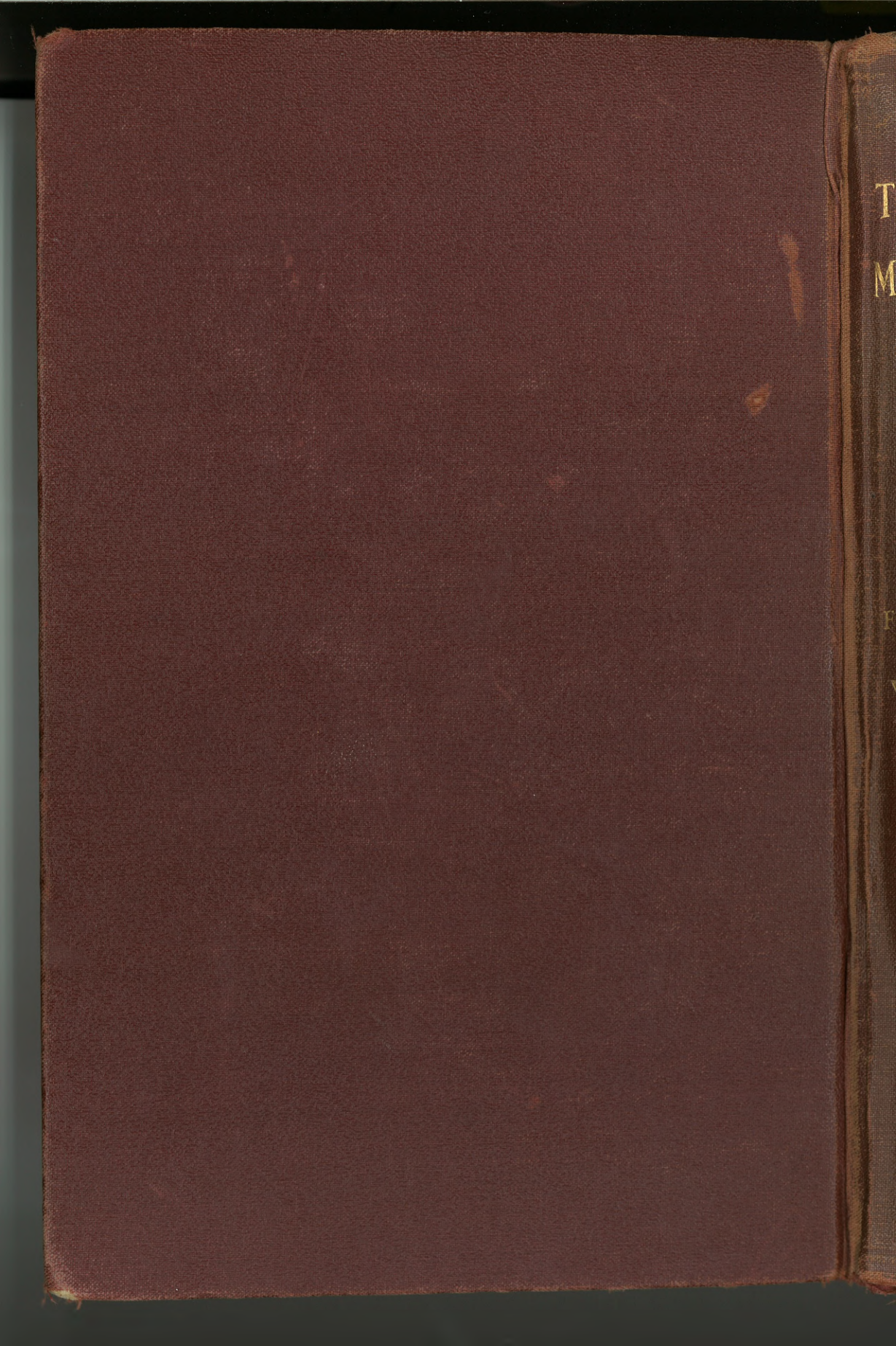




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FOURTH EDITION

By
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FOURTH EDITION, REVISED AND ENLARGED

BY
WILLIAM E. FORD
*Professor of Mineralogy and Curator of the Mineral Collections,
Sheffield Scientific School of Yale University*

F. EYOLF BRONNER

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PREFACE TO THE FOURTH EDITION

It is only a little over ten years since the third edition of this book was published. This period, however, has been one of such active mineralogical investigation that a new edition seemed desirable. The fourth edition, therefore, endeavors to present the important facts of the science as known on January 1, 1932. The changes in the book are essentially as follows: In Part I on Crystallography a section of some seventeen pages has been added on crystal structure and the methods of its investigation by means of X-rays. The remainder of this section remains substantially unchanged. Parts II and III on Physical and Chemical Mineralogy have been revised but have had only minor additions. Part IV on the Origin, Mode of Occurrence and Association of Minerals is new to this book. Part V has been entirely revised. Descriptions of about two hundred and twenty new species have been added. The attempt has been made to give a brief but complete statement of the important facts now known about all well-defined mineral species. In addition brief mention is made of doubtful species or those which have recently been discredited. It is realized that such a complete treatment of the subject would not normally have its place in a book of this character. At the present time, however, there is no book available that gives such a survey of the subject and until such a book is at hand it is thought that the inclusion here of brief descriptions of all known minerals will be of value. As far as possible simple statements of the results of the investigation of mineral structure by means of X-rays have been included in the mineral descriptions. The paragraphs on occurrence have been largely rewritten. In the case of the commoner minerals a careful selection of the localities of their occurrence has been made in order to give only those of most importance either from a scientific or economic point of view. In the case of rarer species all known localities have been mentioned. As far as possible the locality names have been checked, the spelling used by the *Times Atlas* having been followed in most instances. In the case of the south-central European countries, alternative names for the same place have been frequently given.

The mineral data presented have been gathered from the periodical literature, etc., and from many texts. Among the books which have been of particular value are the following: Doelter's *Handbuch der Mineralchemie*, Hintze's *Handbuch der Mineralogie*, *Lehrbuch der Mineralogie* by Niggli, *Mineralogy* by Miers-Bowman, and especially Winchell's *Elements of Optical Mineralogy* and Larsen's *Microscopic Determination of the Nonopaque Minerals*. The editor is also indebted to Professor Esper S. Larsen for the privilege of consulting the manuscript of the new edition of the last-named work. He also acknowledges gratefully many valuable suggestions made by Professor Charles Palache.

WILLIAM E. FORD

NEW HAVEN, CONN., *March 1, 1932*

Microscopic examination has established the fact that serpentine in rock-masses has been largely produced by the alteration of chrysolite, and many apparently homogeneous serpentines show more or less of this original mineral. In other cases it has resulted from the alteration of pyroxene or amphibole. Sections of the serpentine derived from chrysolite often show a peculiar structure, like the meshes of a net (Fig. 997); the lines marked by grains of magnetite also follow the original cracks and cleavage directions of the chrysolite (Fig. 998, a). The serpentine from amphibole and pyroxene commonly shows an analogous structure; the iron particles following the former cleavage lines. Hence the nature of the original mineral can often be inferred. Cf. Fig. 998, a, b, c (Pirsson).

Comp. — A magnesium silicate, $H_4Mg_3Si_2O_9$ or $3MgO \cdot 2SiO_2 \cdot 2H_2O =$ Silica 44.1, magnesia 43.0, water 12.9 = 100. Iron protoxide often replaces a small part of the magnesium; nickel in small amount is sometimes present. The water is chiefly expelled at a red heat.

For chemical relations to the minerals of the Chlorite Group, see p. 668.

Pyr., etc. — In the closed tube yields water. B.B. fuses on the edges with difficulty. F. = 6. Gives usually an iron reaction. Decomposed by hydrochloric and sulphuric acids. From chrysotile the silica is left in fine fibers.

Diff. — Characterized by softness, absence of cleavage and feeble waxy or oily luster; low specific gravity; by yielding much water B.B.

Micro. — Readily recognized in thin sections by its greenish or yellowish green color; low relief and aggregate polarization due to its fibrous structure. When the fibers are parallel, the interference-colors are not very low, but the confused aggregates may show the "ultra blue" or even be isotropic. The constant association with other magnesia bearing minerals like chrysolite, pyroxene, hornblende, etc., is also characteristic. The presence of lines of iron oxide particles as noted above (Fig. 998) is characteristic.

Obs. — Serpentine is always a secondary mineral resulting, as noted above, from the alteration of non-aluminous silicates containing magnesia, particularly chrysolite, amphibole or pyroxene; more rarely from monticellite, chondrodite, vesuvianite, garnet, talc, etc. It may occur as a replacement of the original mineral, forming a pseudomorph, or it may be deposited elsewhere in the rock openings or as replacing some other mineral. It frequently forms large rock-masses, then being derived from the alteration of peridotites, dunites and other basic rocks of igneous origin; also of amphibolites or other similar metamorphic rocks which may have had a sedimentary origin. In the first case it is usually accompanied by spinel, garnet, chromite and sometimes nickel ores; in the second case by various carbonates such as dolomite, magnesite, breunnerite, etc. Serpentine is a mineral which occurs commonly, though rarely in masses of great size. In the metamorphic rocks it is commonly found as layers, lenticular bodies, etc.

Serpentine is so common a mineral and so widespread in its occurrence that only its most important and interesting localities can be mentioned here. In Saxony, massive ornamental material comes from Zöblitz; and the variety *metaxite* from Schwarzenberg; in Silesia at Reichenstein *picrolite* and *chrysotile*. A variety containing soda from the Zillertal, Tyrol, Austria, is called *nemaphyllite*. In Italy pseudomorphs after monticellite occur in the Val di Fassa, Trentino; the variety *antigorite* was originally described from Valle Antigorio, Piedmont. In Switzerland various types of serpentine are found near Zermatt, in Valais. *Thermophyllite* is found in Finland at Hoponsuo. In crystals pseudomorphic after chrysotile from Snarum in Buskerud, Norway. Fine serpentine from the Lizard, Cornwall. Asbestos occurs in the Transvaal in the Barberton district and at various points in Australia.

In the United States fine at Newburyport, Essex Co., Massachusetts. In Rhode Island *bowenite* at Smithfield, Providence Co. In New York from the Tilly Foster mine near Brewster, Putnam Co., pseudomorphic after chondrodite, also in cube-like cleavage forms, presumably pseudomorphous after some unknown mineral; in St. Lawrence Co., at Somerville and elsewhere. In New Jersey *marmolite*, etc., at Hoboken, associated with brucite, magnesite, etc.; at Montville, Morris Co., *chrysotile* and *retinakite* with common serpentine; in Sussex Co., at Vernon and Franklin. In Pennsylvania, at Easton, Northampton Co., pseudomorphous after pyroxene and amphibole; massive, fibrous and foliated of various colors at Texas, Lancaster Co.; at West Chester, Chester Co., *williamsite*; at Bare Hills near Baltimore in Maryland (*baltimorite*). Asbestos is found in Arizona from near Globe, Gila Co., from the Sierra Ancha, and the Grand Canyon.

In Canada abundant among the metamorphic rocks of Quebec between the Vermont boundary and Gaspé Co., at Danville, Richmond Co.; Thetford in Megantic Co.; Brough-

ton in Beauce Co., etc.; in Ottawa Co., at Templeton. The asbestos often forms seams several inches in thickness in the massive mineral and has been extensively mined.

The names *Serpentine*, *Ophite*, *Lapis colubrinus*, allude to the green serpent-like cloudings of the serpentine marble. *Retinalite* is from *ρετινή*, resin; *Picrolite*, from *πικρός*, bitter, in allusion to the magnesia (or bittererde) present; *Thermophyllite*, from *θερμή*, heat, and *φυλλον*, leaf, on account of the exfoliation when heated; *Chrysotile*, from *χρυσός*, golden, and *τίλος*, fibrous; *Metarite*, from *μέταξα*, silk; *Marmolite*, from *μαρμαίρω*, to shine, in allusion to its peculiar luster.

Use. — As an ornamental stone; the fibrous variety furnishes the greater part of the heat insulating material known as asbestos.

Deweylite. — A magnesian silicate near serpentine but with more water. Formula perhaps $4\text{MgO} \cdot 3\text{SiO}_2 \cdot 6\text{H}_2\text{O}$. Amorphous, resembling gum arabic, or a resin. Microscopically fibrous. $H. = 2-3.5$. $G. = 2.0-2.2$. Color whitish, yellowish, reddish, brownish. Index, 1.55. Z parallel to fibers. Deweylite is usually found with serpentine as one of its decomposition products and commonly encloses a carbonate. It occurs as pseudomorphs after talc, etc. It occurs with serpentine at Kuttenberg in Bohemia of Czechoslovakia. From near Kraubat in the Mürztal in Styria, Austria, including the bright red variety called *eisengymnite*. With serpentine from the Val di Fiemme, Trentino, Italy; in granular limestone at Passau, Bavaria. In the United States it occurs at Middlefield, Hampshire Co., Massachusetts; in Pennsylvania at Texas, Lancaster Co., also in Berks, Chester, and Delaware counties. *Gymnite*, named from *γυμνός*, naked, in allusion to the locality at Bare Hills, Maryland, is the same species.

Genthite. Nickel Gymnite. — A gymnite with part of the magnesium replaced by nickel, $2\text{NiO} \cdot 2\text{MgO} \cdot 3\text{SiO}_2 \cdot 6\text{H}_2\text{O}$. Probably should be included as a variety of garnierite. Amorphous, with a delicate stalactitic surface, incrusting. $H. = 3-4$; sometimes very soft. $G. = 2.409$. Luster resinous. Color pale apple-green, or yellowish. From Texas, Lancaster Co., Pennsylvania, in thin crusts on chromite. Also reported from near Prägraten in the Austrian Tyrol; from near Malaga, Spain; and on Michipicoten Island in Lake Superior, Ontario.

Garnierite. Noumeite. — An important ore of nickel, consisting essentially of a hydrated silicate of magnesium and nickel, perhaps $\text{H}_2(\text{Ni}, \text{Mg})\text{SiO}_4$ + water, but very variable in composition, particularly as regards the nickel and magnesium; not always homogeneous. Amorphous. Soft and friable. $G. = 2.3-2.8$. Luster dull. Color bright apple-green, pale green to nearly white. Index, 1.59. In part unctuous; sometimes adheres to the tongue. Occurs in serpentine rock near Noumea, capital of New Caledonia, associated with chromic iron and steatite, where it is extensively mined. A similar ore occurs at Riddle in Douglas County, southern Oregon; also at Webster, Jackson Co., North Carolina. Reported also from the Transvaal in South Africa and from Madagascar. A nickel silicate found in peat in the Ural Mts. has been called *kerzinite*.

Nepouite. $3(\text{Ni}, \text{Mg})\text{O} \cdot 2\text{SiO}_2 \cdot 2\text{H}_2\text{O}$. Monoclinic. In microscopic crystal plates with hexagonal outline. Good cleavages; $\parallel (001)$ and (010) . $H. = 2-2.5$. $G. = 2.5-3.2$. Color pale to deep green. Optically —. Ax. pl. $\parallel (010)$. $X \perp (001)$. $2V$ very small. Indices vary with nickel content; 1.53–1.63. Occurs in the nickel deposits at Nepoui and elsewhere in New Caledonia.

Connarite. — A hydrous nickel silicate, perhaps $\text{H}_4\text{Ni}_2\text{Si}_3\text{O}_{10}$. Hexagonal. In small fragile grains. Perfect cleavage (0001). $H. = 2.5-3$. $G. = 2.5$. Color yellowish green. Optically —. $\omega = 1.59$, $\epsilon = 1.56$. From Röttis, north of Plauen in Saxony.

MAUFITE. Essentially an aluminum, nickel silicate, perhaps $(\text{Mg}, \text{Ni}, \text{Fe})\text{O} \cdot 2\text{Al}_2\text{O}_3 \cdot 3\text{SiO}_2 \cdot 4\text{H}_2\text{O}$. In fibrous-like sheaves. Emerald-green color. $H. = 3$. $G. = 2.27$. Found in a small seam in serpentine near Umvukwe Geodetic Station, Umvukwe Mts., southern Rhodesia.

TALC.

Orthorhombic or monoclinic. Rarely in tabular crystals, hexagonal or rhombic with prismatic angle of 60° . Usually foliated massive; sometimes in globular and stellated groups; also granular massive, coarse or fine; fibrous (pseudomorphous); also compact or cryptocrystalline.

Cleavage: basal, perfect. Sectile. Flexible in thin laminæ, but not elastic. Percussion-figure a six-rayed star, as with the micas. Feel greasy. $H. = 1-1.5$. $G. = 2.7-2.8$. Luster pearly on cleavage surface. Color

apple-green to white, or silvery white; also greenish gray and dark green; sometimes bright green perpendicular to cleavage surface, and brown and less translucent at right angles to this direction; brownish to blackish green and reddish when impure. Streak usually white; of dark green varieties lighter than the color. Subtransparent to translucent. Optically negative. Ax. pl. $\parallel a(100)$. $X \perp c(001)$. Axial angle small, variable. Indices approx.; $\alpha = 1.539$. $\beta = 1.589$. $\gamma = 1.589$.

Var. — Foliated, Talc. Consists of folia, usually easily separated, having a greasy feel, and presenting ordinarily light green, greenish white, and white colors. $G. = 2.55-2.78$.

Massive, Steatite or Soapstone. *a.* Coarse granular, grayish green, and brownish gray in color; $H. = 1-2.5$. *Pot-stone* is ordinary soapstone, more or less impure. *b.* Fine granular or cryptocrystalline, and soft enough to be used as chalk; as the *French chalk*, which is milk-white with a pearly luster. *c.* **Indurated talc.** An impure slaty talc, harder than ordinary talc.

Pseudomorphous. *a.* Fibrous, fine to coarse, altered from enstatite and tremolite. *b.* **Rensselaerite**, having the form of pyroxene from northern New York and Canada.

A peculiar form of clay which swells when wet, found at the Hacienda Santa Lucia near Mexico City, Mexico, and which corresponds in composition to a hydrated talc has been called *lucianite*.

Comp. — An acid metasilicate of magnesium, $H_2Mg_3(SiO_3)_4$ or $H_2O \cdot 3MgO \cdot 4SiO_2 =$ Silica 63.5, magnesia 31.7, water 4.8 = 100. One-half the water is lost below dull red heat; the remainder goes off rapidly at about $900^\circ C$. Nickel is sometimes present in small amount.

Talc shows variations in composition, especially in the water content. A part of the water can be driven off by heat without any change in the crystalline or optical characters, suggesting that some of the water present is out of the crystal structure.

Pyr., etc. — In the closed tube B.B., when intensely ignited, most varieties yield water. In the platinum forceps whitens, exfoliates, and fuses with difficulty on the thin edges to a white enamel. Moistened with cobalt solution, assumes on ignition a pale red color. Not decomposed by acids. Rensselaerite is decomposed by concentrated sulphuric acid.

Diff. — Characterized by extreme softness, soapy feel; common foliated structure; pearly luster; it is flexible but inelastic. Yields water only on intense ignition.

Obs. — Talc or steatite is a very common mineral of secondary origin, and in the form of steatite constitutes extensive beds in some regions. It is often associated with serpentine, talcose or chloritic schist, and dolomite, and frequently contains crystals of dolomite, breunnerite, also asbestos, actinolite, tourmaline, magnetite. It has been formed by the alteration of non-aluminous magnesian silicates, like chrysolite, hypersthene, pyroxene, amphibole, etc. It is very common in pseudomorphs; see above.

Only a few of the most important localities for the occurrence of talc are given. Apple-green talc occurs at Mt. Greiner in the Zillertal, Austrian Tyrol; in Switzerland at St. Gotthard in Ticino and at Fiesch, etc., in Valais. Steatite comes from Göpfersgrün near Wunsiedel, Bavaria. From near Lizard Head in Cornwall with serpentine; from the Shetland Islands. In the Transvaal in the Barberton district. Steatite occurs in large amounts in India and China.

In the United States at various points in Vermont, New Hampshire, and Massachusetts. From Smithfield, Providence Co., Rhode Island; in New York at Edwards a fine fibrous talc (*agalite*); and elsewhere in St. Lawrence Co.; the so-called *rensselaerite* is common in northern New York. In Pennsylvania in Chester, Delaware, and Lancaster counties. In Maryland at Cooptown, Harford Co., with green, blue, and rose colors. Steatite occurs in Cherokee Co., North Carolina. In Canada talc and steatite are found in Brome Co., and elsewhere in Quebec and in Hastings Co., etc., in Ontario.

Use. — In the form of soapstone used for wash tubs, sinks, table tops, switchboards, hearth stones, furnace linings, etc.; the tips of gas burners, tailors' chalk, slate pencils, carved ornaments, etc.; in powdered form as filler in papers, as a lubricant, in toilet powders, etc.

GAVITE is apparently a variety of talc, differing in the amount of water present and in its solubility in acids. From Gava valley, Italy, occurring as a coating on garnet, chlorite, titanite, etc.

SEPIOLITE. Meerschaum.

Compact, with a smooth feel, and fine earthy texture, or clay-like. Microscopically is shown to be a mixture of fine fibrous material and an amorphous substance of apparently the same composition. The mixture forms the variety *meerschaum*. The fibrous mineral has been called α -*sepiolite* or *parasepiolite*; the amorphous material has been called β -*sepiolite*. $H. = 2-2.5$. $G. = 2$. Impressible by the finger nail. In dry masses floats on water. Color grayish white, white, or with a faint yellowish or reddish tinge, bluish green. Opaque. Biaxial, —. Indices, $1.52-1.53$. $2V$ usually very small. *Parasepiolite* has a lower refraction index ($\beta = 1.506$), $2V = 50^\circ$.

Comp. — $H_4Mg_2Si_3O_{10}$ or $2H_2O \cdot 2MgO \cdot 3SiO_2 =$ Silica 60.8, magnesia 27.1, water 12.1 = 100. Some analyses show more water, which is probably to be regarded as hygroscopic. Copper and nickel may replace part of the magnesium.

Pyr., etc. — In the closed tube yields first hygroscopic moisture, and at a higher temperature gives much water and a burnt smell. B.B. some varieties blacken, then burn white, and fuse with difficulty on the thin edges. With cobalt solution a pink color on ignition. Decomposed by hydrochloric acid with separation of silica. *Parasepiolite* gelatinizes with acid.

Obs. — Commonly found as a secondary mineral in connection with serpentine; also with magnesite and at times with opal. Occurs in Asia Minor, in masses in stratified earthy or alluvial deposits near Eski Shehr associated with magnesite. It is also found at Thebes in Boeotia, Greece, with opal and derived from serpentine. In Moravia of Czechoslovakia at Hrubšütz on the Iglawa north of Kronau. Formerly obtained from Morocco where it was used in place of soap and known as *Pierre de savon de Maroc*. In Spain at Vallecás southeast of Madrid. Found in the United States in Chester and Delaware counties, Pennsylvania; in New Mexico near Sapella, San Miguel Co., and in Grant Co.

A fibrous mineral, having the composition of sepiolite, occurs in Utah. The word *meerschaum* is German for *sea-froth*, and alludes to its lightness and color. *Sepiolite* is from *σῆπια*, *cuttlefish*, the bone of which is light and porous.

Spadaite. — Perhaps $MgSiO_3 \cdot H_2O$. Massive, amorphous. $H. = 2.5$. Fusible at 4. Color reddish. Optically —. Indices, $1.51-1.53$. $2V$ small. From Capo di Bove, near Rome, Italy. Noted at Gold Hill, Nevada.

SAPONITE. Piotine.

Monoclinic or orthorhombic. Commonly massive. In nodules, or filling cavities. Soft, like butter or cheese, but brittle on drying. $G. = 2.24-2.30$. Luster greasy. Color white, yellowish, grayish green, bluish, reddish. Does not adhere to the tongue. Biaxial, —. $X \perp$ to a cleavage; $Z \parallel$ elongation. $\alpha = 1.479-1.490$, $\beta = 1.510-1.525$, $\gamma = 1.511-1.527$. $2V$ small (optical description of material from Michigan).

Comp. — A hydrous silicate of magnesium and aluminum; the mineral is usually amorphous and impure. Material from Michigan gave: $9MgO \cdot Al_2O_3 \cdot 10SiO_2 \cdot 15-16H_2O$.

Pyr., etc. — B.B. gives out water very readily and blackens; thin splinters fuse with difficulty on the edge. Decomposed by sulphuric acid.

Obs. — Saponite characteristically occurs in the amygdaloidal openings of basic eruptive rocks, associated with calcite, zeolites, etc. It is commonly one of the last minerals to crystallize and apparently has been formed through the alteration of some magnesium silicate. Occurs at Lizard Head in Cornwall, in veins in serpentine; at various localities in Scotland; *bowlingite* is from near Bowling in Dumbarton, and *cathkinite* from the Cathkin Hills, near Glasgow. In Sweden at Svärdsjö in Kopparberg northeast of Falun (*piotine* and *saponite*). In the United States it occurs with the copper deposits of Keweenaw Peninsula, Michigan, and in Minnesota in amygdaloid on the north shore of Lake Superior (*thulite*), and in the Thunder Bay district of Ontario, Canada. Also occurs on St. George Island off the north shore of Prince Edward Island.