Fig. 1—Crude No. 1 asbestos (natural size) from the property of the Arizona Asbestos Association.

Fig. 2—Asbestos veinlets in serpentine (natural size), San Carlos Indian Reservation, Arizona.
Asbestos

PREFACE

Arizona leads all other states in the production of chrysotile asbestos, and a recent Act of Congress has made it possible to locate, lease, and mine the asbestos heretofore unavailable, but long known to occur, on Arizona Indian Reservations. These facts have lately drawn the attention of many people to the mineral, and the Arizona Bureau of Mines has received a great many inquiries concerning the physical characteristics of, the market for, and the situation of known Arizona deposits of asbestos. This bulletin has been prepared in the hope that it will give the information sought much more satisfactorily than can be done in letters. No attempt has been made exhaustively to cover the subjects presented, and it is admitted that the information contained herein is largely a compilation rather than a contribution to the known facts about asbestos. For more complete data relative to the various matters covered by this bulletin, the reader is referred to the publications listed in the selected bibliography herein given.

Although several different minerals are marketed as asbestos, and are described and mentioned in this bulletin, only one, chrysotile, is known to occur in commercially important deposits in Arizona; and, unless otherwise stated, the word asbestos wherever used in this publication should be interpreted to mean chrysotile asbestos.

ASBESTOS MINERALS

Among the more important substances included under the general trade name of asbestos are chrysotile (serpentine asbestos), amphibole asbestos (including fibrous varieties of tremolite, actinolite, etc.), anthophyllite asbestos, crocidolite (Cape blue asbestos), and amosite.

CHRYSOTILE

Composition: Chrysotile is a variety of the mineral serpentine which has the formula $3\text{MgO} \cdot 2\text{SiO}_2 \cdot 2\text{H}_2\text{O}$ (hydrous magnesium silicate). Iron monoxide usually replaces a little of the magnesia, and
alumina, lime, and other elements may be present in minute quantities. Pure magnesia chrysotile should contain 43.0% magnesia, 44.1% silica, and 12.9% water, but a percent or two more of water is usually present, and the percentage of silica and magnesia are often slightly reduced through the invariable presence of some iron oxides, and, less frequently, alumina.

J. S. Diller gives the following five analyses of Arizona chrysotile:

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>MgO</td>
<td>.4205</td>
<td>41.85</td>
<td>40.69</td>
<td>41.41</td>
<td>40.64</td>
</tr>
<tr>
<td>SiO₂</td>
<td>.4156</td>
<td>41.35</td>
<td>40.75</td>
<td>42.28</td>
<td>43.68</td>
</tr>
<tr>
<td>Al₂O₃</td>
<td>1.27</td>
<td>.91</td>
<td>1.82</td>
<td>1.07</td>
<td>.34</td>
</tr>
<tr>
<td>FeO</td>
<td>.64</td>
<td>.69</td>
<td>.74</td>
<td>.88</td>
<td>a.51</td>
</tr>
<tr>
<td>MnO</td>
<td>None</td>
<td>.07</td>
<td>None</td>
<td>.10</td>
<td>.09</td>
</tr>
<tr>
<td>CaO</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>.11</td>
<td>.14</td>
</tr>
<tr>
<td>K₂O</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>.14</td>
<td>.14</td>
</tr>
<tr>
<td>Na₂O</td>
<td>1.39</td>
<td>1.38</td>
<td>1.86</td>
<td>1.33</td>
<td>1.18</td>
</tr>
<tr>
<td>H₂O−</td>
<td>12.92</td>
<td>11.96</td>
<td>12.65</td>
<td>12.23</td>
<td>13.12</td>
</tr>
<tr>
<td>H₂O⁺</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>99.83</td>
<td>98.21</td>
<td>98.51</td>
<td>99.30</td>
<td>99.98</td>
</tr>
</tbody>
</table>

a—Fe₂O₃

1. Ash Creek Mine; soft fiber. Analyst, R. E. Zimmerman, January 24, 1918.
2. Ash Creek Mine; harsh fiber. Analyst, R. E. Zimmerman, January 24, 1918.
3. Coon Creek Butte of the Sierra Ancha; soft fiber. Analyst, R. E. Zimmerman, January 24, 1918.
4. Coon Creek Butte of the Sierra Ancha; harsh fiber. Analyst, R. E. Zimmerman, January 24, 1918.

Diller further states that "an important difference between the chemical composition of the Arizona variety of chrysotile asbestos and that of the Canadian chrysotile is the small quantity of iron oxide the former contains. This feature was pointed out in the report on asbestos in Mineral Resources of the United States for 1912, where it was suggested that on account of the small quantity of the iron oxide present the Arizona variety of asbestos might be better than the Canadian variety for electric insulation. In order to ascertain the quantity of iron present in the best Canadian fiber, the writer

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sent to Dr. Zimmerman a sample of soft silky Canadian chrysotile which had been furnished by Dr. Huber, president of the Asbestos Fiber Spinning Company, of North Wales, Pa., as the best asbestos he had ever seen from Canada. Dr. Zimmerman reported January 24, 1918:

"We have determined the iron content of the Canadian asbestos you sent, and it contains at least 2.5 percent of FeO. We believe this is an important result and proves to our satisfaction that the Canadian material carries more than twice as much iron as the Arizona asbestos."

"This low content of iron is characteristic of the Arizona variety of chrysotile which deserves the attention of engineers who are searching for asbestos low in iron."

**Luster:** Resinous or greasy to silky.

**Color:** Usually light green, light yellow, ash gray, or white; sometimes dark green to blackish green or brownish red; occasionally weathered outcrops are brown. Fine fibers are usually white no matter what the color of the massive mineral may be.

**Streak** (color of powder): Only material of very poor quality, such as is sometimes found in outcrops, can be pulverized. It always yields a white powder.

**Hardness:** Easily scratched with a knife, but the more or less greasy-lustered, fresh material is usually too hard to be scratched with the finger nail.

**Fracture:** Cross-fiber asbestos breaks into irregular prismatic fragments with fibrous surfaces, whereas slip-fiber breaks into fibrous sheets, and mass-fiber has a very irregular, jagged fracture.

**Specific Gravity:** About 2.3, being considerably lighter than quartz.

**Toughness:** Cross- and slip-fiber asbestos can be easily broken parallel to the fibers, and weathered specimens of all varieties may yield quite brittle fibers. Fresh, high-grade fibers are extremely tough. It is very difficult to break a piece of mass-fiber asbestos in any direction, or cross- or slip-fiber asbestos perpendicular to the direction of the fibers.

**Feel:** Good grades of chrysotile feel very smooth or "soapy."
Occurrence: Chrysotile occurs in three habits designated cross-fiber, slip-fiber, and mass-fiber.

The cross-fiber occurs in veinlets from a small fraction of an inch to several inches wide, and, as the name suggests, the fibers of which the material is composed and into which it may readily be separated lie approximately perpendicular to the walls of the vein. Frequently, however, the fibers cross the vein diagonally (See Plate I, Fig. 1) and often they are bent. The excessively fibrous texture of the material is its most characteristic feature, and a solid fragment of good asbestos can be beaten up or picked apart so as to form a mass of very fine, light fibers. It is not usually true that a single vein of cross-fiber can be mined profitably. Fortunately, however, in most localities a considerable number of more or less parallel or interlacing veinlets of various thicknesses occur in close proximity to each other, and they, together with the intervening barren rock, are all mined together. Cross-fiber asbestos usually appears to have grown out from both walls, and to have met and coalesced along a more or less irregular plane which may or may not be equi-distant from both walls. This plane is shown in sections of veins as a line which is sometimes decidedly serrated, and the fibers tend to break along this plane. In Plate I, Fig. 1, this plane is decidedly irregular, but in Plate I, Fig. 2, such planes are much more regular and occupy approximately the middle of each vein. Often many small, nearly parallel veins are separated by layers of serpentine with about the same width as the veins, as shown in Plate I, Fig. 2. It is believed that this banded appearance suggested to some one the skin of a serpent, and that for this reason the massive mineral, of which asbestos is a variety, and with which it is always associated, is called serpentine.

Slip-fiber occurs in fault planes (slips), and the fibers run approximately parallel to the direction of the movement. This variety is not usually of as high quality as the cross-fiber, is not ordinarily found in as solid masses, and is commonly white or light gray in color.

Mass-fiber asbestos is composed of a confused aggregate of fibers running in all directions or radiating from many centers. Mass-fiber chrysotile is comparatively rare, but yields a larger amount of
available fiber in proportion to the quantity of rock mined than does any other variety.

Blowpipe and Chemical Tests: In a closed glass tube chrysotile yields water. The finest fibers are fused with great difficulty before the blowpipe, and are decomposed by boiling hydrochloric and sulphuric acids leaving the silica in the form of very fine fibers.

Although some specimens of chrysotile are not fused when heated to a temperature of 5000° F., the fibers usually become brittle when exposed for protracted periods to a temperature of 1200° F. or more.

Miscellaneous: The smooth feel, the extreme toughness, the light color of the fibers, and the geological relationships described later will usually suffice to distinguish chrysotile from other forms of asbestos. It should not be forgotten, however, that weathered outcrops may be rather harsh and brittle. In general it is safe to assume that the flexibility of fibers will improve below a weathered outcrop, but this is not always the case, since heat from an igneous intrusion in close proximity to the asbestos may make the fibers brittle, as may other causes mentioned later.

Peculiar Characteristics of Arizona Chrysotile: Diller suggests that "Arizona chrysotile differs so much from the material found in most other localities that it should be designated 'the Arizona variety' of chrysotile. The most distinctive features of the Arizona variety are the unusually low percentage of ferrous oxide present in it, and the fact that a considerable portion of the fiber is somewhat harsh and splintery as compared with the best grade, which is soft and silky."

Diller also says: "In the Globe field both grades occur in the same vein near together without a definitely visible boundary. A comparison of the two grades discloses the fact that the harsh fiber generally, and perhaps always, has a deposit, in places only a thin film, of calcite between the fibers of the asbestos. Searching for a chemical cause adequate to explain the differences of harsh and soft fiber, Dr. R. E. Zimmerman, assistant director of the research laboratory of the American Sheet & Tin Plate Company, of Pittsburgh, made analyses of four samples selected by the writer at the mines on

\footnote{Op. cit., p. 302.}
Ash Creek and the Sierra Ancha." The results are given on page 2 under "Composition." With reference to these analyses, Dr. Zimmerman remarks:

"A study of the results in the table will show that the magnesia and silica contents are practically normal in every case, and this is also true, within reasonable limits, of the water of crystalization. We are especially glad to note that the ferrous oxide is below one per cent in every case.

"One feature of the information contained in the results is the occurrence of lime in samples Nos. 2 and 4 and its absence in samples Nos. 1 and 3. While the amount of calcium oxide in the fiber is small, it may be a matter of significance that it was detected only in the samples of harsh fiber. Whether or not the infiltration of such small amounts of lime could impart the quality of brittleness, its presence seems to go hand in hand with the tendency of the serpentine to produce harsh fiber.

"Another item of interest, although it may not have any great significance, is the fact that the samples of soft fiber, Nos. 1 and 3, contained higher percentages of alumina than samples Nos. 2 and 4.

"Although it is thus possible to point out small differences in the chemical constitution of harsh and soft material, it does not seem to us that the variations are of such magnitude that they can account for the difference in physical properties. The presence of calcite would no doubt make for brittleness of fiber, but it would appear that this quality is dependent more particularly upon the physical structure of the material. If we assume that the peculiar fibrous structure of asbestos is due to an extreme elongation of the crystals, it seems that the original orientation of the crystals ought to play an important role in determining the characteristics of the asbestos in its final form. In view of the properties of the unaltered serpentine rock, it is not difficult to believe that the quality of softness might vary with the degree of transformation."

In discussing further the cause of the harshness of some Arizona fiber, Diller states:

"Most of the asbestos in the Grand Canyon has harsh fiber, and its chemical composition, as shown in the table, accords closely with
that of the harsh fiber of Ash Creek and Sierra Ancha.

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

Professor J. T. Donald claims that chrysotile that contains a high proportion of water is more flexible than specimens with less water. While his conclusions are probably applicable to material found in some localities, there are evidently other factors besides the percentage of contained water that affect the flexibility of the fibers.

Characteristics of the Massive Serpentine Associated With Chrysotile: Chrysotile asbestos always occurs in massive serpentine which has the same composition as the fibrous mineral, but differs therefrom in physical properties.

The serpentine associated with chrysotile varies in luster from somewhat waxy to dull or earthy. It is usually white or grayish, but is sometimes yellow, brown, or green. The color of the powder is white. It may be easily scratched with a knife, but not with the finger nails. It has no cleavage (does not break more or less evenly in any definite direction), and the fracture is usually smoothly rounded, but it may be uneven. It is excessively fine-grained (if at all granular), very dense, and pieces of any considerable thickness are opaque. Like the fibrous variety, it often feels smooth or soapy.

AMPHIBOLE ASBESTOS

Amphibole is a silicate mineral of which there are many varieties that differ from each other in composition and physical character-

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1Transactions General Mining Association of Quebec, 1891, p. 27.
Among the varieties which are fibrous and which are called amphibole asbestos are tremolite \((\text{CaMg}_3\text{Si}_4\text{O}_{12})\) and actinolite \((\text{Ca(Mg,Fe)}_3\text{Si}_4\text{O}_{12})\). Most of the various kinds of amphibole asbestos cannot be distinguished from each other except by chemical analysis; and it is sometimes difficult or impossible to distinguish between amphibole asbestos and chrysotile except by analysis. In general, however, it may be said that the fibers of amphibole asbestos average longer, but more loosely aggregated, than those of chrysotile, and that they are not as strong, are less suitable for spinning, are somewhat harsher to the feel, and are not as good non-conductors of heat as are chrysotile fibers. The fusion temperature is about the same as that of the poorer grades of chrysotile. Amphibole asbestos is usually of the slip-fiber type, is white or ash gray in color, and is never associated with serpentine.

**ANTHOPHYLLITE**

Anthophyllite is a silicate of magnesium and iron with the formula \((\text{Mg,Fe})\text{SiO}_3\). Alumina often replaces a considerable proportion of the magnesia, and lesser amounts of lime and other impurities may be present. The mineral contains from two or three to twenty or more percent of ferrous oxide.

Anthophyllite usually occurs as mass-fiber which is considerably harsher and more brittle than good chrysotile, and which is unsuitable for textile purposes. In fact, it resembles amphibole asbestos more closely than it does chrysotile. It sometimes occurs as slip-fiber, its color is grayish or brownish, and it may be associated with amphibole asbestos, but never with serpentine.

**CROCIDOLITE**

Crocidolite is known to the trade as "Cape blue" asbestos, and is a silicate of iron and sodium with the formula \(\text{MgFeSi}_2\text{O}_6\cdot\text{FeSiO}_3\), nearly. A substance with this formula should contain 22\% of ferric oxide, 19.8\% of ferrous oxide, and 8.6\% soda. Crocidolite always contains several percent of water, and other common impurities are magnesia, lime, potash, and manganese monoxide. The high proportion of iron makes the mineral less resistant to heat and electricity than are most other types of asbestos.
The most distinctive feature of crocidolite is its color. It is nearly black when massive, but the fine fibers have a dull bluish-drab tint, very different from those of any other type of asbestos. Crocidolite always occurs in deposits of the cross-fiber type. The fibers average an inch or two in length, are very tough, and can be used in the manufacture of textiles.

AMOSITE

Amosite is essentially a ferrous silicate containing small amounts of magnesia, alumina, and lime, with or without soda. Its ferrous oxide content averages nearly 40%. It occurs in much the same way, and can be used for the same purposes, as crocidolite, but differs therefrom in that the fibers average longer (four to seven inches) and the color is grayish or greenish when fresh (brown when weathered).

THE GEOLOGICAL OCCURRENCE OF ASBESTOS

CHRYSOTILE

Since chrysotile is a fibrous variety of serpentine, which is an alteration product of basic igneous rocks containing high proportions of olivine and pyroxene, it is always associated with serpentine.

In Canada, which produces most of the world's supply, the mineral occurs, according to Cirkel in two ways: (1) In lenses or vein-like masses of serpentine in crystalline limestone of Laurentian age, and (2) in a thick belt of serpentine that occurs in a series of Cambrian slates, schists, and diorites.

Chrysotile always occurs in serpentine in Arizona, as elsewhere, but the associated rocks differ more or less in the localities where the mineral is known to exist.

Concerning one important Arizona field Diller writes as follows:

"Near Roosevelt Dam and a few miles below it in Salt River Canyon the succession of formations given below in vertical order is well exposed:

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1Chrysotile Asbestos, Its Occurrence, Exploitation, and Uses. Fritz Cirkel, Mines Branch, Department of the Interior, Ottawa, Canada, 1905.
VERTICAL SECTION IN THE GLOBE REGION, ARIZONA

<table>
<thead>
<tr>
<th>FORMATION</th>
<th>AGE</th>
<th>THICKNESS (FEET)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tornado limestone</td>
<td>Carboniferous</td>
<td>1,000</td>
</tr>
<tr>
<td>Martin limestone</td>
<td>Devonian</td>
<td>325</td>
</tr>
<tr>
<td>Troy quartzite</td>
<td></td>
<td>400</td>
</tr>
<tr>
<td>Vesicular basalt flow</td>
<td></td>
<td>25-75</td>
</tr>
<tr>
<td>Mescal limestone</td>
<td></td>
<td>225</td>
</tr>
<tr>
<td>Dripping Spring quartzite</td>
<td>Cambrian</td>
<td>450</td>
</tr>
<tr>
<td>Barnes conglomerate</td>
<td></td>
<td>35</td>
</tr>
<tr>
<td>Pioneer shale</td>
<td></td>
<td>150</td>
</tr>
<tr>
<td>Scanlan conglomerate</td>
<td></td>
<td>0-15</td>
</tr>
<tr>
<td>Pinal schist and intrusive granite rocks</td>
<td>Pre-Cambrian</td>
<td></td>
</tr>
</tbody>
</table>

“A part of the same series of rocks is exposed along the shores of Roosevelt reservoir and to the northeast on Coon Creek Butte, in the Sierra Ancha.

“The limestone of Cerro del Temporal (Windy Hill), on the southwest side of the Roosevelt reservoir, belongs in the regular succession of strata overlying the Troy quartzite, which forms the summit of Coon Creek Butte. It is evident, therefore, that the rocks have been displaced, possibly by folding, but more likely, at least in part, by the faults that dropped the southwestern portion of the region and thus created the Tonto Basin, which contains the reservoir.

“Asbestos occurs only in the Mescal limestone, which has been somewhat altered near its contact with intruded diabase. The mine of the American Ores & Asbestos Company is near the summit of Coon Creek Butte where the Mescal limestone crops out between two sheets of diabase. The asbestos occurs chiefly near the upper contact of the limestone. Another portion of the Mescal limestone lies below the large sheet of diabase, but so far as known it contains only a small quantity of asbestos.”

Further data concerning the geological conditions in the neighborhood of this and other Arizona chrysotile deposits are given in the detailed descriptions of these deposits that form a part of this bulletin.

AMPHIBOLE ASBESTOS

Amphibole asbestos usually occurs in mica, talc, and other varieties of crystalline schists.
ANTHOPYLLITE ASBESTOS

Anthophyllite asbestos has the same general mode of occurrence as amphibole. At Sall Mountain, in White County, Georgia, from which deposit it has been mined for many years, it occurs in the form of large lenses in gneiss.

CROCIDOLITE

Practically all of the crocidolite marketed comes from Griqualand West, in South Africa, where it occurs in a pre-Cambrian or early Paleozoic slaty, green rock interbedded with hard jaspar and other ferruginous rocks.

AMOSITE

According to Crook¹, "amosite occurs extensively in banded, siliceous ironstone near the base of the Pretoria Series in the Lydenburg and Pietersburg districts of the Northeastern Transvaal. The name is from 'amosa,' a word made up from the initials of 'Asbestos Mines of South Africa,' the title of the firm that developed the deposits."

GRADES AND SPECIFICATIONS

There is no standard classification of asbestos in general use in Canada, but the Department of Mines of the Province of Quebec recognizes the following five grades: Crude No. I, Crude No. II, Mill Stock No. I, Mill Stock No. II, and Mill Stock No. III. Some mines ship only No. I Crude, others both Nos. I and II Crude, while still others send the whole product mined to mills which may produce from two to five different qualities of mill fiber.

In order that Arizona prospectors may have some conception of the probable classification of any good asbestos that they may find, the following table has been prepared:

<table>
<thead>
<tr>
<th>DEPARTMENT OF MINES OF THE PROVINCE OF QUEBEC CLASSIFICATION</th>
<th>APPROXIMATE LENGTH OF FIBER</th>
<th>COMMERCIAL NAME</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crude No. I..........</td>
<td>Over 3/4 of an inch.........</td>
<td>Crude No. I</td>
</tr>
<tr>
<td>Crude No. II..........</td>
<td>5/16 to 3/4 of an inch.....</td>
<td>Crude No. II</td>
</tr>
<tr>
<td>Mill Stock No. I.......</td>
<td>5/16 of an inch and over...</td>
<td>Spinning fiber</td>
</tr>
<tr>
<td>Mill Stock No. II.....</td>
<td>1/32 to 5/16 of an inch...</td>
<td>Shingle fiber</td>
</tr>
<tr>
<td>Mill Stock No. III....</td>
<td>Up to 1/32 of an inch...</td>
<td>Paper stock and others</td>
</tr>
<tr>
<td>Asbestos...............</td>
<td>Very short fibers mixed with powdered serpentine</td>
<td>Asbestos for wall plaster</td>
</tr>
</tbody>
</table>

The commercial names in the third column are the terms used in the asbestos quotations given in the Engineering and Mining Journal. Different producers follow different practices, and separate their products into grades of different fiber lengths, so that the above table is not absolute, but should serve as a guide.

While the length of the fibers is a very important factor in determining the grade and market price of asbestos, the value is also dependent upon the fineness of the fibers, the temperature at which they fuse, their flexibility, and their tensile strength. From the tables on the next page it may be seen that the value of chrysotlie does not decrease in direct proportion as the length of fiber decreases. For instance, if fiber one-half inch in length, which might be worth $1400 to $2000 per ton, were broken into half, the resulting material might be worth only $110 to $150 per ton.

USES

The fibrous structure, toughness, incombustibility, and low heat conductivity are the properties that make asbestos valuable. The most important way in which asbestos is utilized is as yarn or thread used in the manufacture of many types of steam packing, fireproof cloth, rope, and brake linings. No known substance can be satisfactorily substituted for asbestos in the manufacture of the better qualities of these articles, and only the highest grades of Nos. I and II Crude can be used for such purposes. Material consisting of shorter or less flexible fibers is used very extensively in the manufacture of insulating material to cover steam pipes, boilers, etc.; asbestos paper and millboard for high pressure gaskets and packings; stove linings; air-cell pipe coverings; shingles and other roofing material; wall plaster; "Bitulithic" paving; "85% magnesia"; acid- and corrosive-proof pipe, wall tile, and desk coverings; filters; asbestos paint, etc. Large quantities of such asbestos is also used in refrigeration and cold storage plants.

DEMAND AND MARKET VALUE

Unfortunately, only a small proportion of the asbestos mined in most places is of high grade—the material chiefly sought and most
widely used. In attempting to meet the demand for the higher grades of the mineral, an over-supply of low grade asbestos is produced. This fact explains why the tables that follow show such striking differences in the value of the better and the poorer grades, and why there have been such disproportionate increases in the prices of the superior and inferior material:

<table>
<thead>
<tr>
<th>GRADE</th>
<th>AVERAGE VALUE PER TON</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1912(a)</td>
</tr>
<tr>
<td>Crude No. I</td>
<td>$263.60</td>
</tr>
<tr>
<td>Crude No. II</td>
<td>100.76</td>
</tr>
<tr>
<td>Mill Stock No. I</td>
<td>64.42</td>
</tr>
<tr>
<td>Mill Stock No. II</td>
<td>31.17</td>
</tr>
<tr>
<td>Mill Stock No. III</td>
<td>13.21</td>
</tr>
</tbody>
</table>

(b) Values from Mineral Industry, 1919.
(c) Mining and Scientific Press, April 9, 1921.

It will be noted that the market price of the higher grades has increased enormously, whereas the price of most of the lower grades has increased much less noticeably. The prices given for 1919 and 1920 are the average for these years, but during the latter part of 1920 the price was considerably higher than in the first months of the year. To date there has been a steady increase in price, and the prices prevailing F. O. B. Canadian mines, February 26, 1921, according to the Engineering and Mining Journal, were:

<table>
<thead>
<tr>
<th>GRADE</th>
<th>PRICE PER TON</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crude No. I</td>
<td>$2000 to $3000</td>
</tr>
<tr>
<td>Crude No. II</td>
<td>$1400 to $2000</td>
</tr>
<tr>
<td>Spinning fiber</td>
<td>$400 to $1000</td>
</tr>
<tr>
<td>Magnesia and compressed sheet fiber</td>
<td>$325 to $500</td>
</tr>
<tr>
<td>Shingle stock</td>
<td>$110 to $150</td>
</tr>
<tr>
<td>Paper stock</td>
<td>$60 to $75</td>
</tr>
<tr>
<td>Cement stock</td>
<td>$17.50 to $30</td>
</tr>
<tr>
<td>Floats</td>
<td>$8.50 to $15</td>
</tr>
</tbody>
</table>

PRODUCTION

The world's production of asbestos of all grades in 1919 was approximately 166,000 tons. The production for 1920 was probably larger. The principal producing countries and the tonnage produced by each are given in the following table:

1Mineral Industry for 1919. Asbestos by Oliver Bowles.
Until the year 1914 Canada ranked as the leading producer of all grades of asbestos, but since that date South Africa has attained first place in the production of the higher grades. Canada, however, still produces most of the mill fiber.

The United States is not only the largest manufacturer of asbestos products, but is also the largest consumer. Approximately 74% of the 1919 foreign production of asbestos was imported into the United States. Since spinning of the "Cape blue" asbestos and the long fiber "Amosite" of South Africa has been accomplished, South Africa is fast becoming an important factor in asbestos production. Russia, although possessing large and valuable deposits of asbestos, is at present a non-producer. The chief producing centers in the United States are Arizona, California, Georgia, Maryland, Oregon, and Wyoming. Of the 1361 tons of asbestos produced by the United States in 1919, Arizona produced 423 tons, all of which was of the highest grade.

Practically the entire spinning fiber production of the United States comes from Arizona, and it is believed that the production of asbestos in 1920 in Arizona exceeded 1000 tons.

The chief producing companies in the state in 1920 were the Arizona Asbestos Association, American Ores & Asbestos Company (both of which have mills operating), the Regal Mine, the Colorado Arizona Asbestos Mining Company, and the Alene Asbestos Association.

MINING AND TREATMENT

The mode of occurrence of any given deposit of asbestos determines the method of mining. In the Canadian asbestos districts the serpentine bodies that contain the veins and veinlets of asbestos outcrop at the surface as irregular masses. The veins of asbestos occur irregularly distributed in these serpentine masses, and are

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2 Mineral Resources of the United States, 1919.
3 Asbestos, by Oliver Bowles, Engineering and Mining Journal, Jan., 1921.
themselves irregular in length and width. They are rarely over two hundred feet long, and are from a fraction of an inch up to several inches wide. Veins of three to four inches in width are rare, although six-inch veins have been reported.

The mining method practiced in Canada has conformed to the mode of occurrence, and the quarry or open cut system is used. Cirkel claims that several attempts at underground mining have proven failures. Some of the quarries have attained a depth of 200 feet and are 600 to 1200 feet in length.

The rock is removed from the quarry by means of cable derricks and, according to Dresser, the average recovery of fiber varies at the different properties, but is from three to eight percent of the rock treated. Cirkel states that the asbestos fiber recovered in the mill varies from six to ten per cent of the rock milled. Those mines in which a considerable amount of long-fiber occurs practice hand clobbing as well as milling. At some of the mines only milling is practiced. The mills consist in the main of crushers, rolls, fiberizers, beaters, cyclones, shaking screens, fans, collectors and pulvizers. A complete description of milling practice is given by Cirkel.

The occurrence of asbestos in the Sierra Ancha district of Arizona is such that its economic mining usually necessitates the use of underground methods. The asbestos zones lie flat or dip at a low angle, and have a heavy overburden of limestone. The asbestos of the lower mill fiber grade in this district has until recently been stocked. Two mills have recently been erected, however, and mill fiber is now being shipped.

LOCATION OF AND ACQUISITION OF TITLE TO ASBESTOS CLAIMS

When asbestos occurs in veins in rock in place on the public domain, it may be located and patented as a lode claim although it is a non-metallic mineral.

Until recently asbestos deposits could not be located or mined on unallotted lands on Indian reservations in Arizona, but by Act of Congress of June 30, 1919, certain unallotted lands on Indian reservations in Arizona were thrown open to prospecting for metalliferous minerals, and deposits found became subject to location and lease.

By Act of Congress of March 3, 1921, on and after twelve o'clock noon, on April 15, 1921, all lands heretofore opened under Sec. 26
of the Act of June 30, 1919, also became subject to exploration for deposits of magnesite, gypsum, limestone, and asbestos, which could be located and leased under the same terms as metallic minerals.

Under these acts the prospector after discovery locates a claim and, within sixty days, files duplicate copies of the location notice with the superintendent in charge of the reservation. Within one year after the location of a claim the locator must apply, through the superintendent of the reservation, to the Secretary of the Interior for a lease which runs for twenty years. If an application for a lease is not made within a year, the locator forfeits all rights to the claim. The lessee may, in the discretion of the Secretary of the Interior, make written relinquishment of all rights in the lease at any time. A royalty of not less than five percent of the net value of the output of the minerals at the mine must be paid to the Government, and, in addition, a rental of twenty-five cents per acre for the first year, fifty cents per acre for the second to fifth years, and not less than one dollar per acre for each year thereafter must also be paid. Besides the payment of royalties and rental, a locator or lessee must expend not less than $100 per year in development work on each claim located or leased. Claims on Indian reservations are limited to parallelograms not over 1500 feet long by 600 feet wide, and lessees "have the right to mine only within the exterior boundaries of the leased lands and to lines drawn vertically downward therefrom." There is no such thing as "extra-lateral rights" on a claim on an Indian reservation.

Full information on the provisions of the laws relating to this matter and the areas that have been thrown open to exploration may be obtained upon application to the Arizona Bureau of Mines.

ARIZONA OCCURRENCES

The known deposits of asbestos in Arizona occur in serpentine in limestone that has been intruded by diabase. The following excerpt from the United States Geological Survey publication entitled "Mineral Resources" for 1917, Asbestos, by J. S. Diller, describes in detail what at present appear to be the most important deposits of asbestos in the state.

"One of the best localities (Area 1, Plate II) in which to study the asbestos in relation to its associated rocks is in the Sierra Ancha."
The mine of the American Ores & Asbestos Company is situated on the outcrop of the limestone. A number of tunnels have been run in along the asbestos veins, of which there were two horizons in the upper part of the limestone, near the summit of Mount Baker. The mine was opened in 1917 by Charles F. Sloane. It is still without a mill and ships only spinning fiber, which is sent to the United States Asbestos Company of Lancaster, Pa. The cross-fiber veins of asbestos are practically parallel to the stratification of the limestone. Mount Baker is one of the local names applied to the south of the Sierra Ancha and is generally capped by thick horizontal sandstone, beneath which extends the asbestos bearing limestone intruded and split by the great sill of diabase. The upper surface of the diabase is irregular. In some places the diabase cuts up through the limestone and completely envelops large fragments of it. At such places the limestone may be fissured, and asbestos is likely to be most abundantly developed.

"The southern portion of the Sierra Ancha is essentially a plateau whose border is deeply cut by the tributaries of Coon Creek and Cherry Creek on the east, as well as by the branches of Sallymay and other creeks that flow into Roosevelt reservoir on the west. Upon this serrated border the limestone and diabase contact is locally well exposed, especially upon the east side and toward the head of Cherry Creek, where deposits of asbestos have been prospected and claims located over a wide stretch of country. The writer was unable to reach the deposits of the Cherry Creek country in 1917, but the specimens sent from that locality and the outcrops on the eastern slope of the Sierra Ancha indicate the probability that deposits of considerable size may occur in that region.

"Ash Creek Deposits. The best known and one of the most productive asbestos localities (Area 2, Plate II) in the United States is on Ash Creek, where the mine of the Arizona Asbestos Association, under the superintendence of N. A. Nelson for the H. J. Johns-Manville Company, has been in successful operation for several years. The company employs about fifty men, and, when visited by the writer in September, 1917, was working night and day. Most of the fiber is carefully cobbled and bagged as Crude Nos. I and II, but a considerable part in run through a small mill
consisting of a Blake crusher, cyclone screens, and sorters, making four grades of mill fiber in addition to the two grades of crude, which constitute the larger portion of the shipments and which are hauled by trucks 42 miles to the railroad at Rice, or are packed about the same distance by burro train to Globe.

"The relations of the rocks at Ash Creek are essentially the same as in the Sierra Ancha, although there is a wide difference in details. In the Ash Creek region the asbestos veins occur near the diabase, for the most part in the lower portion of the limestone, but at one place Mr. Nelson called the writer's attention to commercial pits in limestone overlain by diabase.

"The limestone upon the east side of Ash Creek is much broken and dislocated by the irregular, roughly dike-like mass of diabase, and the greatest amount of fiber generally occurs where the irregularities or uprisings of the diabase contact are most pronounced.

"Two prominent veins of asbestos commonly occur within about five feet of each other, and both of them can be worked from the same tunnel. In such occurrences the asbestos may constitute as much as five per cent of the total rock removed in running the tunnel. In general, however, the commercial fiber is less than one per cent of the rock removed.

"The Ash Creek mine has a total length of more than 7000 feet of underground workings. The longest tunnel penetrates the canyon wall for about 600 feet and passes through portions of diabase intruding the limestone from below.

"North of the Ash Creek mine, near Salt River, prospects are being developed by the Penn Asbestos Mining & Refining Company, the Colorado Arizona Asbestos Mining Company, and others, all of which have taken out small quantities of asbestos for testing but have not yet reached regular production.

"Origin of the Asbestos. There is a common belief among those who have had much experience in mining asbestos in Arizona that it is most abundantly developed near the surface of the ground and decreases more or less regularly as the distance increases from the surface into the canyon wall. However, there has not yet been sufficient detailed observation to establish fully this view, the ten-
dency of which, as advocated by C. W. Barnard in unpublished work, is to connect the deposition of the asbestos more or less directly with the present lines of drainage.

"On the other hand, the constant association of the asbestos and limestone near its contact with diabase strongly suggests that the serpentine and asbestos are the result of hydrothermal metamorphic action of the intruding diabase upon the limestone. The fact that the asbestos is generally found in greatest abundance in fissured limestone, where the heated waters of the intruding diabase may have penetrated the limestone and converted it into serpentine and asbestos, lends support to this view.

"It is gratifying to know that those most interested in the asbestos of Arizona are not mine promoters and speculators, but large consumers of asbestos, who appreciate its value and are developing its resources with intelligent care."

Cirkel\textsuperscript{1} reports the occurrence of asbestos twenty-three miles west of Globe in Gila County (Area 3, Plate II), and says:

"In 1903 a deposit of chrysotile asbestos was found in Arizona at the head of Pinto Creek, twenty-three miles west of Globe, Gila County. This deposit has been located by Mr. M. L. Shackelford, of Prescott, Ariz. The asbestos-bearing serpentine can be traced for over three miles and the asbestos deposits are as a rule found on the contact with the country rock. Samples of this asbestos have been examined and were found to be of good quality, the fibers varying from a fraction of an inch to two and three inches in length. The only work that has been done on this deposit up to the present time is the one year's assessment work, so that there is not very much known as yet regarding the extent of the deposit or the percentage of asbestos that can be obtained in mining."

He also briefly mentions the deposits of the Hance Asbestos Company (Area 4, Plate II) as follows:

"The deposits of chrysotile asbestos in the Grand Canyon, Ariz., which are owned by the Hance Asbestos Company, were mined to a small extent, but the work was more of an exploratory nature. Mr. John Penhale, manager of the Quebec Asbestos Company, at East
Broughton, has spent about ten months in the development of the asbestos occurrences on behalf of New York capitalists and he describes the serpentine, which occurs everywhere in the steep bluff in the canyon, as a yellow-green, harsh rock, sometimes massive, sometimes in a crushed and disturbed condition, overlaid by sandstone. Asbestos veins are few, mostly in a horizontal position and parallel to each other, and the fiber in most of the occurrences is frozen to a serpentine of opaque, cherty appearance. The fiber is whitish, with a yellow-greenish tint resembling much the Templeton asbestos. The quality of the asbestos is good and some of the fibers are two inches in length."

Pratt describes this occurrence at greater length: "The asbestos deposits in the Grand Canyon of the Colorado River, Arizona, belong to the Hance Asbestos Mining Company, of New York City, and are located in the Grand Canyon mining district, Coconino County, Arizona, on the north side of the Colorado River, about seventy miles a little west of north of Flagstaff, the county seat. The deposits are near the bottom of the Grand Canyon about 4,900 feet below the rim, with a portion of the property rising to about 1,500 feet above the river. The nearest point on the railroad is Grand Canyon at the terminus of the Grand Canyon railroad, which connects at Williams, a distance of 63 miles, with the main line of the Santa Fe railroad. There is a good wagon road from Grand Canyon station to the head of Grand View and Red Canyon trails, which lead from the rim to the bottom of the canyon and are 14 and 19 miles, respectively, from Grand Canyon station. Both these trails are in good condition, and pack trains could carry from 80 to 100 pounds per burro, or from 175 to 210 pounds per mule. Grand View, a U. S. postoffice, is on the rim between the two trails.

"The only present means of crossing the river to the asbestos deposits, which are on the north side, is by rowboat. With the installation, however, of a cable and an aerial tramway from the south to the north bank at an elevation of approximately 1,200 feet above the river, the distance from the rim to the crossing point of the

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river would be reduced from three to five miles, and there would also be 1,200 feet less of climbing. The property extends for a distance of about 9,000 feet down the river from the crossing point.

"The rocks of the district in which the asbestos occurs consist of the Algonkian series of sedimentary rocks, lying unconformably beneath the Cambrian and the Carboniferous sedimentary rocks, which extend above them from 3,200 to 4,000 feet. Beneath the Algonkian sedimentary rocks are the Archaen series, consisting of granites and gneisses, cutting which are numerous pegmatitic dikes. Between these two latter series of rocks there is a dike of basaltic rock which penetrates in some cases the strata of the Algonkian sediments, and is separated from the igneous rocks below by a strata of conglomerate which is very constant. Occasionally, however, this basaltic rock is in direct contact with the igneous rock below. These rocks dip at an angle of about 12° to 15° toward the east, and have a general strike of about N. 20° W. They also pitch about 10° toward the north. They are cut out by the Tonto sandstone of the Cambrian series at an elevation of about 1,400 feet just west of Claim 15. From this point they dip uniformly toward the east and disappear under the river at a distance of from 10,000 to 10,100 feet. Within this distance these rocks are faulted four times, the displacement being from 10 to 50 feet; the faults are normal.

"This basaltic dike has broken thru the strata of the sediments (in some cases breaking off and inclosing within itself masses of some of these sedimentary rocks), and small dikes of similar rock were observed cutting across the strata at two other points, one a third of a mile farther up the canyon and directly across the river from the mouth of Red Canyon Creek, and the other one mile up Red Canyon and on its western wall. This basaltic dike is from 30 to 70 feet in thickness and along its contact with the sedimentary rocks, whether they are above or below or included within this rock, it is more or less altered to serpentine. In some instances where the seams of the basaltic dike have penetrated into the strata of the sedimentary rocks they are completely altered to serpentine, and it is in association with these serpentinized areas of the basaltic rock that the asbestos is found. In some instances the basaltic rock is in contact with shales, and when this is the case there has been
little or no serpentine formed. In most cases, however, the basalt is in contact with limestone, and then the serpentine areas are very constant, altho they are only from a few inches to 18 inches, and, in very rare cases, to 24 inches in thickness. The chrysotile asbestos is found only in those areas of the basaltic rock that have been serpentinized. As has been stated, these areas are almost constant for the whole 9,000 feet of the claims, altho the asbestos varies very widely in length of fiber and in quality.

"One noticeable exception to the usual occurrence of asbestos is the regularity of the seams. In some instances they are constant for a distance of 150 feet or more. Another difference is that instead of a thick mass of serpentine containing numerous seams of asbestos, the Grand Canyon deposit is a thin body of serpentine with but two or three prominent seams, which are, however, regular and nearly constant.

"Most of the development work has been done near the western end of the property on what is known as Claim 14, or Wool Claim. The asbestos deposits have been developed at different points on this claim, following three different seams or zones of serpentine, which are in contact with three distinct layers of limestone. Openings were made on the upper and lower contact of a middle seam of basaltic rock and on the extreme upper contact. At the middle opening a tunnel has been run for a distance of about 75 feet in a direction N. 10° E. following the pitch of the rock, which is about 10° N. From this tunnel cross-cuts have been driven and there has been considerable stoping. Just to the north of the mouth of the tunnel a quarry face has been opened for a distance of 126 feet in length and 20 feet in height, which exposed asbestos for a small area near the bottom of the face of the quarry. The asbestos seams, as exposed in the quarry and in the underground workings, vary considerably in width, widening and pinching, and sometimes splitting up into a number of seams in like manner, as has been observed in all deposits of chrysotile asbestos. The quality of asbestos is exceptionally good and equal to the Canadian. This claim lies about 1,300 feet above the level of the river.

"The next point at which there has been considerable development work is near the center of the property on Claim 8. The
deposit on this claim has been developed extensively by means of quarrying and the asbestos is exposed for a distance of about 160 feet. Asbestos of splendid quality, ranging from three-quarters to one and one-half inches in length, has been obtained from this claim. One peculiar quality of this asbestos is the beautiful golden color which it assumes in the massive specimens, altho the individual fibers are pure white and very silky. In the mass it is almost transparent.

"The third point at which there has been considerable development work is near the eastern end of the property, where a quarry face about 25 feet in length has been opened from which two tunnels, one about ten and the other about twenty feet long, have been drifted on the asbestos seam. Some of the asbestos fiber from this claim was three inches in length, but it is not of as good quality as that obtained from Claim 14 and Claim 8.

"Altho this property is located at the bottom of the Grand Canyon, thus making the cost of transportation of the asbestos to the railroad very high, still there are no mechanical problems in connection with the mining and the transportation of this asbestos that cannot be readily overcome when it has been definitely and positively determined that there is a sufficient quantity of the asbestos to warrant the outlay necessary. The quality of the asbestos, which is of the best, is a practical guarantee of a constant demand for any of the material that may be mined."

The description of another occurrence in the Grand Canyon is given by J. S. Diller in the United States Geological Survey publication entitled "Mineral Resources of the United States," 1907, as follows:

"Within the last few years deposits (Area 5, Plate II) have been found on the north side of the canyon, 25 miles northwest of Grand Canyon station, in the vicinity of Bass Ferry. The Grand Canyon at this point is 4,500 feet deep, and the asbestos occurs about 450 feet above the bottom. When the river is low it is crossed in a rowboat, but when it is high by means of a suspended car. The most direct line of trail, when completed, will be about eight miles long, and transportation up to the rim is effected by means of
burros, each animal carrying about 90 pounds.

"The Grand Canyon exposes an excellent section of the Carboniferous, Cambrian, Algonkian, and Archean rocks. The Algonkian is markedly unconformable with the overlying Cambrian as well as the underlying Archean, and forms a wedge-shaped mass with its edge along the canyon near its bottom and thickening rapidly to the north. The asbestos occurs in the basal portion of the Algonkian. This is made up, first, of a few feet of siliceous conglomerate overlain by about 50 feet of variously colored fine shaly beds, locally calcareous or serpentinous. Then follows 15 feet of whitish limestone containing layers and nodules of serpentine with more or less asbestos. Above the asbestos limestone comes a heavy layer of compact diabase about 200 feet thick, and above the diabase is a bed of limestone and shaly rocks similar to those immediately below the diabase. A little asbestos may be seen in the limestone above the diabase, but it is much more abundant in the lower limestone.

"The asbestos-bearing limestone below the diabase varies considerably from place to place, but for the most part has approximately the following section:

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<thead>
<tr>
<th></th>
<th>FEET</th>
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<tbody>
<tr>
<td>Compact limestone</td>
<td>1.8</td>
</tr>
<tr>
<td>Serpentine with veins of asbestos</td>
<td>1.2</td>
</tr>
<tr>
<td>Banded whitish limestone</td>
<td>12.0</td>
</tr>
</tbody>
</table>

"The upper and lower portions of the limestone may contain some bands and nodules of serpentine, but they are not as persistent as the intermediate layer of serpentine, in which is found nearly all the asbestos. It occurs in cross-fiber veins which lie parallel to the bedding in the limestone.

"The cross-fiber veins range from a small fraction of an inch to about three inches in width, and are remarkable for their golden-yellow color as well as for the tensile strength of the fiber.

"The overlying diabase looks unaltered, and its contact with the limestone is distinct, except where the top of the limestone is serpentine.

"The facts observed in the field appear to indicate that the serpentine, which includes the asbestos (chrysotile), is derived from some mineral in the limestone and not from the diabase. Con-
clusive evidence concerning its derivation can not be obtained until the rocks are examined in the laboratory. If the suggested conclusion proves to be true, the Grand Canyon asbestos affords a type quite different in origin from any yet found at other localities in the United States.

"Four asbestos claims have been taken up, one on the upper and three on the lower limestone, along which the thin belt of included asbestos-bearing serpentine has been prospected in a number of shallow open cuts for over half a mile. The continuity of the narrow asbestos belt is very irregular, and it disappears locally; but it is abundant enough in places to suggest the probability that Nos. I and II crude fiber carefully selected from the veins may be mined to a small extent at a profit. It does not seem at all probable, however, considering the limited quantity, location, and distribution of the deposit, that it would pay to mill."

Through the courtesy of Philip S. Smith of the United States Geological Survey, it is possible to give a brief resumé of the results of recent work done by J. S. Diller and Edward Sampson in the asbestos areas (Area 6, Plate II) that are located in the Apache and San Carlos Indian reservations. The following data is quoted in full from Mr. Smith's communication:

"In the Fort Apache and San Carlos Indian reservations asbestos occurs associated with rocks of the Apache group. The principal asbestos field is in the region of the Salt River. Here the Apache group is principally represented by the Dripping Springs quartzite, the Mescal limestone, and the Troy quartzite, these rocks being everywhere intruded by sills of diabase. Throughout the whole area there has been much diabase intruded at the horizon of the Mescal limestone, and it is in the limestone near contacts with the diabase that asbestos is found. In places the limestone has been much broken by the diabase and such places have been particularly favorable for the formation of asbestos. The asbestos usually occurs in limestone above the diabase contact, though it has been found below the contact. Serpentine is invariably associated with the asbestos which occurs in the serpentine as cross-fiber veins parallel to the bedding of the limestone. Although serpentine often occurs
without asbestos, serpentine float is a valuable aid in prospecting. Asbestos itself usually occurs as float for a considerable distance below the outcrop.

"Asbestos is known to occur at a considerable number of places within the reservation. It is reliably reported as occurring on Sloane Creek, a tributary of Canyon Creek, near the reservation line and not far from the mine of Messrs. Kyle and Pierce. Above the canyon of Canyon Creek conditions appear to be unfavorable for the occurrence of asbestos, but on the east side of the creek in the region of the mouth of Rock House Canyon, another tributary, there is a considerable development of serpentine. To the east of Canyon Creek several small deposits of asbestos were found on the north side of the canyon of the Salt River between the Salt Bank and Salt River Draw. The fiber is of good quality, but the deposits are small. Another deposit was found in the canyon of Salt River Draw on the west side, about two miles above the confluence of Salt River Draw and Salt River. Here again, although the fiber is of good quality, the quantity is small.

"Reports of the occurrence of fiber on Cibecue Creek are in general circulation. For about seven miles Cibecue Creek flows through a canyon impassable for beast and difficult of access on foot. It was traversed to beyond the point where the asbestos bearing rocks pass beneath the ground. No asbestos was found either in place or in float, but serpentine is abundantly developed where the Mescal limestone is last seen. Careful prospecting since the visit of the survey party failed to discover more than a trace of asbestos.

"The most promising deposits found are high above the bend of the Salt River known as the 'Peninsula' or 'Mule Shoe.' One occurs on the north side of the river and one on the south side. In both of them the fiber is of good quality and fair length. Both of these deposits have been staked.

"In all this region the asbestos-bearing limestone, the Mescal, outcrops only in the canyons, the mesas being capped by younger rocks. For this reason the maximum limit of the field may be given with some accuracy. On Canyon Creek the Mescal limestone is found to about three miles above the mouth of Sloane Creek. It extends about
two miles up Salt River Draw and about three miles up Cibecue Creek. It does not extend up the Salt River farther than the mouth of Saw Mill Canyon.

"One other important occurrence of asbestos is known on the San Carlos Indian reservation, namely that on Bear Creek, three miles east of Cassadero Springs. Here a quite extensive deposit of somewhat harsh fiber is exposed in a cliff face. There are two asbestos horizons five feet apart. This deposit lies on the Blue Mile group of claims. A road has been cleared to the rim of the small canyon in which Bear Creek flows."

It has been reported to the Arizona Bureau of Mines that a deposit of asbestos occurs twelve miles south of Winkelman and one and one-half miles west of the county highway on Putnam Wash. (Area 7, Plate II.) The samples sent to the bureau by Charles F. Davis, owner of the property, show the asbestos to be up to an inch in length, amber yellow in color, and of good quality. Parts of the sample contained asbestos that was slightly brittle, but these pieces were probably taken from the surface and had been subjected to weathering. From the reports received, it is believed that the asbestos occurs as a single veinlet upon which a tunnel has been driven while prospecting for copper ore. Another deposit is reported to exist east of the one mentioned, but details relative to it are lacking.

The occurrence of asbestos twelve miles northwest of Quartzsite and nine miles east of the Colorado River (Area 8, Plate II) has been reported to the Arizona Bureau of Mines by Jos. Bowyer upon whose property it occurs. Mr. Bowyer reports that the asbestos was discovered by accident while building a road, and that it occurs in a zone five feet wide in limestone which has been intruded by diabase.

The United States Bureau of Mines reports the recent discovery of high grade asbestos in Apache County on the Fort Apache Indian reservation. The exact location of the deposit is not known to the Arizona Bureau of Mines.

Carl Lausen, geologist with the Arizona Bureau of Mines, has given the following description of two Arizona occurrences:
“Asbestos occurs on the east side of Cherry Creek (Area 9, Plate II) in Mescal limestone intruded by diabase. The fiber varies in length up to one-half inch and is of good quality. Several inches of serpentine occur on each side of the asbestos.

“Claims have been located in this area, but the only development has been a small amount of assessment work.

“About six miles west of Cutter, (Area 10, Plate II) a station on the Arizona Eastern Railway, and in the foothills south of the Pinal Mountains, is an area of Cambrian sediments intruded by diabase. These sediments have been dislocated and tilted by numerous normal faults, and the dips are usually greater than thirty degrees.

“Asbestos occurs in Mescal limestone intruded by diabase. The fiber is generally less than one-half inch in length and not of the best quality. The owners were offered $500 per ton in 1918 for material hand-sorted and free from serpentine. Although the fiber has some strength, it is usually somewhat brittle. Numerous bands of serpentine occur on each side of the asbestos seen.

“Claims have been located in this area, which is just off the reservation boundary, and some development work has been done. A tunnel driven into the hillside for eighty feet cut the asbestos seam, but it had pinched down to less than a quarter of an inch.”

PRODUCERS AND PROSPECTIVE PRODUCERS OF ASBESTOS IN ARIZONA

Alene Asbestos Association, Globe, Arizona.
Arizona Asbestos Association, Ash Creek, Globe, Arizona.
Bass, W. W., Grand Canyon, Arizona.
Berry, J. R., Christmas, Arizona.
Bowyer, Jos., Quartzsite, Arizona.
Coffield, J. P., 29 N. Meyer St., Tucson, Arizona.
Colorado Arizona Asbestos Mining Company, 1138 First National Bank Building, Denver, Colorado.
Davis, Charles F., Mesa, Arizona.
Hance Asbestos Company, Grand Canyon, Arizona.
Harderman, F. M., Globe, Arizona.
Helm, P. R., care Pratt Gilbert Co., Phoenix, Arizona.
Kennedy, Clyde, Box 837, Globe, Arizona.
Muller, H. C. G., Winkelman, Arizona.
Penn Asbestos Mining & Refining Company, Chrysotile, Arizona.
Smith, R. C., Snowflake, Arizona.
U. S. Asbestos Mining Company, Sierra Anchas, Globe, Arizona.
Watkins, C., Box 1795, Globe, Arizona.
Wightman, H. P., Globe, Arizona.
Wolfe, A. B., Globe, Arizona.

ASBESTOS PURCHASERS

Asbestos Fiber Spinning Company, North Wales, Pa.
Asbestos & Mineral Corporation, Whitehall Building, New York City.
General Asbestos & Rubber Company, Charleston, S. C.
Hoff Asbestos Company, John D., 1850 Eighth St., Oakland Calif.
Hoffman, F. G., 13 Francis Ave., Trenton, N. J.
Hudson, John H., 314 100th St., New York City.
Johns-Manville Company, New York City.
Philip Carey Company, Lockland, Cincinnati, Ohio.
Schulte, August E., 142 Berkeley St., Boston, Mass.
Wilson, Elwood J., 34 W. 33d St., New York City.

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