

suitable scoria. The cost of separation of the suitable from the unsuitable material may make production from the deposit economically unfeasible.

S-3, *Dotsero Crater deposit, Eagle County* (fig. 3)—Scoria from this deposit in western Eagle County has had some use as a lightweight aggregate in construction in a few nearby towns. The deposit is in T. 4 S., R. 86 W., sec. 23, at an altitude of about 7300 feet. It is about 0.6 mile north of U. S. Highways 6 and 24 at a point about a mile east of the Denver & Rio Grande Western Railroad at Dotsero, Colo. A bulldozed dirt road extends from the highway to the deposit.

The scoria was ejected from a vent that developed in the bottom of a small tributary to the Eagle River, reportedly within historic time. The crater is well preserved; it has a diameter of about 2100 feet and a depth of 600 to 800 feet. Bedded scoria, dipping into the crater, is exposed along the valley walls. Lapilli and bomb fragments of scoria cover the surrounding, pre-existing hills of red sandstone of Triassic age. The minable area, which lies a short distance east of the crater, is 1200 feet long by 800 feet wide. The average thickness of the scoria is 3 to 4 feet, with a maximum thickness of 8 feet.

Most of the scoria is purplish-black, with a minor amount of red material. It contains a rather high percentage of fines and dirt and some unexpanded bomb fragments. Little crushing is necessary, as most of the material ranges in maximum diameter from a quarter of an inch to half an inch. The scoria is suitable for use as a lightweight aggregate.

A basalt flow also issued from a vent within the crater, and flowed down a pre-existing valley to the valley of the Eagle River, a distance of about $1\frac{1}{2}$ miles. Remnants of this flow are preserved along the banks of the small valley. The major part of the flow forms a fan, about 5000 feet long and 2500 feet wide, that covers some of the terraces cut by the Eagle River and has also forced the river to the south side of its valley. The basalt is scoriaceous, but in general it is too heavy for use as a lightweight aggregate.

The workings consist of three bulldozed opencuts, 200 feet by 50 feet, 220 feet by 20 feet, and an exploratory working 35 feet by 45 feet. The material was bulldozed to a chute and loaded directly into trucks. Total production from this deposit was small.

S-4, Crater deposit, Routt County (fig. 3)—Large tonnages of scoria are available at this undeveloped deposit in southern Routt County, in T. 1 S., R. 83 W., sec. 16, at an altitude of about 7600 feet. The deposit is at Crater Siding, on the Denver & Salt Lake Railroad, 6 miles by dirt road from McCoy, Colo.

Scoria comprises the bulk of a rounded volcanic cone that lies upon the flat surface of Conger Mesa. A saucer-shaped depression 500 feet in diameter marks the position of the original crater. The cone is about 225 feet high and about 2000 feet in diameter at its top. The scoria beds are about 200 feet thick and are underlain by dense black basalt flows.

The scoria on the southern section of the cone is predominantly red; there is a less abundant, dark gray-black scoria to the north. Most of the material is in the form of bombs or bomb fragments. Numerous unexpanded or partly expanded bombs are intermixed with the suitable material and would lead to difficulty in its use as a lightweight aggregate. There has been no production, but a few shallow prospect pits have been opened on the cone.

S-5, Volcano deposit, Routt County (fig. 3)—Scoria from this deposit in southern Routt County has been used for ballast on northern Colorado railroad lines. At the time of the examination it had not been used for lightweight aggregate. The deposit is in T. 1 S., R. 83 W., sec. 17, at an altitude of about 7900 feet. It is at Volcano Siding on the Denver & Salt Lake Railroad, about 7½ miles by poor dirt road from McCoy, Colo.

The Volcano deposit is a part of a volcanic cone on the west side of Rock Creek, about 1½ miles northwest of deposit S-4. Erosion by Rock Creek has removed a large part of the cone, but the remainder is well exposed as a result of

large-scale quarrying operations. Workings consist of two adjacent opencuts in east flank of the cone, with a total length of about 1100 feet. The quarry faces, along the length of the cuts, are 175 to 200 feet high and are entirely in scoria. In general, the scoria beds dip toward the center of the cone. The writer recorded apparent dips of 25° N. at the southern end of the deposits and of 15° S. at the northern end. Large tonnages of the material are available. No information on past production has been obtained.

The cone overlies pre-Cambrian granite and Cambrian Sawatch quartzite as mapped by Donner.¹ At the south end of the exposure, sericitized pre-Cambrian granite is overlain by a buried soil. The soil underlies 5 feet of loose-pebble beds that do not include any volcanic material. The pebble beds are overlain by 15 feet of bedded scoria, granite, and quartzite fragments. This zone represents the earliest ejecta from the vent. Above it are the major bedded scoria deposits. Individual beds are conformable to the underlying beds for some distance and then truncate them. At the north end of the exposure the sequence is similar. The scoria here overlies a buried soil developed on weathered Cambrian Sawatch quartzite.

The scoria occurs as bombs and bomb fragments; the smallest pieces are 1 to 2 inches across, whereas some of the larger bombs are 12 to 14 feet long and 2 to 4 feet thick. Because of varying amounts of expansion, the larger masses vary considerably in weight. All the material requires crushing and grading before use as a lightweight aggregate. Grayish scoria forms streaks and zones within predominantly red scoria. The larger bombs are bluish-black or black, and toward the ends of the deposit all the scoria is black.

S-6, *Riveira deposit, Rio Arriba County, N. M.* (fig. 6)
—As the Riveira deposit is about $2\frac{1}{2}$ miles south of the Colorado boundary, it is included with the description of Colorado deposits. Large tonnages of scoria are available and the deposit is conveniently located with respect to the

¹Donner, H. F., Geology of the McCoy area, Eagle and Ruott Counties, Colo., Geol. Soc. America Bull., vol. 60, No. 8, pp. 1215-1247, 1949.

Denver & Rio Grande Western Railroad. It is in T. 31 N., R. 8 E., sec. 6, and T. 32 N., R. 8 E., sec. 31, at an altitude of about 8300 feet. The deposit is about $2\frac{1}{2}$ miles by dirt road from a siding on the Denver & Rio Grande Western Railroad and is about 11 miles by dirt and gravel roads from the town of Antonito, Colo.

The deposit covers an area approximately 3000 feet by 2500 feet. The apparent maximum thickness is about 140 feet, but the average thickness is about 20 to 25 feet. The scoria beds are essentially flat. In general, the overburden is 1 to 2 feet thick, but in some places it is absent.

In the eastern part of the area, scoria is exposed on the slopes of a 210-foot hill that rises above extensive basalt flow plains. Here the apparent thickness of the scoria is about 140 feet. Red and black scoriaceous to dense basalt flows are exposed for 70 feet above the scoria. In this area most of the scoria is in the form of bomb fragments, but numerous unbroken bombs also are present. About 1500 feet to the west, scoria is exposed at the top of the east bank of the Rio de Los Pinos. Here the scoria occurs as the upper scoriaceous zone of a pink to pinkish-gray flow, possibly andesitic in composition. The relationship between the two types of scoria has not been adequately investigated. Of the two kinds, the scoria in bomb and fragment form attains the greater thickness but has a smaller areal distribution.

Most of the scoria is red or purplish red, but near the surface it is coated with white calcium carbaronate. Most of the bomb fragments range from 1 to 10 inches in longest dimension, but a few are larger. The vesicles in the larger bombs increase markedly in size from the surface to the center, and the weight varies accordingly. Unexpanded and partly expanded material is rare. Most of the deposit is amenable to opencut mining operation. The scoria requires crushing and grading before it can be used as a lightweight aggregate.

S-7, *San Antonio Mountain deposit, Rio Arriba County, N. M.* (fig. 6)—As San Antonio Mountain is only 6 to 7 miles south of the Colorado-New Mexico boundary, south and

east of deposit S-6, a brief examination was made of the deposit, and it is included with the descriptions of Colorado deposits. It is in T. 31 N., R. 9 E., SW $\frac{1}{4}$, at an altitude of about 8000 to 8500 feet. The deposit is 0.7 mile west of U. S. Highway 285, about 13 miles south of the Denver & Rio Grande Western Railroad at Antonito, Colo.

Two hills that rise about 200 feet above the general valley floor on the northeast flank of San Antonio Mountain are capped by 75 to 80 feet of scoria. The area covered by the scoria is estimated to be 1500 feet long by 600 feet wide. Overburden ranges in thickness from 1 foot on the tops of the hills to 3 or 4 feet at their bases.

These hills are classed as probable volcanic cones, although the site of the original crater or craters cannot be established definitely. The scoria overlies basalt flows that do not crop out but are represented by numerous scoriaceous to dense basalt boulders in the float.

The scoria is predominantly red or purple and closely resembles that at deposit S-6. Most bomb fragments range from 1 to 6 inches in length, but some are as much as 12 inches. Most of the scoria bombs are fragmented, but a few unbroken bombs occur throughout the deposit. The material requires crushing and grading before it can be used as a lightweight aggregate. The deposit is suitable for open-cut mining operations.

Other areas (figs. 2, 3, 5 and 6)—Scoria is reported in the following areas. In the opinion of the writer other areas also merit further investigation. A list of locations by township, range, and section is given in table 2.

In Chaffee County, the area surrounding "Crater Mountain," about 5 miles east of Salida, merits examination. Scoria, reported in three areas in the San Luis Hills northeast of Antonito, could not be located. The three areas are indicated on the map of south-central Colorado, figure 6. In New Mexico, close to the Colorado boundary, there are two favorable areas in Taos County and one in Rio Arriba County. Figure 6 includes parts of these two counties and shows the favorable areas.

Two areas in Costilla County are worthy of investigation. They are 6 and 11 miles south of the town of Blanca, some miles west of the Blanca-San Acacio highway. Scoria and pumice also have been reported in the vicinity of Coal-dale in Fremont County. The deposit could not be located in the time available for the examination. According to MacQuown² scoria occurs in the vicinity of Willow Peak in Garfield County. At the time of the field study, the only road to the area was impassable. Scoria also is reported from northeastern Grand County, but the deposit could not be located in the time available.

Residents of Gunnison County report that scoria is present in the area east of State Highway 149, between Iola and Powderhorn. Scoria or pumice is reported in the vicinity of Devil Lake in Hinsdale County. The area is accessible only on foot or by horseback. In Rio Grande County, scoria is reported near the headwaters of San Francisco Creek in the vicinity of Pentada del Norte Peak.

PERLITE

Most of the Colorado perlite deposits are in Custer, Fremont, Chaffee, Saguache, and eastern Gunnison Counties. Within this area, the deposits are concentrated in northern Saguache County, near the northeastern periphery of the San Juan Mountains. The material is indigenous to regions that contain flows of volcanic glass.

P-1, Nathrop or Ruby Mountain deposit, Chaffee County (fig. 5)—The Nathrop perlite deposit is closely associated with the Nathrop pumice deposit described above as Pm-1 (see pages ———). It is in T. 15 S., R. 78 W., secs. 11, 12, and 13,, at an approximate altitude of 8000 feet; at the time of the examination it was not accessible by car or truck. It lies on the east side of the Arkansas River, 0.8 mile east of the Denver & Rio Grande Western Railroad at Nathrop, Colo., and about a mile south of the nearest road. Bulldozing and

²MacQuown, W. C., Jr., Structure of the White River Plateau near Glenwood Springs, Colo.; Geol. Soc. America Bull., vol. 56, No. 10, pp. 877-1892, 1945; personal communication, April 18, 1947.

blasting would be required to extend this road to the deposit.

A thin perlite flow is traceable for about 300 feet along the east flank of Ruby Mountain. The strike of the flow essentially parallels the trend of the ridge, and the flow appears to be relatively horizontal. Perlite also is exposed for about 200 feet at the north end of Ruby Mountain. The entire thickness does not crop out, but it appears to be greater than 15 feet.

Along the east flank of Ruby Mountain the perlite is overlain by a rhyolite flow and rests upon pumice and pumiceous tuff. The relation of the obsidian to the pumice and tuff is not clear. Both materials underlie the perlite but the contact between them is not exposed. At the north end of Ruby Mountain, a rhyolite flow overlies the perlite. A red and black obsidian flow underlies the perlite and is exposed for several hundred feet to the north, beyond the outcrop limits of the perlite.

The perlite is a partly granular gray-black to black volcanic glass. Most of the material has the typical shelly perlitic texture. Other parts lack the shelly texture and are characterized by alternating thin bands of gray-brown and black glass. Individual bands are about 0.1 mm thick. It is not known if the two types of glass are equally suitable for expansion. Devitrified perlite also is present but is of scientific interest only.

P-2, Rosita Hills deposit, Custer County (fig. 5)—The Rosita Hills deposit is one of the largest and most important in Colorado. Development work and production began some months after the area was examined. Some of the following information has resulted from development work and has been obtained from representatives of the operators.

The deposit is in the Rosita Hills, half a mile to 2 miles south and southwest of Rosita, Colo., in T. 22 S., R. 71 W., secs. 32 and 33, and in T. 23 S., R. 71 W., secs. 5 and 6, at an altitude of about 8700 feet. It is accessible from Rosita by dirt and gravel roads. The nearest railroad is the Denver &

Rio Grande Western Railroad at Texas Creek, Colo., about 35 to 40 miles from the deposit.

Perlite crops out along the gentle, lower slopes of the Rosita Hills, extending over an area of about a square mile. The perlite is a relatively horizontal flow that is 40 to 75 feet thick. It overlies a bedded tuff that is described by the operators as "pumiceous" material. In general a rhyolite flow overlies the perlite, but at two of the workings, perlite is reported to be both underlain and overlain by a "pumiceous" perlite. Except where the perlite is covered by a rhyolite flow, the overburden ranges from 6 inches to 2 feet in thickness.

Two types of perlite, reported to grade into each other in places, are present, but the relative abundance of the two types is not known. Type "A" is light greenish-gray and tends to break into oval-shaped balls or long splinters. Type "B" is dark gray, harder than type "A," and has an irregular fracture. In one working, type "A" perlite overlies type "B" perlite. In another deposit, type "A" perlite is associated with a dark obsidian that lies near the base of the flow.

The workings consist of bulldozed opencuts at right angles to the trend of the perlite outcrops. Although exact production figures are not available, it is estimated that several thousand tons of perlite ore were produced in the first four years of operations.

P-3, Morning Star deposit, Gunnison County (fig. 5)—Two dikes of glassy material are exposed in the adit of the Morning Star mine near White Pine in southeastern Gunnison County. The deposit is in T. 50 N., R. 5 E., sec. 35 (?), at an altitude of about 9800 feet; it is about 9½ miles from the Denver & Rio Grande Western Railroad at Sargents, Colo.

Both dikes are reported to have a relatively steep dip. The smaller dike, which is about 5 feet thick, is reported to be composed of perlite of moderate expansibility. The larger dike, approximately 50 feet thick, is reported to be granular and glassy. No information is available as to the expansion characteristics of the material in the larger dike. The re-

ported geologic relations indicate that these two dikes are of intrusive origin.

Because of the relatively small amount of material available and the necessity for underground mining, the deposit was classed as not of commercial interest at the time of the field reconnaissance and was not examined.

P-4, Prosser's Rock deposit, Saguache County (fig. 5)—A brief examination was made of this perlite deposit in northern Saguache County, in T. 47 N., R. 3 E., secs. 6 and 7, at an altitude of about 9500 feet. A gravel road ends about a mile from the deposit, 8 miles south of the Doyle Siding of the Denver & Rio Grande Western Railroad, near Doyleville, Colo.

Perlite is exposed on the east flank of Prosser's Rock, a long, high ridge, at a point 300 to 350 feet above Razor Creek. The areal extent of the perlite is not determinable without additional prospecting. The flow is relatively horizontal in attitude. Perlite crops out for a thickness of 7 feet near the top of the flow; a second 7-foot layer is exposed near the base of the flow. Between the two exposures the float is composed predominantly of perlite with minor amounts of obsidian. A 60- to 70-foot layer of perlite with some interbedded obsidian is indicated.

The perlite is predominantly grayish black and most has the characteristic perlitic texture. Much of the material is banded, with alternate pearly zones and thin glassy bands. The glassy bands vary from yellowish gray to black. Flow texture is well developed.

A black obsidian is associated with the perlite as bands within the perlite and as an overlying flow. A glassy rhyolitic (?) flow and a white to cream-colored rhyolitic (?) tuff are exposed below the perlite.

A part of the deposit is suitable for open-cut mining operations. However, increasing depth of cover to the west limits the amount of open-cut work that can be done economically.

P-5, Cathedral deposit, Saguache County (fig. 5)—The Cathedral deposit in western Saguache County was in-

accessible in the time available for examination. It is in T. 45 N., R. 1 W., SW $\frac{1}{4}$, at an altitude of about 10,500 feet. The nearest railroad head is at Iola, Colo., about 40 miles to the north. Connecting roads are in fair condition only in good weather.

The perlite flow crops out in a 300-foot cliff, most of which is reported to be composed of perlite. The length and areal extent of the perlite are not known, but available tonnages appear to be very large. The material is reported to be suitable for use as a lightweight aggregate. However, the deposit is poorly situated with respect to marketing centers and transportation.

P-6, Cochetopa Dome deposit, Saguache County (fig. 5)
—This perlite deposit is associated with the Cochetopa Dome pumice deposit, described as Pm-4 (see pages ____). It is in T. 46 N., R. 2 E., sec. 36, at an altitude of about 9700 feet, and is a mile north of State Highway 114, about 24 miles south of the Denver & Rio Grande Western Railroad at Parlin, Colo.

The perlite exposures are in the south-facing cliffs that form the southern and southwestern edges of Cochetopa Dome. The cliffs are about 1 $\frac{1}{2}$ miles long and are breached by the present drainage. The average thickness of the perlite flow is 40 to 50 feet. The relatively horizontal flow forms the major portion of the cliff base. No attempt was made to determine the extent of the perlite to the north as other rocks overlie it in this direction.

The perlitic material is not homogeneous. Certain zones have a concentration of material with typical perlitic texture, whereas in other zones this texture may be almost entirely lacking. Zones that contain both kinds of material are common. These zones are characterized either by pearly globes intermingled with blebs of red obsidian or by rounded masses of reddish-brown, non-perlitic volcanic glass in a perlite ground mass. The expansibility of the material decreases with increase of non-perlitic glass.

The rocks that underlie the perlite flow are not exposed. A spherulitic rhyolite (?) flow overlies the perlite. The

relation of the perlite flow to the pumice beds (deposit Pm-4) that lie to the south could not be determined because of lack of exposures.

The great thickness of rock that overlies the perlite flow limits the amount of open-cut mining that can be done economically.

Other areas (figs. 2, 3, and 5)—A reddish-brown perlite is reported in Custer County, north of the towns of Westcliffe and Silvercliffe. The reported location is too indefinite to be indicated on figure 6. In southwestern Eagle County, perlite is reported on the south and east flanks of Basalt Mountain, north of the town of Basalt. Perlite is reported from northern Fremont County, near the headwaters of Tallahassee Creek. In northeastern Grand County, perlite is reported from the western slope of the Front Range and from an area north of the town of Stillwater. A deposit of expansible volcanic ash, or pumicite, known locally as the Polvo Blanco deposit, is reported from T. 25 S., R. 70 W., sec. 10 and adjoining areas, in northwestern Huerfano County, near the town of Gardner. This deposit is not shown in the figures. An expansible perlite (or pumice sand) is reported from Rio Grande County, between Del Norte and Monte Vista. The reported location was so indefinite that the deposit was not found, and it is not shown on figure 6.

Several perlite deposits are reported in Saguache County. The area to the south of deposit P-4 at Prossers Rock is thought to merit further investigation. The Cochetopa Dome area, north of deposit P-6, also is worthy of further examination. Perlite is reported from the area west of Needle Creek, in the north-central section of Saguache County. A perlite deposit north of the old mining town of Bonanza, in the northeastern corner of the county, is reported. Perlite (and vermiculite) is reported from the area west of Mineral Hot Springs, in the eastern part of Saguache County.

VERMICULITE

Vermiculite deposits are concentrated in five main areas: the Wet Mountain Valley, the Arkansas River Valley (north

of Salida), eastern South Park, the northern end of North Park, and the area south of Powderhorn in Gunnison County.

The vermiculite deposits of Colorado were examined only for their suitability for use as a lightweight aggregate, not for their other physical and chemical uses. Because of its very low compressive strength, vermiculite concrete is not suitable for many of the uses to which other lightweight concrete is put. It is most suitable for use in non-load-bearing blocks, in plaster, and as loose-fill insulation.

Certain features are common to almost all the vermiculite deposits. The country rocks usually are pre-Cambrian granites and hornblende gneisses and schists. Vermiculite is formed from the alteration of the hornblende and biotite in the hornblende rocks, presumably by deep-seated hydrothermal solutions. The alteration may proceed directly from hornblende to vermiculite, or an intermediate biotite or phlogopite stage may be present in the alteration. Pegmatites are present in almost all the deposits examined. According to Goldstein,³ the pegmatites precede or are contemporaneous with the alteration of the hornblende to vermiculite. No post-alteration pegmatites were noted in the deposits examined by the writer.

V-1, *Turret deposit, Chaffee County* (fig. 5)—Although a search was made for the Turret deposit, it could not be reached in the time available for the examination. It is in T. 51 N., R. 9 E., sec. 28, at an altitude of about 8300 feet. The deposit is more than half a mile from the nearest road and is about 14½ miles from the Denver & Rio Grande Western Railroad at Salida, Colo. The vermiculite is reported to be a 20-inch "vein" in pre-Cambrian granites and amphibolites. If the deposit has the characteristics of most of the other deposits examined, the vermiculite is an alteration zone in the amphibolites. It may be that the alteration of a 20-inch amphibolite band is so complete that only vermiculite remains as a band in the surrounding granite.

³Goldstein, August, Jr., The vermiculites and their utilization: Colorado School of Mines Quart., vol. 41, No. 4, 64 pp., 1946.

The deposit is reported to have produced about 8 carloads of material between 1910 and 1930. According to local report, there has been no production since 1930.

V-2, "*Tung Ash*" deposit, *Chaffee County* (fig. 5)—Although a search was made for the Tung Ash deposit, it could not be found. It is reported to be in T. 15 S., R. 77 W., sec. 29 (?) at an altitude of about 8000 feet. There are no roads to the deposit. The Arena Siding of the Denver & Rio Grande Western Railroad is about 4 miles southwest of the deposit area, and the Nathrop Siding, near Nathrop, is about 5 miles to the northwest.

The vermiculite is in "veins" between "gray granite" and "black schists." The "veins" are probably alteration zones. They are described as being as much as 4 feet thick. "Shoots" of vermiculite are as much as 40 feet long. The "shoots" are zones in which the vermiculite content is high, approaching 100 per cent. In these zones the vermiculite forms solid, bunched masses of crystals 2 or 3 inches in diameter. Between the "shoots" the vermiculite forms about 50 per cent of the filling. No other information on the geology of the deposit is available.

V-3, *Abe Lincoln Number 2 deposit, Chaffee County* (fig. 5)—Information on the exact location of this deposit was received after field examinations had been completed. The deposit is in T. 14 S., R. 77 W., sec. 14, at an altitude of about 8000 feet. It lies along the old route of U. S. Highway 24 west of Trout Creek Pass, at McGhee Gulch, about 8 miles from the Denver & Rio Grande Western Railroad at Buena Vista, Colo.

The vermiculite is an alteration product of a hornblende schist associated with pre-Cambrian granite. The alteration zone is reported to be 10 to 12 feet wide and several hundred feet long. No information is available as to the size of the vermiculite books or the attitude of the alteration zones. The material is reported to break out in fairly hard, small pieces.

V-4, "*Shorty*" *Robison or Marjorie Lode deposit, Custer County* (fig. 5)—Although the Marjorie Lode deposit is only

partly explored and developed, reserves of vermiculite appear to be large. The deposit is in T. 22 S., R. 71 W., sec. 7, at an altitude of about 8300 feet. It is about half a mile by dirt road from State Highway 96, 7½ miles east of Westcliffe. The nearest railroad facilities are the Denver & Rio Grande Western Railroad at Canon City or Texas Creek, Colo.

The deposit is on a 20-acre tract, of which a 3-acre section has been prospected by 55 shallow pits laid out in equilateral triangles with 50-foot sides. According to local report, 51 of the pits contain vermiculite; this fact indicates the presence of numerous alteration zones. Most, if not all, the alteration zones dip steeply. The area defined by the prospecting is about 200 feet by 450 feet. Within this area, one alteration zone is as much as 40 feet thick, and the other exposed zones range from 3 to 13 feet in thickness.

The dominant country rock is pink granite, with many bands of dark hornblende gneiss that appear to be intrusive in the granite. The vermiculite deposits are in alteration zones within the gneiss. Several stages of alteration are present from hornblende to biotite to vermiculite, although all stages of the alteration cannot be seen in any one zone. Both the granite and the gneiss are cut by quartz-microcline pegmatites that are up to 2 feet thick. In general the vermiculite grades from golden brown and brown to green and gray green. It is reported that the green vermiculite requires higher temperatures for expansion than the brown, and that it fuses before complete expansion can take place.

The main working is an east-trending open-pit 75 to 100 feet long and 40 feet wide. It is reported to have been 32 feet deep at the time of the operation. It is now filled by slump from the walls to a depth of 20 feet. Good minable vermiculite is reported to have been exposed in the floor of the pit. In the west wall, there is a horse of unaltered gneiss, 6 to 7 feet wide, which is reported to extend from the surface to the base of the pit. The basal 12 feet of the wall is now concealed by slump material. The vermiculite grades from golden brown and brown along the south wall to green and

gray green along the north wall, and the line of gradation between the two types of vermiculite extends in an irregular northeasterly direction from the base of the horse to the north wall of the pit.

An incomplete adit 300 feet long was started 750 feet southeast of the main working at a lower elevation in order to drift in under the opencut. The plan was to mine the vermiculite by stoping and to use a gravity feed to the bins. The drift was not completed at the time that the work was discontinued. Other workings in the area consist of 6 small opencuts and a 30-foot shaft.

Production of 250 tons of material is reported from the deposit. The numerous alteration zones of vermiculite indicate that the area merits further exploration and prospecting.

V-5, Young deposit, Custer County (fig. 5)—The Young deposit adjoins the Marjorie Lode deposit (V-4) on the southeast. Because exposures were better at the Marjorie Lode deposit, the time available for examination was spent there, and the Young deposit was not examined in detail. The geologic relations of the Young deposit are similar to those of the Marjorie Lode, and it is believed that the description of the major features of the Marjorie Lode deposit applies equally to the Young deposit.

There are 6 to 8 openings on the Young deposit, consisting of 4 to 6 opencuts and 2 shafts 10 to 12 feet deep. Local residents report that the material at the Young deposit is of somewhat better grade than that at the Marjorie Lode.

V-6, Sparling Ranch deposit, Custer County (fig. 5)—This vermiculite deposit was not examined, but general geologic relations are assumed to be similar to those at the nearby Marjorie Lode and Young deposits (V-4 and V-5). The deposit is in T. 21 S., R. 71 W., secs. 22 and 27, at an altitude of about 9000 feet. It is 4 miles by dirt and gravel roads from State Highway 143, about 13½ miles east of Westcliffe, Colo. The nearest railroad facilities are at the Denver & Rio Grande Western Railroad at Canon City, Colo.

The following information is abstracted from a report

by the Colorado State Bureau of Mines. A number of shafts are present, ranging in depth from 15 to 80 feet. The workings are along two steeply dipping alteration zones. One is 5 feet wide; the other, more recently discovered, is 10 feet wide. A 15-foot shaft has been sunk on the wider zone, and the zone has been prospected also by several shallow open-cuts. The largest working is in the 5-foot zone. A 170-foot drift extends southwest along the zone from the base of a 30-foot shaft, with a raise to the surface 100 feet from the shaft. No information is available on the quality of the vermiculite or on the extent of the vermiculite deposit.

V-7, Quist Claim 72 deposit, Custer County (fig. 5)—Fairly large reserves of vermiculite are present at this deposit in T. 21 S., R. 72 W., sec. 16, at an altitude of about 7800 feet, about 1 mile north of the DeWeese Reservoir. The deposit is 10 miles by dirt and gravel roads from Westcliffe, Colo., and about 25 miles by road from the Denver & Rio Grande Western Railroad at Texas Creek, Colo.

Steeply dipping vermiculite-bearing alteration zones are exposed in opencut workings that occupy an area 300 feet by 50 feet on a 10-acre tract. The largest zone is exposed for a length of 100 feet and a width of 50 feet. Thinner stringers are exposed in other workings.

The predominant country rock in the area is a pink granite, apparently intruded by hornblende gabbros, although the contact between the granite and the intrusive rocks is not exposed at this deposit. Some facies of the gabbro approach peridotite in composition. The vermiculite is an alteration product of the hornblende and biotite of the basic intrusives.

It is reported that the vermiculite material as mined contains 24 per cent expansible vermiculite. Most of the vermiculite books are less than half an inch in largest dimension.

The workings consist of a large opencut (100 feet long, 50 feet wide, and 12 feet deep), four smaller opencuts, and a shaft 8 feet deep.

V-8, Voss Land or "Vermiculite King" deposit, Custer

County (fig. 5)—The Voss Land deposit adjoins the Quist deposit (V-7) on the south. It is in T. 21 S., R. 72 W., secs. 16 and 17, at an altitude of about 7800 feet. Distances to Westcliffe, Colo., and to the railroad are similar to those for the Quist deposit.

As at the Quist deposit, the country rock is pink granite intruded by hornblende gabbros, and the vermiculite is in steeply dipping alteration zones in the gabbros. The main deposit, approximately 15 feet wide, is exposed in two open-cut workings that are 240 feet apart. Thinner deposits, not continuous with the main one, also are present.

The two opencuts on the main deposit are 15 to 20 feet long, 10 feet wide, and 10 feet deep. A 25-foot inclined shaft also has been sunk on the zone, and a drift 10 feet long extends west along the zone from the base of the shaft. The thinner deposits have been prospected with seven small and shallow opencuts.

The number and size of the alteration zones at deposits V-7 and V-8 suggest that the entire surrounding area merits further investigation and prospecting.

V-9, *Phares and Allen deposit, Custer County* (fig. 5)—In contrast to the steeply dipping alteration zones present at the vermiculite deposits described above, the alteration zone at this deposit is a flat-lying, blanket type and therefore has proved to be more amenable to open-cut mining. The deposit is in T. 21 S., R. 73 W., sec. 26, at an altitude of about 8000 feet. It is $5\frac{1}{2}$ miles north of Westcliffe, Colo., on a good gravel road, and is about 22 miles from the Denver & Rio Grande Western Railroad at Texas Creek, Colo.

Exposures are absent for some distance around the workings at this deposit. The vermiculite is an alteration product of a hornblende gneiss, which is exposed only in the south wall of the main working. On the basis of the geology of nearby deposits, it is assumed that granite, although not exposed, is associated with the gneiss.

The alteration zone is a blanket type more than 10 feet thick. The workings consist of a single bulldozed open-cut 85 feet wide by 100 feet long and 4 to 6 feet deep. In the south-

eastern corner of the cut, a glory hole with a 10-foot opening, inclined steeply to the southwest, has been sunk for a depth of 20 feet.

The vermiculite is of fairly good grade, although it is rather fine grained. Most books are a quarter of an inch in longest dimension. The overburden ranges in thickness from 2 to 4 feet.

V-10, *Gem Park deposit* ("Goldenite" and "Silverite" Mines) (fig. 5)—The Gem Park vermiculite deposit is another large, blanket-type occurrence. It is in T. 21 S., R. 73 W., secs. 3 and 4, and T. 20 S., R. 73 W., secs. 33 and 34, at an altitude of about 8600 feet. It is on the boundary between Custer and Fremont Counties, about 2½ miles east of State Highway 69, approximately 5 miles by road from Hillside, Colo. The deposit is about 17 miles from the Denver & Rio Grande Western Railroad at Texas Creek, Colo.

The country rock consists of hornblendic gneiss associated with granite. The vermiculite, an alteration product of the hornblendic gneiss, occurs in at least two large, blanket-type alteration zones. The largest is 100 feet long by 50 feet wide and as much as 25 feet thick. Inferred reserves are of the order of 10,000 tons.

The main working is a semicircular opencut as much as 25 feet deep, with a radius of approximately 150 feet. Overburden at the deposit is as much as 10 feet thick. A large tonnage of material has been produced, and it is reported to be of good grade.

The area surrounding the Gem Park deposit should be systematically prospected for other deposits of the same general size and type of alteration.

V-11, *Parkdale deposit*, *Fremont County* (fig. 5)—The Parkdale vermiculite deposit could not be found in the time available. The deposit is in T. 18 S., R. 72 W., sec. ?, at an altitude of about 6500 feet.

The host rock at the Parkdale deposit is reported to be a hornblende gneiss, associated with pre-Cambrian granite. Vermiculite occurs as an alteration zone in the hornblende gneiss.

The deposit is reported to be small and may be completely worked out. The workings consist of one small open-cut, originally a copper prospect, that was probably put down on a copper-bearing pegmatite that cuts the hornblende rocks. Wilfley reported that the deposit is not favorable for further production except on a very small scale. The general area, however, merits further investigation for vermiculite deposits.

V-12, *Powderhorn Number 1 deposit, Gunnison County* (fig. 5)—Reserves of vermiculite are moderate and the material is somewhat impure at the Powderhorn Number 1 deposit. It is in T. 46 N., R. 2 W., sec. 14, at an altitude of about 8600 feet in hilly country east of Cebolla Creek and about 200 feet above the creek level. The distance to the nearest railroad is about 20 miles—the Denver & Rio Grande Western Railroad at Iola, Colo. The country rock consists of hornblende gneiss associated with poorly exposed pre-Cambrian granite. Steeply dipping zones in the hornblende gneiss have been altered to vermiculite; they range in thickness from a few inches to as much as 10 feet.

Most of the vermiculite books are less than a quarter of an inch in longest dimension, with a few 2- to 3-inch books. In general the material is relatively impure, containing unexpandable biotite and certain weathering products. The deposit is reported to have been abandoned because of its impurity. A garnet-bearing quartz-biotite pegmatite cuts the hornblende gneiss but the chronologic relationship of the pegmatite to the alteration of the hornblende gneiss is not clear.

The main working is an open-cut 300 feet long by 75 feet wide that ranges in depth from 5 to 18 feet. A few prospect pits to the east and northeast are in vermiculite.

V-13, *Powderhorn Number 2 deposit, Gunnison County* (fig. 5)—Reserves of vermiculite appear to be fairly large and the material is reported to be of good grade at the Powderhorn Number 2 deposit in southern Gunnison County. The deposit is in T. 46 N., R. 2 W., sec. 12, at an altitude of about 8800 feet, approximately 2 miles northeast of the

Powderhorn Number 1 deposit (V-12). The distance to the Denver & Rio Grande Western Railroad at Iola, Colo., is about 22 miles.

The country rocks consist of hornblende-rich intrusives, some of which approach hornblendite in composition, associated with pre-Cambrian granites, which are highly decomposed near the surface. The vermiculite is in a blanket-type alteration zone in the hornblende intrusive. The extent of the zone is uncertain because the walls of the workings have slumped. A large percentage of the vermiculite books are more than half an inch in longest dimension, and there are many individual books up to 3 inches long.

The workings consist of five interconnecting opencuts, which cover an area about 175 feet by 300 feet. The opencuts range from 4 to 8 feet in depth. The size of the deposit and the type of alteration suggest that nearby areas should be systematically prospected for deposits of the same general size.

V-14, *Quaintance Number 1 deposit, Jackson County* (fig. 2)—Deposits V-14, V-15, and V-16 are all in northern Jackson County, a few miles south of the Colorado-Wyoming boundary in T. 12 N., R. 80 W., SE $\frac{1}{4}$. In general the discussion of the country rocks applies to all three deposits.

The Quaintance No. 1 deposit is in T. 12 N., R. 80 W., sec. 34, at an altitude of about 8000 feet. It is 1 $\frac{1}{2}$ miles east of State Highway 125, about 8 miles from the Laramie, North Park & Western Railroad at Northgate, Colo.

The country rocks of the area consist of pre-Cambrian granite, granite gneiss, hornblende gneiss, and hornblende-biotite gneiss. The mechanism of emplacement of the hornblendic rocks is not clear. It is possible that they are metamorphosed volcanics rather than intrusives. The general schistosity of the country rocks trends northeast but in detail it is considerably varied. Two ages of pegmatites are present. An early set appears to be cut off by the hornblende gneiss and a later set crosscuts the hornblendic rocks. Many of the pegmatites are gradational from the normal granite. A gradual increase in the grain size of the individual miner-

als can be traced from the granite to the pegmatite. The usual lithologic associations found in areas of vermiculite deposits are present: granite, hornblende rocks, and cross-cutting pegmatites. Vermiculite has been developed in the alteration of the hornblende rocks.

The alteration zones at the Quaintance No. 1 deposit are exposed in a series of connected opencuts and a short adit to the south. The northern altered zone is steeply dipping and ranges in width from about 6 feet to 18 feet. The vermiculite is fine-grained, greenish gold, and somewhat impure. Parts of the hornblende gneiss exposed in the workings are completely altered to vermiculite but elsewhere the alteration is incomplete. The northern workings, interconnected opencuts, are 90 feet long and 5 to 6 feet wide, with maximum depth of about 12 feet. Near the east end a side-cut extends 22 feet to the south. The trend of the workings is S. 85° E., approximately parallel to the schistosity in this area.

The southern altered zone is also steeply dipping, but is only 2 feet thick. It was penetrated near the face of the south working, a 45-foot timbered adit. Most of the vermiculite books are fine-grained and badly weathered, but there are a few large crumpled books. In this zone the vermiculite is an alteration product of a hornblende-biotite gneiss.

The area surrounding this deposit, and deposits V-15 and V-16, is favorable for the presence of other bodies; however, relatively small deposits are anticipated.

V-15, *Fourney deposit, Jackson County* (fig. 2)—Reserves of vermiculite at the Fourney deposit appear to be small, and the material is somewhat impure. The deposit is in T. 12 N., R. 80 W., secs. 26 and 35, at an altitude of about 8000 feet. It is 2 miles east of State Highway 125, approximately 8 miles from the Laramie, North Park & Western Railroad at Northgate, Colo.

A partly altered hornblende gneiss is the host rock for fine-grained vermiculite at the Fourney deposit. Quartz-microcline pegmatites and quartz stringers cut the hornblende gneiss.

The vermiculite deposit is exposed along the west side

of the canyon of the North Platte River, about a mile north of deposit V-14. The workings consist of a 60-foot timbered but inaccessible adit and two opencuts. A small prospect pit lies 60 feet north of the adit. The opencuts are 35 feet long, 4 to 5 feet wide, and 10 to 15 feet deep. Most of the production is reported to have been from the adit. In general the area is not considered favorable for the occurrence of large vermiculite bodies.

V-16, *Resort Claim deposits, Jackson County* (fig. 2)—These deposits were inaccessible at the time of the examination. The deposits are in T. 12 N., R., 80 W., sec. 26, at an altitude of about 8000 feet. No road leads to the deposits, which are about 2 miles from State Highway 125, on the east bank of the North Platte River, about 8 miles from the Laramie, North Park & Western Railroad at Northgate, Colo.

The country rocks at the Resort deposits consist of pre-Cambrian granite and granite gneiss, hornblende gneiss, and crosscutting pegmatite. The discovery cut at the Resort No. 1 claim contains an alteration zone 6 feet wide in hornblende gneiss. One boundary of the alteration zone is exposed in the face of the cut; it contains a layer of large-leaved vermiculite that is at least 2 feet thick. The rest of the alteration zone is composed of fine-grained, somewhat impure vermiculite. The discovery cut at the Resort No. 2 claim contains 2 to 3 feet of vermiculite, reportedly of good quality. Fine-grained vermiculite also is present. Both discovery pits are about 15 feet long and up to 10 feet deep.

The general area surrounding the Resort deposits is considered to merit further investigation.

V-17, *Spinney Mountain deposit, Park County* (fig. 4)—Reserves of vermiculite are fairly low and the material is somewhat impure at the Spinney Mountain deposit. It is in South Park, in T. 12 S., R. 74 W., sec. 13, at an altitude of about 9000 feet. The deposit is accessible by a dirt road that extends 3 miles south from U. S. Highway 24 at Glentivar, Colo.

A low pass divides Spinney Mountain into two sections. The vermiculite deposit is in about the center of the northern section. Spinney Mountain is composed of granite and

granite gneiss with associated quartz-biotite and hornblende-biotite schist. The schist bands approximately parallel the northerly trend of the mountain. The vermiculite is an alteration product of the hornblende and biotite of both the hornblende-biotite and quartz-biotite schist.

Exposures of the altered zones are poor. One alteration zone in a hornblende-biotite schist crops out in the bottom of a small draw, where it is exposed for a length of 20 feet and a width of 40 feet. A thin quartz-microcline pegmatite dike cuts the alteration zone. Float and overburden prevent tracing the zone along its strike to the north and the south. Most of the vermiculite in this zone is impure. A more detailed investigation may reveal areas of more complete alteration.

A basic "dike," 50 feet wide and exposed for a length of several hundred feet, is reported to be present at the south end of the mountain. The percentage of vermiculite in the "dike," however, is reported to be very low.

V-18, *Haymon deposit, Park County* (fig. 4)—The Haymon vermiculite deposit is fairly favorably located with respect to marketing centers. It is about 5 miles west of the town of Lake George, Colo., northeast of Wilkerson Pass, in T. 12 S., R. 72 W., sec. 11, at an altitude of about 8300 feet. The deposit is about a mile north of U. S. Highway 24 and is accessible by a dirt road.

The country rocks are pre-Cambrian granite, schist, and hornblende gneiss with some later pegmatite. The vermiculite is in steeply dipping alteration zones in the hornblende gneiss.

The deposits were examined briefly in two small clearings about half a mile apart. In the southeastern clearing, vermiculite, in a sandy, somewhat decomposed hornblende gneiss, is exposed in several shallow pits. The exposures are not sufficient to define the size of the zone. In the northwestern clearing, fine-grained vermiculite is exposed in two shafts 15 feet deep and a small shallow pit. At least one of these alteration zones is more than 5 feet wide. The material is reported to exfoliate easily.

The general area is considered to merit further investi-

gation and systematic prospecting. Favorable geologic conditions are present and the deposits are relatively near good transportation facilities and marketing centers.

V-19, *San Isabel deposit, Pueblo County* (fig. 5)—In the San Isabel deposit the vermiculite zones are so thin that selective mining is difficult. The deposit is in T. 24 S., R. 68 W., sec. 5 or 8, at an altitude of about 8000 feet. It lies about 2 miles east of the town of San Isabel, Colo., along the old highway between the towns of San Isabel and Rye, and is about 30 miles from the nearest railroad at Cedarwood, Colo.

The country rock is a medium- to coarse-grained pink granite with varied amounts of biotite, and some gneissic structure. In places it is distinctly foliated and has augen of quartz and orthoclase up to 1½ inches long. The granite and gneissic granite are cut by altered peridotite dikes and aplitic pegmatites. In general these intrusions are conformable to the foliation of the country rock. Numerous thin quartz veins cut the granite.

The vermiculite occurs in thin, roughly vertical alteration zones in the peridotite. The zones are up to 6 inches thick and usually comprise the entire width of the peridotite dikes. None of the peridotites is exposed for its entire length. In general the peridotites have been altered to vermiculite for their entire visible length. The thinness of the altered zone makes selective mining difficult and the cost of the mining operation will be thereby raised. Workings and prospect pits cover an area about 200 feet by 100 feet. The workings consist of three opencuts, the largest 20 feet long by 12 feet wide, with one face 8 to 10 feet high. Vermiculite also is exposed in five small prospect pits.

Other areas (fig. 4)—Numerous small zones of vermiculite are exposed in road cuts along the highway on the west side of Wilkerson Pass. The area to the north and south of these deposits is considered to merit further investigation.

WELDED TUFF

WT-1, *Castle Rock area, Douglas County* (fig. 4)—A welded rhyolite tuff containing tridymite and biotite forms

the cap rock of several buttes west and northwest of Castle Rock in Douglas County. The tuff was examined at a locality about 2 miles northwest of the town, where it has been extensively quarried for use as a cut building stone. The deposit is in T. 8 S., R. 67 W., sec. 3, at an altitude of about 6700 feet. It is about half a mile by dirt road from State Highway 214, about a mile north of Castle Rock, Colo. The nearest railroads are the Atchison, Topeka & Santa Fe and the Denver & Rio Grande Western Railroads at Castle Rock.

The horizontally bedded tuff is in the upper part of the Dawson arkose of late Cretaceous and Paleocene age. Several miles to the east, it is unconformably overlain by the Castle Rock conglomerate of lower Oligocene age.

The deposit covers the entire top of the butte, an area about 1100 to 1200 feet long by 800 feet wide. The tuff is at least 35 feet thick. The main working is roughly oval; it is 725 feet long, 440 feet wide, and 10 to 15 feet deep. Large tonnages of welded tuff are available at this locality and at other buttes in the vicinity.

The tuff varies from a dark pink and red along the west side of the deposit to a light pinkish-gray, gray, and bluish-gray along the east side. The types are quite similar in lithology, but the red material has undergone more alteration and it is slightly heavier. Tests conducted by the materials testing laboratory of the U. S. Bureau of Reclamation indicate that the tuff is suitable for use as aggregate in medium-weight concrete. Concrete made with this aggregate weighs 115 to 125 pounds per cubic foot.

WT-2, Seller's Creek area, Douglas County (fig. 4)—A welded rhyolite tuff, very similar to that at deposit WT-1, is exposed at the top of the section along the east bank of Seller's Creek. It is in T. 8 S., R. 67 W., sec. 13 and T. 8 S., R. 66 W., secs. 19 and 30, at an altitude of about 6700 feet. The deposit lies about 3 miles by good gravel road southeast of Castle Rock, Colo. The nearest railroads are the Atchison, Topeka & Santa Fe and the Denver & Rio Grande Western Railroads at Castle Rock.

There is little doubt that the tuff of the Seller's Creek