BUREAU OF ECONOMIC GEOLOGY
The University of Texas
AUSTIN 12, TEXAS
JOHN T. LONSDALE, Director

Report of Investigations — No. 40

Vermiculite in Central Texas

By

S. E. CLABAUGH and V. E. BARNES

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Vermiculite in Central Texas

S. E. CLABAUGH and V. E. BARNES

ABSTRACT

Vermiculite deposits in the Central Mineral region of Texas, chiefly in Precambrian metamorphic rocks, are situated in Llano County and adjacent parts of Mason, Gillespie, and Burnet counties with minor occurrences in Blanco and San Saba counties. All of the known deposits contain a lesser percentage of vermiculite than the deposits now being exploited in South Carolina and Montana; however, the deposits are substantial in size and will probably be mined when the richer domestic and foreign sources are exhausted.

The bulk of the vermiculite is from weathering of biotite formed in the following suggested manner: (1) intrusion of sills and irregular masses of gabbro into the Valley Spring gneiss prior to or during regional metamorphism; (2) metamorphism of gabbro to produce amphibolite; and (3) partial conversion of amphibolite to biotite schist by metasomatism accompanying the emplacement of granites and pegmatites. In one deposit the process seems to have been arrested in the amphibolite stage with introduction of nonoriented biotite and feldspar by potash metasomatism.

A third distinct type of vermiculite deposit associated with serpentine and soapstone appears to be primary hydrothermal rather than a weathering product of biotite. Suggested events leading to the formation of this type of deposit are: (1) emplacement of dunite and gabbro in Valley Spring gneiss; (2) metamorphism of gabbro to form amphibolite with deformation of dunite into lenticular masses; (3) alteration of dunite to nonfoliated serpentine during static conditions and through the influence of aqueous solutions; (4) alteration of serpentine to soapstone from periphery inward through influence of fluids from nearby granite intrusions; and (5) formation of vermiculite veins along fractures in soapstone and serpentine through the influence of fluids from pegmatites which closely followed the granite intrusion.

INTRODUCTION

Vermiculite is a micaceous mineral, a hydrated silicate related to the montmorillonite group of clay minerals and to micas and chlorites. Common varieties contain considerable magnesium and iron, although composition varies widely. The property which causes some vermiculite to be of economic importance is its ability to expand, when heated, to many times its original size. First-class material when expanded weighs 6 pounds or less per cubic foot.

Vermiculite has become an important commercial mineral during the past two decades. The first commercial production in the United States was in 1923, and by 1956 this relatively new mineral industry had become a producer of about 2.5 million dollars worth of raw material (valued at about $13.20 per ton) which when expanded was worth about 9.7 million dollars (an average value of about $61.00 per ton). Vermiculite is used chiefly for heat and sound insulation and for this purpose may be used as loose fill, included in plaster and concrete, or made into blocks, bricks, and wallboard. It has many other uses also such as for lightweight aggregate, packing material, soil conditioning, hatchery litter, carrier for herbicides, insecticides, fungicides, and fumigants, and in lubricants, rubber goods, paper, ink, and paint.

Vermiculite in the Precambrian rocks of central Texas has attracted the attention of private companies and governmental agencies. All of the known deposits contain a lesser percentage of vermiculite than the deposits now being exploited in South Carolina and Montana; however, they will probably be mined when the richer domestic and foreign sources are exhausted.

The earliest discoveries of vermiculite in central Texas are not recorded. Baker (1935, p. 609) mentioned that vermiculite had been found near Kingsland in Llano County and elsewhere in the Precambrian rocks of the Llano uplift. Exploratory pits and an inclined shaft were opened on vermiculite veins on the Carl Moss property 8 miles south of Llano by 1935, and the first few tons of vermiculite from the T. K. Bush deposit 4 miles north-northeast of Llano were mined in 1938. The Mineral Products Company of San Antonio leased the Bush deposit in 1942 and began production but ceased operation the following year and moved the exfoliation plant to Burnet to treat vermiculite shipped from outside the region. In 1946 the Southwestern Graphite Company of Burnet mined 6,464 tons of vermiculite-bearing rock from the Bush deposit and processed it at the graphite mill near Burnet. Only 1,459 tons of vermiculite concentrate was recovered; it was supplied to the exfoliation plant of the Mineral Products Company in Burnet. The operation was unprofitable; however, for a while both the Southwestern Graphite Company and the Southwestern Talc Company of Llano contemplated construction of mills and exfoliation plants in Llano. The United States Bureau of Mines made preliminary reports on the vermiculite deposits in 1944 and in 1947 completed an investigation of several of the larger deposits which involved extensive drilling and sampling (McMillan and Gerhardt, 1949).

In 1946 Barnes spent several weeks searching for additional deposits of vermiculite in the Llano region. He sampled and studied briefly the known occurrences and located numerous outcrops of vermiculite-bearing rock in road cuts and creek banks north of Llano. Reconnaissance in Mason and Burnet counties also disclosed new occurrences. Clabaugh made a further search during 1951 for new deposits of vermiculite in the region and sampled and appraised the new finds for the Zonolite Company. Additional sampling was done by Clabaugh during the summer of 1955.

ACKNOWLEDGMENTS

Barnes' investigations, part of the program of the Bureau of Economic Geology, were aimed at encouraging development of the mineral resources of the State. Clabaugh's acquaintance with the vermiculite deposits resulted from the work done for the Zonolite Company. Subsequent studies by Clabaugh were financed by research grants from The University of Texas Research Institute and the Geology Foundation of The University of Texas. Expansion tests were made by R. M. Wheeler and D. A. Schofield of the Bureau of Economic Geology. Professors E. J. Weiss, R. L. Stone, and E. C. Jonas of The University of Texas assisted in mineralogical studies. The mineralogy and genesis of the deposits will be described more fully after mineralogical studies are completed. They are being financed by a grant from The Geological Society of America.

GEOGRAPHIC SETTING

The known vermiculite deposits are situated chiefly in Llano County and adjacent parts of Mason, Gillespie, and Burnet counties (fig. 1). Minor occurrences have been found also in the northwestern tip of Blanco County and the southern part of San Saba County.

One railroad enters the area from the east and terminates at Llano, which is centrally located. All potentially important vermiculite deposits lie within 25 miles of the railroad. Paved highways cross all of the counties mentioned above, placing most mineral occurrences within 10 to 15

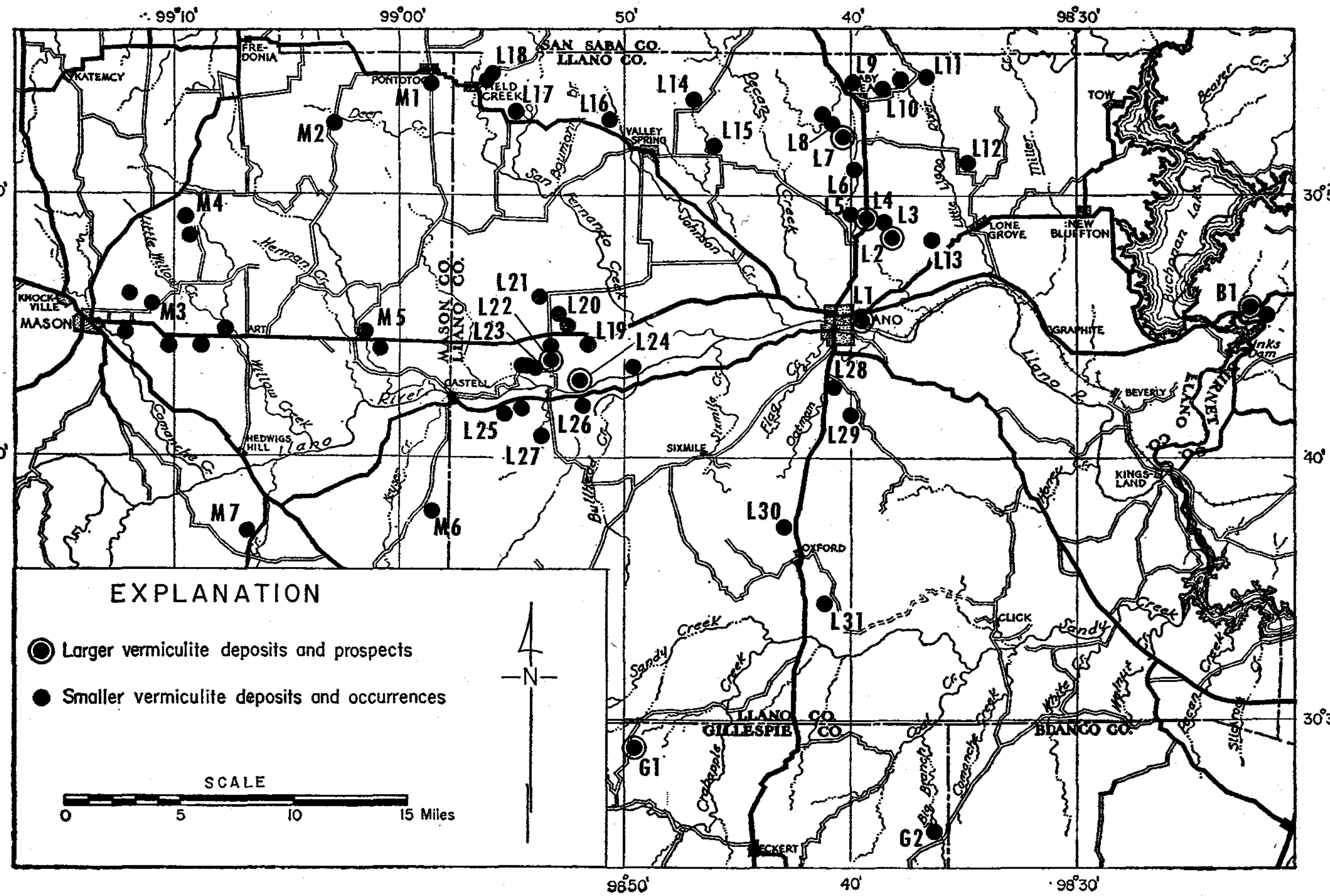


Fig. 1. Index map showing location of vermiculite occurrences in central Texas.

miles of a hard-surfaced road. County roads are graded but not surfaced, and after rains some of them are difficult to travel.

The rainfall of the area is approximately 25 inches a year, which is insufficient to maintain flowing water in more than a few major streams. Beneficiation plants requiring water would therefore be restricted to such sites as the Llano River below Llano, which is adjacent to the railroad, or to Colorado River and its chain of lakes.

Vermiculite in central Texas is confined to metamorphic rocks of Precambrian age. Exposures of these rocks are chiefly in the Llano and Burnet quadrangles, which were mapped by Spencer et al. (Paige, 1912). Paige named the two major units Packsaddle schist and Valley Spring gneiss.

The Valley Spring gneiss is dominantly light pink gneiss composed chiefly of microcline, plagioclase, and quartz with a small amount of biotite and opaque minerals. It grades into mica schist and amphibole schist in places and contains a few layers of quartzite and wollastonite-bearing rock.

The Packsaddle schist generally lies above the Valley Spring gneiss and as a whole is characterized by darker color and more conspicuous foliation. The formation includes a varied assemblage of rocks: amphibole schist, mica schist, graphite schist, marble, quartzite, and quartzo-feldspathic rock resembling quartzite.

Dark igneous rocks invaded the Precambrian sedimentary rocks before their metamorphism was complete and were converted to serpentine, soapstone, and amphibolite. In the southern part of the Llano uplift a gray gneiss of igneous origin is abundant; it has the composition of quartz diorite. Barnes (1945, p. 56) named it the Big Branch gneiss and gave the name Red Mountain gneiss (Barnes, Schock, and Cunningham, 1950, p. 7) to a metamorphosed granite in southeastern Llano County.

Granite intruded the metamorphosed sedimentary and igneous rocks throughout the Llano region at the close of the main cycle of regional metamorphism. Several types of granite have been distinguished; all have been shown by radioactive age determinations to be near the same age, approximately 900 to 1,000 million years. The granites were accompanied by aplites, pegmatites, and quartz veins which penetrated the metamorphic rocks. Hydrothermal solutions related to the granites and their pegmatites brought about widespread alkali metasomatism and retrograde metamorphism of susceptible rocks.

ORIGIN AND TYPES OF DEPOSITS

All of the vermiculite deposits that appear to have potential economic importance, as well as most of the minor occurrences, are associated with metamorphosed basic igneous rocks. The largest deposits, of which the T. K. Bush deposit is the best explored, occur in irregular bodies of biotite schist within the Valley Spring gneiss. The dark schist is unlike the surrounding gneiss; it ranges from nearly pure biotite schist to nearly pure hornblende rock and shows wide variation in texture and grain size, being generally coarser than the adjacent gneiss. Actinolite and epidote are commonly found in veins and clots in the schist, and garnet is present in a few places. The igneous parentage of the schist is not clearly evident but is suggested by both the composition of the rock and its distribution in irregular and locally cross-cutting masses. A chemical analysis of a sample of the fresh biotite schist from a pit in vermiculite-bearing rock at the Faris deposits is given in table 1. In the second column of the table the analysis has been adjusted by subtracting 3% K_2O and 6% SiO_2 and recalculating the remainder exclusive of H_2O to total 100%. The adjusted analysis approaches the composition of olivine gabbro, as is shown by its norm (column 6) and by comparison with gabbro analyses (columns 3, 4, and 5).

The suggested paragenesis of the vermiculite schist is as follows: (1) intrusion of sills and irregular masses of gabbro into the Valley Spring gneiss prior to or during regional metamorphism; (2) metamorphism of the gabbro to produce amphibolite; (3) partial conversion of amphibolite to biotite schist by metasomatism accompanying the emplacement of granites and pegmatites; and (4) conversion of biotite to vermiculite by weathering. The subtraction of K_2O and SiO_2 from the chemical analysis prior to norm calculation was made on the assumption of alkali metasomatism and silica introduction. The evidence for conversion of biotite to vermiculite by weathering is the restriction of vermiculite to a zone of friable rock which extends only 15 to 40 feet below the surface of the ground, as demonstrated in numerous pits and in the U. S. Bureau of Mines drill holes. Below the weathered zone, biotite instead of vermiculite is present.

Metamorphosed gabbro occurs also in the Packsaddle schist but is less conspicuous there than in the contrasting light-colored Valley Spring gneiss.

A second type of deposit is vermiculite-bearing hornblendite. The hornblendite was not converted to foliated amphibolite, possibly because it was emplaced too late in the regional metamorphic cycle to undergo severe deformation. Biotite and feldspar were introduced by potash metasomatism, but the resulting micaceous rock is not schistose. Weathering has converted the biotite to vermiculite. Only one deposit of this type, the Welgehausen deposit in northern Gillespie County, has been discovered.

The third type of deposit consists of veins and disseminated flakes of vermiculite in serpentine and soapstone. Many of the veins are associated with pegmatites, and at the Gregory deposit, southern Llano County, vermiculite occurs as a reaction border on soapstone fragments engulfed in pegmatite. In the veins in soapstone and serpentine the vermiculite is probably a primary hydrothermal mineral rather than a weathering product of biotite. Vermiculite is as abundant at the bottom of deep pits and shafts as at the top; no biotite occurs in the veins, although it is present in adjacent parts of the schist and gneiss. This type of deposit is discussed in more detail on pages 19–24.

TABLE 1. *Comparison of chemical composition of biotite schist and average gabbro* (in percent).

	1	2	3	4	5	6 (norm)	
SiO_2	51.47	51.30	48.36	47.90	49.37	orthoclase	1.1
Al_2O_3	9.87	11.34	16.84	11.84	10.33	plagioclase:	
Fe_2O_3	2.19	2.47	2.55	2.32	1.09	ab 21.5	40.4
FeO	6.10	7.06	7.92	9.80	11.25	an 18.9	
MgO	14.55	16.42	8.06	14.07	16.64	pyroxene:	
CaO	6.68	7.58	11.07	9.29	8.09	di 12.4	40.3
Na_2O	2.24	2.53	2.26	1.66	1.50	hy 27.9	
K_2O	3.19	0.23	0.56	0.54	0.48	olivine	12.4
Rb_2O	0.01	....	....	....	....	magnetite	3.5
BaO	0.04	....	....	....	....	ilmenite	1.1
H_2O+	2.03	....	0.64	0.59	....	apatite	1.0
H_2O-	0.06	....	....	....	....	fluorite	0.1
TiO_2	0.49	0.55	1.32	1.65	1.00		
P_2O_5	0.39	0.44	0.24	0.19	0.13		
MnO	0.16	....	0.18	0.15	0.12		
Cr_2O_3	0.18	....	....	....	....		
F	0.06	0.07	....	....	....		
S	0.01	0.01	....	....	....		
	99.72	100.00	100.00	100.00	100.00		99.9

1. Chemical analysis of biotite schist from the Faris vermiculite deposit, Llano County, Texas. Eileen Oslund, analyst; Rock Analysis Laboratory, University of Minnesota.
2. Analysis of biotite schist (column 1) adjusted by subtracting 3% K_2O and 6% SiO_2 and recalculating the remainder exclusive of H_2O to total 100%. The small amount of Rb_2O was added to the K_2O, the BaO to CaO, the MnO to FeO, and the Cr_2O_3 to Al_2O_3.
3. Average of 160 analyses of gabbro (Nockolds, 1954, p. 1020).
4. Average of 137 analyses of normal tholeiitic basalt and dolerite (Nockolds, 1954, p. 1021).
5. Average of 2 analyses of olivine diabase from the Palisades of the Hudson (Daly, 1933, p. 406).
6. Norm calculated from adjusted analysis of biotite schist (column 2).

The data on location, grade, and size of deposits covered by pages 11–26 are summarized by Dietrich and Lonsdale (1958, pp. 75–77 and table 9); their tabulation is not repeated herein.

BURNET COUNTY

Reed deposit (*Locality B1*).—Vermiculite is exposed along the Burnet-Llano highway (State Highway 29) in a road cut about 8 miles west of Burnet and 2.25 miles east of the Colorado River bridge. The adjacent property and mineral rights are owned by S. H. Reed of Burnet. Vermiculite is most abundant in the road cut on the south side of the highway and in a large test pit northeast of the road cut on the Reed ranch. The location of the pit and of the road cut suggests that the richest part of the vermiculite-bearing rock is in a northeast-striking zone 50 to 75 feet wide and about 100 yards long. A composite sample, B1–1, from the pit contains 33.5% vermiculite, and another sample, B1–2, from the better material in the road cut contains 34.5% vermiculite. These samples cannot be considered representative, because the composition of the vermiculite-bearing rock is highly variable, ranging from nearly pure vermiculite to nearly pure hornblende in adjacent layers. Most of the vermiculite is fine grained and fragile when expanded.

Along the highway additional vermiculite occurs in pockets and streaks in contorted hornblende schist for a distance of more than 250 feet west of the richest zone. The average vermiculite content of the rock is small, and the rock is hard and unweathered in places only a few feet below the surface of the ground. In the vermiculite-rich zone at the east end of the cut, weathering extends at least 10 to 15 feet below the surface. Test pits are reported to have been dug in vermiculite rock south of the highway, but the pits have since been filled. Nearby outcrops are chiefly Valley Spring gneiss.

In 1951 Reed drilled a water well in a soil-covered flat area in a valley about a mile southeast of the road cut. The upper 30 to 40 feet of the well was dug in soil and soft vermiculite-bearing rock, the remaining 60 feet in firm biotite-rich rock. Hornblende and traces of vermiculite occur in the soil in a large area around the well, but the soil cover obscures the size of the vermiculite deposit.

NORTHERN LLANO COUNTY

Smith deposit (*Locality L1*).—Vermiculite-bearing schist is poorly exposed at the head of a small valley a few hundred feet south of the Llano-Burnet highway (State Highway 29) about 1.5 miles northeast of Llano on property belonging to J. W. Smith of Llano. Drilling by the U. S. Bureau of Mines (McMillan and Gerhardt, 1949) delineated an area of 55,600 square feet underlain by vermiculite-bearing rock covered by 1 to 10 feet of overburden and extending to depths ranging from 3 to 32 feet. The vermiculite content of composite samples from 777 feet of drill holes in vermiculite-bearing material is 31.5%. McMillan and Gerhardt reported that the deposit extends about 700 feet in a northwest direction and is cut off at each end by granite. To the southwest it is bounded by gneiss which strikes N. 40° W. and dips 40° SW.

Bush deposit (*Locality L2*).—The Bush vermiculite deposit (fig. 2) is crossed by a county road about three-fourths of a mile east of the Llano-San Saba highway (State Highway 16) and 4 miles north of the main highway intersection in the northern part of Llano. Mining of vermiculite on the Bush property was attempted at least as early as 1938, and the Southwestern Graphite Company of Burnet mined 6,464 tons of vermiculite-bearing rock here in 1946. The U. S. Bureau of Mines drilled the deposit in 1947.

The main pit is on the south side of the county road about 700 feet east of the T. K.

Bush house (fig. 2, locality 1–59A). Drill holes disclosed sporadic occurrences of vermiculite for about 600 feet northwest of the pit, but none was found in holes immediately southeast of the pit. About 800 feet south of the main pit a smaller pit was dug in vermiculite rock on the east side of a low ridge. Drilling near the small pit disclosed an area of about 35,000 square feet underlain by vermiculite schist as much as 27 feet thick in places. Another area of approximately 28,000 square feet of vermiculite-bearing rock lies adjacent to the Bush house and south of the county road. The vermiculite content of 828 feet of vermiculite rock drilled on the Bush property is 43.2%, according to the report of the U. S. Bureau of Mines (McMillan and Gerhardt, 1949); the Southwestern Graphite Company, however, recovered 1,459 tons of vermiculite concentrate, which is 22.6% of the rock processed.

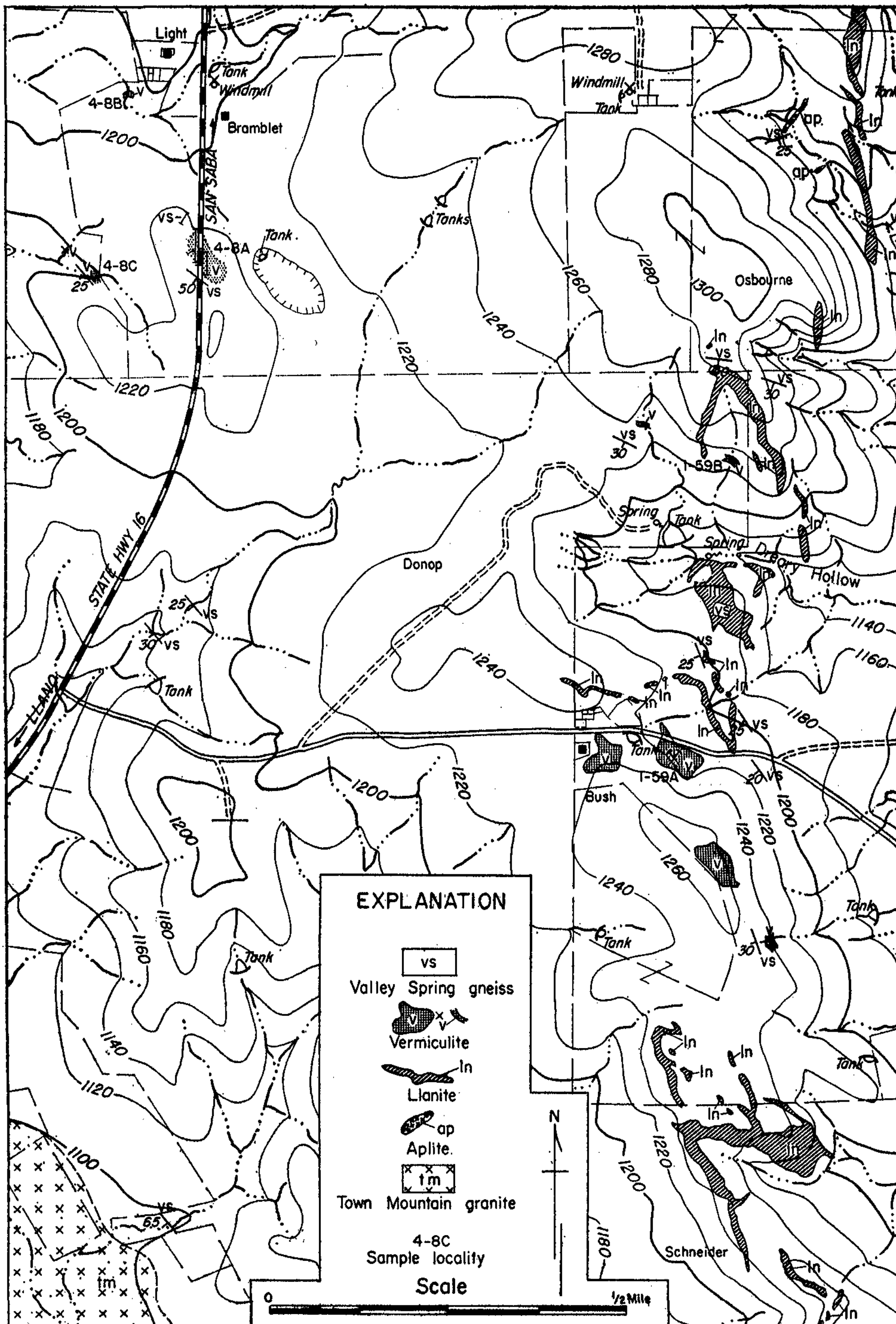
A sample, L2–1, of what appears to be average brown vermiculite schist from the northeast end of the large pit contains 37.7% vermiculite. A nearby layer of green schist rich in hornblende, sample L2–2, contains only 19.2% vermiculite, and two samples, L2–3 and L2–4, of dark schist from the western part of the pit contain only 8.7% and 17.5% vermiculite, respectively. A sample, L2–5, of weathered green schist from the western end of the pit contains 21.6% vermiculite, and a selected sample, L2–6, of a layer containing an abundance of large flakes of dark brown vermiculite from the south side of the pit contains 56.4% vermiculite.

Aplite and pegmatite dikes are common in the area of the Bush deposit, and the vermiculite schist is surrounded by Valley Spring gneiss, which strikes generally northwest and dips about 25° to the southwest. A distinctive granite porphyry of the Llano region, called llanite, is exposed near the northeastern side of the main pit and at several points to the north and south of the pit.

Donop ranch (Locality L3).—About half a mile north of the main pit in the Bush deposit an exposure of vermiculite schist was found in a small valley about 600 feet northeast of a stock tank (fig. 2, locality 1–59B). It is on the Donop ranch about 150 feet from the eastern boundary of the property. Granite porphyry (llanite) crops out in the form of an inverted V about the vermiculite, and a second small showing of vermiculite can be found in the next small valley about 700 feet to the west-northwest. Valley Spring gneiss is abundantly exposed in the area, and the vermiculite schist bodies are probably small. The gneiss dips about 30° to the southwest, and the vermiculite schist appears to be concordant with the gneiss. Sample L3–1 is probably representative of the exposed material; it contains 19.1% vermiculite.

Highway 16 deposit (Locality L4).—Vermiculite schist is exposed in the ditches beside State Highway 16 (fig. 2, locality 4–8A) approximately 4.5 miles north of the main highway intersection in the northern part of Llano. The best exposures are on the east side of the highway. Nine samples from the east ditch, L4–1—L4–9, contain 23.1% to 38.8% vermiculite. Vermiculite is less well exposed in the ditch on the west side of the highway, but it is present both there and in a trench on the Light ranch to the west. Drilling by the U. S. Bureau of Mines disclosed vermiculite schist to a depth of as much as 42 feet, and a composite sample taken by the Bureau of Mines from 34.6 feet of the drilled vermiculite rock contains 41.9% vermiculite. The distribution of soil, vegetation, drill holes, and outcrops suggests that the deposit occupies a surface area about 140 by 300 or 400 feet, elongated in the direction of the strike of the schist, approximately N. 45° W.

Light ranch (Locality L5).—Vermiculite is exposed at several places on the Light ranch to the west and northwest of the Highway 16 deposit (fig. 2). One trench



Contours from U.S.G.S. Topographic quadrangle map Llano-North, Texas. Datum is mean sea level. Contour interval 20 feet.

FIG. 2. Map of vermiculite occurrences north of Llano along State Highway 16 and on Bush, Donop, and Light properties, Llano County.

adjacent to the Highway 16 deposit contains vermiculite, but the next trench north is barren. About a quarter of a mile farther northwest, vermiculite is exposed in a creek 400 feet southwest of the Light residence and in a trench on the creek bank (fig. 2, locality 4–8B). Sample L5–1 from the creek and the nearby pit contains 43.8% vermiculite. This deposit is said to have been investigated by drilling before 1946 and to have been found to be extensive.

About 700 feet due west of the Highway 16 deposit is another outcrop of vermiculite schist in a drain at the west edge of a field (fig. 2, locality 4–8C). Sample L5–2 was collected from the upstream half of the outcrop and sample L5–3 from the downstream half; they contain 37.9% and 24.7% vermiculite, respectively. The outcrop is small, but the deposit may widen under the soil cover of the adjacent field.

The Valley Spring gneiss has an average dip of about 30° to the southwest on the Light property, and aplite and pegmatite dikes are common.

Fox ranch (*Locality L6*).—A relatively thin layer of vermiculite schist occurs in the east bank of Wright Creek about three-fourths mile west of the Llano-San Saba highway (State Highway 16), 6.5 miles north of the main highway intersection in the northern part of Llano. It is located about 100 feet from the north boundary of the L. T. Fox ranch. Valley Spring gneiss is exposed on both sides of the vermiculite schist, and the schist layer is not more than a few feet thick. The gneiss dips 35° southwest. Sample L6–1 from the schist contains 22.7% vermiculite.

Faris deposits (*Localities L7 and L8*).—Two vermiculite deposits on the V. H. Faris ranch were drilled by the U. S. Bureau of Mines. The southernmost of these is located about a mile west of State Highway 16 and approximately 8 miles north of Llano. The other is located on Black Jack Creek about a mile northwest of the first. The Faris residence is adjacent to the highway 8.1 miles north of the main highway intersection in the northern part of Llano. Access to the deposits is by an unimproved ranch road leading from the residence through the pastures.

The main deposit, the *south deposit* of the U. S. Bureau of Mines (McMillan and Gerhardt, 1949), exposed in discontinuous outcrops for about 400 feet along a small creek, extends at least an additional 100 feet to the south beyond the Faris property line into the E. W. Osborne ranch. A sample, L7–1, of nearly average material contains 31.3% vermiculite. The deposit is elongated toward the northwest, and its maximum width disclosed by drilling is only about 100 feet. Only 3 of 12 drill holes in the northern third of the deposit penetrated vermiculite-bearing material. The maximum depth to which vermiculite persisted in any of the holes is 37 feet. A sample of relatively unweathered biotite schist was collected for chemical analysis (table 1) from a deep pit west of the small creek near the Faris ranch south fence. The biotite schist is similar to that in the bottom of the main pit in the Bush deposit, and the vermiculite in the Faris deposits, like most of that in the Bush deposit, yields only small, fragile flakes on expansion.

Vermiculite-bearing rock is exposed at several places northwest of the southern deposit on the Faris ranch. Most of these occurrences can be located best by reference to a windmill on the bank of Babyhead Creek. The most promising of these is a small lens of vermiculite schist exposed for less than 100 feet along the north bank of Black Jack Creek about 1,000 feet south of the windmill. This is the *north deposit* of the U. S. Bureau of Mines. Drilling disclosed vermiculite in only 5 of 12 holes; therefore, the mass appears to be very small. A sample, L8–1, contains 38% vermiculite.

About 1,000 feet west of the windmill, firm biotite hornblende schist is exposed in the bed of Babyhead Creek for about 100 feet. A sample of the weathered schist, L8–2, from the north bank of the creek contains 24.4% vermiculite.

Dark schist containing vermiculite also

crops out in the bed of Babyhead Creek about 300 to 400 feet north of the windmill. Sample L8–3 from this exposure contains 16.3% vermiculite. Along small creeks tributary to Babyhead Creek northeast and east of the windmill, vermiculite occurs at several places in weathered schist. The vermiculite-bearing rock grades into firm hornblende schist and hornblende feldspar gneiss, part of which resembles the Big Branch gneiss. Sample L8–4 was collected about 1,000 feet north of the windmill; it contains 14.2% vermiculite. Sample L8–5 from an exposure of schist about 700 feet east of the windmill contains 31.6% vermiculite, and sample L8–6 from a small valley 1,500 feet east of the windmill contains 48.1% vermiculite. Most of the dark schist in the vicinity contains no more than 10% to 20% vermiculite, and larger deposits are not likely to be present unless they are completely covered in the soil-blanketed areas of low relief.

Minor occurrences near Babyhead (Localities L9–L11).—The small community known as Babyhead lies on the east side of the Llano-San Saba highway (State Highway 16) 10 miles north of Llano. In several road cuts between the Highway 16 deposit and Babyhead, a little vermiculite can be found associated with layers of dark micaceous hornblende schist surrounded by light-colored Valley Spring gneiss. Along the highway north of Babyhead, dark schist with associated amphibolite is more abundant in a few places. Layers of soft vermiculite-rich rock as much as 2 feet thick are present in the schist about 1 mile north of Babyhead in a road cut on the east side of the highway (Locality L9).

Along a county road which runs due east from the old Babyhead school, numerous showings of vermiculite have been found (Locality L10). A small creek valley about 50 feet north of the county road 0.8 mile east of the school presents excellent exposures of layers of hornblende schist in Valley Spring gneiss. The larger layers contain little vermiculite, but they grade into vermiculite schist at their margins. Along the south side of the road 0.9 mile east of the school, weathered vermiculite-bearing schist has been excavated for road fill. About 1.6 miles east of the Babyhead school, a few stringers of vermiculite are present in dark gneiss on the north side of the county road. About 0.1 mile farther east additional streaks of vermiculite are present in folded gneiss on the north side of the road. The richest layer, near a zone of contorted tremolite schist, contains more than 50% vermiculite, but the layer is only a foot wide.

About 2.8 miles east of the Babyhead school the county road turns north and crosses a dike of llanite (granite porphyry) near several prospect pits in copper-stained epidote-garnet rock. A few hundred feet south of the pits vermiculite-bearing hornblende schist is exposed in the valley of a small creek that drains to the south (Locality L11). The vermiculite is similar to that in the Bush and Faris deposits but is much less abundant.

Minor occurrences near Lone Grove (Localities L12 and L13).—About 3 miles north of Lone Grove, ditches beside the county road between 100 and 400 feet east of a sharp bend disclose several layers of fine-grained vermiculite-bearing schist (Locality L12). The vermiculite content of the rock appears to be low, ranging from 5% to 25%.

A small amount of vermiculite occurs in dark schist layers in several of the pits and shafts of the old Heath gold mine about 2.5 miles west of Lone Grove (Locality L13), but the quantity is too small to indicate that deposits such as those north of Llano will be found in the area.

Minor occurrences near Valley Spring and Field Creek (Localities L14–L18).—About 4 miles by road northeast of the village of Valley Spring, micaceous gneiss and schist are poorly exposed beside the county road (Locality L14). Only a little fine-grained vermiculite is present; most of the micaceous material is muscovite. Between 1 and 2 miles due east of Valley Spring, metamorphosed basic igneous rock and associated fine-grained vermiculite are poorly exposed in the ditches beside the road. The largest layers of vermiculite-bearing rock are only a few feet thick and contain less than 25% vermiculite. Farther east, about 2.5 miles from Valley Spring and 250 feet east of Willow Creek, the road excavations exposed tremolite rock, talc, chlorite schist, and a little vermiculite-bearing schist (Locality L15). Vermiculite probably does not make up more than 10% of a zone 15 feet wide, and when expanded it is exceedingly fine-grained.

When they are freshly scraped, the shoulders and ditches beside the highway 1.8 miles northwest of the center of Valley Spring disclose serpentine-talc-chlorite rock cut by small pegmatite dikes. Vermiculite and chlorite occur in irregular pockets and veinlets distributed unevenly through the rock for a distance of 200 to 300 feet on the south side of the highway (Locality L16). Only a small amount of serpentine is exposed north of the road, but it may extend a greater distance southward in an area of nearly flat grassland. Although a few of the pockets yield small samples of nearly pure vermiculite, the average vermiculite content of the rock is probably less than 10%, and even selective mining would not yield rock containing much more than 25% vermiculite. A sample, L16–1, of the brown vermiculite from the larger pockets contains 31.5% vermiculite. The green chloritic flakes in some veinlets expand poorly, and the black vermiculite which occurs in thin stringers in the Valley Spring gneiss adjacent to the serpentine expands only moderately well when heated.

About 2.4 miles southeast of Field Creek the highway to Valley Spring and Llano intersects a county road from the south. Vermiculite-bearing metamorphosed basic igneous rock is exposed on the north side of the highway about 200 feet east of the junction (Locality L17) and at several spots between the junction and Field Creek. Sample L17–1 from about 15 feet of the rock with the highest vermiculite content east of the junction contains only 21.7% vermiculite. Similar occurrences of poor quality vermiculite rock are exposed at a few spots along the county road to San Saba for a distance of 3.8 miles from Field Creek (Locality L18). The first of these are in a ditch at the south edge of the road immediately east of the first cattle-guard at the northeast edge of the town. None of these occurrences near Field Creek shows any promise of sufficient vermiculite for commercial development.

WESTERN LLANO COUNTY

Roy Kothman deposit (Locality L19).—Vermiculite occurs in a large pit dug for road material on the Roy Kothman ranch about 250 feet south of State Highway 29 and 12.2 miles west of the highway intersection in northern Llano (Locality L19). The pit now serves as a small reservoir to hold surface water for livestock use. Mineral rights belong to the Downmans Estate, New Orleans. The zone of vermiculite-bearing, weathered schist seems to extend northwest through the eastern two-thirds of the pit. It is about 100 feet wide and cannot be traced laterally because of the relatively deep soil cover in the area. Barnes collected two samples, one of which, L19–1, contains 24.4% vermiculite and the other, L19–2, contains 26.3%. Exposures of bedrock are very poor in the area, and the discovery of other bodies of vermiculite-bearing rock in the vicinity will be dependent on excavation or drilling. The pit is in an area which appears relatively dark on aerial photographs, and it is possible that some of the other dark areas nearby are also underlain by vermiculite-bearing material. Barnes found an exposure of a small amount of vermiculite-bearing rock in the road cut on the north side of the highway half a mile west of the vermiculite occurrence in the pit. Very little vermiculite schist is exposed there, although a sample of the material, L19–3 contains 34.8% vermiculite.

Vernon Otto deposit (Locality L20).—About a mile west of the Roy Kothman vermiculite deposit a county road crosses the Llano-Mason highway (State Highway 29), 13.3 miles west of Llano. On the east side of the county road vermiculite-bearing, weathered schist is very poorly exposed in the drainage ditch for a distance of 600 feet approximately 0.8 mile north of the highway (Locality L20). The adjoining property to the east belongs to Vernon Otto. The best exposures are near the south end of the vermiculite-bearing material disclosed by the ditch. Sample L20–1 is a composite sample collected from 35 feet of the ditch; it contains 38.1% vermiculite. Sample L20–2, which contains 26.0% vermiculite, is from material which resembles the vermiculite rock mined at the T. K. Bush deposit north of Llano, but it does not expand as freely. The vermiculite content of the weathered schist appears to be lower in the northern three-fourths of the ditch, but beyond the last bedrock exposure the ditch continues 250 feet in dark red soil in which small vermiculite flakes are abundant. Exposures of bedrock in the whole area are very poor, but prospecting could be done easily with shallow excavations, and the length of the exposure in the ditch indicates the possibility of a large deposit here.The weathered schist in which the vermiculite occurs cuts diagonally across the road, striking about N. 35° W. and dipping about 50° NE. Unless the drainage ditch has been freshly excavated or recently washed by heavy rains, vermiculite will hardly be noticed at this locality, even by an experienced person making a search for it.

Fritz Otto deposit (Locality L21).—About 1.6 miles north of the Mason-Llano highway (State Highway 29), beside the same county road that exposes the Vernon Otto deposit 13.3 miles west of Llano, a road material pit about 150 feet west of the road has been excavated on the Fritz Otto ranch (Locality L21). The pit is a large one; it was dug in weathered, light-colored Valley Spring gneiss and dark schist, both of which are cut by pegmatite dikes. Vermiculite makes up 35% or more of part of the weathered schist, but most of it contains less. Sample L21–1 was taken from about a 6-foot width of the schist with the highest vermiculite content exposed in the north wall of the pit; it contains 37.4% vermiculite. The deposit is small, for gneiss and pegmatite crop out nearby, and there are no other exposures of vermiculite-bearing rock near the pit.

About half a mile northwest of the pit a layer of vermiculite-bearing hornblende schist overlain by Valley Spring gneiss is exposed in the bed of a small creek. The schist strikes about N. 35° E., dips about 45° SE., and contains many small dikes of pegmatite. The average vermiculite content of the rock is low, probably less than 20%, and the flakes are small; a few thin layers of the rock consist chiefly of vermiculite.

Kothman-Oestreich deposit (Locality L22).—Vermiculite-bearing rock is exposed south of the Mason-Llano highway (State Highway 29) at several places beside the county road that crosses the highway 13.3 miles west of Llano. The greatest abundance of vermiculite appears to be adjacent to the old Adolf Schneider property now owned by Gleason Kothman, situated east of the road about 1.2 miles south of the highway (Locality L22). The northern part of the property on the west side of the road adjacent to the vermiculite occurrences is owned by Carolina Oestreich and the southern part by Max Oestreich; their common boundary begins approximately west of the entrance to the old Schneider ranch. Sample L22–1 is average material gathered from a 50-foot length of the roadside ditch opposite the gate to the Schneider ranch. It contains 32.2% vermiculite and is similar to the weathered schist mined at the T. K. Bush deposit. On the west side of the road about 75 feet south of the gate, a few small pockets of exceptionally pure vermiculite occur beside small pegmatite dikes. Dark red soil overlies the vermiculite-bearing rock in the roadside exposures and extends several hundred feet from the road on both sides; therefore, the deposit may be large. Test pits 1 to 4 feet deep should be adequate to determine the presence of vermiculite in the underlying rock. The vermiculite rock appears to be less friable here than at the Bush and Faris deposits; therefore, it may not be as deeply weathered, and vermiculite may not be present to as great a depth.

About 1,500 feet north of the Schneider ranch gate vermiculite-bearing hornblende schist crops out beside the road about 100 feet north of a small creek. Sample L22–2 from this locality contains 21.9% vermiculite. Most of the rock contains less, and the extent of the vermiculite-bearing material to either side is probably not great.

Minor occurrences west of Lehmberg schoolhouse (Locality L23).—The old Lehmberg schoolhouse is a small stone building about a mile south of the Kothman-Oestreich vermiculite deposit at the intersection of the north-south county road with a road that extends westward to Castell. About 0.65 mile west of the schoolhouse, vermiculite occurs in about 200 feet of the shallow ditch on the north side of the road to Castell (Locality L23). Streaks of vermiculite-rich, weathered schist alternate with layers of feldspathic gneiss; therefore, the average vermiculite content of the deposit is low. Sample L23–1 is from a 3-foot layer of schist with relatively high vermiculite content; it contains 52.6% vermiculite.

About 0.9 mile west of the old school, fine-grained vermiculite-bearing schist is exposed about 50 feet south of the road in the second of a series of earthen tanks for watering livestock. None of the weathered schist appears to contain as much as 25% vermiculite. Approximately 800 feet farther west on the west side of a small creek, a few small pockets of vermiculite are present in light-colored gneiss cut by pegmatite dikes.

About 1.55 miles west of the schoolhouse, vermiculite is present for approximately 100 feet in the ditch on the south side of the road. It occurs in a belt of a firm, dark schist which trends nearly parallel to the road and is probably not more than 50 feet wide.

Jordan deposit (Locality L24).—About 0.3 mile south of the Lehmberg schoolhouse a county road branches eastward from the north-south road. Near the turnoff to the J. B. Jordan house, about 1.4 miles east of the county road intersection, vermiculite-bearing rock is exposed for a distance of 275 feet (Locality L24). The exposure is in a shallow drainage ditch on the south side of the road, and bedrock can be seen in place only after fresh excavation or heavy rain has cleaned the drain. Sample L24–1 was collected in the interval between 40 and 70 feet west of the entry road to the Jordan ranch, and sample L24–2 between 40 and 90 feet east of the entry road; both are composite samples of average material. The first contains 26.8% vermiculite and the second contains 24.7%. The vermiculite-bearing rock is weathered hornblende biotite schist similar to that in the Bush deposit. The dark soil covering this deposit can be seen to extend about 500 feet southeast through a field and to occupy an area of more than 10,000 square yards. North of the road the bedrock appears to be chiefly aplitic granite.

About 0.3 mile west of the Jordan deposit, the county road passes through an area of dark red soil containing hornblende and magnetite. Bedrock is not exposed, but the soil resembles that above nearby vermiculite deposits. About 2.6 miles east of the Jordan deposit the drainage ditches at the side of the road expose dark schist and red soil with associated vermiculite in several places. A few layers contain an abundance of vermiculite, but most of the rock contains very little, and pegmatite dikes are exceptionally abundant.

Minor occurrences near Castell (Localities L25–L27).—Small flakes of vermiculite are common in the weathered schist 2.3 miles east of Castell for a distance of about 500 feet on the south side of Ranch Road 152 from Castell to Llano (Locality L25). The vermiculite is more fine grained and less abundant than that in the Jordan, Kothman-Oestreich, and other deposits in the vicinity. Additional vermiculite is present in feldspathic schist about 0.9 mile farther east, and a few small layers of the rock are chiefly vermiculite. Pastures on both sides of the road have good soil cover, and vermiculite flakes can be found in the soil north of the road; therefore, the area may deserve further exploration.

Adjacent to the J. W. Bauer ranch about 6 miles east of Castell (Locality L26), vermiculite-bearing rock is exposed in the south shoulder of Ranch Road 152 for a distance of 75 feet. The locality is about 300 feet west of the Lee Bauer mailbox, and the vermiculite is inferior to that in the Bush deposit and the larger nearby deposits.

About 5 miles southeast of Castell a 2-foot layer of vermiculite-bearing schist on the H. C. Keese ranch (Locality L27) has been prospected by a small pit located about 100 yards northeast of the Keese house. The same or a similar layer is exposed in the ditch beside the county road on the adjacent Robert Oestreich ranch southeast of the Keese prospect. Other exposures of dark schist in the vicinity contain a minor amount of vermiculite, but the area does not appear favorable for large deposits.

The county road that extends due north from Castell crosses an 8-foot layer of vermiculite schist 1.6 miles south of the Llano-Mason highway (State Highway 29). Several other small bodies of vermiculite-bearing schist are present in road cuts beside this highway between the Mason County line and the Roy Kothman deposit, 6.2 miles to the east.

SOUTHERN LLANO COUNTY

Stewart ranch (Locality L28).—Altered biotite which resembles some of the vermiculite of the region occurs in the weathered diorite in a road material pit on the Dave Stewart ranch 2 miles south of Llano. The pit is about 600 feet east of the Llano-Fredericksburg highway (State Highway 16) and immediately south of the Sharp Mountain road. The diorite contains no more than 5% biotite except where pegmatite stringers finger out into it and it is coarser and more micaceous. The diorite surrounds large inclusions of Packsaddle schist and either includes or has been invaded by irregular bodies of granite. None of the weathered biotite expands freely when heated; most of the flakes swell to only three or four times their original thickness in a blowtorch flame; therefore, it is not suitable for commercial use.

Texas Mines magnesite mine (Locality L29).—A few flakes of white vermiculite can be gathered from the waste dumps and found in place in the dolomite and magnesite marble which was quarried near the south end of Sharp Mountain about 5 miles southeast of Llano (Locality L29). The magnesite mine has been described briefly by Chelf (1941; repeated in Barnes, Dawson, and Parkinson, 1947, pp. 105–106). Serpentine, olivine, phlogopite, and other silicates are common in the dolomite and to a lesser extent in the magnesite. The vermiculite appears to have been produced by weathering of phlogopite within 40 feet of the surface of the ground. The quantity of vermiculite in the deposit is insignificant, and vermiculite occurrences of this type in the Llano uplift are not likely to have economic importance, although they may yield information on the origin and range of composition of vermiculite.

Carl Moss deposit (Locality L30).—Vermiculite is present in irregular veins in soapstone and serpentine on the Carl Moss ranch about 8 miles south of Llano. The deposit is easily accessible by road, lying only one-third mile west of the Llano-Fredericksburg highway on the south flank of Yearlinghead Mountain. Part of the serpentine mass in which vermiculite occurs was being quarried for use as roofing chips in 1956. In a study of soapstone and serpentine deposits of central Texas, Barnes (1945, p. 82) recorded that vermiculite had been produced at the northern end of the serpentine body from small irregular masses of coarse flakes situated mostly along the border of the serpentine and in the adjacent schist. Subsequent prospect holes and other development showed that some of the veins can be traced for 50 or more feet through serpentine and

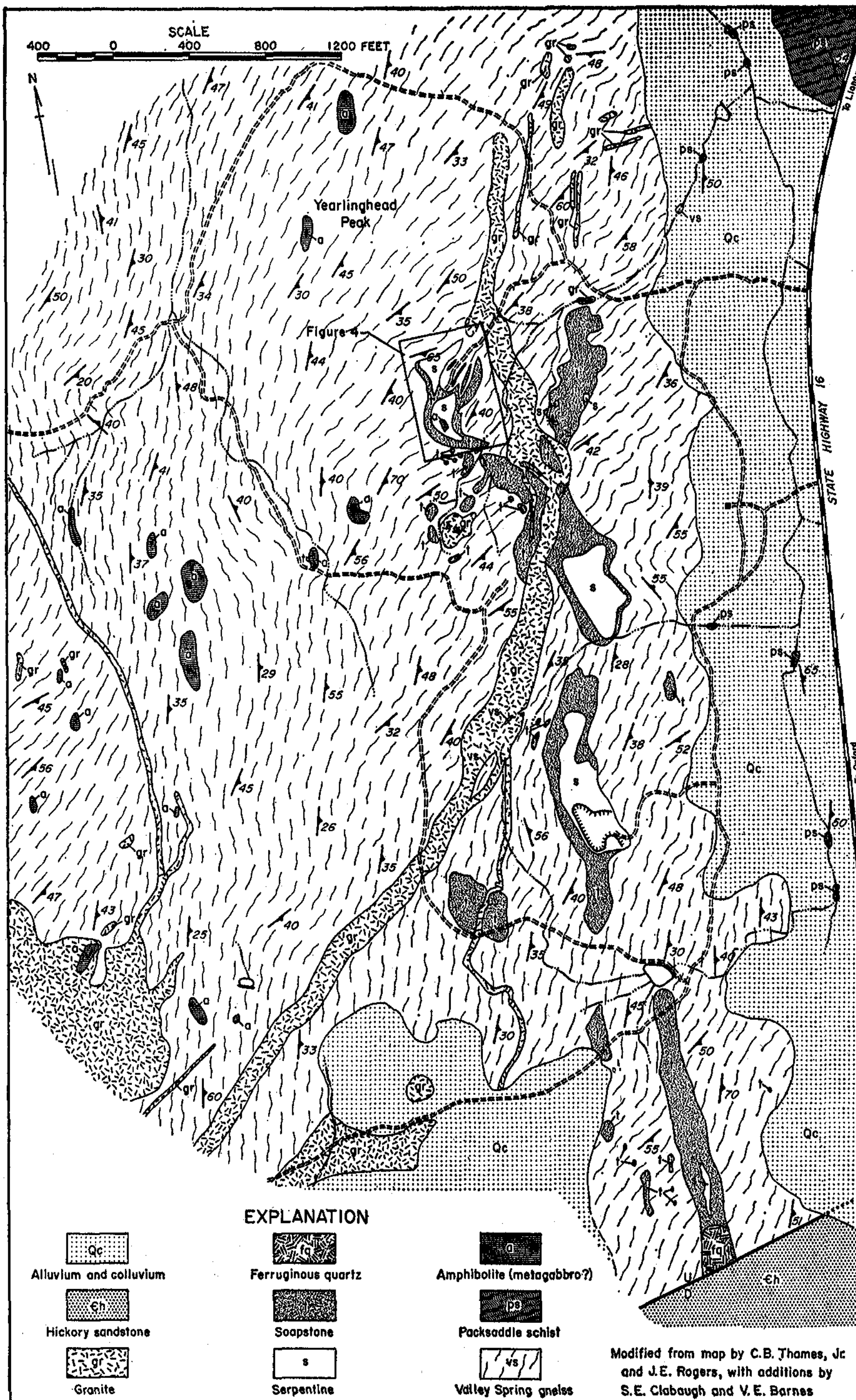


FIG. 3. Geologic map of Yearlinghead Mountain area, Llano County.

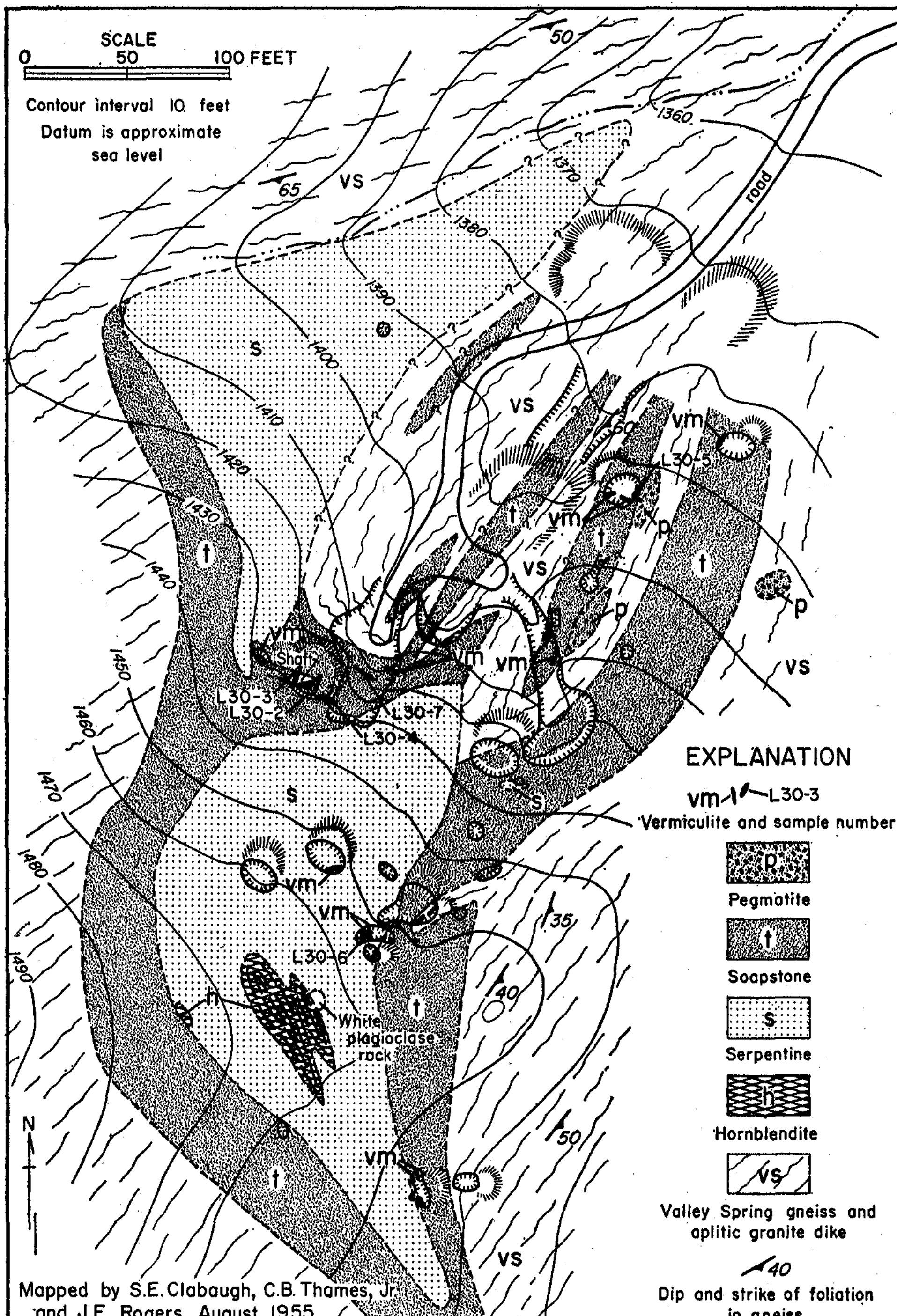


FIG. 4. Map of vermiculite occurrences in Yearlinghead Mountain area, Llano County.

soapstone, and that they branch and intersect other veins of vermiculite.

Thames and Rogers (Thames, 1957) remapped the Yearlinghead Mountain area in 1955 (fig. 3) and assisted Clabaugh in making a detailed map of the vermiculite occurrences. The detailed map (fig. 4) shows two roughly triangular masses of serpentine, each about 600 feet long, almost completely enclosed in an envelope of soapstone. The surrounding Valley Spring gneiss contains almost innumerable dikes of aplitic granite and pegmatite, and the foliation of the gneiss does not conform to the shape of the soapstone-serpentine body, although soapstone and gneiss interfinger in the northeastern part of the deposit (fig. 4). A lens of black amphibolite is enclosed in the southern serpentine mass, and a small mass of white, hard plagioclase rock is present at the eastern edge of the hornblendite lens. Between the two serpentine bodies an inclined shaft was dug in soapstone down the dip of several veins of vermiculite at an angle of 45° to 55° for a distance of 75 feet. At the bottom of the incline the shaft widens where it was excavated eastward a few feet in vermiculite, soapstone, and serpentine. Sample L30–1 is greenish vermiculite from the bottom of the shaft; it contains 70.0% vermiculite which weighs 7.1 pounds per foot when expanded. Sample L30–2 is from a vein of similar green vermiculite about 2 or 3 inches thick along the floor of the inclined shaft at its entrance, which is about 10 feet below the original surface of the ground. It contains 78.0% vermiculite. Along the roof of the inclined shaft at its entrance is a vein of coarser, greenish bronze-colored vermiculite. Sample L30–3 was taken from this vein at a point about 4 feet below the original surface of the ground; it contains 70.5% of vermiculite which weighs 9.4 pounds per cubic foot when expanded. Sample L30–4, which contains 62.0% vermiculite, is from inferior, fine-grained brown vermiculite from the southeast margin of the pit in which the shaft is located. The brown vermiculite surrounds a mass of tremolite in sheared soapstone and serpentine. Sample L30–5 from the margin of a pegmatite dike in contact with soapstone contains 59.1% vermiculite, and sample L30–6 from a 4-inch vein in serpentine contains 53.4% vermiculite. Sample L30–7 from a 3-inch vein in the quarry east of the shaft contains 88.0% vermiculite.

All of the samples contain more vermiculite than do samples of weathered schist from the Bush, Smith, Jordan, and similar large deposits, but they represent very small quantities of material in narrow and irregular veins; therefore, the vermiculite cannot be mined profitably, except perhaps on a very small scale accompanying the quarrying of serpentine or soapstone.

The serpentine with which the vermiculite is associated probably originated as intrusive masses of dunite accompanied by gabbro which were emplaced in Valley Spring gneiss during regional metamorphism. At the peak of metamorphism the gabbro was converted into foliated amphibolite, and the dunite may have been deformed into discontinuous lenticular masses. The serpentine is not foliated; therefore, it must have developed after maximum deformation and at lower temperature in the presence of aqueous solutions. The amphibolite enclosed in serpentine (fig. 4) is also unfoliated, probably because it was shielded by its envelope of dunite. The serpentine bodies have been altered to soapstone from their margin inward, leaving a core of serpentine partly or completely surrounded by soapstone. Smaller masses were completely replaced. A large dike of fine-grained granite projects into the belt of serpentine-soapstone occurrences from the southwest where a larger body of granite is present. The two largest serpentine bodies show the greatest replacement by soapstone on the sides nearest the granite. This suggests that the fluids which converted serpentine to soapstone originated in the granite. Pegmatite dikes followed the granite, and hydrothermal fluids related to them penetrated fractures in the soapstone and serpentine to produce veins of vermiculite. Even in samples from the bottom of the shaft no mica is present, and the vermiculite has the same appearance and properties as that at the surface; therefore, it is probably a hydrothermal mineral here rather than a weathering product as in the Bush, Smith, and other deposits where it occurs in schist. The X-ray patterns obtained from samples L30–1 and L30–2 are almost identical, even though one sample came from weathered rock 10 feet below the surface and the other from the bottom of the shaft at least 50 feet below the surface.

Gregory deposit (Locality L31).—Vermiculite is associated with soapstone on the T. G. Gregory ranch about 13 miles south of Llano. The ranch may be reached by traveling east and south from Oxford via the county road for a distance of slightly more than 2.5 miles to a branch road which continues 0.4 mile southwest to the Gregory house. The deposit is about 100 yards west of the house (Locality L31), and the soapstone continues southward into the M. C. Sagebiel ranch (Barnes, 1945, p. 82 and fig. 26). Vermiculite was first noticed here when the Southwestern Talc Company was recovering soapstone from the top of the ground and digging out the rock at shallow depth. The vermiculite became plentiful enough in places to discourage further production of soapstone. In 1947 the Southwestern Graphite Company leased the Gregory property, excavated a shaft about 32 feet deep, and drilled an additional 12 feet at the bottom of the shaft, all in soapstone and vermiculite. A channel sample (L31–1) from the wall of the upper part of the shaft contains 11.2% vermiculite, and one from the lower part of the shaft (L31–2) contains 18.3% vermiculite. Sample L31–3 was collected from the shaft wall where vermiculite is more abundant 22 feet be-

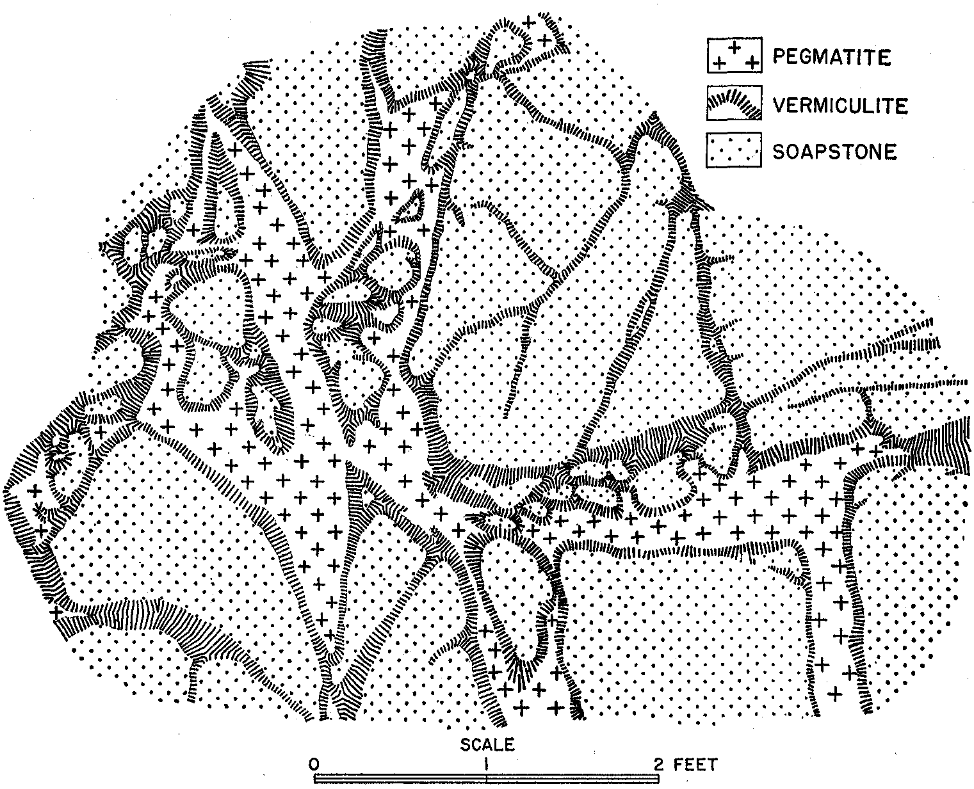


Fig. 5. Sketch of face of open cut, Gregory vermiculite deposit, Llano County.

low the surface; it contains 34.2% vermiculite. In the shaft the soapstone occurs in rounded masses ranging in diameter from a few inches to several feet. The margins of many of these masses are made up of radiate talc plates in a layer about 0.25 inch thick. Vermiculite occurs around and between the boulder-like masses and also as scattered flakes in the central part of many boulders. An open cut 50 feet east of the shaft discloses pegmatite intricately injected into the shattered soapstone with vermiculite replacing the margins of the soapstone masses. Figure 5 is a sketch of a few square feet of the face of the open cut. Some of the smaller remnants of soapstone are platy talc; others contain an abundance of tremolite. The pegmatite is chiefly microcline and quartz with minor biotite. Actinolite is common in the pegmatite adjacent to the wallrock. Gneiss and schist are also present in the open cut.

The U. S. Bureau of Mines drilled the Gregory deposit in 1947, but nearly half of the 20 holes encountered granite or pegmatite dikes before reaching soapstone. Drill hole no. 5, located 50 feet south of the shaft, penetrated soapstone to a depth of 64 feet, and continuous sampling showed a vermiculite content of 18.5% to 32.9% (McMillan and Gerhardt, 1949, p. 17). Vermiculite from samples near the bottom of the hole weighed slightly less per cubic foot when expanded than that from shallow samples, indicating that the mineral is as well developed 60 feet below the surface as in the weathered rock. There is no evidence here that it altered from chlorite or mica. More than 50% of the vermiculite from a composite sample of the vermiculite-bearing material recovered from the drill holes is finer than 65 mesh. The deposit appears to contain no more than 10% to 15% of commercially usable vermiculite, which would require selective mining and milling for recovery. An interesting suggestion of the Southwestern Graphite Company is that the deposit might be milled to produce both a good grade of talc and a vermiculite concentrate.

GILLESPIE COUNTY

Welgehausen deposit (Locality G1).—Vermiculite occurs in weathered hornblende-rich rock in the drainage ditch on the east side of the county road through the Felix Welgehausen ranch. The deposit (Locality G1) is one-fourth mile north of the Welgehausen house, which is about 2 miles southwest of Enchanted Rock. In July 1955 a Mr. Sutherland of Houston was negotiating purchase of the Felix Welgehausen property.

The rock in which the vermiculite occurs is a nonfoliated to very slightly foliated hornblendite which appears to have undergone metasomatic alteration as granite and pegmatite were introduced into the area. Part of the hornblende was replaced by biotite, and alkali feldspar was introduced into the rock. The metasomatic changes were not uniform; some of the rock is chiefly hornblende; some contains 50% or more vermiculite (weathered biotite); and some streaks are so enriched in feldspar that they resemble contaminated granite. The hornblende-rich portions are least susceptible to weathering and tend to crop out as low ridges, whereas the vermiculite-rich rock weathers deeply and develops a soil cover. The distribution of the various rocks and the sample localities are shown diagrammatically in figure 6. Sample G1–1 is a composite sample from the vermiculite-bearing hornblendite at the north end of the deposit; it contains 22% vermiculite. Samples G1–2—G1–6 are average samples of each successive 25 feet of weathered rock in the 125-foot interval in which vermiculite is most abundant. Their vermiculite content ranges from 22.8% to 31.8% and averages 26.9%. Most of the vermiculite flakes are small; they are randomly oriented in the rock and are not bent or crimped like many of the flakes in the weathered schist deposits north and west of Llano. Before a blowtorch the flakes expand well and are less fragile than those from the Bush deposit.

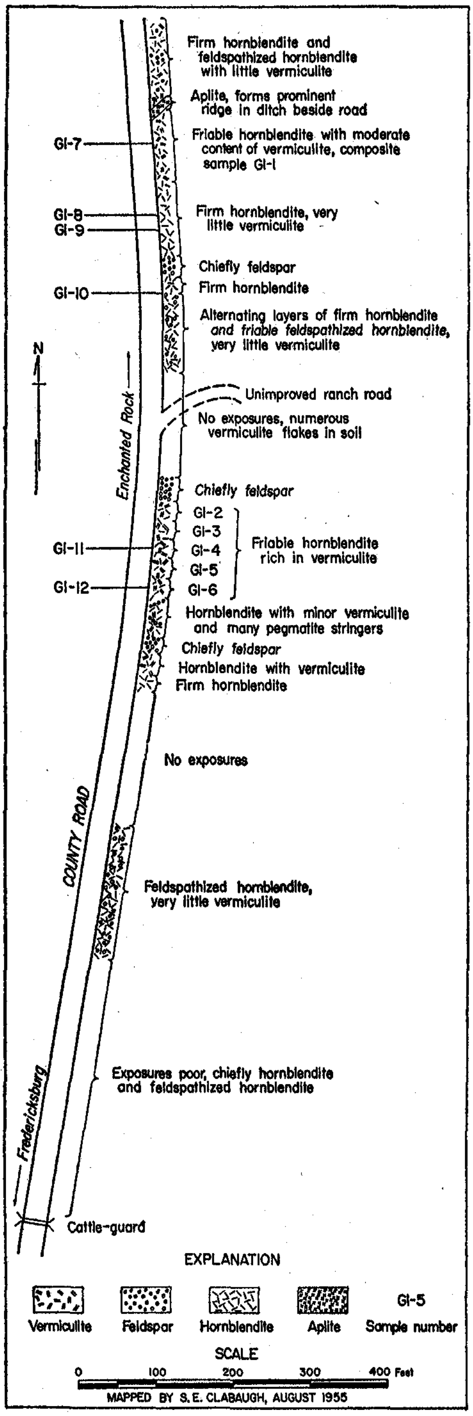


FIG. 6. Welgehausen vermiculite deposit, Gillespie County.

Exposures of bedrock are poor on both sides of the road; therefore, no estimate of the area underlain by vermiculite-bearing rock can be made. If the exposure in the roadside ditch (about 225 feet) is typical and if the deposit is equidimensional, it contains more than 15,000 cubic yards per 10 feet of depth. The depth to which the rock is friable (and the biotite weathered to vermiculite) is also undetermined, but it is probably less than 30 feet. Some of the soil-covered areas in which the drainage ditch failed to reach bedrock are probably underlain by vermiculite-bearing rock; therefore, the deposit may be larger than the present exposure suggests.

Minor occurrences northwest of Willow City (Locality G2).—In a study of the soapstone deposits in the Big Branch area (Locality G2), Barnes and Mathis (Barnes, 1945, pp. 60–73) recorded the presence of vermiculite in a few of the numerous samples taken from more than 100 exploratory trenches. The vermiculite occurs chiefly in layers of chlorite at the contact of soapstone with surrounding schist or gneiss on the Alfred Davis property about 6 miles northeast of Willow City in northeastern Gillespie County. Close examination of the soapstone, serpentine, and other metamorphosed mafic igneous rocks in this area and in the adjacent northwest corner of Blanco County will undoubtedly disclose many similar occurrences of vermiculite, but there is little indication that they will have potential economic importance.

MASON COUNTY

None of the vermiculite occurrences in Mason County has been explored by trenching or drilling, and exposures of bedrock are generally poorer than in the eastern and central part of the Llano uplift. It is hardly surprising, therefore, that relatively few deposits have yet been discovered and that information about them is scanty.

In the northeast corner of Mason County vermiculite occurs in micaceous schist at the south edge of the town of Pontotoc

(Locality M1). The best exposures are beside a north-south county road a short distance north of an old bridge over a small creek about 0.3 mile south of the highway through the town. Sample M1–1 was collected from the 3-foot layer of friable rock with the highest vermiculite content. It contains 53.8% vermiculite. Most of the micaceous flakes in the adjacent rock expand less freely than the vermiculite from other deposits in weathered schist in the region, and some of the flakes are pale golden brown. The rock in which they occur is firmer also than that in other deposits. Thus it appears that most of the mica in the schist at Pontotoc is less susceptible to conversion to vermiculite by weathering.

About 3 miles west of Pontotoc a county road branches southwest from the paved highway. At the east side of the county road 2.6 miles south of the intersection, a 3-foot layer of fine-grained vermiculite-bearing schist is exposed in the drainage ditch (Locality M2).

Small amounts of vermiculite-bearing schist can be found in many places in the shallow ditches beside roads a few miles east and northeast of Mason. Two miles east of the Mason courthouse a county road extends north 1 mile to a junction from which one branch runs north and one east. Dark schist with a few layers of vermiculite is poorly exposed about 0.4 mile north of the junction. Between 1.2 and 1.5 miles east of the junction thin stringers of vermiculite are exposed in the shoulders of the road when the road is freshly graded. Sample M3–1 from a 2- to 3-inch layer contains 65.0% vermiculite. The vermiculite-bearing layers are too thin and too widely spaced to be of potential economic interest. Farther east, 3.8 miles from the junction, the county road again divides, one branch running north and the other east. About 2.1 miles north of the second junction small quantities of vermiculite are present in weathered schist poorly exposed along the west side of the road. Farther north, 2.8 to 2.9 miles north of the second junction and 0.3 mile south of an old cemetery (Locality M4), vermiculite is present in the margins of the road and in the banks of a small creek about 200 feet west of the road. Sample M4–1 was collected from a layer of vermiculite-rich rock about 2 feet thick on the east side of the road approximately 125 feet north of a small bridge. It contains 24.9% vermiculite. Exposures of bedrock are fairly good in this vicinity, and further search may disclose more promising vermiculite occurrences nearby.

Between Mason and the east boundary of Mason County there are many minor occurrences of vermiculite in road cuts adjacent to the Mason-Llano highway (State Highway 29), but none contains sufficient vermiculite to indicate that they merit exploration for commercial development. Small pockets or disseminated flakes of vermiculite were found at points 1.8, 2.0, 4.0, 5.6, and 6.4 miles east of the Mason courthouse. Farther east, about 5.8 miles east of the Art post office, road cuts on both sides of a bridge (Locality M5) disclose layers of dark rock made up almost entirely of biotite enclosed in pink gneiss. The layers range from a few inches to more than a foot thick, and near the surface of the ground the biotite has weathered to form vermiculite which expands readily before a blowtorch. Numerous layers and pockets of vermiculite-rich rock are present in the gneiss about 0.6 mile farther east. Some of the vermiculite is coarse grained, but the quantity is small.

About 5.6 miles south of Castell on the east side of the road to Loyal Valley (Locality M6), a shallow road material pit contains a minor amount of vermiculite associated with muscovite-bearing gneiss. Approximately 14 miles southeast of Mason a 2-foot layer of vermiculite-bearing schist is exposed beside the farm road to Hilda, 2.2 miles south of the Mason-Fredericksburg highway (U. S. Highway 87) (Locality M7). No occurrences of more than a few small flakes of vermiculite were found in road cuts west of Mason near Grit and Streeter and north of Mason near Katemcy.

SAMPLE DATA

The results of heating tests and size analysis of the samples of vermiculite-bearing rock are summarized in table 2. The samples were processed in the Mineral Technology Laboratory of the Bureau of Economic Geology. More than half were tested by R. M. Wheeler prior to 1955, the remainder by D. A. Schofield with the assistance of Wheeler and E. E. Culver in 1957–1958. Each sample was dried by exposure to air; Wheeler found that drying the samples at 105° C. for four hours caused an average weight loss of only about 3%. The average bulk weight of the loose sample material was about 70 pounds per cubic foot. A 100-gram fraction of the sample was heated at 770° C. in an inclined, rotating, stainless steel tube to produce as much expansion of the vermiculite as possible (Schofield's procedure), and the exfoliated material was then separated (by floating it on water), screened, and weighed. Wheeler's data were obtained by heating the vermiculite in open crucibles, resulting in incomplete expansion, thus giving a consistently greater weight per cubic foot of the expanded material. A factor of about 0.5 should be used to make Wheeler's results comparable to those of Schofield (table 2) and those of McMillan and Gerhardt (1949).

Table 2. Sample data.

		EXPANDED VERMICULITE					
		Sieve analysis, % by weight				Lbs./Cu. Ft.	
SAMPLE NUMBER	VERMICULITE % by weight	+10 mesh	−10 +20	−20 +60	−60 mesh	WHEELER	SCHOFIELD
B1–1	33.5	10.1	9.7	54.9	25.3	27.4	......
B1–2	34.5	18.5	20.8	43.2	17.5	23.7	......
L2–1	37.7	15.8	24.3	38.0	21.9	28.7	......
L2–2	19.2	16.1	13.4	28.0	42.5	42.4	......
L2–3	8.7	16.1	21.8	43.7	18.4	35.4	......
L2–4	17.5	21.7	14.3	44.6	19.4	36.6	......
L2–5	21.6	8.3	3.2	10.1	78.4	67.4	......
L2–6	56.4	6.6	46.8	36.9	9.7	......	9.9
L3–1	19.1	23.6	14.7	36.1	25.6	38.8	......
L4–1	34.0	22.9	29.7	34.4	13.0	30.0	......
L4–2	29.7	23.1	25.9	34.0	17.0	24.5	......
L4–3	35.0	22.7	29.5	31.2	16.6	23.6	......
L4–4	32.4	24.1	25.3	32.1	18.5	24.1	......
L4–5	38.8	25.8	27.6	36.1	10.5	23.0	......
L4–6	35.6	22.2	27.2	35.4	15.2	20.3	......
L4–7	23.1	30.7	14.3	29.0	26.0	28.3	......
L4–8	24.2	14.1	31.1	22.0	32.8	30.1	......
L4–9	30.4	31.8	22.9	28.1	17.2	28.5	......
L5–1	43.8	24.8	16.1	41.0	18.1	32.0	......
L5–2	37.9	44.2	24.6	19.0	12.2	32.5	......
L5–3	24.7	25.1	19.0	30.4	25.5	31.9	......
L6–1	22.7	28.1	15.4	27.6	28.9	29.3	......
L7–1	31.3	21.6	16.9	42.7	18.8	31.2	......
L8–1	38.0	15.3	23.9	37.1	23.7	30.6	......
L8–2	24.4	21.7	16.8	32.4	29.1	26.7	......
L8–3	16.3	23.9	14.1	25.8	36.2	32.3	......
L8–4	14.2	18.5	29.3	28.6	23.6	25.7	......
L8–5	31.6	40.4	19.6	16.7	23.3	31.4	......
L8–6	48.1	25.5	24.9	39.5	10.1	32.9	......
L16–1	31.5	4.5	30.1	49.2	16.2	......	11.7
L17–1	21.7	0.0	16.6	65.0	18.4	......	13.3
L19–1	24.4	22.5	31.2	38.5	7.8	16.7	......
L19–2	26.3	27.8	19.7	38.8	13.7	18.0	......
L19–3	34.8	33.0	28.2	31.3	7.5	22.6	......
L20–1	38.1	0.0	10.2	63.6	26.2	......	30.9
L20–2	26.0	0.0	27.3	60.8	11.9	......	60.0
L21–1	37.4	0.8	35.0	50.8	13.4	......	9.9
L22–1	32.2	0.0	15.8	61.2	23.0	......	11.0
L22–2	21.9	10.0	24.2	55.3	10.5	22.6	......
L23–1	52.6	5.1	33.3	45.2	16.4	......	12.7
L24–1	26.8	0.4	21.9	60.6	17.1	......	10.3
L24–2	24.7	0.4	35.9	52.0	11.7	......	9.4
L30–1	70.0	30.1	28.5	27.8	13.6	......	7.1
L30–2	78.0	6.2	28.5	49.3	16.0	......	6.8
L30–3	70.5	30.6	24.2	30.1	15.1	......	9.4
L30–4	62.0	6.6	12.3	48.7	32.4	......	20.4
L30–5	59.1	5.6	33.5	47.8	13.1	......	12.3
L30–6	53.4	27.4	28.3	28.0	16.3	......	7.4
L30–7	88.0	35.6	19.8	33.0	11.6	......	7.3
L31–1	11.2	20.5	12.5	47.3	19.7	131.0	......
L31–2	18.3	9.3	21.3	33.9	35.5	95.5	......
L31–3	34.2	12.4	23.1	41.6	22.9	29.6	......
G1–1	22.0	6.4	25.7	41.7	26.2	......	13.0
G1–2	23.1	7.4	27.1	41.0	24.5	......	12.5
G1–3	26.6	23.5	36.9	29.7	9.9	......	23.0
G1–4	30.0	2.7	18.1	42.6	36.6	......	16.5
G1–5	22.8	3.4	19.5	45.9	31.2	......	15.1
G1–6	31.8	3.4	16.4	46.6	33.6	......	15.5
M1–1	53.8	0.0	9.5	54.8	35.7	......	26.7
M3–1	65.0	5.1	29.4	48.7	16.8	......	12.4
M4–1	24.9	0.4	17.3	50.0	32.3	......	11.3

POTENTIAL ECONOMIC DEVELOPMENT OF THE DEPOSITS

The vermiculite deposits of central Texas are inferior in content and quality of vermiculite to those currently being exploited elsewhere in the United States and in foreign countries. Nevertheless, a large quantity of vermiculite-bearing rock is present in easily accessible deposits in the region, and the flakes can probably be concentrated for commercial use by simple milling procedures. When superior domestic and foreign sources are depleted, the central Texas deposits will probably support a local vermiculite mining and processing industry.

RESERVES

The drilling program of the U. S. Bureau of Mines is the most intensive investigation of vermiculite reserves that has yet been attempted in the Llano region. McMillan and Gerhardt (1949) presented no tonnage estimates but concluded that the area underlain by vermiculite-bearing rock at the Smith deposit is 55,600 square feet and that at the Bush deposit is 63,000 square feet. The auger holes penetrated as much as 32 feet of vermiculite rock in the Smith deposit and 48 feet in the Bush deposit; vermiculite content ranged from 9% to 46% at the Smith and from 25% to 56% at the Bush deposit. From these figures it seems reasonable to suggest that the Smith and Bush deposits together contain about 100,000 tons of rock with a vermiculite content greater than 25%. The other three deposits drilled by the U. S. Bureau of Mines are much smaller.

The undeveloped deposits in western Llano County look as promising from surface exposures as the deposits that were drilled north of Llano, and the Welgehausen deposit in northern Gillespie County may also be large. The deposits now known may therefore contain as much as 250,000 tons of vermiculite-bearing rock, and further prospecting should disclose additional deposits readily.

Vermiculite-bearing rock can be mined from the larger deposits by open-pit methods, but attention will have to be paid to selective excavation to avoid ribs of barren schist and gneiss and dikes of pegmatite and granite. The vermiculite-bearing rock crumbles readily; therefore, much undesirable material can be eliminated by screening following gentle crushing, because the barren rock is generally firm. Milling will be necessary, but dry milling may be adequate to produce a usable concentrate.

QUALITY

Among the qualities which influence the usefulness of vermiculite, grain size and bulk weight after expansion are of prime importance. It is desirable that the mica-like flakes expand to 10 or more times their original thickness without crumbling and yield a loose aggregate with a bulk weight of less than 15 pounds per cubic foot. Coarse grain size is preferred for some uses, particularly for house insulation and for use in walls of heaters and coolers. Medium grain size is desirable for aggregate in light-weight plaster, concrete, acoustical plaster, and wallboard. Standard commercial grades of expanded vermiculite have been established by the Vermiculite Institute, an association of American producers and users of vermiculite. Between 30% and 60% of the standard *No. 1* grade vermiculite is retained by a 4-mesh U. S. screen, 65% to 95% by an 8-mesh screen. Between 75% and 95% of the *No. 2* grade is retained by a 16-mesh screen, and at least 75% of the *No. 3* grade by a 50-mesh screen. The central Texas vermiculite, by comparison, is excessively fine grained (table 2). Expanded vermiculite in the U. S. Bureau of Mines composite sample from the Bush deposit is chiefly finer than 28-mesh, and more than half of that in the composite sample from the Smith deposit is finer than 35-mesh (McMillan and Gerhardt, 1949, p. 10). Moreover, some of the vermiculite flakes in weathered schist in the larger Texas deposits are bent or crimped, causing them to break apart readily after expansion. Vermiculite in the Welgehausen deposit does not have this defect, but it also is fine grained. Vermiculite from the veins in soapstone and serpentine is generally superior in size and resilience of flakes, but the deposits are probably too small for significant production.

The determinations of weight of exfoliated vermiculite per cubic foot made by Wheeler (table 2) are 2 to 3 times greater than the bulk weight generally desired in good commercial vermiculite, which suggests that the central Texas vermiculite does not expand properly. Fortunately this is not so; the difficulty lies instead in the methods used for heating and weighing the samples. The heating of the samples was not performed by Wheeler under optimum conditions, but his samples were treated uniformly and the results for different samples which he tested can be compared with each other. Measurement of loose bulk weight is difficult on small samples, for it varies with packing and size and shape of containers. Bulk weight measurements made by Schofield (table 2) and those made by the U. S. Bureau of Mines yielded values comparable to those for standard grades of commercial vermiculite. Expanded Vermiculite in composite samples from the Bush and Smith deposits, for example, weighed 11.1 and 11.3 pounds per cubic foot respectively (McMillan and Gerhardt, 1949, p. 10). Wheeler's weights in table 2 should evidently be divided by 2 to obtain realistic estimates of the probable bulk weight of the vermiculite in the samples when expanded by commercial methods. The chief quality defect of the Texas vermiculite is its small grain size. Commercial exploitation of deposits in the Llano region will depend partly on increased demand for fine-grained vermiculite.

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