

UNITED STATES  
DEPARTMENT OF THE INTERIOR  
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BUREAU OF MINES  
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INFORMATION CIRCULAR

MARKETING VERMICULITE



BY

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UNITED STATES DEPARTMENT OF THE INTERIOR - BUREAU OF MINES

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By G. Richards Gwinn<sup>2/</sup>

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INTRODUCTION

Vermiculites are secondary minerals formed by the alteration of biotite and phlogopite mica and are associated with basic rocks such as dunitic serpentines, and pyroxenites.

Vermiculite was first described by T. H. Webb in 1824. It remained a mineralogical curiosity until 1913, when the first commercial deposit was discovered in the Turrent mining district of Colorado. Expanded or exfoliated vermiculite was first marketed in 1915 from a deposit in this district 5 miles southeast of Hecla, Colo. This activity was brief, but successful and continuous commercial development began in 1921 in Montana. Deposits in other States have been found and developed, but Montana is by far the largest producer. Vermiculite has also been found in South Africa, West

<sup>1/</sup> The Bureau of Mines will welcome reprinting of this paper provided the following footnote acknowledgement is used: "Reprinted from Bureau of Mines Inf. Circ. 7270."

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ustralia, Russia, and Japan. Many varieties of vermiculite have been identified, because chemical composition varies widely. Various names have been assigned to them, but some of the names merely connote the locality in which the specimens were first found or the name of the finder. The commercial importance of vermiculite depends on the degree of exfoliation on rapid heating.

### DESCRIPTION

The vermiculites are hydrated magnesium aluminum silicates formed by hydrothermal alteration of biotite and phlogopite mica. They retain more or less the micaceous cleavage and form soft, pliable, inelastic lamellae. The most pronounced characteristic of vermiculites is their extraordinary expansion upon heating the volume may increase up to 20 times the original. The question whether vermiculites are distinct minerals has puzzled mineralogists for many years, and their aim to be ranked as separate minerals has been doubted, but X-ray studies by Gruner (6)<sup>3/</sup> and Hendricks and Jefferson (7) indicate that they constitute a specific type with a definite structure different from that of mica or chlorite.

From the tabulation of a number of analyses Gruner has shown that their average composition can be represented as  $22\text{MgO} \cdot 5\text{Al}_2\text{O}_3 \cdot 2\text{Fe}_2\text{O}_3 \cdot 22\text{SiO}_2 \cdot 40\text{H}_2\text{O}$ . When heated, they expand, giving off considerable water. This expansion or exfoliation seems to be a mechanical disintegration of larger particles owing to the formation of steam. The increase in volume due to exfoliation varies from 6 to 20 times that of the unexpanded material, with an average of 16. So-called vermiculites containing alkalis (potassium or sodium) to an appreciable extent are probably mixtures of mica, vermiculite, and chlorite, but they retain in varying degree the exfoliating properties of true vermiculites. Seventeen varieties of vermiculite have been identified and listed by Dana, (4) as follows: muscovite, dudgeonite, hallite, jefferisite, kervite, lennillite, lucasite, saconite, painterite, pelhamite, philadelphite, protovermiculite, pyrochlorite, roseite, vaalite, vermiculite, and willcoxite. Commercially valuable deposits of only two of these have been found - vermiculite and jefferisite.

Vermiculites range in color from dark yellowish-brown to light brownish-yellow to green or bronze; hardness, 1.5; specific gravity, 2.30 to 2.80 for the unexpanded material and 0.9 for expanded vermiculite. When heated in an open tube, the color changes to a golden brown, and in

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<sup>3/</sup> Figures in parentheses refer to references in the bibliography at the end of this report.

the closed tube or reducing atmosphere to a silvery hue. The fusion point is 2,462° F. The total water content (free water and water of crystallization) ranges from 4 to 20 percent.

### GEOLOGIC OCCURRENCE AND ORIGIN

Vermiculite is commonly associated with intrusions of ultra basic igneous rocks composed largely of pyroxene or olivine, such as dunites, serpentines, and pyroxenites. It may occur as a zone or envelope of alteration products surrounding the basic intrusion or as irregular veins within the intrusion. Quartz, feldspar, corundum, biotite, and chlorite are typical associated minerals.

In a few places it is found in almost clean or unmixed bodies large enough to mine. A few occurrences have been noted in which vermiculite is not associated with basic rocks, but the quantity of material is not large, and it does not exfoliate on heating.

As vermiculites are secondary minerals resulting from the hydrothermal alteration and weathering of biotite and phlogopite, the composition of the rocks associated with the original minerals (biotite and phlogopite) and the degree of alteration account for the variation in composition of the many varieties.

### HISTORY

Vermiculite was first described by Thomas H. Webb (20) in 1824. He found the mineral in a talc deposit near Worcester, Mass. It is described as follows:

The mass has a brownish cast and is composed of two parts. The one is compact, of a dirty white and yellowish color, constituting the base; the other is in thin plates of a yellowish and blackish cast and resembles mica very much in appearance. When pulverized it seems to consist of a yellowish powder interspersed with small shining laminae. If subjected to the flame of a blowpipe or that of a common lamp it expands and shoots out into a variety of fanciful forms - resembling most generally small worms having the vermicular motion action. The vermiform remnants are composed of small irregular scales, loosely adhering to each other, having a silvery white appearance and metallic luster. If this proves to be a new variety, would it not be better in giving it a distinctive appellation to select one that

will indicate the peculiar property it possesses than to make use of an arbitrary name. I term it vermiculite (worm breeder) from vermicular, to breed or produce worms.

Jefferisite was first found in 1851 by W. W. Jefferis in a serpentine quarry near West Chester, Pa., in a vein about 2 feet wide composed of a silicate of iron and magnesia of a pearly bronze-yellow material (1). A sample was sent to Prof. G. J. Brush, of Yale College, for analysis and identification. He identified it tentatively as a biaxial chlorite member of the hydrous magnesium silicates and thought it was vermiculite because of its exfoliating properties. In 1861, Brush decided that on the basis of its optical properties it was not vermiculite, but a new mineral, since vermiculite at that time was thought to be a uniaxial mineral (although it is now known to be biaxial with a very small axial angle). Brush proposed the name of jefferisite after Wm. W. Jefferis, of West Chester, Pa., the original discoverer (2). The properties of jefferisite, as described by Brush, are: A bronze-yellow material, optically biaxial, with a small axial angle; resembles phlogopite; exfoliates before a spirit lamp and resembles vermiculite; occurs in six-sided prisms with a mica-like structure and basal cleavage; specific gravity, 2.30; hardness, 1.5.

Culsageeite was found in North Carolina in 1873 by Col. C. W. Jencks, manager of the American Corundum Co. mine near the Culsagee River in Macon County. The mineral was described by Dr. F. A. Genth and named after the Culsagee River. Culsageeite, ripidolite, and chlorite are associated as prominent gangue minerals in the corundum deposits of North Carolina and Georgia and were used as guide minerals in prospecting for corundum (5).

Nickeliferous vermiculite has been found in several dunite deposits in North Carolina. The largest showing (and it is not of commercial importance) is in the dunite body at Webster in Jackson County, (12), where nickel-bearing vermiculite occurs in narrow veins in the fractured dunite. It displays a transition of colors from bright green in the nickel veins and the residual red soil of the completely weathered dunite to dark green near the contact with the fresh dunite to dark bronze in the fresh dunite.

#### DOMESTIC DEPOSITS

Vermiculite has been reported in eleven States in the United States, and production has come from seven. The deposits vary considerably in composition, and variations may also occur in single deposits.

Vermiculite in commercial quantities was first discovered in 1913 in Colorado. The deposits are in the Rocky Mountains in Chaffee,

Fremont, Custer, and Gunnison Counties. The first find, which was of the jefferisite variety occurring as a vein 20 inches wide, was made by W. B. Thomas in the Turrett mining district in Chaffee County, 14 miles north of Salida. Because of high operating costs only a small tonnage was produced. Vermiculite was first marketed in 1915 by the Denver Mining & Manufacturing Co. from a deposit discovered in 1913 in the same mining district, about 5 miles southeast of Hecla, Chaffee County. The material was marketed under the trade name "tung ash," and was classified at that time as hydrated biotite mica of a dull brownish-black color. The crystals consist of flexible but inelastic plates, which when heated expand greatly and assume various tints of bronze, (17). Production from this deposit and the other Colorado deposits near Salida, Canon City, Iola, and Westcliffe continued intermittently for the next 10 years.

Continuous production on a commercial scale began in 1921 from deposits in the Rainy Creek district in Lincoln County, Mont., about 7 miles east of Libby. These deposits were discovered by E. N. Alley in 1916 while prospecting for vanadium minerals. The heat from his candle or lamp caused the coarse micalike mineral to swell and assume a golden color, and he called it "feather gold."

The deposits are on the spur north of Kearney Creek in the form of dikes striking N. 20° W. about 100 feet wide and about 2 miles long. Production is confined to pits in the most favorably mineralized zones. Complications are the presence of syenite dikes and zones of biotite incompletely altered to vermiculite. These are the largest known vermiculite deposits in the United States. The main body is on the southeastern side of the spur, and several small bodies occur on the northwestern slope. Alley and a group of associates formed the Zonolite Co., now the University Zonolite Insulation Co., which is by far the major producer and exfoliator of vermiculite in the United States.

Production from eastern deposits was first reported in 1929 from the Brinton Quarry at West Chester, Pa., by the John Warren Watson Co. of Philadelphia. This is the locality where jefferisite was first found. Continuous production in the East began in 1933 from deposits at Ellijay (Macon County) and Swannanoa (Buncombe County), N. C. Deposits have also been found in Avery, Clay, and Jackson Counties. Production in Wyoming, California, Nevada, Colorado, and South Carolina has been small and intermittent, although in the past year production in South Carolina and Colorado has increased considerably.

Production figures for 1924 through 1942 follow. Although commercial production of vermiculite began in 1915, the yearly production was reported as part of the mica total or under the heading "Minerals allied to mica" until 1924.

Screened and cleaned vermiculite sold or used  
in the United States 1924-42

Year	Short tons	Value	Year	Short tons	Value
1924.....	2	\$68	1934.....	4,746	\$56,965
1925.....	102	2,818	1935.....	7,068	88,445
1926.....	150	3,750	1936.....	16,933	185,787
1927.....	51	1,318	1937.....	26,556	260,664
1928.....	1,006	38,118	1938.....	20,700	192,000
1929.....	982	24,483	1939.....	21,174	174,587
1930.....	831	13,682	1940.....	22,299	137,698
1931.....	1,256	24,758	1941.....	23,438	125,444
1932.....	1,643	16,950	1942.....	57,848	319,931
1933.....	2,247	21,993			

Prices of cleaned and screened vermiculite quoted in Metal and Mineral Markets of September 23, 1942, are per short ton f.o.b. mine, \$9.50 in North Carolina and \$12 in Montana. There is about 10 percent loss per ton between the raw material and the exfoliated product. Assuming an average value of \$75 to \$80 a ton for exfoliated and otherwise prepared vermiculite, the value of sales in 1942 would exceed \$4,000,000.

#### FOREIGN DEPOSITS

A mineral that exfoliates when thrown into the fire was mentioned by Raphael Pumpelly in his report of a reconnaissance survey for the Japanese Government in 1865. The material was found in a body of serpentine in the mountains of the Kadzua peninsula south of Yedo (11). Sunashirō Wada, in 1904, described a vermiculite found at Hajikano in the Province of Kai Pr., Japan, known locally as "Hiru-ishi," or leech stone (19). Vermiculite also has been found in the Ural Mountains in Russia, in the Union of South Africa and Tanganyika, Africa; and at Bulong and Kalgoorlie in the southeastern part of Western Australia.

Only the Russian and South African deposits are worked commercially. The Australian deposits are in process of development within the scope of the Australian market.

In Soviet Russia vermiculite is associated with the dunite and pyroxenite intrusions in the Ural Mountains, which are widely known as sources of platinum. Very little is known concerning the size and volume of the vermiculite deposits, but the product is marketed as loose fill and refractory bricks. Small tonnages of low-grade Russian vermiculite have been received in the United States.



Vermiculite has been reported in Tanganyika and the Union of South Africa. It was first reported in the Union from the corundum fields of northern and eastern Transvaal, where it occurs as a thin casing around the corundum reefs. Large deposits were later found in the pyroxenite and serpentine rocks of the Palabora region in north-eastern Transvaal. In this area it seems to have been formed from phlogopite mica, which it closely resembles. It is genetically related to apatite, with which it is closely associated. Production of vermiculite in Africa began in 1938, and though small is increasing, because in addition to supplying the local market there is an export market in Great Britain.

### PREPARATION AND EXFOLIATION

Vermiculite is of little use as mined, its commercial importance depending on its property of exfoliating on rapid heating. The most successful exfoliation is obtained when the material is dry, uniformly sized, and reasonably free of gangue.

#### Preparation

Most of the vermiculite mines in the United States are open pits, and very little blasting is necessary. The vermiculite and gangue as mined is usually sent to a crusher for preliminary separation, from which the oversize gangue goes to the waste pile and the partly crushed and cleaned vermiculite goes to the drier. The percentage of free moisture in crude vermiculite is variable, depending largely on weather conditions. The moisture is removed to facilitate grinding, screening, and sizing. The drier may be of the rotary type or the conical flash type, equipped with baffles. The charge is subjected to a heat of 200° to 300° F for a short time. Care must be exercised to avoid temperatures high enough to disturb the combined moisture content and thereby retard full expansion. From the drier the material passes through hammer mills for separation of the vermiculite and gangue and to break up the large books of vermiculite. The hammer mill discharges to air separators, which produce concentrates, middlings, and a tailings product. The middlings consist mainly of small thick books of vermiculite, which are returned to the hammer mill for further grinding. The separator concentrate passes to jigger screens, which classify it into the five commercial sizes - 1/2-inch to +3-mesh, -3+14, -10+20, -16+24, and fines, which include all sizes that pass through the 24-mesh screen. Screening has the twofold advantage of separating the material into commercial sizes and of providing uniform sizes, assuring rapid and maximum expansion in the exfoliator. When unsized vermiculite is placed in the exfoliator,

he fine material blankets the larger particles, thereby preventing their maximum exfoliation. The sized material is then bagged for shipment to the exfoliating companies, or it passes directly to the exfoliator in integrated plants.

### • • Exfoliation

When vermiculite is brought very quickly to a red heat, it expands to a corklike consistency by the sudden expulsion of the chemically combined water, which has been changed to steam.

The properties desired in the expanded material are light weight, toughness, and complete expansion. The exfoliating properties of vermiculites vary, not only from deposit to deposit but within a single body. Some expand more than others, and the temperature at which expansion begins or reaches its maximum varies, whereas still others decrepitate when expanded. Therefore, considerable fuel or power may be saved if before using material from individual or composite sources the temperature at which the greatest exfoliation occurs while maximum toughness is retained is determined. Thus, materials from various sources may be blended properly.

Exfoliation is produced most successfully at 1,600° to 2,000° F.; the charge is subject to heat 4 to 8 seconds, followed by rapid cooling. Cooling imparts pliability and toughness to the brittle, expanded particles. Heat above the specified range drives out all the combined water in the material and renders it permanently brittle.

Several types of exfoliators are in use, and although they vary in structure, they are similar in principle. One is a modified vertical shaft furnace heated by oil-fired burners. The charge is fed into the top of the furnace and in falling is impeded by staggered baffles and, upon coming in contact with the heat from the burners, exfoliates into the characteristic accordianlike porous granules. The exfoliated material cools rapidly in its fall from the heated zone to a series of oscillating sizing screens. From the screens the sized material is carried through chutes to bins, where it is bagged for marketing. However, the expander, which is in general use, consists of a double-walled cylinder with an air space between the walls. The inner cylinder contains conical baffles that impede the fall of the sized vermiculite, which is charged in at the top of the furnace. The burners may be fired by gas or oil. The air for them has been preheated as it passes through the annular space between the two walls of the cylinder. The expanded material continues its fall from the heated zone to a flight conveyor below, which carries it to the bigger bins. The material cools rapidly in its fall from the hot

zone to the conveyor. Between the conveyor and bins is an air blast, which is regulated to be strong enough to carry the light expanded material to the bins, but against which any unexpanded vermiculite or rock drops to a screen and a chute to the waste pile.

The color of the expanded material ranges from near silver to gold, depending on conditions during expansion. A reducing atmosphere induces the silver color. Because of its light weight and consequent bulk, it is impracticable to ship expanded vermiculite far. Therefore, expanding plants have been established at market centers to process the cleaned and screened material.

### USES

The low specific gravity, comparatively high refractoriness, low thermal conductivity, freedom from deterioration, and a weight of only 6 to 8 pounds per cubic foot make vermiculite suitable for thermal and acoustic insulation. Until recently, this material has been used principally as "loose-fill" insulation for dwellings. However, many new uses have been found, and in 1942 the chief one was as lightweight aggregate in the manufacture of concrete.

In loose, granular form, vermiculite is used extensively as a fill insulation in the walls and roofs of dwellings, industrial buildings, furnaces, ovens, and refrigerators. It is also used in thermal jugs, as filling in life preservers, and as a loose fill in packing shells and bombs. The motion picture industry uses vermiculite to imitate desert sandstorm because it settles slowly and can be kept in the air with a comparatively light artificial wind.

Expanded vermiculite, combined with bonding materials, is fabricated into a wide variety of products, such as pipe covering, insulating blocks, refractory insulating concrete, roof fill, high temperature insulating cements, insulating and acoustical plasters, acoustical tiles, and structural roof slabs.

Vermiculite concrete is an extremely light-weight building material weighing 20 to 40 pounds per cubic foot. It has a compressive strength of 50 to 250 pounds per square inch and a thermal conductivity of 0.60 to 0.80 B.t.u. at 50° to 90° F. It is made like ordinary concrete in which expanded vermiculite of 3- to 20-mesh size is used as aggregate in place of sand, gravel, or stone. It is most commonly used as insulating roof fill, lightweight soundproofing and insulating floor fill, and insulated structural roof deck. Experiments have been completed in which precast

Slabs of vermiculite concrete have been used in erecting prefabricated buses. Cants, saddles, and slopes for roof drainage also may be made from this concrete. When poured around steel girders, vermiculite concrete protects them from buckling if they are exposed to prolonged, intense heat; and, because of its light weight, it greatly reduces the dead weight in building construction. Slabs and blocks of this concrete have been placed on decks and used as fire walls of tankers likely to be subjected to bombing attacks. Also, it has been specified by the Army and Navy for use on roofs of temporary and permanent buildings in defense areas.

Insulating bricks of vermiculite are being used increasingly. They are of two types - lightweight for use where structural strength is not required, and brick that may be used for building purposes. The lightweight type is made expressly to obtain the lowest possible conductivity, even though structural strength is sacrificed. Such bricks are used largely in arches of open-hearth furnaces, where no structural strength is required and where the brick must be used repeatedly. The weight of a standard brick of this type is 24 ounces. Where strength is needed, a binder must be added that increases heat conductivity. It is impossible to combine low heat conductivity with high structural strength. The weight of the standard building brick is 33 ounces. The petroleum industry is using increasing quantities of these structural bricks on the inside walls of cracking units, where they serve as a combination refractory and insulator.

A plastic insulation made with vermiculite is used on the exterior of boilers and refinery columns for heat insulation and on the interior of automobiles and airplanes as a sound-proofing agent.

A British patent (485,512) was taken out in 1938 for a method of reinforcing granules of expanded vermiculite by coating them with liquid or molten carbonaceous material, such as tar, pitch, or asphalt, for use as lightweight aggregate for concrete and as insulating material. It is reported that a South African paint company is using vermiculite to obtain special coloration and metallic effects. An enamel made with processed vermiculite is more resistant to impact than ordinary enamel.

#### PRODUCERS

J. B. Stroud, Inglewood, Calif.  
 Vermiculite Engineering Co., Alexander Film Bldg., Colorado Springs, Colo.  
 Universal Zonolite Insulation Co., 2601 W. 107th Street, Chicago, Ill.  
 Mikolite Co., 1100 South Mill St., Kansas City, Kans.  
 Vermiculite Mining Co., 406 Thorpe Bldg., Minneapolis, Minn.

Vermiculite Corporation, Amber, Nev.  
 Industrial Minerals, Inc., 8 Wall Street, Asheville, N. C.  
 Minerals, Inc., Franklin, N. C.  
 Mrs. B. S. Tipton, Asheville, N. C.  
 George B. Coggins, Travelers Rest, S. C.  
 W. S. Bradley, Greenville, S. C.  
 Mrs. Phoebe Cox, Taylors, S. C.  
 Lewis and Martin Smith, Glenrock, Wyo.

## EXFOLIATING PLANTS

### California:

R. W. Clinger, 2510 Central St., Alameda.  
 Armor Laboratories, Inc., Glendale.  
 Gladding, McBean & Co., 2901 Los Feliz Boulevard, Los Angeles.  
 Hill Brothers Chemical Co., 2159 Bay St., Los Angeles.  
 Mission Lime Products Corporation, 841 Ducommun St., Los Angeles.  
 Standard Insulation Co., 6420 Avalon Boulevard, Los Angeles.

### Colorado:

Gustavis Sessinghaus, Denver.  
 William B. Miller, 633 Copper Building, Denver.  
 Western Vermiculite Co., 1221 12th St., Denver.

### District of Columbia:

Vermiculite Products Corporation, 3100 K St., N. W., Washington, D. C.

### Illinois:

48 Insulating Products Co., Aurora.  
 International Vermiculite Co., Springfield.  
 George B. Smith Chemical Works, Springfield.  
 Universal Zonolite Insulation Co., 2601 West 107th St., Chicago.  
 Utica Hydraulic Cement Co., Utica.  
 F. E. Schundler & Co., Inc., 504 Rail Road St., Joliet.

### Kansas:

Dodson Mfg. Co., 1463 Barwise, Wichita.

7270

Missouri:

Mikolite Co., 1100 South Mill St., Kansas City.

Minnesota:

G. A. McArthur Co., 2387 Hampden Avenue, St. Paul.

B. F. Nelson Mfg. Co., 459 Harding St., Minneapolis.

Western Mineral Products Co., 1720 Madison St., N. E., Minneapolis.

Missouri:

C. B. R. Fitzwilliam & Co., Ltd., 907 Security St., St. Louis.

Zonolite Insulation Co., 5100 Manchester Ave., St. Louis.

Vermiculite Products, Inc., 911 Mulberry St., Kansas City.

Montana:

Robinson Insulation Co., 12 St. North & River Drive, Great Falls.

Nebraska:

Western Mineral Products Co., 2602 E. Creighton Ave., Omaha.

New Jersey:

Munn & Steel, Inc., 130 Lister Ave., Newark.

New Mexico:

Insulation Service Co., 1822 N. First St., Albuquerque.

New York:

Minerals & Insulation Corporation, 141 Spring St., New York City.

North Carolina:

Bee Tree Vermiculite Co., 8 Wall St., Asheville.

Minerals, Inc., Franklin., Ellis C. Soper.

Ohio:

Eagle Picher Lead Co., Cincinnati.

Wyodak Chemical Co., 4600 East 71 St., Cleveland.  
Wyo-Lite Insulating Products, 4600 East 71 St., Cleveland.

Oklahoma:

V. S. Cook Lumber Co., Oklahoma City.

Oregon:

Fir-Tex Insulating Board Co., St. Helene.

Pennsylvania:

Hyzer and Lewellen, Southampton.  
Harbison-Walker Refractories Co., Farmers Bank Bldg., Pittsburgh

Texas:

Mineral Products, National Bank of Commerce Bldg., San Antonio.  
Vermiculite Mines & Industries, Inc., 1004 Frost Bank Bldg.,  
San Antonio.  
Mineral Products, Care of Blue Diamond, 2722 Logan St., Dallas.

Utah:

Intermountain Insulation Co., 333 West First South St., Salt Lake City

Washington:

Asbestos Supply Co., First St. at Jackson St., Seattle.  
Asbestos Supply Co., South 10 Bernard St., Spokane

Wyoming:

J. B. C. Mining Co., Wheatland.

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