of 3,700 feet.

The country rock in the area is predominantly granite which is intruded by small irregular bodies and narrow dikes of fine-grained dioritic rock. The granite is cut by north- to northwest-striking faults and fractures and is locally replaced by quartz, sericite, and chlorite.

Several pits, cuts, and two shallow inclines have been driven on a north-trending shear zone in granite (fig. 78). This zone dips from 40° to 65° W. at its northernmost exposure, but in the southernmost pit the dip is reversed and is 70° E. The zone of crushed and sheared granite is in part occupied by a discontinuous vein having a maximum width in one pit of 9 to 18 inches; in the other pits, the vein is absent or is represented by one or more stringers. The vein contains quartz, calcite, barite, rhodochrosite, and sparse pyrite grains. Malchite stain is also present in minor amounts, but the tenor of the vein material in copper is very low.

In the area extending about 600 feet to the east of the north-trending shear zone a number of pits, shallow trenches, and a 35-foot vertical shaft have been excavated (fig. 78). None of these exposes any veins or shows any marked content of copper-metallized rock. The shaft was sunk on a northwest-trending slip surface that shows minor amounts of copper carbonate stain.

It is probable that in the area of the Peacock workings there has been some weak disseminated copper mineralization. However, it appears meager and limited in areal extent. There is little residual limonite, probably owing to the rarity of pyrite, and there are very few voids with "relief" limonite of the type usually interpreted as indicating the former presence of copper sulfides.

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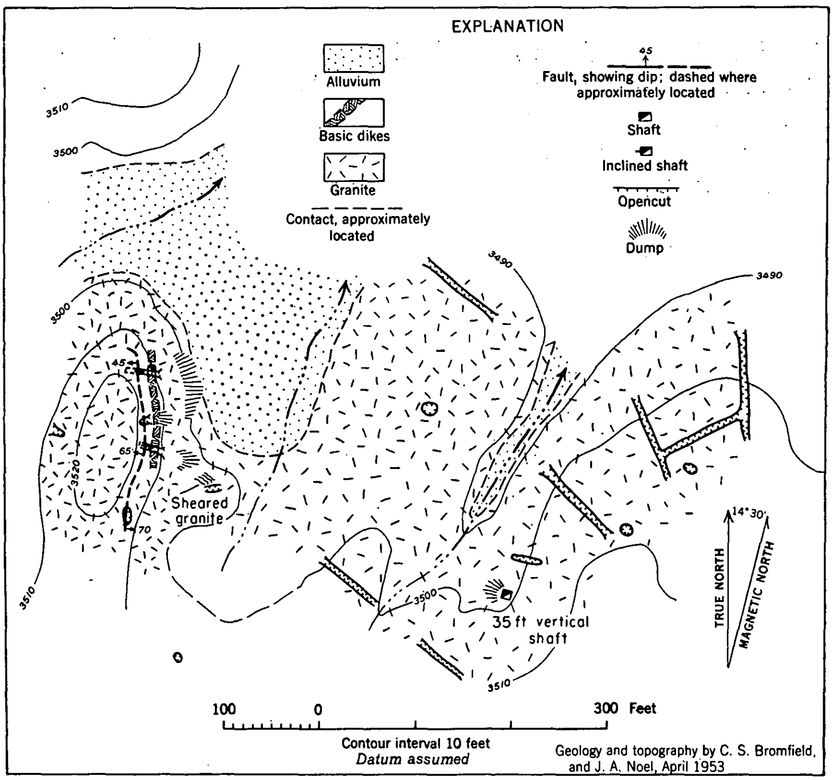

FIGURE 78.—Geologic sketch map of the Peacock copper workings.

BITTER SPRING PROSPECT

Some old workings are near the upper end of Bitter Spring trap, on the northwest slopes of Mount Turnbull, in sec. 17, T. 4 S. R. 20 E. (pl. 53). The locale can be reached only by foot or horseback. The prospect is accessible from San Carlos as follows:

Miles	*Directions*
0.0	From San Carlos, travel 30.4 miles via Peridot road to U. S. Highway 70, thence east toward Safford.
30.4	Turn right on truck road to south.
38.0	Turn left on dim truck trail.
38.5	Park, and follow horse trail east for about 1.5 miles to Bitter Spring trap. Prospect at upper end of fenced area.

Claims in this area were located by F. C. Crockett in 1920. An adit of unknown length, now flooded, and a shallow shaft, now caved, are the only workings that were noted. No production is recorded.

The area is of moderate ruggedness on the intricately dissected slopes of Mount Turnbull. At the workings the altitude is about

4,650 feet. The country rocks in the vicinity of the workings are largely rhyolitic and andesitic volcanic rocks, but at two place there are small outcrops of limestone of indeterminate age. Each of these small outcrops is weakly mineralized and has been prospected.

At one of the outcrops, on the east side of a north-trending gulch above Bitter Spring trap, a shallow shaft has been sunk on a contact between limestone and rhyolitic rock. At this contact, a little magnetite has replaced the limestone. Minor malachite stains on magnetite, as well as a little pyrite, were noted. The mineralization is less than 10 feet in length.

The second of these isolated limestone outcrops is a few hundred feet south of the first outcrop, on the west side of the gulch. The exposures are poor, but near the bottom of the gulch an adit has been driven S. 15° W. on a quartz-pyrite-magnetite zone of mineralization. The zone is 5 to 10 feet wide. Upslope, for a distance of 100 to 150 feet, magnetite float is found along the projected strike of the zone. No copper or other minerals were noted. Within 25 feet of the zone, andesitic and rhyolitic float is found, but the soil cover obscures the contact between these rocks and the limestone.

A sample of the quartz-pyrite mineralized rock assayed 0.01 ounce of gold per ton, and 1.0 ounce of silver per ton.

GERONIMO PROSPECT

Some workings, including a 100-foot shaft and two shallow cuts, are located 3 miles southwest of Bylas in the foothills of the Turnbull Mountains in sec. 11, T. 4 S., R. 21 E. (pl. 53). These workings are believed to be a part of the claims known originally as the Geronimo group, which were located July 1, 1920, by B. F. Baker and others. Subsequently, a lease was obtained; in 1929, the lessees were in arrears with their payments, and the lease was lost. There was no production.

In this area, a medium- to fine-grained dioritic rock is intrusive into granite. The age of the rocks is not known. Both rocks have been faulted and fractured, but no attempt has been made to determine the structural relations.

The shaft has been sunk on an outcrop of dioritic rock that is chloritized and cut by narrow fractures along which scattered grains of quartz, pyrite, and chalcopyrite occur. The individual fractures average less than a centimeter in width. Though the shaft is inaccessible, rock on the dump indicates that sulfides were not abundant in the shaft. Iron oxides have formed, but unoxidized sulfides can be found at the surface. This indicates that erosion has kept pace with, or has exceeded, the rate of oxidation and that little or no secondary enrichment can be expected at depth. The length of the zone along which sulfides sparsely coat fractures is a few tens of feet.

TRIBAL CLAIMS

The claims known locally by this name are about 5 miles north, and a short distance east, of Bylas at the foot of the southern slope of the Gila Mountains in sec. 33, T. 2 S., R. 22 E. (pl. 53). They are not accessible by road; however, they can be reached by jeep or truck by fording the Gila River at Bylas and going north 5 miles on the bed of a southerly-draining wash.

These claims were first located in July 1920 by James Stevens, William Stevens, Richard Bylas, and John Rope. The claims were visited in January 1953 in the company of Jeff Davis, who acted as a guide. There has been no production.

At the foot of the Gila Mountains in this area, Cambrian quartzites and Devonian and Carboniferous limestones are exposed. These are overlain by Tertiary volcanic flows. In general, the Paleozoic rocks strike northwestward and dip at low angles toward the southwest or northeast.

The workings consist of three shallow cuts which expose a weakly metallized vein over a length of 200 feet along a fault striking N. 75° W. and dipping 75° NE. This fault brings Cambrian quartzite on the south against Devonian to Carboniferous limestones on the north. At the center cut, the fault zone is composed of about 2 feet of greenish to reddish clay gouge and about 2 feet of milky-white quartz veinlets containing calcite, specular hematite, malachite, and possibly a little fine-grained pyrite. The vein is in sharp contact with the clay gouge on the footwall side, but the hanging wall contact with the limestone is bordered by irregular, narrow stringers of specular hematite and quartz which penetrate into the limestone.

About 200 feet northwest at the westernmost pit, located where the fault is exposed in a saddle, the vein is composed largely of quartz veinlets, specular hematite, and minor amounts of malachite-stained rock. Here, in the partly caved pit, some much weathered, light-colored porphyry was observed, thus suggesting the presence of a dike in places along the vein. The easternmost pit is in talus and does not expose the vein.

A grab sample from a small pile of sorted vein matter from near the central pit assayed 0.01 ounce of gold and 0.4 ounce of silver to the ton, and 2.27 percent copper.

COPPER PROSPECT (NAME UNKNOWN)

This prospect is 4 miles north of San Carlos and about ¼ mile east of the San Carlos-Sawmill road (pl. 53). Here, erosion has created a topography of gullies and low mesa-like divides in generally flat-lying late Tertiary lake beds. The maximum relief is a few tens of feet.

Three pits have been dug along the east side of a gully that follows a fault striking about N. 20° W. and dipping steeply to the west. On the west side of the fault are calcareous silty sandstones, which are faulted against alternating thin beds of limestone and tan siltstones on the east side of the fault.

Copper, principally in the form of malachite, exists in small amounts as incrustations along seams and solution cracks in a 2-foot limestone bed, which is underlain by siltstones and overlain by silty sandstones. The copper is almost completely confined to the limestone, though in the most northerly of the three pits, at the contact with the limestone, some malachite stain was found in the overlying slightly calcareous sandstone bed. The pits are not on the fault but are within 10 feet of it, and they expose this meager copper mineralized rock over a length of 70 feet. No copper minerals were observed along the fault.

The occurrence of copper near the fault, though perhaps accidental, suggests an access for the copper-bearing solutions. The writer does not think that this meager ocurrence is derived from the oxidation of indigenous primary copper minerals; instead, it probably is due to precipitation from migrating ground water containing some available copper.

PROSPECT NEAR BUCKET MOUNTAIN (NAME UNKNOWN)

Approximately 1 mile southeast of Bucket Mountain in sec. 36, T. 1 S., R. 17 E. (pl. 53) are several pits on a "bull" quartz vein cutting pre-Cambrian granite. Presumably, these pits were made in a search for base or precious metals. The vein is typical of a number of veins of this type found in the granite in this general area. The trend of the vein is about N. 30° W., and the thickness ranges from 1 to 3 feet. Sporadic float and outcrop indicate that the body or vein is at least 125 feet long. The quartz, which is white and vitreous, is in places stained rusty brown to red on fracture surfaces; pyrite is rarely seen, but pink feldspar crystals were noted.

IRON

Several small iron deposits are on the reservation. These consist of (1) scattered deposits on the flanks of Mount Turnbull, in which magnetite and minor amounts of copper minerals replace small isolated remnants of limestone along the contact of the limestone with light-colored felsitic rocks (see description of Bitter Spring prospect); (2) a deposit near Seneca, where magnetite replaces Mescal limestone near a diabase intrusion; and (3) a deposit southwest of San Carlos, where hematite replaces a limestone breccia. All of these deposits appear too small to be of significance as commercial sources of iron.

IRON CLAIMS

Three miles west of San Carlos and about half a mile south of the Southern Pacific Railroad tracks in sec. 16, T. 1 S., R. 18 E. (pl. 53), conspicuous concentrations of massive hematite are exposed along a northwest-trending fault. Claims are known to have been located in this area by Martin Wright, and others, in September 1926, and by William Sparks in June 1927. No production of any mineral is recorded. The deposit is explored by a vertical shaft about 100 feet deep (but now inaccessible), two short adits, and several cuts and pits (fig. 79).

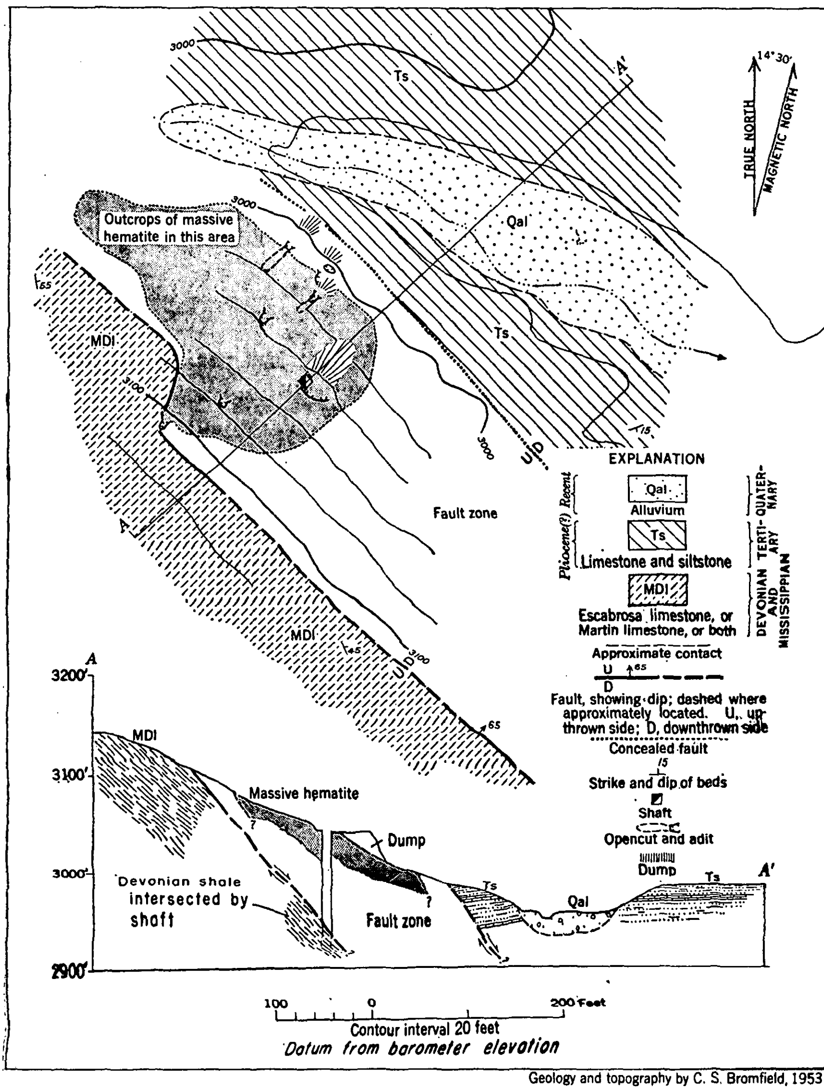

Figure 79.—Geologic map and section of the "Iron" claims workings.

In this area, two low hills of Paleozoic quartzite and limestones are surrounded by late Tertiary lake beds which are overlain by basalt. In general, the area is one of broad meandering washes between flat basalt-capped mesas or low rounded hills. The upturned rocks of Paleozoic age are an isolated southeastward projection of the ridge that extends from Chromo Butte southeastward to Gilson Creek. Near the workings, the Paleozoic rocks strike northwestward, dip toward the northeast, and are in contact with the late Tertiary rocks along a fault zone that strikes northwestward and has a general northeastward dip of about 60°. Paleozoic quartzite and limestone compose the footwall block, and late Tertiary rocks compose the hanging-wall block. The footwall limestone is generally shattered adjacent to the fault zone, and brecciated limestone is common within the fault zone. Near the workings, the fault zone is about 150 feet wide. The relations are shown in the plan and section of figure 79.

Within this fault zone, in an area about 150 feet long, prominent masses of iron oxides crop out. Coloration of soil indicates iron oxides may be present in some abundance for another 150 feet to the northwest along the strike, whereas to the southeast, though some iron oxides may be present, the float indicates the fault zone to be largely of a limestone-chert breccia. The iron oxides are in part a replacement of the limestone breccia and in part a filling of fractures. In places, large masses of unreplaced limestone-chert breccia are in sharp contact with massive hematite, and, in contrast, other contacts appear gradational. Some of the hematite masses contain unreplaced chert fragments. The iron oxides have been brecciated since their formation.

The hematite ranges in color from black to orange, but is commonly deep brick red; it ranges in firmness from pulverulent to compact; the compact material is the most common. Small quartz crystals line cavities in hematite. No other minerals were noted. The writer does not believe that this material represents a gossan, because there is no indication of the presence of former sulfide minerals such as boxwork, or earthy oxides. On the contrary, the hematite is massive and in places appears to have directly replaced the limestone breccia.

SENECA IRON PROSPECT

Several small lenses of magnetite occur in the Mescal limestone just north of the road to the Phillips asbestos mine and about half a mile west of U. S. Highway 60 in sec. 19, T. 4½ N., R. 18 E.

Diabase is intrusive into the Mescal limestone, and, at and near the contact at least three thin lenses of magnetite, ranging from 100 to 400 feet in length and from 2 to 3 feet in thickness, replace the limestone. The lenses parallel the bedding which strikes northwest and dips from 5° to 10° NE.

URANIUM

Several occurrences of uranium have been discovered recently in the Dripping Spring quartzite in two areas—one area is north of Roosevelt Lake at the south end of the Sierra Ancha, and the other is a short distance southeast of Young, Ariz. These prospects suggest the possibility that other occurrences of radioactive material, some of which might be of commercial importance, may be found by more intensive prospecting within the Dripping Spring quartzite. This formation is widely distributed in the western part of the reservation (pl. 52). On plate 52, more than half of the outcrop indicated by the symbol p€ds is Dripping Spring quartzite, and less than half of the outcrop indicated by this symbol consists of the underlying Barnes conglomerate, Pioneer shale, and Scanlan conglomerate.

Several days were spent by R. B. Raup, Jr., D. V. Haines, and the senior author in making a reconnaissance for radioactivity in the Dripping Spring quartzite. The metalliferous occurrences of the reservation were also checked for radioactivity; no abnormal radioactivity was observed except in the Dripping Spring quartzite. Traverses were made through this formation in the Mescal and Hayes Mountains, the Apache ridge, the south rim of the Natanes Plateau, and in the Salt River Canyon near U. S. Highway 60. Radioactivity was measured with a scintillation survey meter. Although no material was found to be of commercial grade, the Dripping Spring quartzite was found to have higher radioactivity than adjacent formations. In addition, the radioactivity was found to be higher in the upper siltstone part of the formation than in the lower light-colored quartzite part of the formation.

A complete section typical of the Dripping Spring quartzite in the reservation is exposed in Ranch Creek, 5 miles south of Cutter. Here, the lower light-colored quartzite part of the formation, approximately 120 feet thick, has an average scintillation counter reading of 0.015 milliroentgens an hour (mr per hr), background 0.010 to 0.012 mr per hr, and the upper silty quartzite part of the formation, approximately 300 feet thick, has an average reading of 0.025 mr per hr. The highest reading obtained was in a zone, about 15 feet thick, approximately 20 feet above the base of the upper part. In this zone, the average readings ranged from 0.040 to 0.080 mr per hr.

Although these readings, and those of other traverses of the Dripping Spring, do not indicate a commercial grade of radioactive material, they indicate a significant concentration of radioactive material in the Dripping Spring quartzite, particularly in the upper part of the formation. It is possible that other places may exist where conditions were favorable to greater concentration; therefore, further prospecting is warranted.

As a result of his examination of an occurrence at the Red Bluff prospect at the south end of the Sierra Ancha, near Roosevelt Lake, Kaiser (1951, p. 26) offered the following suggestions for the most favorable places to prospect for similar uranium deposits in this region of Arizona: "(1) The upper member of the Dripping Spring quartzite, with special attention to the lower third of this member. (2) Favorable rock in the vicinity of dikes and faults. (3) Northwesterly-trending fracture zones that cut Dripping Spring quartzite."

The observations of Kaiser in the Red Bluff area as to the relative favorability of the upper part of the formation are also valid for the widespread exposures of the Dripping Spring quartzite on the reservation. Therefore, in prospecting, the upper part of the formation, which is characterized by rusty-brown and black, thin-bedded siltstones and fine-grained silty quartzites, should be distinguished from the medium- to thick-bedded, medium-grained, light-colored quartzites of the lower part of the formation.

NONMETALLIC DEPOSITS

ASBESTOS

The asbestos of east-central Arizona, and of the San Carlos Indian Reservation, is chrysotile—the principal asbestiform mineral used in commerce. The demand for chrysotile asbestos is large and is likely to remain large. However, because of high production costs and difficulties of marketing, Arizona chrysotile cannot easily compete with asbestos from other sources for use in the construction industries. Arizona chrysotile has a low magnetic iron content and is particularly useful for electrical insulation. Asbestos from the San Carlos Reservation and other Arizona sources is likely to remain in demand for uses that require low-iron content. Arizona asbestos, of length and quality suitable for textiles, usually sells at premium prices.

Typically, the asbestos of east-central Arizona occurs as cross-fiber veins in 6- to 18-inch thick zones of limestone that are partly or completely metamorphosed to serpentine. These serpentine zones parallel the bedding of the Mescal limestone. The deposits are spatially associated with thick sills and narrow dikes of diabase that intruded and caused metamorphism of the limestone. As noted earlier in this report, limestone of Devonian, Mississippian, and Pennsylvanian age exist on the reservation. Asbestos does not occur in these limestones because they were deposited after the diabase was intruded and therefore were not subjected to the metamorphic processes that resulted in the formation of asbestos.

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In east-central Arizona, most of the asbestos deposits lie flat; however, a number of the occurrences of the San Carlos Reservation are exceptions. Essentially horizontal deposits are to be expected in the northern part of the reservation—in the part of the reservation that is within the boundaries of Colorado Plateau geologic province. South of the Natanes Plateau, in the Basin and Range portion of the reservation, the Mescal limestone (and therefore the asbestos deposits) can be expected to be moderately to steeply tilted.

Typical deposits of asbestos are roughly elliptical in plan, and are distributed over areas of from 1,000 to 20,000 square feet. The Bear Canyon deposit, which was the largest known deposit on the reservation and one of the largest discovered in Arizona, has been developed by stopes totaling 100,000 square feet in area (fig. 83).

Most of the asbestos deposits are mined by a modified room and pillar method. Because the asbestos-bearing serpentine zone is but a small part of the stope face that must be opened, and because the asbestos veins are only a part of the serpentine zone that must be extracted for milling, 10 to 50 tons of rock must be mined per ton of asbestos marketed. In general, 25 to 35 tons of rock are moved per ton of asbestos fiber produced.

Studies of approximately 100 Arizona asbestos deposits, including several on the San Carlos Reservation, indicate that four geologic factors were essential in order that asbestos be formed in sufficient quantities to be mined. If adequately understood, these factors can be very useful as criteria in prospecting or in appraising the potential of asbestos deposits. These factors are: (1) favorable stratigraphic units (certain favorable limestone beds), (2) proximity of the diabase to these beds, (3) thrust and bedding-plane faults, and (4) small open folds in the limestones.

Although small quantities of asbestos can be found in most beds of the pre-Cambrian Mescal limestone, deposits of sufficient areal extent and thickness to warrant mining exist, with few exceptions, only in, or immediately adjacent to, the thickest, most massive beds of the lower, flat-bedded member of the Mescal limestone. In the northwestern part of the reservation—the part of the reservation where the Mescal limestone is exposed in the Salt River Canyon adjacent to U. S. Highway 60—the beds that are favorable to concentrations of asbestos occur within the following stratigraphic units:

(1) The uppermost 2 to 7 feet of the lower member of the Mescal limestone—in other words, the limestone beds immediately below the massive middle (algal) limestone member (see p. 20–23).

(2) A 10- to 12-foot-thick section of limestone beds about 30 feet below the top of the lower member. This unit is made up of limestones

that are 8 inches to 3 feet thick; partings between beds include little shale or clay.

(3) A section of beds that is as much as 20 feet thick, approximately 40 feet above the contact between the Mescal limestone and the underlying Dripping Spring quartzite (about 100 feet below the algal member). A few beds in this unit are 1 to 3 feet thick, but most beds of the unit are 3 to 6 inches thick.

The units 30 and 100 feet below the top of the lower member are readily recognized because they crop out as prominent ledges, in contrast to the bulk of the lower member which crops out as slopes or is poorly exposed. The unit at the top of the lower member can be readily identified because it crops out immediately below the massive algae-bearing limestone, which forms thick ledges or cliffs in many places on the reservation. With the exception of the above-described units, most of the lower member is of thin limestone beds, ½ to 4 inches thick, intercalated with calcareous (limy) shales and clays. The thinner-bedded limestones commonly contain serpentine and in places contain asbestos; however, the asbestos is not present in minable quantities in such beds.

Only the more massive, purer units should be seriously considered for prospecting. There are no prominent examples known on the San Carlos Reservation of an asbestos deposit in the unit at the top of the lower member. However, these beds should be considered for prospecting, because approximately one-half of the known Arizona asbestos deposits are in this unit. The Apache and Bear Canyon deposits are in the more massive limestones 30 feet below the top of the member. The Emsco and Salt River deposits are examples of asbestos deposits in the lowest favorable unit. The Pine Top harsh asbestos is the only deposit on the reservation known to be in an exceptional stratigraphic position. In the vicinity of this deposit the upper part of the algal (middle) member of the Mescal limestone is made up of impure, flat-bedded limestones, 6 inches to 2 feet thick, rather than of the thick-bedded algae-bearing limestones that make up most of the middle member. Similar limestones have not been observed in the middle member elsewhere on the reservation. The cliff-forming, algae-bearing middle member is not a favorable host for asbestos deposits. In many places, determination of the stratigraphic position of asbestos deposits is difficult because thick diabase sills separate the limestones containing asbestos and those including a readily recognized stratigraphic horizon, such as the contact between the middle and lower members. However, this should be of little concern to the prospector if he uses the rule that only the thicker, ledge-forming limestones (excepting the middle member) are likely to contain minable quantities of asbestos.

Asbestos was formed in considerable quantities only where sills or dikes of diabase were intruded into, or near, the favorable limestone beds. Few minable deposits are more than 25 feet above, or below, a diabase sill; most of the significant deposits are associated with diabase intrusions that cut across the favorable limestone beds. Some of the larger deposits—the Emsco and Bear Canyon deposits are examples on the reservation—are in "slivers" of limestone partly, or completely, surrounded by diabase (see cross-sections, figs. 81 and 83).

Pre-mineral faults along the planes between beds and thrust faults, which transect the beds at small angles, were probably the most significant factor in determining the areal extent of the asbestos deposits. These bedding-plane and thrust faults seldom resulted in displacements of more than a few inches, and the effects of faulting are in most places obscured by later metamorphism of the limestones. Therefore, pre-mineral faults are difficult to discern. For the prospector's guidance, the following features may indicate that pre-mineral bedding-plane faulting affected large areas:

(1) Vertical, or near-vertical, small faults, some of which include small amounts of serpentine, apparently are numerous in areas of widespread bedding-plane faulting. In rare instances, narrow dikes of diabase occupy some of these faults and are offset by faults along bedding planes.

(2) Much of the contact between limestone and diabase may be faulted, and both the limestone and diabase adjacent to the contact may be impregnated with serpentine.

(3) An irregular contact between diabase sills and limestone may indicate that diabase was intruded into much-faulted limestone.

(4) Narrow veins of a white or pink, opaque, relatively hard serpentine, which is in contrast with the generally green or brown, translucent, soft serpentine common to the deposits, is suggestive of faulting before and during mineralization. The above features are suggestive, but not diagnostic, to prove widespread bedding-plane faulting.

(5) Bedding-plane faulting can be judged to have been distributed over areas of moderate to large size if clear-cut evidence of thrust faulting is observed. This evidence may consist of limestone beds that are offset adjacent to a fault-plane which cuts across bedding planes at a low angle. If such a fault is pre-mineral, unusual concentrations of serpentine and possibly asbestos may be observed in the favorable beds near the fault. Also, thin limestone beds that are observed to contain little or no serpentine in most exposures may be largely converted to serpentine near such faults. Narrow serpentine zones that transect the limestone beds at low angles represent thrust faults completely obliterated by later metamorphism. If dikes of diabase exist, they

should be closely observed for evidence of low-angle offsets along thrust faults.

Small open folds, caused by intrusion of the diabase, were favorable structural loci for the concentration of serpentine and asbestos. Commonly, these folds occupy an area 20 to 50 feet wide and 50 to 100 feet long. The height of an anticline, dome, or syncline may be 5 to 15 feet. The stope boundaries of the Emsco mine (see fig. 81) roughly outline a dome.

Two precautions should be used in appraising folds in the Mescal limestone as indicators of possible asbestos deposits. First, prediction that the folds will continue for more than a few tens of feet from the observed exposure is hazardous. The folds are the result of the diabase magma forcing its way into the limestone in a haphazard pattern, and therefore many folds are not continuous along a definite line of weakness. Second, care should be taken that the topographic expression of moderately or steeply dipping beds is not confused with the outcrop pattern of folds.

The premise that unusual quantities of serpentine are a good indication of a possible nearby body of minable asbestos is widely held among mine operators and prospectors. The phrase "unusual quantities of serpentine" means a zone of serpentine more than 4 or 5 inches thick, or large amounts of serpentine erratically distributed through a 2- to 5-foot thickness of limestone. In general, this premise is true, but exceptions are so numerous that this criterion should be used with much caution in prospecting. The ratio of asbestos to serpentine in the metamorphosed limestones varies greatly. For some deposits that have been mined, the ratio of asbestos to serpentine is approximately 1 to 1; for other deposits, the ratio is less than 1 to 10. Some beds of the Mescal limestone characteristically were metamorphosed to soft, talc-like serpentine. This type of serpentine, which may be difficult to distinguish from other varities—especially in a weathered outcrop—has not been observed to include asbestos veins. Some limestones of the formation were altered to a serpentine that occurs in wave-like, in many places discontinuous, bands. Although large amounts of such serpentine may exist, and although locally this serpentine may include wide veins of asbestos, few such deposits are continuous; consequently, the mining of asbestos from such deposits has not been esconomically feasible. In places, considerable amounts of serpentine, which includes asbestos veins, have been observed in the massive cliff-forming algae-bearing limestones of the middle member of the Mescal. Such deposits have proved not to be minable. If the above exceptions are kept in mind, the degree of serpentinization of the limestones can be effectively used as suggesting a possible minable deposit of asbestos.

Bedding-plane faults in the limestone were the result of adjustment during diabase intrusion. Therefore, asbestos deposits of Arizona can be segregated into two categories: (1) those deposits localized in a narrow belt where adjustments between beds were confined to the vicinity of a single discordancy between diabase and limestone, and (2) deposits localized where bedding-plane adjustments prepared the limestones over an area of considerable lateral extent. Most examples of extensive bedding-plane faulting occur where several discordant diabase-limestone contacts exist within an area of a few acres. Most of the asbestos deposits of east-central Arizona fall in the first category and are readily recognized as limited in potential. In general, deposits of the first category have a potential of 10 to 50 tons of all grades of asbestos; exceptionally, deposits of this type may yield a few hundred tons of fiber. Deposits of the second category may yield a few hundreds to a few thousands of tons of asbestos. Therefore in prospecting, those areas where multiple discordancies between diabase and favorable limestones exist warrant the greater attention. Folds and thrust faults are likely to be common in such areas; the limestones—including those not favorable to the formation of asbestos—also are likely to be much metamorphosed where multiple structures exist.

The usability of chrysotile asbestos depends in large part on adequate tensile strength and flexibility. In a number of instances, prospectors have been disappointed on developing an asbestos deposit because the asbestos had been altered by percolating ground waters and thus rendered useless or of low value. The asbestos of most outcrops is of poor quality due to weathering; the prospectors should estimate the depth away from the outcrop that weathering and leaching of the rock is likely to persist. If the limestone and serpentine along vertical, or near vertical, fractures and joints is chalky, bleached, or pulverulent, and if these openings have been widened by solution, the asbestos is likely to be deleteriously altered for a considerable distance from the outcrop. The asbestos-bearing limestones that crop out along steep canyon walls also are likely to have slumped from their original position where there has been considerable alteration by percolating waters. The same criteria can be used, in part, to judge whether or not mine workings will stand without timber.

Chrysotile asbestos also has a range of physical characteristics inherent in the original mineral and not related to the later leaching and decomposition noted in the preceding paragraph. Chrysotile may be soft, silky, and very flexible (soft fiber) or brittle and relatively inflexible, like a broom straw (harsh fiber). Usually, soft fiber has high tensile strength, and harsh fiber has low tensile strength. All gradations in degree of brittleness and tensile strength exist between soft fiber and harsh fiber. Semiharsh fiber has a moderate degree of flexibility and moderate tensile strength, but it cannot be used for all purposes for which soft fiber can be used. Harsh fiber has a much smaller range of uses than soft fiber and therefore is in little demand. Both soft and harsh asbestos occur on the reservation.

The Mescal limestone and associated diabase instrusions crop out only over a small part of the western third of the San Carlos Reservation (pl. 52); therefore asbestos deposits can be expected only in a few areas. Five areas that can be considered for asbestos potential are: (1) the extreme northwestern part of the reservation—roughly that part visible from the portion of U. S. Highway 60 that traverses the Salt River Canyon, (2) the area of Mescal limestone outcrop that extends northwest from Blue River to the western boundary of the reservation along the southwestern escarpment of the Natanes Plateau, (3) the small area of outcrops of the Mescal, located 1 to 2½ miles south and southwest of Cassadore Spring along Oak Creek and its tributaries (pl. 52), (4) the ridge termed in this report Apache ridge, southeast of Chromo Butte, and (5) the Hayes-Mescal Mountains area.

The Mescal limestone of the northwestern part of the reservation is the most likely host for asbestos deposits of all the Mescal limestone on the reservation. This part of the Mescal includes competent limestones favorable to the localization of asbestos, and the limestones are intricately intruded by diabase. This area, because of ready access, has been thoroughly prospected; therefore it is unlikely that many new asbestos occurrences will be found. Additional asbestos resources may result from more extensive exploration of known occurrences. However, most of the deposits of the northwestern part of the reservation have been moderately well to thoroughly explored.

The Salt River upstream from its junction with Sawmill Creek is in a steep-walled canyon that is difficult of access. Mescal limestone crops out in this section of the canyon as far east as sec. 30, T. 5 N., R. 19 E. In section 30, all of the Mescal limestone except the bottom half of the lower member was eroded prior to deposition of the Martin limestone. This easternmost outcrop of the Mescal includes two asbestos deposits on the north side of the river; no asbestos was found in reconnaissance of the Mescal on the south side of the river on the San Carlos Reservation. Prospecting is probably warranted between section 30 and Sawmill Creek; however, it is possible that the Mescal is missing due to pre-Martin erosion through a large part of this interval. No asbestos deposits have been reported in this part of the canyon.

Most of the Mescal limestone that crops out along the southwestern rim of the Natanes Plateau is difficult of access, and the potential for asbestos deposits in this belt is poorly known. West of the vicinity of Hilltop the distribution of limestone and diabase is poorly understood; the Mescal outcrop pattern shown on plate 52 for this area is extrapolated from knowledge of the position of adjacent formations. Until field work, beyond the scope possible in this investigation, demonstrates the existence of Mescal limestone in juxtaposition with diabase, the potential for asbestos deposits cannot be appraised along this part of the escarpment. It is possible that the Mescal limestone was eroded prior to deposition of the Paleozoic sedimentary rocks, or it is possible that it may not crop out because of fault displacement.

The Bear Canyon mine, the largest producer of asbestos on the reservation, is near the southeastern end of the outcrop of the Mescal limestone that parallels the Natanes escarpment. The limestones of this area are favorable for the localization of asbestos, and diabase is intruded in proximity to the favorable limestone units in several places in the vicinity of, and up, Bear Creek from the Bear Canyon mine. The upper tributaries of Bear Creek have been rather thoroughly prospected. Unfortunately, most of the deposits discovered have contained harsh or semi-harsh asbestos. However, favorable units of the Mescal limestone have been folded and intricately inflated by diabase in this area; therefore, continued search could result in the discovery of significant deposits of asbestos.

South of Cassadore Spring the area available for prospecting is small. Although this area could easily be made accessible for mining, and is adequately accessible for prospecting, the asbestos found to date has not been in sufficient quantities to encourage development.

Although Mescal limestone crops out along a large part of Apache ridge (pl. 52), much of the limestone is not intruded by diabase; therefore, asbestos deposits cannot be expected along the length of a large part of the ridge. The limestone beds immediately below the middle member of the formation, and a 5- to 10-foot limestone unit approximately 40 feet below the top of the lower member, are favorable to the formation of asbestos; the lowest favorable unit of the Salt River part of the reservation has not been observed in this area. Where diabase is not intruded into the Mescal, the outcrops of unmetamorphosed dolomitic limestone of Apache ridge are buff to brown in color and no serpentine can be observed. By use of this criterion, large parts of the Mescal along Apache ridge can be rejected for prospecting. The metamorphosed limestones, in which additional asbestos deposits might be found, are gray to white in color and serpentine is not uncommon.

Two general areas for prospecting are known on Apache ridge. One of these areas is adjacent to the western boundary of the reservation. Asbestos deposits discovered to date in this part of Apache ridge have been too small to warrant development. The second area is in the vicinity of the Apache mine, 5 miles northeast of Cutter. There has been production from the Apache mine since 1951, and a number of asbestos-bearing outcrops are known within ½ mile of the mine. The existence of favorable limestone beds in proximity to minor diabase intrusions, and the number of known occurrences of asbestos in the vicinity of the Apache mine, suggests that considerable prospecting is warranted along this part of Apache ridge. The formations of this subarea dip as much as 30° to the south and west, and northwest-trending faults offset the formations in a number of places. Because of the dip of the formations, and because of the depths to which water percolation along faults and joints has caused decomposition of serpentinized limestones, difficulty in mining can be anticipated if other significant deposits are discovered. A minor deterrent to prospecting in this area is the fact that asbestos of many of the known occurrences tends to be harsh.

Reconnaissance of the Hayes Mountains and of that part of the Mescal Mountains included in the reservation suggests that these mountains are not promising areas for minable quantities of asbestos, because the limestones of these mountains are not of the type favorable to the localization of significant asbestos deposits. Individual limestone beds of the lower member of the Mescal become thin, and the lower member includes progressively more calcareous shale as the Mescal limestone is traversed from north (in the vicinity of the Salt River) to south (in the Hayes and Mescal Mountains). Thin-bedded and shaly limestones of this area probably were not favorable hosts for the localization of asbestos. South of Red Whiskers Spring in the Hayes Mountains, the formation thins, and the lithology changes from a section characterized by thin cherty limestone beds intercalated with calcareous shales to a section made up almost exclusively of chert and siltstone. Asbestos does not occur in siliceous sections of the Mescal.

In the Hayes Mountains, asbestos is likely to occur in minable quantities only at one horizon (at the base of the middle member). The massive limestones of the bottom few feet of the middle member, and the thin, but relatively shale-free beds of the topmost 5 to 10 feet of the lower member, are the only limestones of the Mescal of this area that are likely to be sufficiently competent to have favored formation of considerable quantities of asbestos. Although occurrences of asbestos do exist at several horizons in the lower member in the Hayes Mountains, the only occurrences promising enough to encourage exploration have been found at the contact between the middle and lower members. None of these occurences have proved large enough to be mined.

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For convenience, descriptions of individual deposits of the northwestern part of the reservation are included under the following geographic headings: Sawmill Canyon subarea, I. S. Hole Canyon subarea, and the Salt River-Cienega Canyon subarea.

SAWMILL CANYON SUBAREA

In the past, several claims have been made in the area at, and near, the junction of Sawmill Canyon with the Salt River Canyon. This junction is located about 2 miles east of the U. S. Highway 60 bridge crossing of the Salt River, in secs. 29 and 30, T. 5 N., R. 18 E. (pl. 53). The area is accessible only by foot or horse trail from U. S. Highway 60 south of the river, or from the north side of the river by a steep road, which descends from U. S. Highway 60 to within about 100 feet of the north bank of the Salt River. The claims can then be reached by fording the river on foot.

WONDER CLAIMS

In this area, the Salt River flows in a southerly course and is joined by Sawmill Creek, which at its mouth has a westerly course. The Wonder Claims are located along the Salt River, just south of its junction with Sawmill Creek. These claims were first located by John E. Malone in December 1921, and a lease was obtained in July 1922. Some prospecting and a little underground work was done. No production is recorded, and the lease lapsed because of delinquent rental payments. In 1947, Skinner, Reidhead, and Lovier relocated this ground and some of the adjoining Silk claims as the Apache claims. A lease obtained in 1948 was subsequently cancelled because no work was done.

A segment of generally flat-lying Mescal limestone located from 100 to 150 feet above the bottom of the canyon is enclosed between two thick diabase sills (fig. 80). The segment of limestone at the workings is about 70 feet thick. A 9- to 12-inch thick serpentine band that contains several asbestos veins occurs about 6 to 7 feet above the lower diabase sill and about 1 foot below the bottom of the middle member. The main workings consist of two adits located about 100 feet apart along the outcrop. At the southernmost adit, which is 26 feet long with a 20-foot left-hand branch, 3/4 to 2 inches of soft to semiharsh fiber is exposed; at the mouth of the second adit, which is 48 feet long, and which is located 100 feet north of the first adit, only 3/4 to 1 inch of fiber is exposed and little or no fiber is exposed at the face.

About 300 feet northeast along the outcrop is a cut that apparently explores the asbestos horizon described above. In the cut, a vein of 3/4-inch semiharsh fiber is exposed 4 to 5 feet above the diabase contact and

1 foot below the algal limestone contact. Another intermittent asbestos vein, ranging from a knife-edge to ½-inch in thickness, occurs about 10 inches below this horizon.

SILK CLAIMS

The Silk claims on the north side of Sawmill Canyon were located by William M. Malone in 1921. A lease was obtained in July 1922, and some underground work (fig. 80) was done that resulted in a reputed production of 3 tons of fiber. The workings are situated

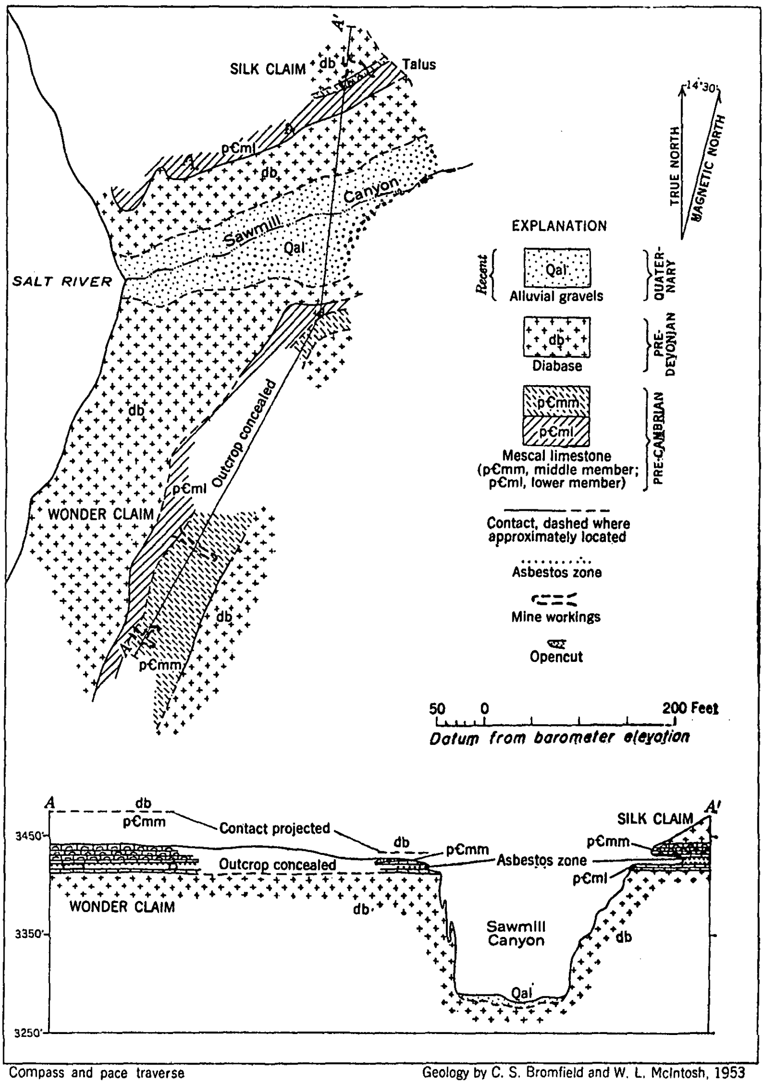


FIGURE 80.—Geologic map and section of the Silk-Wonder asbestos claims area.

about 150 feet above the canyon floor at the top of a nearly vertical diabase cliff. An aerial tram, still in existence, was built across Sawmill Canyon to facilitate transportation of supplies and equipment. There is no trail to the workings, which can be reached only by scaling the cliff.

The main workings are on the same segment of Mescal limestone on which the Wonder and Apache claims are located. Here on the north side of Sawmill Canyon, the segment of limestone included between the diabase sills is approximately 23 feet thick, considerably thinner than that at the main workings on the Wonder claims.

Two asbestos zones are exposed 4 feet and 10 feet, respectively, above the lower sill. The lower zone is at the floor of the workings and consists of a serpentine band about 9 inches thick. About 1½ to 2 inches of harsh fiber are exposed. The upper serpentine band, about 1 foot below the bottom of the middle member, is 9 to 12 inches thick and contains 1 to 2 inches of fiber.

About 30 feet to the east, the asbestos veins are covered by talus, but, where last observed along the outcrop, the upper serpentine band contains a maximum of ½ inch of fiber; the lower band is not exposed. To the west, the asbestos veins are poorly exposed by two pits within 200 feet of the main workings. One of these, within 100 feet, shows 1 to 1½ inches of harsh fiber. Only small amounts of fiber was seen in the westernmost cut.

I. S. HOLE CANYON SUBAREA

I. S. Hole Canyon is drained by a north-flowing tributary of the Salt River; the juncture of the river and the tributary is located about 1 mile east of the Salt River bridge (pl. 53). The canyon is rimmed by Martin limestone and Troy quartzite. These formations are underlain by a thick diabase sill which forms the major part of the rock exposed in the canyon sides. A thin segment of Mescal limestone both overlain and underlain by diabase sills occurs in places near the canyon bottom.

UNNAMED ASBESTOS PROSPECT

An old cut is located on the east side of I. S. Hole Canyon at a point ⅔ mile south of its mouth; no details of the history of this cut have been found. In the bottom of the cut an asbestos-bearing serpentine band is incompletely exposed. The segment of Mescal limestone is about 8 feet thick at this place, and the asbestos horizon is about 5 feet above the lower diabase contact. A few tens of feet along the outcrop to the south the limestone segment pinches down to a thickness of about 3 feet; a similar distance to the north the segment thickens to 12 feet or more.

Only ½ to ¾ inch of harsh to semiharsh fiber is exposed in the pit. About 50 feet along the outcrop to the north some 1-inch fiber float was found.

SULPHUR SPRINGS CLAIMS

At the head of I. S. Hole Canyon, in sec. 29, T. 4½ N., R. 18 E. (pl. 53), 1 mile east of Seneca, a few pits have been dug on an outcrop of Mescal limestone that is intruded by diabase below, and overlain by Troy quartzite. The location can be reached by a poor truck trail leading east from U. S. Highway 60 at Seneca.

Two claims, known as the Sulphur Springs 1 and 2, were located here by Ned Brown in 1950. No earlier history is known. The only observed workings were a cut and a 10-foot adit, which were located about 15 feet apart along the outcrop.

The Mescal limestone here strikes N. 70° W. and dips 35° NE. Diabase is not exposed, but float and soil about 30 feet downslope below the asbestos suggest that diabase intrudes the limestone a short distance below the outcrop.

The fiber zone exposed in the two workings is composed of white to light-green serpentine, which is 24 to 30 inches thick. In the cut, 1½ to 2 inches of soft fiber is present. The stub adit to the west contains 2 inches of fiber in numerous narrow veinlets averaging less than ⅛ of an inch in length. Some slip fiber was seen. The base of the limestone is 5 feet above the fiber zone.

Lateral extension of the fiber zone is untested. Outcrops are poor, and stripping or facing of the outcrop would be necessary to properly test its extent.

SALT RIVER-CIENEGA CANYON SUBAREA

Diabase is in discordant contact with favorable limestone units in many places in Salt River-Cienega Canyon. The area was thoroughly prospected in the early 1920's and has been frequently reviewed by prospectors, especially after the building of U. S. Highway 60 which made the area readily accessible. The deposits described below are the only deposits in the area that have attracted especial attention from prospectors and mine operators. It should be noted, however, that in addition to the described deposits, a number of asbestos occurrences, all presumed to be small (by mine operators), crop out along Cienega Canyon between the Emsco and Pine Top deposits.

EMSCO MINE

The Emsco mine is approximately 1¾ miles southwest of the Highway 60–Salt River bridge and a few hundred feet east of the west boundary of the reservation. The deposit, which crops out on a steep canyon wall, is accessible from Globe by 38 miles of paved road, 3.3 miles of good dirt road, and about 1,500 feet of poor trail. Claims, including this deposit, were located in 1921. The principal years of production were 1928–30 and 1936–38. Wilson (1928, p. 58) reported that during intermittent operations before 1928 about 30 tons of crude fiber were produced. From records of the U. S. Bureau of Indian Affairs it is estimated that 80 tons of No. 1 and No. 2 fiber, and 130 tons of No. 3 fiber (Arizona classification), plus 2,700 tons of mill rock, were mined between 1928 and 1941. No information is available as to the quantity of asbestos recovered from the mill rock. Most of the asbestos taken from this deposit was soft; much of the remaining asbestos either is harsh or is in such small quantities that mining is not feasible. The mine has been abandoned and stripped of all equipment.

The asbestos of the Emsco deposit is in two zones that are 14½ feet apart; these zones are in a sliver of Mescal limestone, 35 to 40 feet thick, overlain and underlain by thick diabase sills. The limestone sliver is bounded on the southeast side by a southwest-trending diabase dike that connects the sills. Approximately 100 feet northwest of the northernmost portal of the mine the outcrop of this sliver terminates against crosscutting diabase (fig. 81); travertine covers this discordance at the surface, therefore the strike of the contact can only be postulated.

The favorable limestone beds were folded upward in the area now outlined by the stope (fig. 81), on intrusion of the underlying diabase sill, and were folded downward adjacent to the dike, which bounds the sliver on the southeast. The resulting structure is dome-like (see sec. B–B′, fig. 81). The area of greatest deformation is now approximately outlined by a stope, 200 feet in diameter, on the upper asbestos zone. In this area, stresses imposed by the "doming" were relieved along numerous small-scale thrust and bedding-plane faults. Asbestos was concentrated where faults are most numerous.

The upper zone was the most productive; asbestos has been mined from the lower zone only where it is adjacent to a minor discordancy in the underlying sill (see sec. A–A′, fig. 81).

The lower zone has been explored by several hundred feet of drifts that extend southwestward from the stoped area. In many places, the beds adjacent to the lower horizon contain little serpentine and no asbestos. In other places, traces of asbestos can be noted, and in a few places along these drifts the serpentine zone is 4 to 9 inches thick and includes asbestos veins aggregating 1 to 3 inches in thickness. The thickest concentrations of asbestos exposed by the drifts are harsh fiber.

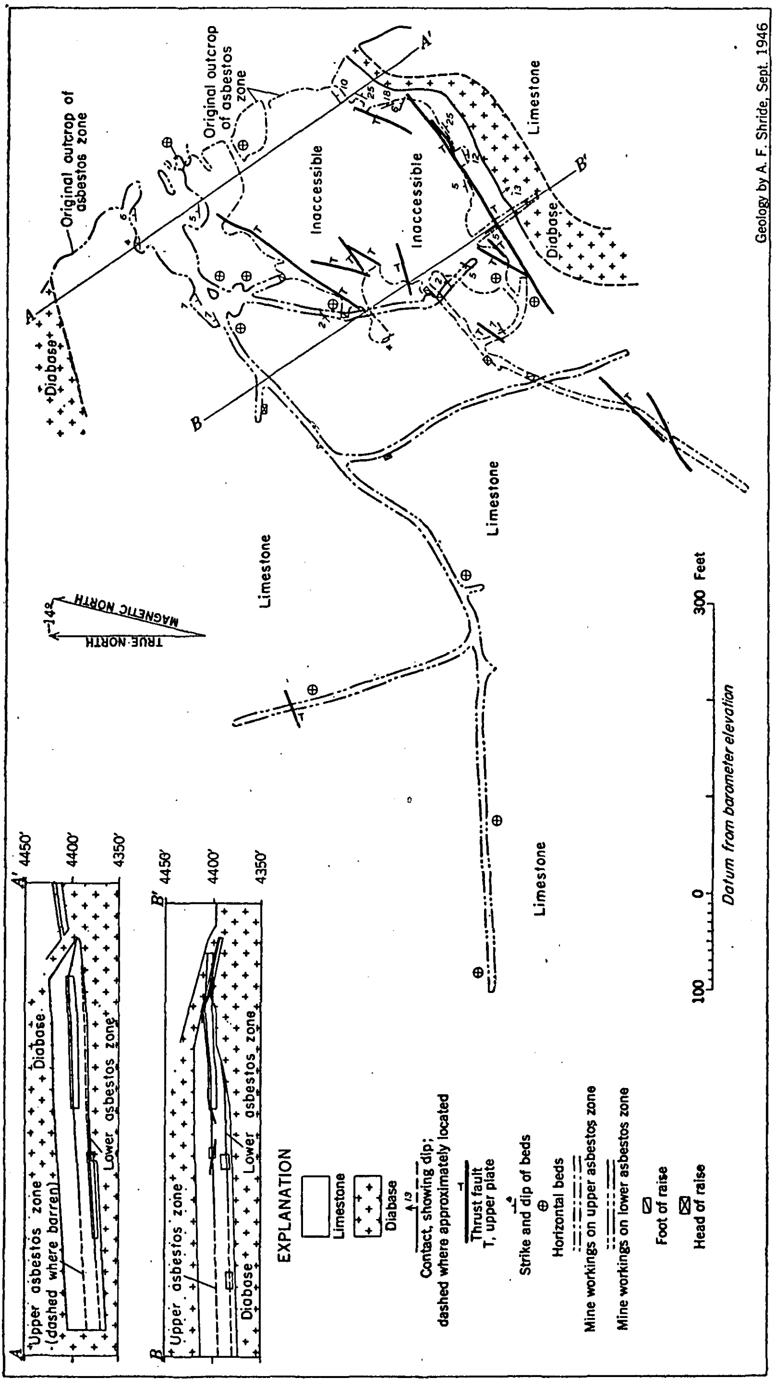


FIGURE 81.—Geologic map and sections of the Emsco asbestos mine.

The upper horizon is explored southwest of the stope by a few raises from the drifts that explore the lower horizon, and by a drift that extends 350 feet southwest from the main stope. Traces of asbestos can be observed in a few places where the upper horizon is exposed by these workings; in general, very little serpentine exists at the level of the upper horizon where it is exposed south and west of the stoped area.

The exploratory workings southwest of the stoped area penetrate flat-lying limestones that were deformed very little by intrusion of the diabase. Very little bedding-plane adjustment can be observed in these flat-lying beds. There is a distinct correlation between the lack of folds and faults and the lack of asbestos in the explored areas.

The limestone adjacent to the dike that bounds the limestone sliver on the southeast are most likely to have been deformed and therefore favorable to localization of asbestos. Unfortunately, the exploratory workings are not adequate to confirm the existence of the dike south and southwest of the stope area. Northeast-trending low-angle faults of minute displacement, which can be seen in the southernmost mine workings, may represent the belt of fractures along which the dike was intruded, and thin (6-inch) discordant diabase sills along a few of these fractures may represent thinned extensions of the dike. If this interpretation is correct, it is doubtful that additional minable asbestos bodies exist in the immediate vicinity of the Emsco asbestos deposit. As an alternative, the diabase dike may not have pinched out; instead, it may have been diverted in a southerly direction, as interpreted on figure 81. If the dike bends in a southerly direction, there is a possibility that additional ore shoots exist adjacent to the dike. It has been adequately demonstrated that the area encompassed by the exploratory drifts southeast of the stopes is devoid of minable quantities of asbestos.

PINE TOP ASBESTOS CLAIMS

The Pine Top deposits are 1 mile south-southwest of the Highway 60-Salt River bridge, and crop out on the steep north slope of a hill that overlooks the "Mule Hoof Bend" of the Salt River. The deposit is readily accessible from U. S. Highway 60 by 1½ miles of dirt road. From oral reports of several past operators it is estimated that 100 to 125 tons of harsh fiber and 2 to 3 tons of soft fiber were mined from these deposits prior to 1943. Since World War II possibly as much as a few hundred tons of harsh fiber have been mined from the Pine Top deposits. The following descriptions are from notes made by Shride in July 1946; recent mine developments have not been observed by the writers.

Two asbestos-serpentine zones, 8 feet apart, occur near the top of the middle member of the Mescal limestone. In this locality, there is a gradation upward from the massive, relatively pure, algae-bearing limestones usually observed in the middle member to impure, silty, thinly laminated, flat-bedded limestones. The lower of the two zones is at the top of a 2-foot thick, siliceous limestone bed and is 4 to 6 feet above a diabase sill approximately 200 feet thick. These zones, which include only harsh asbestos, have been exposed intermittently along 1,800 feet of east-trending outcrop by benches and short adits. The limestones dip 5° to 12° SE. (average 6°) at the west end of the outcrop and 6° to 13° (average 10°) at the east end of the outcrop. Exposures are almost continuous for 500 feet along the westernmost part of the outcrop, which has been exposed by benching. Only thin veinlets of asbestos can be observed in parts of the lower zone; in other parts of the zone, two or more veins totaling 6 inches in thickness exist. The easternmost 300-foot part of the outcrop tends to slough; therefore, asbestos is observed only intermittently at the outcrop. However, in 1946, four adits—two of which were 140 feet long—exposed considerable quantities of harsh fiber along this easternmost interval of the outcrop.

The asbestos horizons of the 1,000-foot interval between the eastern and western parts of the outcrop are, in most places, poorly exposed; however, the broken material in a few pits and dumps suggests that 2 to 3 inches of harsh asbestos exists in places within this interval.

The eastern part of the Pine Top area is the most promising site for large quantities of asbestos, because of the presence of thrust faults and minor flexures in the limestones. This is the only part of the deposit in which the harsh asbestos has been found in sufficient quantities to encourage much underground mining. Veins aggregating 3 to 8 inches in thickness were observed in several places; most of the asbestos seen was in the upper zone. A stope, 120 feet long and 20 to 60 feet wide, had been made in this part of the deposit before 1946. It is said that considerable additional stoping has been done since 1949; however, only harsh fiber was mined.

Everywhere in east-central Arizona that deposits have been observed in the impure beds near the top of the middle member of the Mescal limestone the asbestos has been very harsh. Although considerable quantities of asbestos may be found in this part of the limestone on the Pine Top claims, probably all of it is harsh. It should be noted also that the host beds for the harsh asbestos are very friable. Therefore, considerable timbering is necessary, and large stopes are difficult to keep open. Unless a special market can be developed for this asbestos, the harsh-fiber deposit of the Pine Top claims will probably continue to be difficult to exploit economically.

Additional asbestos-serpentine zones crop out approximately 300 feet below, and on the same north-facing hillslope as, the harsh-fiber deposit of the Pine Top claims. The 200-foot sill that underlies the harsh-fiber deposit overlies a section of algae-bearing limestone approximately 80 feet in thickness. A partial section of the lower member (about 50 feet thick) exists immediately below this part of the middle member and is, in turn, underlain by another thick diabase sill.

Veins of soft to semiharsh asbestos are exposed for several hundred feet along the outcrop at horizons, 1, 4, and 27 feet below the top of the lower member of the Mescal limestone. Along most of the outcrop of the three zones the asbestos veins total less than 1 inch in thickness. An 80-foot adit, and a stope 20 feet wide and 40 feet long, expose a segment of the zone 1 foot below the middle member. Only a few tons of soft asbestos were mined from this zone. At the outcrop in the vicinity of the adit and the stope, which are 30 feet apart, 1 to 2 inches of asbestos exist. However, the asbestos veins pinch out in places. For example, at the portal of the 80-foot adit 2 inches of asbestos occur; but 30 feet into the adit the veins pinch out, and in the last 50 feet of the adit only traces of asbestos can be found.

The serpentine zone 1 foot below the middle member contains more asbestos than the other two zones. Although the asbestos of this zone is mostly of good quality, the fiber exposed is not in great enough quantities to be minable. There are no indications of geologic structures that would be suitable for exploration in the vicinity of these outcrops.

GREAT VIEW MINE

This property is in sec. 35, T. 5 N., R. 17 E. (pl. 53) about half a mile east of the southern extremity of Mule Hoof Bend on the Salt River. The workings are a few hundred feet west of U. S. Highway 60 at an altitude of 4,400 feet.

George P. Bartlett, John C. Bartlett, Andrew J. Dunaway, and John B. Cobb located claims in this area in 1921. A lease was approved in January 1922, and a small amount of work was done—including an adit and several cuts. In early 1953 Ernest Victor was working this prospect.

At the main workings is an asbestos-bearing serpentine band, 1½ to 2 feet thick, in the Mescal limestone. This band has been explored by an 80-foot adit with two left-hand branches, 40 and 35 feet long respectively. A concordant diabase sill is about 9 feet below this zone. Fifty feet south of the adit portal the diabase becomes discordant and breaks sharply up across the beds. To the north along the outcrop, at a point about 100 feet from the adit, the sill is discordant and cuts downward away from the asbestos zone (fig. 82).

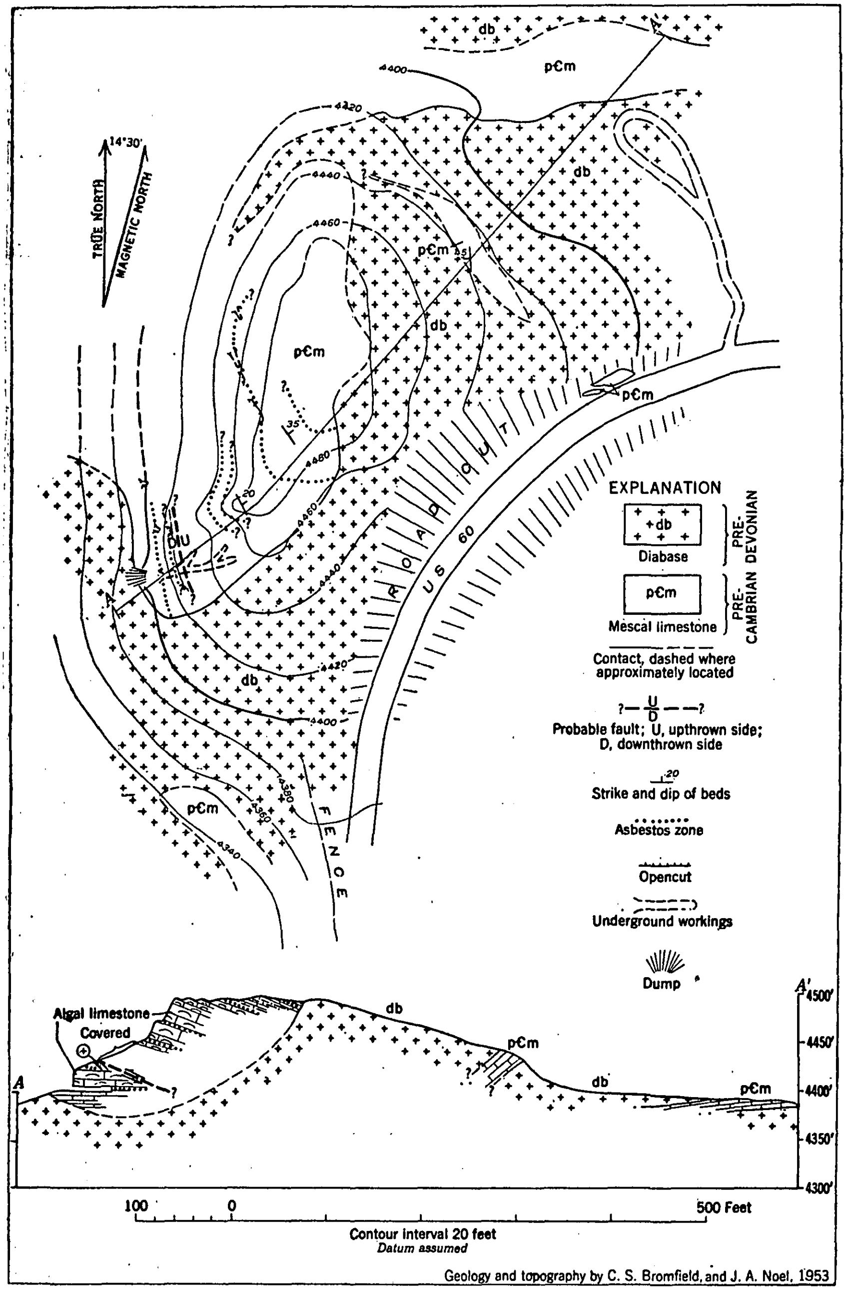


FIGURE 82.—Geologic map and section of the Great View asbestos mine area.

At the south end of the outcrop the asbestos-bearing serpentine zone abuts against the crosscutting diabase. Immediately adjacent to the diabase contact the serpentine zone is essentially barren of asbestos; but asbestos appears within 20 feet, and for about 50 feet along the outcrop the fiber averages from 1 to 2 inches in thickness. In a stub adit, 100 feet north along the outcrop from the diabase only ½ inch of fiber is present; in a cut 200 feet from the contact no fiber was seen.

Within the workings the fiber averages between 1½ and 2½ inches in aggregate length. Most of the fiber is semiharsh though some of it is of better quality. The face of the 80-foot adit is in diabase, and apparently it has penetrated the discordant diabase dike against which the asbestos-bearing band abuts at the surface. At the face, this discordant contact strikes approximately N. 50° E. and dips from 30° to 35° NW.

As indicated by the surface and underground exposures, the best asbestos showing appears to be limited to an elongate zone 40 or 50 feet wide which trends northeastward and parallel to the discordant diabase contact.

From the lower fiber zone (which is just below the base of the middle member) to the top of the hill, approximately 150 feet of Mescal limestone is exposed. In addition to the lower fiber zone, five more fiber zones were noted. Of these five, the best two have been prospected in a small way.

One of these two zones about 20 feet above the lower workings is explored by a cut that exposes a 6- to 9-inch serpentine band containing ½ to 1½ inches of semiharsh fiber. The zone is an algal limestone of the middle member. A 2-foot diabase dike, located 3 feet above this fiber horizon, crosses the bedding at a low angle and may follow a thrust fault (see cross-section, fig. 82).

The other prospected fiber zone (also in the algal limestone) is about 80 feet above the main lower workings; this zone is prospected by two cuts and two stub-adits. Some fiber was being "gophered" here in June 1953. These workings are distributed along an outcrop length of 120 feet and expose a fiber zone which contains an aggregate of 1 to 2 inches of fiber. This zone shows evidence of faulting, and slip fiber is present. The areal extent of this fiber zone is definitely limited by the discordant diabase contact to the south, east, and north, and by the topography on the west. The other zones contain short harsh fiber in veins ranging from ¼ to ½ inch in thickness.

Though six asbestos zones are apparently present, repetition of the beds is suggested by the section, and it is believed a thrust fault may be present (sec. A–A, fig. 82). If this interpretation is correct, there are actually only four asbestos-bearing zones. Several small-scale thrusts of northwest trend and southwest dip are exposed in the underground workings. Movement on these thrusts amounts to only a few inches. Several low-angle slip surfaces of northwest trend and northeast dip are present in the massive algal limestone above the main lower workings, but these are not shown on the map.

SALT RIVER (SORSEN-WILLIAMS) CLAIMS

The Salt River claims are located ½ mile southeast of the U. S. Highway 60-Salt River bridge. Highway 60 ascends the south wall of the Salt River Canyon, as a series of "horseshoe-like" loops. The westernmost exposure of asbestos on the Salt River claims is at the top of the roadcut of the lowest of these loops. From this point southeastward and southward, asbestos crops out discontinuosly through an interval of 1,800 feet along the rim of the lowest topographic bench of this part of the canyon.

A few pits and short adits, made prior ot 1940, exposed a part of this outcrop. However, no attempt was made to extensively prospect the asbestos deposits of this area until W. W. Sorsen and W. C. Williams, as the Sorsen-Williams Mining Co., started an exploration program in 1951. During 1951, 1952, and 1953, several hundred feet of the rimrock were cleared of debris by bulldozing to expose the asbestos-serpentine zones. The western part of the outcrop was further tested by two adits, 80 and 100 feet long respectively, and one area near the eastern end of the outcrop was explored by an adit and drifts totaling 600 feet in length.

The asbestos of the Salt River claims occurs at two or more horizons in competent, medium- to thick-bedded limestones. These limestones are those of the favorable stratigraphic unit that is a few tens of feet above the base of the lower member of the Mescal limestone. The beds are generally horizontal in attitude.

A sill, at least 500 feet thick, overlies the limestone. The contact between the diabase and the underlying limestones undulates; this undulation is significant in a discussion of these deposits. Along three intervals of the rimrock, the base of the sill is in contact with limestones stratigraphically lower than those favorable to asbestos localization, and in three places on the claims the base of the sill is stratigraphically above the favorable beds. The favorable beds can be visualized, in cross-section, as occurring near the tops of "islands" or "hummocks" of limestone that are separated by shallow troughs filled by diabase.

The following description refers to the exposure of asbestos in the roadcut of Highway 60. Much of the contact between the sill and the limestones and much of the rimrock exposure of the asbestos zones can not be seen at the present time because debris has slumped down across the stripped outcrops. Therefore, the descriptions are based on exposures observed at various times during the 1951–53 exploration program.

Asbestos apparently exists continuously for a distance of 450 feet southeast of the roadcut exposure. This zone, which is 1 to 3 feet below the diabase sill, is 4 to 8 inches thick and includes veins of soft asbestos totaling ½ to 3 inches in thickness. The cumulative thickness of the veins in most exposures is 1 to 1½ inches. The asbestos, limestone, and overlying diabase of this interval are much decomposed due to weathering. Near-surface slump and creep of the limestone and diabase has occurred. The exposures observable in bulldozer cuts and in the 100-foot adit suggest that broken heavy ground can be expected through a minimum distance of 150 feet away from the outcrop. Because the asbestos will be decomposed, and because mining costs would be excessive in the broken ground, the asbestos deposit adjacent to this interval of the outcrop would be very difficult to explore or mine.

In an interval 450 to 550 feet southeast of the roadcut, the outcrop is partly covered by debris; however, it is likely that through this interval the contact between the limestone and the overlying diabase is troughlike, and the sill is in contact with limestone of a lower stratigraphic horizon than that of the asbestos zone. Therefore it is probable that there is no asbestos in this 100-foot interval.

Southeast of this troughlike depression the asbestos-bearing limestones are exposed in the contact on the nose of a small ridge that trends northeastward. On this nose, the base of the sill is 5 to 15 feet above the asbestos-serpentine zones. The asbestos-bearing outcrops are truncated on the east side of the ridge where the contact with the overlying sill cuts discordantly down across the limestone. This discordancy trends westerly and dips to the south; thus, the asbestos-bearing limestones are truncated southward into the hill, and only a small area beneath the nose of the ridge is available for prospecting. Quarry faces on the north and east sides of the nose, and an 80-foot adit on the east side of the nose, expose two serpentine-asbestos zones, which are 1 foot apart. Each zone ranges from 3 to 6 inches in thickness. The upper zone includes veins of asbestos totaling ¾ to 2½ inches in thickness; the veins of the lower zone are ½ to ¾ inch thick. The fiber tends to be harsh, but it is of moderate strength. Most of the veins are minutely parted, and the fiber is short.

Between the asbestos deposit on the nose of the ridge and a third deposit to the south, the base of the diabase sill (through a rimrock length of 650 feet) is at a stratigraphic horizon below that of the favorable limestones. Therefore, asbestos-bearing limestones do not exist through this 650-foot interval.

At the south end of this interval, the diabase-limestone contact transgresses discordantly upward and across the limestone beds. Southward from this discordancy, which probably strikes toward the northwest, the sill is concordant at a stratigraphic horizon about 15 feet above an asbestos-serpentine zone in the limestones. The base of the sill persists at approximately this horizon before cutting down across the horizon 300 feet farther south. The asbestos-bearing limestone in this southernmost limestone remnant is exposed along a bulldozer cut, 250 feet long, and by an adit and several drifts totaling 600 feet in length. The southern half of the bulldozer cut is barren of asbestos. Asbestos occurs as continuous veins only along the northernmost 120 feet of the cut, in the vicinity of the mine portal. In places in the mine workings there is no asbestos, but, throughout most of the area exposed by the workings, veins totaling ½ to 3 inches in thickness occur in a 4- to 15-inch zone of serpentine, or partially serpentinized, limestone. Commonly, a thin sill, 4 to 15 inches thick, is 6 to 12 inches above the asbestos horizon, but in a few places the sill was intruded at this horizon. Asbestos was not deposited where the sill inflated the limestone at the favorable horizon. The asbestos of the southern deposit is soft and, in general is of moderate tensile strength, but weathering has caused partial decomposition of some of the asbestos.

Northwest-trending fractures are numerous where the southern deposit is exposed by mine workings. As a result of water solution along the fractures, and of slumping of the blocks bounded by the fractures, vertical openings as much as 2 feet wide exist throughout much of the deposit. As a result, the ground is very heavy—the limestone above and below the ore zones caves readily, and workings are difficult to maintain.

Asbestos is exposed in the south deposit in adequate quantities to be mined, if the ground was not heavy. Some asbestos was produced during 1953, but mining was stopped when the mine openings became large enough that further exploitation was difficult. The concentration of serpentine and asbestos seems to be greatest in the northernmost of the mine workings, and therefore it seems reasonable that asbestos would increase in quantity toward the discordant northwesterly-trending diabase contact that must exist a few tens of feet northeast of the mine workings. In this direction, it is also reasonable to suppose that the openings along fractures would be wider, the rock would be more difficult to support in mine workings, and the fiber would be more decomposed. Therefore, this extension of the deposit would be difficult to explore or exploit.

ASBESTOS PROSPECTS NORTHEAST OF SENECA

Some workings, including three short adits and a cut, explore an outcrop of Mescal limestone on the west slope of the hill lying northeast of Seneca—about 1 mile northeast of Seneca, in sec. 20, T. 4½ N., R. 18 E. (pl. 53). No monuments were seen on the property, and there is no history available about the workings, which are visible from U. S. Highway 60.

At this place, a segment of pre-Cambrian Mescal limestone, about 20 to 30 feet thick, is underlain by a thick diabase sill and is overlain by pebbly crossbedded Cambrian Troy quartzite. The hill on which the prospects are found is capped in part by Tertiary basalt flows.

Several minor workings explore the outcrop of the Mescal limestone over a length of about 400 feet. Two short adits at the northern end, within 50 feet of each other, were driven on a 1-foot asbestos-bearing serpentine band which occurs 1½ to 3 feet above the diabase-limestone contact. The average aggregate amount of fiber in, and between, these workings is ½ to ¾ inch. An equivalent amount of the columnar jointed serpentine, which includes minute veinlets of chrysotile and which is termed "bone" by the miners, is also present.

The southernmost working shows ½ to ¾ inch of harsh fiber in a 12- to 15-inch green serpentine band. The diabase is about 4 feet below the fiber zone at this locality.

BEAR CREEK SUBAREA

BEAR CANYON DEPOSIT

The Bear Canyon asbestos mine is approximately 14 miles northeast of San Carlos and is accessible from San Carlos by 19½ miles of dirt road (pl. 53). Tertiary basalts and gravels, which lap against the south-facing escarpment of the Natanes Plateau, have been stripped away along the canyon of Bear Creek to expose Mescal limestone and diabase.

The Bear Canyon mine has been one of the largest producers in the Arizona asbestos district; approximately 1,200 tons of all grades of asbestos have been mined from this deposit. The main period of production, between 1927 and 1930, was by the Bear Canyon Asbestos Co., a subsidiary of the Keasbey and Mattison Co. of Ambler, Pa. During this period, long fiber was the main material recovered from the ore, and it is likely that large amounts of short fiber were discarded into mine and mill dumps. Because a large part of these dumps has been carried away during flood stages of Bear Creek, comparatively little short-fiber asbestos remains in the dumps to be recovered if a salvage operation was feasible. Although a part of the asbestos recovered from the ore was soft and of good tensile strength and flexibility, a large part was harsh and little in demand. Therefore, between April 1930 (when the Keasbey and Mattison Co. abandoned the property) and 1949 (when a market for harsh and semiharsh fiber became available) little mining was done in the Bear Canyon deposit. Since 1949, a few hundred tons of soft, semiharsh, and harsh asbestos have been mined. During 1953, several hundred feet of exploratory drifts and raises were driven. These mine workings have defined the outlines of the limestone block in which the asbestos occurs and have shown that little further production can be expected from the Bear Canyon deposit. However, the deposit is worthy of description because it is an excellent example of a deposit that is large because of the genetic association with multiple geologic structures.

Most of the asbestos of the Bear Canyon deposit occurred in a 30- to 50-foot thick limestone block, or "sliver", overlain and underlain by diabase sills (fig. 83). Laterally, the block is almost completely isolated from the main limestone mass by diabase. The block is bounded on the southeast by a cross-cutting portion of the enclosing diabase intrusion along a contact that strikes N. 15° to 30° E. and dips 50° to 70° NW.; 750 feet to the northwest, a diabase dike of parallel trend bounds the block on the northwest (fig. 83). This dike, which limits the ore-bearing block, is not exposed at the outcrop but pinches out underground approximately 70 feet northeast of the southwest portal of the mine. From the southwest end of this dike, several vertical 4- to 12-inch thick dikes trend S. 20° E. along the axis of a fold in the limestone. Southwest of this swarm of dikes, the limestones dip 4° to 10° to the north; northeast of the swarm, the dip is 11° to 16° (average 12°) NE. The limestone block is terminated down-dip to the northeast by a cross-cutting portion of the enclosing sill; this contact, which is 1,100 feet northeast of the dike swarm, strikes N. 30° W., approximately parallel to the dikes.

Asbestos was concentrated particularly along an arch, which parallels the dike that bounds the northwest side of the deposit, and adjacent to the fold along which the dike swarm was intruded. Pre-asbestos bedding-plane and thrust faults caused much shattering and preparation of the limestones for mineralization in the vicinity of both of these folds. A lesser concentration of asbestos was formed in the vicinity of a minor northwest-plunging syncline or trough (fig. 83) in the northwestern part of the block. Along the contact that bounds the block on the southeast the limestone was folded and fractured only locally; the resulting concentrations of asbestos were small. The central part of the stoped area included only marginal amounts of asbestos, as evidenced by pillars remaining in the workings (fig. 83). If the northeast-trending discordant intrusion that bounds the block on the southeast had not existed, it is probable that only those

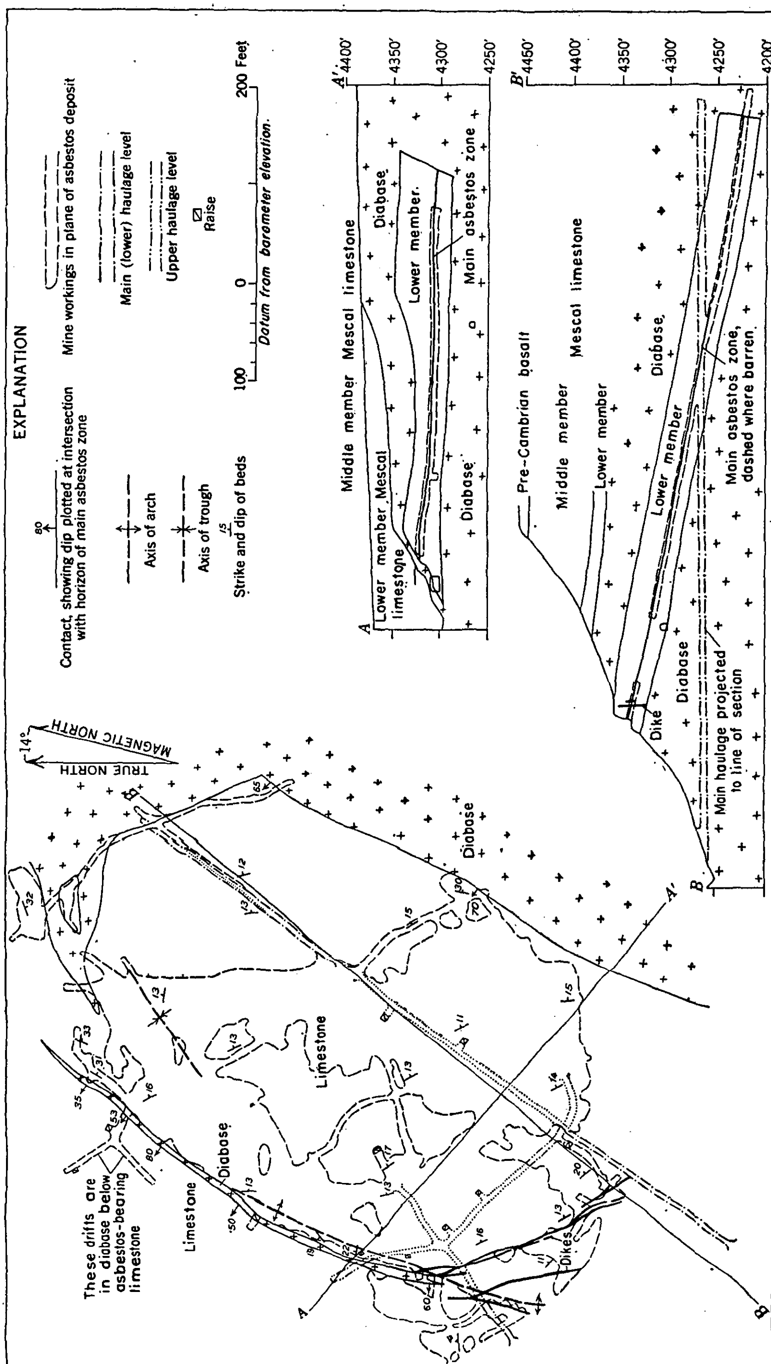


FIGURE 83.—Geologic map and sections of the Bear Canyon asbestos mine.

parts of the area adjacent to the two folds parallel to the northeast-trending dike and the dike swarm would have been sufficiently mineralized to warrant mining.

This deposit also affords examples of folded limestones that do not include much asbestos, and of favorable limestones which are adjacent to discordant diabase intrusions but which are essentially barren of asbestos. The limestones in the vicinity of the small stope that is shown on the northernmost part of figure 83 dip as much as 30 degrees and would appear to be particularly favored for the localization of asbestos. In this part of the area, however, the stresses caused by intrusion of diabase were apparently relieved by movement on one bedding-plane along which a thin diabase sill was intruded. The beds of the limestone block, where they are terminated to the northeast against diabase, were little deformed except along short portions of the contact; therefore, only a small amount of asbestos was formed adjacent to this contact.

The limestone on the northwest side of the dike that bounds the deposit on the northwest has been tested by raises and drifting. Asbestos was found in appreciable quantities only where stoped near the southwestern termination of the dike. It will be noted that this stope is adjacent to the intersection of the northeast-trending dike and the northwest-trending dike swarm. At this intersection, some warping of the beds and some adjustment between beds took place before asbestos was formed. North of this stope, the limestones on the west side of the dike, where exposed by raises, were little deformed and therefore contain little asbestos.

The main asbestos-serpentine zone that was exploited in the Bear Canyon deposit is 16 feet above the lower diabase sill (or approximately 40 feet below the bottom of the middle member of the Mescal). In general, this zone ranged from 10 to 20 inches in thickness and included asbestos veins totaling 2 to 6 inches in thickness. Other serpentine zones, which included asbestos only in the areas of greatest mineralization, are 2½, 4½, and 7 feet below the main zone.

A large part of the asbestos produced from the Bear Canyon deposit was harsh or semiharsh. Some of the semiharsh fiber had moderate tensile strength. Much of the asbestos produced was soft and of good tensile strength.

PROSPECTS ALONG UPPER BEAR CREEK

Four prospects were visited briefly in the area north of the Bear Canyon mine. Three of these are on claims leased by the present operators of the Bear Canyon asbestos mine. Recently, the operators built an access road to one of these prospects; the road passes near the other two prospects.

The first prospect visited lies about 1/2 mile north of the Bear Canyon mine along the west slope of the ridge between the east and west fork of Bear Creek (pl. 53), and a few hundred feet north of that junction.

Here, the Mescal limestone strikes N. 20° W. and dips 10° NE. and is cut by a discordant diabase body striking N. 10° E. and dipping 60° SE. The diabase bounds the asbestos-bearing limestones on the west. Asbestos has been developed in the limestone in a white to light-green serpentine zone, which, near the diabase contact, has a thickness of 6 inches. The asbestos-bearing zone is 2 to 3 feet below the base of the middle member. An adit, whose portal is at the diabase-limestone contact, has been driven in the limestone for a distance of about 75 feet N. 55° E.; apparently, the adit diverges from the discordant contact. An average aggregate thickness of 1 1/2 inches of semiharsh fiber is developed within a few feet of the contact. As now exposed, the asbestos is confined to within 15 to 20 feet of the discordant diabase contact.

The second prospect is on the east side of the east fork of Bear Creek, about 1/2 mile northeast of the previously described prospect (pl. 53). Several hundred feet east of the access road, a prominent bluff of Mescal limestone crops out.

The limestone has been intruded by a thick diabase sill that forms a slope below the bluff. An adit has been driven 15 feet into the cliff on an asbestos-bearing horizon located 20 feet above the diabase sill. Asbestos is localized in an 8- to 10-inch cream to white serpentine band; the maximum fiber length observed in the lower 4 inches of the band was 3 1/2 inches, although the average was about 2 inches. The fiber is harsh.

Near the face of the adit, a narrow diabase dike, which dips flatly into the face and cuts the fiber zone, is exposed. On the side of the dike nearest the face, the fiber zone is absent. It is probable that there has been displacement of the fiber zone along the plane now occupied by the dike.

Five feet above the asbestos horizon exposed in the adit is another asbestos-bearing serpentine band. One cut formerly exposed the band but is now caved; harsh fiber float, 1 1/2 to 2 inches in aggregate length, is found near this cut.

A cross-cutting diabase body cuts off the fiber zones about 100 feet to the southeast along the outcrop from the adit. Asbestos float can be found for a distance of about 100 feet to the northwest. The exposed fiber zones are 50 and 55 feet below the top of the lower member.

The third prospect is also on the east slope of the east fork of Bear Creek a few tenths of a mile south of the last-described prospect (pl. 53). It is at the end of the newly built access road. A block of Mescal limestone, underlain by diabase, crops out on the south side of a gully tributary to Bear Creek. At the east end of a prominent limestone outcrop, diabase cuts upward and across the limestone beds. The contact of the limestone and the diabase strikes N. 5° W. and dips steeply to the west. The limestone beds are arched downward against the discordant diabase contact, and the axis of the arch parallels the diabase contact. A branching adit has been driven on the west side of the contact in the limestone adjacent to the diabase. One branch follows the axis of the arch for 25 feet, and the other branch diverges from the contact on a bearing of S. 29° W. for about 45 feet.

In the adit, a serpentine band, which ranges in thickness from 6 to 15 inches, contains a maximum of 3 inches of fiber and averages from 1½ to 2 inches. The fiber is semiharsh. The workings show fiber over a width of 25 feet from the limestone-diabase contact. Five feet above this fiber zone, another zone that is exposed for a few feet contains at least 2 inches of semiharsh fiber. About 80 feet to the west of the two zones at the adit, a pit discloses a poorly exposed zone containing a total of 1 to 2 inches of fiber. The fiber in the pit is weathered and appears to be semiharsh. The outcrops are poor, and the fiber zones do not outcrop between the two occurrences.

A fourth prospect is on the east fork of Bear Creek about 1 mile north of its junction with the west fork (pl. 53). It is on the east side of the creek a short distance above the creek bottom. This claim was visited by James A. Noel, from whose notes this description is taken.

This area is not included in the group of claims held by the operators of the Bear Canyon asbestos mine. W. J. Andrews located the Upper Bear claims in this vicinity in September 1928. An adit about 40 feet long was driven N. 85° E. on a meager showing of fiber. There was no production.

Relatively flat-lying Mescal limestone has been intruded by a diabase sill, and within several feet above the contact two serpentine bands have been formed. The lower band is 3 inches thick and contains a maximum of 1 inch of fiber; the upper band, about 3 feet above, is 4 to 6 inches thick and contains a total of $\frac{1}{10}$ to ½ inch of fiber. The fiber is semiharsh.

PROSPECT WEST OF BLUE RIVER

The rocks of the Apache group, which crop out under the Natanes Rim, disappear east of Blue River under a cover of Tertiary volcanic rocks. Just west of Blue River, the Mescal limestone has its easternmost exposure on the reservations; in this area, in sec. 17, T. 2 N., R. 20 E. (pl. 53), are some surficial workings on a showing of asbestos. This prospect is located 3 miles east of the Bear Canyon deposit and about ¼ mile west of the Whitetail Spring road, at an altitude of about 4,500 feet on the southeast side of a hill capped with volcanic rocks.

Here, approximately 40 feet of thin-bedded Mescal limestone is underlain by diabase and is overlain by red to rusty-brown siltstones and quartzites and brown to yellow-brown silty limestone of undetermined age, and Paleozoic limestones. The hill is capped by Tertiary basalt. The beds strike N. 45° E. and dip from 5° to 10° SE.

An opencut and a short stub-adit have been driven on an asbestos vein that occurs at a horizon about 25 to 30 feet above the underlying diabase-limestone contact. A white to gray-green serpentine band, about 18 inches thick, contains ½ to ¾ inch of chrysotile asbestos. The fiber is harsh to semiharsh in quantity. A small pit about 300 feet northeast of this location shows $\frac{1}{10}$ inch of fiber.

CASSADORE SPRING-OAK CREEK AREA

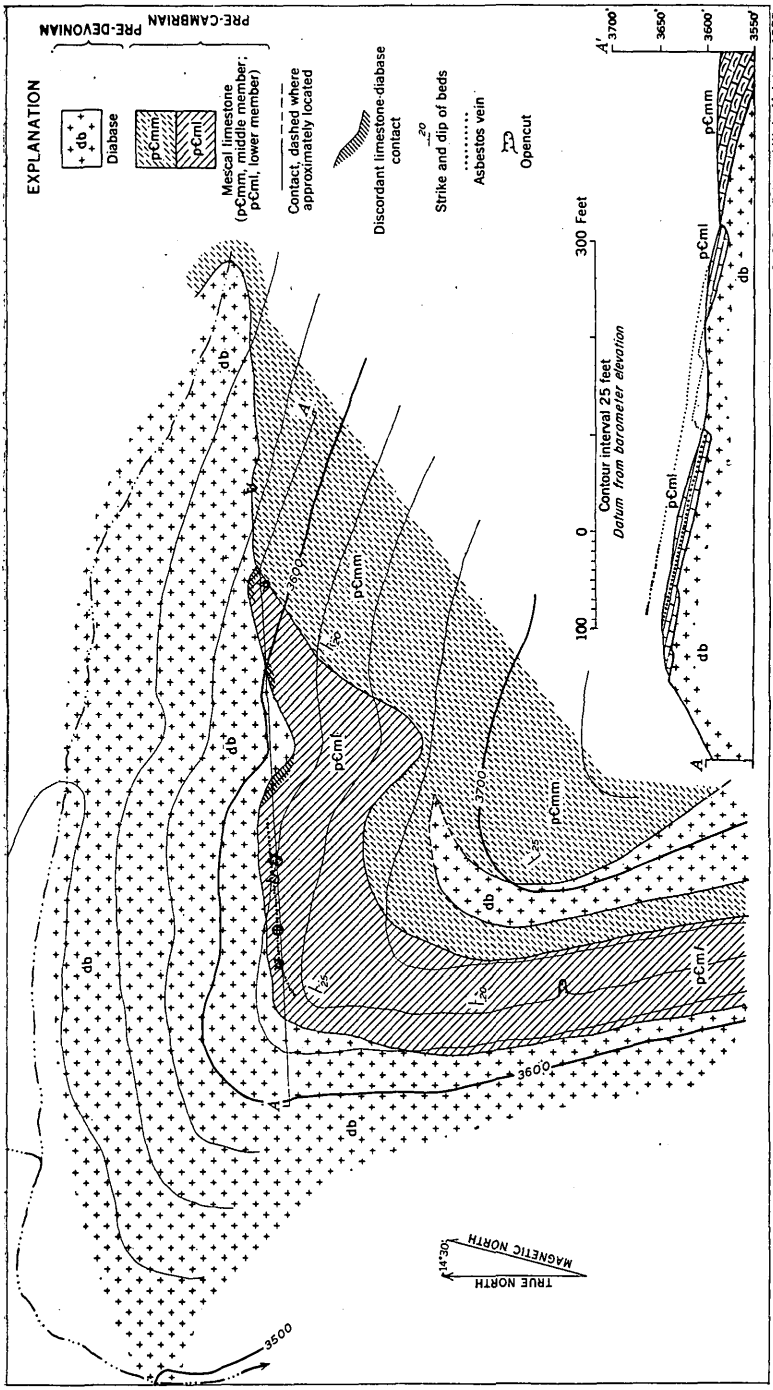
BLACK MESA DEPOSIT

Asbestos showings have been prospected in sec. 30, T. 2 N., R. 19 E. (pl. 53) about 2 miles south of Cassadore Spring and just north of Black Mesa. The San Carlos-Sawmill Road passes within 1 mile of the area, and it can be reached by following the road for about 1½ miles north of Cassadore Spring, turning east at a corral on the mesa, and then proceeding south for 2 miles along a southerly-sloping ridge line that parallels the San Carlos-Sawmill Road. The history and original names of the claims are in doubt, although it is known that several claims were located in this area in 1922 by J. C. Anglin. There has been no production.

The area is at an altitude of about 3,600 feet. Here a branch of Oak Creek has stripped away the overlying late Tertiary basalt and aluvium cover and has exposed Mescal limestone, which is intruded below by a thick diabase sill and above by a thin diabase sill. The Mescal limestone is tilted from 15° to 30° to the east. Serpentine and asbestos have been developed in the limestone near the locally discordant diabase sills (fig. 84).

Fiber occurs in two zones; one zone is located just below the base of the middle member and the other is 20 feet lower in the section. The upper zone has little or no fiber and is of only minor importance; the second or lower fiber zone contains more fiber.

Pits and trenches show asbestos in a few places along an outcrop that is 800 feet long. The two eastermost pits are on the upper zone at the base of the middle member where they expose ½ inch, or less, of semiharsh fiber. To the west along the outcrop, the diabase sill becomes discordant and cuts downward and away from the middle member, and about 40 feet of thinbedded limestone makes its appearance between the algae-bearing limestone and the diabase. Here, on



Geology and topography by C. S. Bromfield and W. L. McIntosh, 1953

FIGURE 84.—Geologic map and section of the Black Mesa asbestos prospect.

the lower zone, four pits covering an outcrop length of 150 feet reveal fiber in a serpentine band that ranges from 9 to 15 inches in thickness. The pits disclose fiber that averages 1½ to 2 inches in aggregate length. No asbestos is in the southernmost pit on the west-facing hillside (fig. 84).

ASBESTOS OCCURRENCE ON OAK CREEK

A small outcrop of Mescal limestone, which is intruded by diabase and overlain by Troy quartzite, occurs in sec. 24, T. 1 N., R. 18 E. (pl. 53) about 5 miles northeast of San Carlos on the east side of Oak Creek. The outcrop of older rocks, which dip gently to the east, is surrounded by flat-lying Tertiary lake beds. The limestone is the Algal type of the middle member of the Mescal limestone and has locally been irregularly altered to green serpentine near diabase contacts. The names and history of the claims in this area are unknown. Some rather short fiber was seen in one locality.

APACHE RIDGE AREA

PROSPECT NEAR CHROMO BUTTE

A few pits and underground workings are found in an outcrop of Mescal limestone in sec. 5, T. 1 N., R. 16 E., adjacent to and just inside, the western boundary of the reservation. This occurrence is 3 miles south of Chromo Butte and 5 miles northeast of Globe (pl. 53). The prospect is accessible as follows:

Miles	*Directions*
0.0	Junction of U. S. Highway 60 and 70, Globe, Ariz.
4.0	Turn right on ranch road at south end of landing field.
4.1	Gate, and fork. Take left-hand road.
5.0	Fork; take dim road to left (right fork goes to ranch house).
6.3	End of road at reservation fence. Prospect is about ½ mile north along, and just inside the reservation fence.

The area is one of low hills with a maximum relief of not more than 200 feet. The workings, which include several cuts and a branching adit, are at an altitude of about 4,300 feet in a saddle at the head of a south-draining wash.

At the workings, about 15 feet of thin-bedded white to gray limestone is underlain by a sill and is overlain by 10 feet of algal limestone and 70 feet of rusty-brown siltstones interbedded with a few
branching adit, are at an altitude of about 4,300 feet in a saddle at
Mescal limestone. The beds strike N. 55° W. and dip 25° to 30° SW.

At least three minor fiber zones were noted within 7 feet above the diabase-limestone contact. A cut on the contact shows an asbestos vein of a maximum width of ¼ inch in a 3-inch white to yellow serpentine band. Five feet above the contact in the adit a second 3-inch serpentine band contains ½ to 1 inch of soft to semiharsh fiber; 1 to 1½ feet higher a third 3-inch serpentine band contains ⅛ to ¼ inch of fiber.

About 50 to 60 feet southeast of the workings along the diabase limestone contact the diabase breaks across the limestone bedding and apparently wedges out within a few tens of feet. To the northwest of the workings, as far as the boundary fence, the contact is approximately concordant with the bedding in the limestone.

APACHE CLAIMS

The asbestos deposits of the Apache claims are on Apache ridge approximately 10 miles east of Globe. The claims are accessible from the Globe-San Carlos road by 3.6 miles of dirt road which is readily traveled except during wet weather.

These claims were first prospected in 1922, and small amounts of asbestos were shipped prior to 1925. The properties were idle from the middle 1920's until the Metate Asbestos Mines Co. took a lease on the claims in 1950. During the 1951–53 period, these properties have been one of the principal sources of asbestos on reservation lands.

The Mescal limestone, and an underlying diabase sill, dip 20° to 30° SW. in this area. Through a part of the area, erosion has stripped away the middle member of the Mescal and overlying strata, thus leaving a thin plate of the lower member as a capping on a thick sill of diabase. This capping crops out as a hogback near the crest of the northwest-trending Apache ridge.

Two deposits have furnished most of the production from these claims. One deposit crops out near the crest of the hogback; a second deposit crops out 400 feet to the south on the dip slope of the hogback and has been developed down-dip below the bottom of a small valley at the base of the dip slope. These deposits will be referred to as the north and south deposits, respectively. The limestones are offset approximately halfway between the two deposits by a high-angle, east-trending pre-diabase fault that is downthrown about 20 feet on the north.

The limestones of the lower member are, in general, very thin bedded and shaly in this part of the reservation. However, one competent limestone bed, 4 feet thick, occurs approximately 40 feet below the top of the member. The minable serpentine-asbestos zones on the Apache claims occur at the top and bottom of this bed.

North of the east-west fault between the two mines, the underlying diabase sill is 12 to 15 feet stratigraphically below the favorable 4-foot bed and is concordant northward to the vicinity of the north deposit. The outcrop along the ridge line to the northwest of the north deposit indicates that the diabase was intruded upward and across the beds of the lower member at a slight angle and that it truncates the favorable bed. This discordant contact is so poorly exposed that the strike of this part of the contact is poorly known, but it probably is somewhat north of east.

Immediately south of the easterly-trending fault, the diabase-limestone contact is concordant and at a stratigraphic horizon 2 feet above the favorable limestone. Along the outcrop, this contact continues southward at this horizon to the northeastern portal of the south mine. At this portal, the diabase-limestone contact cuts abruptly downward through the limestone section. The strike of this discordant contact is S. 70° W. The contact truncates the favorable limestone bed and bounds the northwest side of the south deposit. Northwest of this discordancy, the diabase-limestone contact parallels the bedding at a stratigraphic horizon 2 feet above the favorable limestone bed; south and east of the discordancy, the diabase is, in general, concordant with the bedding and the contact is 8 to 10 feet below the favorable limestone bed.

Asbestos of both the north and south deposits occurs in sizable concentrations only where the competent 4-foot limestone bed was deformed adjacent to discordancies in the sill. The discordancy adjacent to the north deposit is poorly exposed. However, this ore shoot plunges S. 60°–70° W., and it is very likely that the strike of the discordant diabase-limestone contact approximately parallels this direction. Minute details of folds and fractures exposed in the mine suggest that the favorable limestone bed is truncated against diabase at a distance of only a few feet northwest of the mine workings.

In the north deposit, the asbestos exists in quantity only at the bottom of the 4-foot favorable bed; fiber is exposed in the upper zone, at the top of the favorable bed, only in one small area. Nowhere in the vicinity of the north deposit does the degree of serpentinization suggest that minable quantities of asbestos will be found at the upper horizon. Where mined, the lower serpentine zone is 10 inches thick and includes veins of asbestos totaling 2 to 6 inches in thickness. The asbestos and serpentine content of the zone decreases abruptly to the southwest, 30 to 50 feet away from the inferred position of the line along which the diabase truncates the favorable bed. The ore shoot has been exposed for a length of 120 feet. The asbestos is semiharsh and much weathered. As a result, the fiber is weak, shatters on mining, and requires much hand sorting. The limestone that overlies the north deposit is no more than a few tens of feet thick, and fractures and joints along which water can percolate downward are numerous. Therefore, although the asbestos content of the southwest face of the stope where mining was discontinued is about the same as that of the area stoped, and although it is likely to persist in quantity to the southwest beyond the mine face, future development is likely to expose asbestos of comparable poor quality.

The asbestos of the south deposit occurs in minable quantities in a shoot, 20 to 80 feet wide, that parallels the discordant dibase contact bounding the deposit on the northwest. As of January 1954, this shoot had been mined throughout a length of 515 feet. The diabase was intruded discordantly along a fracture that trends N. 70° E. Southeast of this discordancy the diabase is generally concordant and is 8 to 10 feet below the ore-bearing bed. In detail, a few irregularities in the linear discordant contact exist. These irregularities can be visualized as "mounds" or "hummocks" of the diabase that project above the planar surface of the concordant diabase sill and merge with the discordant portion of the sill. These "hummocks" are most pronounced adjacent to the discordancy, and the limestone is much folded and fractured at these places.

The ore shoot is narrow, and the cumulative thickness of asbestos veins is least where the discordant diabase-limestone contact is relatively linear in plan view. In contrast, the ore shoot is widest and asbestos is in greatest quantities in the vicinity of the diabase "hummocks"; in these places, pre-mineral folding and fracturing of the limestone was more widespread.

Most of the asbestos in the southern deposit is at the top of the favorable bed. The bottom of the 4-foot bed includes minable quantities of asbestos only sporadically where the limestones are much deformed. The top zone is 10 to 20 inches thick and includes veins 2 to 8 inches thick. Locally, 3 to 4 inches of asbestos have been exposed in the lower zone. The asbestos tends to be harsh; some soft fiber of good quality has been mined from this deposit.

It is difficult to predict continuity for this type of asbestos occurrence. If there is persistent high-angle discordant contact between the favorable limestone beds and diabase, asbestos may be anticipated adjacent to the discordant contact. If, at intervals along this contact, "hummocks" of diabase exist on the sill that underlies the asbestos-bearing bed, then the serpentine zones are likely to be continuous and it is likely that asbestos will occur in significant quantities. In contrast, if the discordancy persists without adjacent "diabase hummocks" the ore shoot may narrow and asbestos may exist in quantities too small to be minable. Development parallel to the discordant contact will be necessary to prove the persistence of this deposit.

Several occurrences of asbestos crop out north and northwest of the north deposit (described above). The outcrops that include these occurrences are in part covered by surface debris; therefore it is difficult to appraise these deposits. Most of the occurrences appear to be confined to the immediate vicinity of discordant limestone-diabase contacts. The number of asbestos occurrences, and the juxtaposition of diabase and favorable limestone beds in a number of places near the Apache mine, suggests that additional prospecting is warranted in this vicinity.

HAYES MOUNTAINS AREA

CHIRICAHUA PROSPECT

The Chiricahua prospect is in the north-central part of the Hayes Mountains, about 13 miles southeast of Globe. The prospect is accessible from U. S. Highway 70 as follows:

Miles	*Directions*
0.0	Go south on Highway 70 from the junction of Highway 70 and the San Carlos road.
5.0	Turn right (west) on dirt road.
6.3	Follow right (west) fork of road across stream bottom.
10.3	Chiricahua deposit is at base of limestone cliffs above road. (Last 4 miles of road are difficult to travel by light truck.)

The Chiricahua deposit crops out along a steep east-facing escarpment at an altitude of about 4,500 feet. At this locality, the Mescal limestone strikes N. 10° W. and dips 20° to 25° SW. This attitude reflects post-Paleozoic deformation and is not related to deformation caused by diabase intrusion. Four asbestos-serpentine zones parallel the bedding of the limestone and are exposed almost continuously for 400 feet along an outcrop that roughly parallels the strike of the formation. The only development is one shallow pit, probably dug in the early 1920's; however, the natural exposures of the fiber-bearing zones are good.

The asbestos veins of the upper zone are distributed through partly serpentinized limestone that constitutes the uppermost 12 to 18 inches of the lower member of the Mescal. The next lower fiber-bearing zone is a 2- to 4-inch thick serpentine layer that is 2½ feet below the top of the member. The third zone is 2 to 4 inches thick and is 6½ feet below the top of the member. The fourth, or lowest, asbestos-bearing zone is 9½ feet below the contact between the lower and middle members and, in most places, consists of less than 6 inches of partly serpentinized limestone.

On the Chiricahua claims, the limestone beds of the lower member range from 1 to 8 inches in thickness; most beds are less than 3 inches thick. In the northern part of the reservation, a part of the limestone of the equivalent stratigraphic section is medium-bedded. Scanty asbestos content of the Chiricahua claims is probably, at least in part, related to the lack of competent limestones in the section.

The outcrop that includes the most asbestos is exposed by the shallow pit. At this place, all of the four serpentine zones include asbestos, and a thick underlying concordant sill is 1 foot below the lowest zone. Sixty feet south of the pit, the diabase sill cuts discordantly downward through 12 feet of the limestone before continuing concordantly to the south. The asbestos veins of the four zones pinch out about 20 feet south of this discordancy. One hundred feet north of the pit, the diabase cuts discordantly upward and across the lowest asbestos horizon. Eight inches above the horizon, the sill is again concordant and continues to be concordant along the outcrop to the north for at least 200 feet. Folds that would be favorable to the localization of concentrations of asbestos were not observed in the area. The limestones that are adjacent to the two discordancies in the sill contact are distorted very little.

In most places along the 400-foot outcrop the four zones include little serpentine or asbestos. Where asbestos exists in the upper zone it is soft and of good tensile strength; the fiber veins are discontinuous, and asbestos occurs only sporadically along the outcrop. At the pit, asbestos veins of the upper zone total 1½ inches; elsewhere along the zone the maximum content is 1 inch. The asbestos of the lowest three zones is harsh and of moderate to poor tensile strength. Asbestos in the second zone ranges from traces to as much as ½ inch in thickness. At the pit, the third zone contains ¼-inch of asbestos; in most places along the outcrop no asbestos is visible. Asbestos veins of the lowest zone total ½ to 1 inch in thickness. Beyond a point 300 feet north of the prospect pit all horizons are covered by soil and talus.

MYSTERY PROSPECT

The Mystery asbestos occurrences are ½ mile (airline) southwest of the Chiricahua prospect and are accessible from the Chiricahua prospect by 0.9 mile of dirt road.

Two asbestos deposits crop out in this area. The most extensive asbestos-serpentine zones crop out along a steep, east-facing hillslope. The zones are observable almost continuously for 300 to 350 feet roughly parallel to the strike of the enclosing limestones. The limestone beds of this deposit strike N. 10°–20° W. and dip 25°–30° SW. Two (and, in places, three) asbestos-serpentine zones are well exposed. The topography is such that the deposit is well exposed in the strike dimension and moderately well exposed in the dip dimension. Therefore, the observed zones probably are typical of the deposit.

The uppermost of the three zones is about 60 feet below the top of the lower member of the Mescal limestone. Most limestone beds of the stratigraphic section that includes the asbestos range from 1 to 3 inches in thickness and are interbedded with calcareous shales. None of the purer, more-brittle beds of the section exceed 8 inches in thickness.

The upper serpentine zone, which is the most persistent, is 3 to 6 inches thick and includes asbestos veins ranging from 1/4 to 1 3/4 inches in cumulative thickness. The average thickness of the veins in this zone is probably less than 1 inch. The fiber is semiharsh and of poor strength.

The veins of the second zone, which is 1 foot below the top zone, average 1/2 inch in cumulative thickness in the best-mineralized parts of the outcrop. In places, this zone contains no asbestos; in other places, a maximum of 3/4 inch of fiber occurs. The asbestos, which is semiharsh, is in a 4- to 5-inch thick bed of partly serpentinized limestone.

Minute veinlets of asbestos, in only a few places totaling as much as 3/4 inch, occur sporadically along a 6-inch thick zone of incompletely serpentinized limestone that is 12 to 18 inches below the second zone. Only traces of asbestos occur throughout much of the outcrop of this zone.

At the north end of the outcrop, the top of a thick diabase sill is 3 inches below the top serpentine zone. Thirty feet south of the northernmost exposure of asbestos the diabase sill cuts at a steep angle downward and through the limestone. South of this discordancy, beneath most of the deposit, the top of the sill is 6 to 8 feet below the top asbestos zone. No folds in the limestones can be observed, even in the vicinity of the discordancy.

Approximately 250 feet northeast of the southernmost outcrop of the deposit described above, and 150 feet lower in altitude, a second asbestos deposit crops out in the bottom of a narrow, southeast-trending gully. This deposit is immediately below the contact between the middle and lower members of the Mescal. A part of the interval between this deposit and the one previously described is covered by thick talus. However, because the base of the middle member of the Mescal is obviously about 200 feet lower at the second deposit than at the first, displacement occurs in the talus-covered area along a fault or a discordant diabase intrusion. The limestones strike N. 25°–30° W. and dip 23° SW. A concordant diabase sill underlies the asbestos deposit at a stratigraphic distance of about 15 feet.

The original north-trending outcrop of this deposit was 20 feet long and included an asbestos-serpentine zone, 24 to 30 inches thick, that contained veins of soft asbestos totaling 2½ to 4 inches in thickness. During June and July 1953, adjacent outcrops were stripped of overburden, a quarry face was cut into the original crop of the zone, and a 135-foot adit was driven westward and northwestward on the strike of the asbestos-bearing beds. Veins, totaling a maximum of 1½ to 2½ inches of asbestos, are exposed in places in the quarry face. The zone pinches out 30 feet north of the portal of the adit, but it is continuous to a point 20 feet to the south of the portal where the zone is covered by thick talus. The asbestos pinches out 20 feet west of the portal of the adit. Only traces of asbestos are exposed in the remainder of the adit.

The concentration of asbestos exposed in the original outcrop was localized where several pre-mineral small-scale bedding faults had prepared the limestones for mineralization. Exposures along the quarry face and in the adit indicate that fracturing of the limestone was less intense in all directions from the point represented by the original discovery.

PROSPECT NORTH OF RED WHISKERS SPRING

Along the hill slope just north of Red Whiskers Spring in sec. 20, T. 2 S., R. 17 E., (pl. 53), in the Hayes Mountains, the Mescal limestone has been split into at least three segments by widespread diabase intrusions. The upper segment is the algal limestone of the middle member. The next-lower segment contains meager asbestos showings and consists of thin-beded cherty limestone and siliceous beds. This segment ranges in thickness from a knife-edge to 15 feet. The beds strike northwest and dip 25° SW.

Two horizons have intermittent showings of asbestos along an outcrop length of several hundred feet. These two horizons are separated by a 7-inch light-colored siliceous bed. Fiber with a maximum aggregate length of 1 inch was seen, however, the average length of the fiber is ¼ to ½ inch. The fiber is semiharsh to harsh. The lower diabase-limestone contact, which is generally concordant with the beds, is locally undulating, and the asbestos zones are from a few inches to 3 feet from the contact.

"TUFA" STONE, GYPSUM, AND DIATOMACEOUS EARTH

The lake beds and interbedded tuffs, which crop out over a large part of the San Carlos-Gila River basin, contain several nonmetallic resources that may be of future value. These include "tufa" stone, gypsum, and diatomaceous earth.

The lake beds crop out over most of the area north of the Gila River to the Triplets, thence to several miles west of San Carlos, and north of San Carlos to Black Mesa. They underlie much of the basalt-capped mesa north of the Triplets. An excellent and easily accessible exposure is at the north end of this mesa where the road crosses Blue River; here, a thick sequence of lake-bed limestones is exposed in the canyon walls. Prospecting throughout the area in which lake beds are exposed might disclose other deposits of gypsum and diatomaceous earth, and possibly some deposits of low-grade clay.

"TUFA" STONE

Second to asbestos in value has been the "tufa" stone production on the San Carlos Indian Reservation. This stone was utilized early in the construction of buildings at San Carlos (known as Rice prior to 1931). The quarry area is about 1 mile northwest of San Carlos in sec. 2, T. 1 S., R. 18 E. (pl. 53), and can be reached from San Carlos by a road leading northwestward from the west side of the Indian Bureau school campus.

By order of the Secretary of the Interior on February 5, 1931, the areas known to be underlain by the "tufa" stone were withdrawn from prospecting, location, and leasing. Specifically, all areas in secs. 1, 2, and 3, T. 1 S., R. 18 E.; secs. 4, 5, 6, 7, 8, 9, 16, 17, and 18, T. 2 S., R. 18 E.; and secs. 27, 28, 29, 32, 33, and 34 T. 1 N., R. 18 E., were closed. All rights to these deposits are reserved to the Indians of the reservation.

The stone—an attractive white, light-weight tuff—is known locally as "tufa" stone. It occurs in approximately horizontal beds interbedded with the late Tertiary or Quaternary lake beds that occupy a major part of the San Carlos River basin. The tuff ranges from 1 to 5 feet in thickness and averages 3½ feet in thickness over a wide area. It is underlain by calcareous, tan to brown mudstones and is overlain by mudstones and interbedded limestone. Overburden in the vicinity of the quarry, and northwest for a mile or more, ranges from a few feet to about 20 feet. Easily available reserves are very large.

The stone is usually quarried by hand and wedged out in blocks 12 by 12 by 36 inches in size. When quarried, the stone reputedly weighs 76 pounds per cubic foot; when dry it weighs 55 pounds per cubic foot. It is soft and easily cut, but it contains a few scattered basaltic fragments that average between ¼ and ½ inch in diameter.

The matter of strength in a stone that is to be used for construction is important. No data on crushing strength were available to the writer, but the strength appears to be adequate. All major government buildings in San Carlos—including schools, offices, hospital, churches, and many residences—have been constructed of this stone. All of these one-story buildings are in excellent condition. Larger, two-story structures have been built of the tufa stone—examples are the Catholic and Baptist Churches of Globe, Ariz.

GYPSUM

Gypsum is found on the San Carlos Indian Reservation at a location 3 miles west of San Carlos and south of the railroad tracks, in sec. 16, T. 1 S., R. 18 E. (pl. 53). These deposits have never been commercially exploited. The Reverend F. J. Uplegger, Lutheran missionary to the Apaches, utilized a small amount some years ago to make a plaster for inscriptions. It was found quite satisfactory for this purpose.

The area is in the San Carlos River basin, a broad intermontane valley. The topography is characterized by gently sloping surfaces that are crossed by meandering washes and gullies; a few hills and basalt-capped mesas project above these surfaces. The area is underlain in large part by late Tertiary or Pleistocene (or both) lake beds. The gypsum occurs in these lake beds.

The gypsum beds crop out along the north slope of a low basalt-capped hill where they can be traced intermittently for about 2,500 feet (fig. 85). At the northwest end of the outcrop they are covered by the gravels of a northeast-trending wash; at the southeast end, about 400 feet south of the last exposure of gypsum beds, the Tertiary sediments are faulted against Paleozoic rocks. In general, the beds dip from 15° to 25° to the southwest and strike northwest; however, at the northwest end of the outcrop the beds are nearly flat, or have a slight northward dip (see sec. A–A′, fig. 85).

A section of gypsum-bearing lake beds, ranging in thickness from 100 to 150 feet is exposed in gullies on the hillslope. Within this section, three to five gypsum beds are exposed and are interbedded and overlain by tan mudstones, which are in part gypsiferous. These beds are succeeded by thin- to medium-bedded gray limestones, which are, in turn, overlain unconformably by a basalt flow that caps the hill (fig. 85).

The base of the gypsum-bearing section is not exposed—it is covered by later gravels which cover the surface of the flat that slopes gently northward for a distance of ¾ mile to Gilson Creek. Numerous low mounds of gypsite [5] and gypsum protrude through the otherwise flat gravel surface. Efflorescence is characteristic on the surface of these mounds. The gypsum-bearing section, as suggested by these mounds, may be considerably thicker than the part that is better exposed along the hillslope. It is possible, however, that faulting may result in some duplication. The thickest gypsum bed occurs near the top of the sec-

[5] Gypsite is an earthy mixture of gypsum and clay or sand.

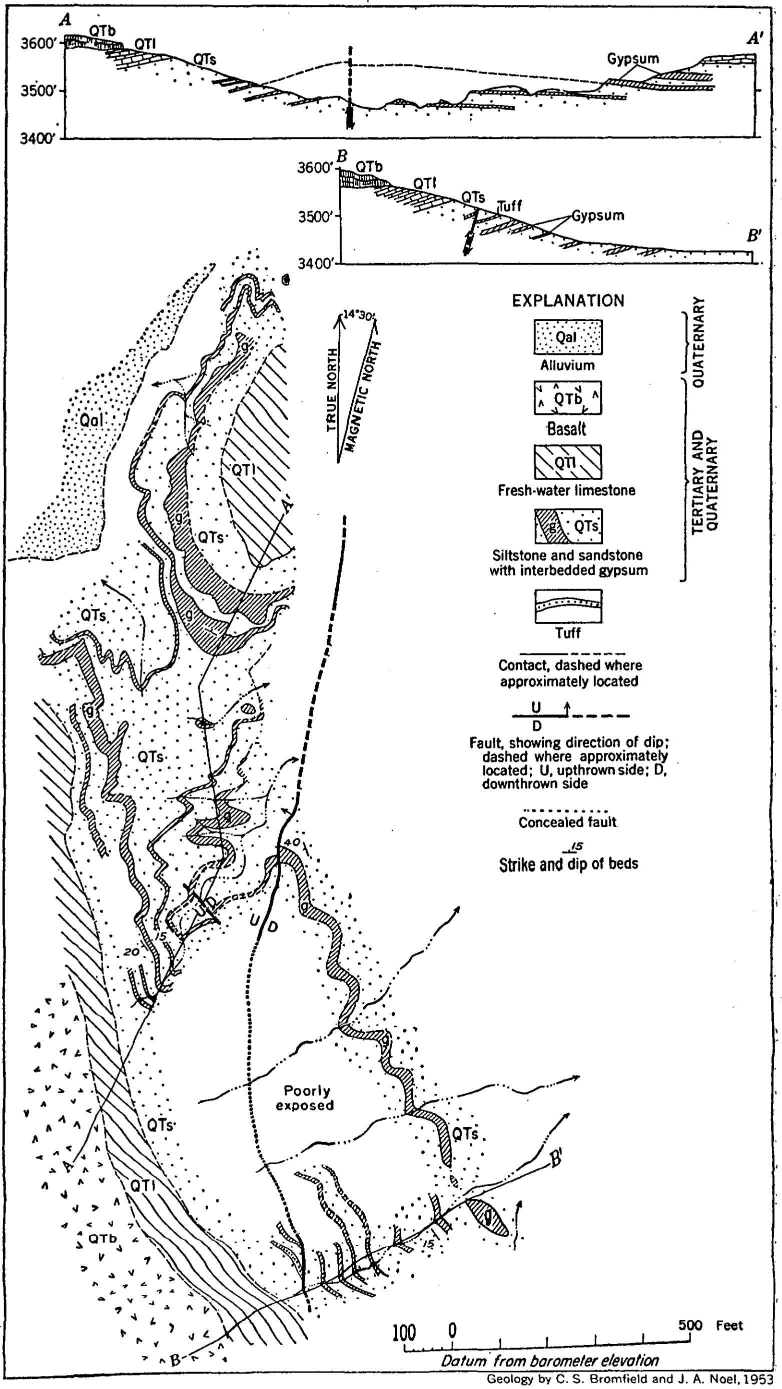


FIGURE 85.—Geologic map and sections of the gypsum area.

tion and ranges in thickness from 3 to 10 feet. Two other gypsum beds, averaging about 2 feet in thickness, are located in the 50-foot stratigraphic interval below this bed.

The gypsum is generally white and granular and in the outcrops has a few seams and pockets of clay scattered through it.

In an area covering about 9 acres along the hillside the thickest gypsum is covered by overburden ranging in thickness from a knife-edge to 30 or 40 feet. As a rough estimate, perhaps 100,000 tons of gypsum might be recovered from the thickest bed by open-pit methods. Downdip, the gypsum passes under limestone, siltstone, and the basalt that caps the hill; here, underground methods would be needed to recover the gypsum. The amount, grade, and thickness of the gypsum underlying the flat north to the railroad is unknown. However, gypsiferous mounds protruding through the soil indicate that the whole area is underlain by a gypsiferous section. In any future consideration of the area as a source of gypsum, drilling would be useful in determining the extent, thickness, and the grade and distribution of the thickest and purest beds.

This deposit is similar to the occurrence of gypsum in the San Pedro valley near Feldman, Ariz. Gypsum from the latter locality has been used by the Rillito Cement Plant near Tucson, Ariz., and has been used in agriculture.

Gypsum deposits of good quality are widespread in this country, and demand is limited in a large part to local markets. Gypsum is utilized in southern Arizona as a fertilizer on alkaline soils. The gypsum and gypsite from this deposit could probably be used for this purpose as well as for use in the manufacture of cement. Tests would be needed to determine whether this gypsum could be used for plaster. A favorable feature of the deposit is its location less than ½ mile from the railroad.

DIATOMACEOUS EARTH

In 1950, Eugene Case (an Apache Indian) brought specimens of a light, white rock to A. H. Hale, traffic agent for the Southern Pacific Railroad at San Carlos and now serving in that same capacity at Globe, Ariz. Mr. Hale recognized the material as diatomaceous earth. He accompanied the writer to the deposit whose location he has aptly named "Skeleton Wash," after the microscopic diatom skeletons that compose diatomaceous earth.

The original find was in sec. 26, T. 1 N., R. 18 E. about 2½ miles north and a little east of San Carlos (pl. 53). The diatomaceous earth is found in association with the late Tertiary or Pleistocene (or both) lake beds. These lake beds and associated interfingering and peripheral coarser materials, in part interbedded with basalt flows, occupy a large part of the San Carlos–Gila River basin within the reservation boundaries. These rocks are tentatively considered to be the equivalent of the Gila conglomerate, which, in the vicinity of Safford and the San Pedro Valley, have been shown to be of upper Pliocene age.

The deposit at "Skeleton Wash" may be reached by taking the San Carlos-Sawmill road north from San Carlos across Seven Mile Wash to the top of the ridge, where the main road turns toward the north; then take the right fork, which runs down the east side of the ridge to a point where the road crosses the first southerly-draining wash. Proceed north (up-wash) for about 1 mile, taking the first right fork of the wash. The deposit crops out prominently on the west bank of the wash, where interbedded limestones and diatomaceous beds form a cliff about 20 feet high.

The area is one of flat, gently-sloping ridges dissected by southerly-draining washes. The maximum relief in the area is probably not more than 100 feet.

From the prominent outcrop, the diatomaceous beds can be traced discontinuously northward for approximately 600 feet. Immediately to the south of the prominent outcrop, on the west side of the gulch, the beds are cut off by a northerly-trending fault. The beds are approximately horizontal; however, in detail, they have an undulating surface.

The section, as exposed in the wash and gully sides, is approximately as follows:

Section in "Skeleton Wash"

Top not exposed.	Feet
Limestone, white to buff, very thin-bedded, dense; contains some interbedded, very thin diatomaceous beds	10
Diatomaceous earth, white to light-yellow, probably clayey in part; contains some very thin limestone beds	6
Limestone, light-buff to white, dense	6
Diatomaceous earth, white, soft	2
Limestone, white to buff, very thin-bedded, dense; some very thin diatomaceous beds probably included	10
Tuffaceous sandstone, gray-green to olive-green, conglomeratic; contains numerous basaltic pebbles and cobbles	20+
	54+
Base not exposed.	

Further reconnaissance in the lake beds within the San Carlos-Gila River basin brought to light other occurrences of diatomaceous earth, particularly in secs. 1 and 11, T. 2 S., R. 19 E. This locality can be reached by taking the dirt road going east from the newly built rodeo grounds east of Peridot. The road log is as follows:

Miles	*Directions*
0.0	Rodeo grounds east of Peridot. Take dirt road going east toward Salt Creek.
3.0	Fork, take left turn.
3.6	Fork, take right turn.
7.1	Locality is about ½ mile south of road.

Here, about 4 miles south of the Triplets and 8 miles southeast of the location in Skeleton Wash, an outcrop of diatomaceous earth forms an especially prominent white cliff on the south slope of an isolated basalt-capped butte. The length of the outcrop is about 1,000 feet. The beds strike to the northwest and dip 20°–25° NE. They are cut by northwest-trending faults, one of which has a displacement of 30 feet. The section is as follows:

Generalized section south slope of basalt-capped butte in sec. 1, T. 2 S., R. 19 E.

	Feet
Talus cover.	
Diatomaceous marl, white, thin-bedded	50+
Tuffaceous sandstone, gray-green, conglomeratic; contains numerous basaltic pebbles	2
Diatomite, white, calcareous, some very thin hard limestone beds	30
Diatomite and limestone, alternating, thin-bedded	15
Tuffaceous sandstone, gray-green to olive-green, conglomeratic; contains numerous basaltic pebbles, cobbles, and boulders	100+
	197+
Base not exposed.	

Laterally, the section is variable; the diatomaceous zone below the 2-foot conglomeratic tuffaceous sandstone bed ranges from 45 to 60 feet in thickness. In a section ½ mile to the northeast, on the slopes of another butte, apparently the same zone is about 40 feet thick but contains mostly limestone, marl, and impure clayey diatomaceous beds.

At both the location in Skeleton Canyon and the location south of the Triplets thin limestone beds are common in the section, and the diatomaceous beds themselves generally contain considerable amounts of lime as an impurity and laterally grade into diatomaceous marls. Several samples showed amounts of lime ranging from 10 to 20 percent.

The deposits examined contain too much impurity in the form of lime and clay to compete with larger and purer deposits such as those in California, Oregon, and Nevada. The best material was in the 2-foot bed in "Skeleton Wash", but this bed is too thin to be of economic value.

The chief uses of diatomite are as filters, fillers, insulation, and in lightweight aggregate and abrasive. The low-grade San Carlos material would not be suitable for use as a filtration material (the chief use of diatomaceous earth) because of the high amounts of reactive impurity. The material might be suitable for the making of low-grade insulation brick. Limited, local use might be found for some of the material as a heat insulator; diatomaceous earth from the San

Pedro valley has been used in Tucson for this purpose. Diatomaceous earth has been used in making lightweight aggregate, but the strength of the aggregate is low.

PERIDOT

The presence of peridot, the gem variety of olivine, near San Carlos (Rice) has been known for many years. The geology of the occurrence has been studied adequately by Lausen (1927). The area is immediately southwest of San Carlos and can be reached from there by the power-line road (pl. 53), which ascends and crosses Peridot Mesa.

Peridot Mesa is roughly rectangular in plan and extends from 1½ to 2 miles in a northerly direction and from 2 to 2½ miles in an easterly direction (pl. 52). The mesa is capped by a basalt flow, 10 feet to more than 100 feet thick, which is underlain by flat-lying tuffs, siltstones, and gravels. These sedimentary rocks are regarded as the equivalent of the Gila conglomerate and therefore of Pliocene or Pleistocene age. The basalt may be late Tertiary or Quaternary.

The peridot occurs in roughly ellipsoidal bombs, or segregations, in basalt and cinders erupted from a volcanic cone which occupies the southwest corner of Peridot Mesa. This cone rises in a gentle slope to a height of about 100 feet above the surrounding mesa, and it is about ½ mile in maximum diameter. Its southwestern perimeter has been eroded away. In an exposure in Peridot Canyon, a basalt flow containing a concentration of the peridot segregations ranges from 5 to 15 feet in thickness. The ellipsoidal segregations make up 25 to 40 percent of the rock volume and average from 3 to 8 inches in maximum diameter.

Stones have been gathered by the Indians from a number of places on Peridot Mesa, particularly from the rim of the cone, in washes adjacent to the cone, and in small canyons that breach the north rim of the mesa. Most of the stones are not broken from firm basalt, but are gathered from the debris resulting from erosion of the basalt. The gathering and selling of the peridot over the years has been sporadically carried on by individual Indians who sell their gleanings, usually in quantities of only a few pounds, to collectors and stone cutters in Globe. Occasionally, the local trading posts have bought a few pounds.

In recent years, Luther Martin of Globe has been the principal purchaser. According to Mr. Martin, he has paid $3.00 to $5.00 per pound, and he estimates that it takes approximately 10 pounds of "mine run" material to get 1 pound of usable gem material. The so-called "mine run" material itself, however, represents selected stones chosen by the one who collects the material, therefore the actual ratio of usable stones in the segregations would be much lower than 1 in 10. Martin estimates that he has bought about 600 pounds of peridot. He cuts and polishes the stones, makes jewelry from them or sells the cut stones to mineral collectors. The finished stone brings about $5.00 a carat; the average stone runs from 1 to 3 carats; the largest he has cut was 15 carats; a 22-carat stone is reputed to exist.

Recently Mr. Martin has left Globe, and this outlet for the stones is no longer available. A local curio shop in Globe occasionally buys a few pounds for sale in the rough to the tourist trade.

GUANO

Several guano caves have been found on the reservation, and from one of these a small production was obtained. This cave is on the San Carlos River about 10 miles northeast of San Carlos (pl. 53). Here, the San Carlos River has eroded a deep precipitous canyon into the basalt-capped mesa which occupies the broad area north and east of the Triplets. The cave, located near the floor of the canyon, can be reached by a trail that descends the canyon wall at a point opposite the Rocky Creek junction, which is located about 2 miles downstream from the cave.

The cave is probably not more than 30 or 40 feet long and 50 feet wide. Bat guano has accumulated to a depth of several feet over the irregular floor of the cave. C. A. Kumke, who formerly was interested in the cave, stated that hand drilling indicated a thickness of guano of as much as 10 feet in places.[6] Elbert Stevens had a lease on the claims in 1933 and 1934 and removed about 63 tons which sold for $15 a ton.

Other guano deposits were not visited. The Hart Tine Bat and Twin Peaks deposits are similar occurrences in lava caves. The Cave Creek deposit, 21 miles north of San Carlos, probably occurs in one of the caves in the Redwall limestone that are common along Cave Creek, Black River, and Bronco Creek.

Although there are a number of these guano deposits scattered over the reservation, their individual potential is rather small. The recoverable guano from any one cave probably does not exceed a few hundred tons.

SUMMARY OF RESOURCES

No production is recorded from any of the minor base-metal occurrences known on the reservation. These occurrences do not appear to be of commercial value at present. The extensive cover of rocks younger than the main period of metallization in southeastern Arizona and the general absence of Laramide intrusives are contributing factors to the lack of extensive base-metal deposits.

[6] Oral communication.

The discovery of the Red Bluff uranium deposit north of Roosevelt Lake in the Dripping Spring quartzite, coupled with the fact that the formation has a higher degree of radioactivity than that normal to adjacent formations, suggests that additional economic concentrations of uranium might be found. Until the spring of 1954, there had been no prospecting for uranium within the reservation.

The nonmetallic deposits of the reservation are the most important, and of these, asbestos is outstanding. The areas of outcrop of Mescal limestone that are most favorable for asbestos prospecting are the Salt River area, the Bear Canyon area, and the Apache mine area. Areas that are considered poor for asbestos prospecting include most of the Apache ridge and the Hayes Mountains.

Lake bed deposits of late Tertiary or Pleistocene age (or both), which underlie a large area, contain several nonmetallic resources of possible future value. These include "tufa" stone, gypsum, and diatomaceous earth. "Tufa" stone, with its huge reserve, would seem to offer commercial possibilities as a building stone; especially if, in conjunction with its utilization for this purpose, other uses could be developed, such as in lightweight aggregates. Gypsum is present in some quantity, and the deposit is easily accessible to the railroad. Perhaps the gypsum and gypsite could be utilized as agricultural fertilizer to counteract the alkaline soils so common in this part of Arizona. Similar deposits have been worked commercially in the San Pedro Valley near Feldman, both for this purpose, and for use by a cement plant near Tucson, Ariz. Diatomaceous earth is also found in the lake beds, but the deposits thus far investigated have contained impurities in the form of calcium carbonate and clay. Other nonmetallic resources include peridot and bat guano.

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