

**The Clay Minerals Society Glossary of Clay Science, 2020 version**  
**Part 2. Natural Clay-Related Materials**

**achlusite** a poorly defined material, possibly sodium mica

**adamsite** an obsolete term for muscovite

**adularia** see alkali feldspar

**agalite** an obsolete, local term for a fibrous talc from New York State, USA; or for pyrophyllite from China (also obsolete)

**agalmatolite** an obsolete term for pyrophyllite or a mixture with dominant pyrophyllite

**albite** see feldspar, alkali feldspars

**aliettite** a regularly ordered interstratification of a talc-like layer and trioctahedral smectite-like layer in a ratio of 1:1 (Veniale and van der Marel, 1969; Bailey, 1981). *Cf.*, interstratification

**alkali feldspar** Alkali feldspars represent a subgroup of feldspar minerals occurring in the solid solution series between albite [Ab: Na(Si<sub>3</sub>Al)O<sub>8</sub>] and orthoclase [Or: K(Si<sub>3</sub>Al)O<sub>8</sub>] end members. The series includes minerals of albite, sanidine (a high-temperature monoclinic polymorph of K-rich feldspar with disordered Al-Si distributions, occurs in lava flows), microcline (triclinic polymorph of K-rich feldspar, may be referred to as low, intermediate and high for variations in temperature of occurrence, and “maximum” with ordered Al-Si distributions), adularia (a K-rich feldspar with monoclinic and triclinic domains formed from partial Al-Si order states, often designated as a varietal name, occurs hydrothermally, in pegmatites and under diagenetic conditions), and orthoclase (a K-rich feldspar with an intermediate Al-Si ordering state, occurs in small plutons at moderate depths). The boundary between albite and sanidine is at ~Or<sub>40</sub> (i.e., ~40 mole % of K-rich feldspar) and this region between Ab<sub>90</sub> to ~Or<sub>40</sub> (with <10 mole % of anorthite component) is also defined as “anorthoclase”. *Cf.*, feldspar

**allevardite** obsolete name replaced by rectorite, see rectorite

**allophane** a semiordered hydrous aluminosilicate, Al<sub>2</sub>O<sub>3</sub>(SiO<sub>2</sub>)<sub>1.3-2.0</sub>2.5-3.0(H<sub>2</sub>O), that is closely related to imogolite because both seem to be incipient 1:1 minerals structurally and chemically, although it has been suggested that allophane may be an incipient montmorillonite. The ratio of SiO<sub>2</sub> to Al<sub>2</sub>O<sub>3</sub> is usually 1.3 to 2.0 for allophane, but has been reported as low as 0.83, a greater variation than in imogolite. Allophane shows curved walls with a more spherical morphology (30 - 50 Å spherical diameters) than imogolite, which is tube-like. Allophane is common in soils derived from volcanic ash, but may be present in soils derived from basic igneous rocks in tropical climates or in podzol soils derived from more acidic rocks. Allophane may precipitate in

hot springs rich in silicic acid and aluminum. Allophane is white or colorless when moist, but earthy when dried. *Syn.*, disordered allophane, *Cf.*, imogolite

**aluminoceladonite** a dioctahedral member of the true mica group. The end-member formula is  $\text{KAl}(\text{Mg}, \text{Fe}^{3+})\square\text{Si}_4\text{O}_{10}(\text{OH})_2$ , where  $\square$  = vacancy. Typical range in composition is:  ${}^{\text{vi}}\text{R}^{2+}/({}^{\text{vi}}\text{R}^{2+} + {}^{\text{vi}}\text{R}^{3+}) \geq 0.25$ ,  ${}^{\text{vi}}\text{Al}/({}^{\text{vi}}\text{Al} + {}^{\text{vi}}\text{Fe}^{3+}) = 0.5 - 1.0$ ,  $\text{Mg}/(\text{Mg} + {}^{\text{vi}}\text{Fe}^{2+}) > 0.5$  (Rieder et al., 1998).

**alurgite** an obsolete varietal term for manganoan muscovite and manganoan illite

**alushtite** known only in the Russian literature and not an official mineral name; the accepted name is tosudite

**amesite** a (trioctahedral) platy serpentine mineral of ideal composition of  $\text{Mg}_2\text{Al}(\text{Si}, \text{Al})\text{O}_5(\text{OH})_4$ .  $\text{Fe}^{2+}$ , Mn, Cr, Ni, and vacancies may substitute for Mg and  ${}^{\text{vi}}\text{Al}$  in natural samples. Natural occurrences are rare and have been noted from the Saranovskoye chrome deposit, North Urals Mountains, Russia; Chester, Massachusetts, USA; Mount Sobotka, Poland; Postmasburg, South Africa; Lake Asbestos Mine, Black Lake, Quebec, Canada; and Antarctica. The Quebec occurrence involves a rodingitized granite within a serpentized peridotite. Stacking disorder is common but, where regular layer stacking occurs, it is most often based on a distorted  $2H_2$  layer sequence (space group  $C1$ ). *Cf.*, kellyite, zinalsite.

**ammochrysos** an obsolete term for muscovite

**ammonium muscovite** an obsolete term for tobelite

**ammonium hydromica** an obsolete term for tobelite

**amphilogite** an obsolete term for muscovite

**anandite** a trioctahedral member of the brittle mica group. The end-member formula is:  $\text{BaFe}^{2+}_3(\text{Fe}^{3+}\text{Si}_3)\text{O}_{10}\text{S}, \text{OH}$ . Typical site substitutions include:  $\text{Ba} > \text{K}, \text{Na}$ ; Mg,  $\text{Fe}^{3+}$ , Mn, Al for  $\text{Fe}^{2+}$ ; and  $\text{S} > \text{OH}, \text{Cl}, \text{F}$ . Anandite occurs in a banded magnetite-barite-sulfide ore within meta-sedimentary granulite facies at the Wilagedera iron ore prospect, North Western Province, Sri Lanka, and it has been reported at Rush Creek and Big Creek, Fresno County, California, USA, and Sterling Hill, New Jersey, USA, although the latter occurrences are in doubt because of the lack of structural S, a requirement for the species (Bujnowski et al., 2009). Anandite occurs as  $2O$  and  $2M_1$  polytypes, and a  $2M$  polytype based on a  $1M$  stacking sub-structure.

**anauxite** a discredited term for kaolinite

**andesine** see plagioclase feldspar

**ankangite** a discredited manganese oxide mineral better described by the H<sub>2</sub>O-free variety of mannardite, see hollandite

**annite** a trioctahedral member of the true mica group. The ideal end-member formula is  $\text{KFe}^{2+}_3\text{AlSi}_3\text{O}_{10}(\text{OH})_2$ . The ideal end-member composition is unlikely to occur because of tetrahedral-octahedral misfit (the inability of the tetrahedral sheet to link with the octahedral sheet at certain compositions), with at least 10 %  $\text{Fe}^{3+}$  required to minimize misfit. Annite occurs in granites, granitic pegmatites, greisens, and some alkalic (syenite) rocks. Annite forms most commonly in the 1M polytype and belongs to the collective name “dark” mica. *Cf.*, biotite

**anomite** an obsolete term for biotite

**anorthite** see feldspar, plagioclase feldspar

**anorthoclase** see alkali feldspar

**antigorite** a platy serpentine with lath-like characteristics. Diffraction studies have shown an atomic superstructure arrangement approximately along the [100] direction. The origin of the superstructure is the tetrahedral repeat unit involving tetrahedral reversals in + or - directions along the *c* axis to form a wave-like structure. Antigorite structures have been shown by single-crystal X-ray diffraction to have, for example, a wave structure involving a tetrahedral repeat of 17 and one with two waves of tetrahedral repeats of 16, although other wavelengths are possible (from 12 to 21). For the 17 tetrahedral repeat, there is a half-wave width of 8 tetrahedra and 9 tetrahedra (Capitani and Mellini, 2004). At one reversal in each unit cell, there are 4- and 8-fold tetrahedral rings, but only 6-fold tetrahedral rings at the other reversal. Between reversal points, the tetrahedral rings are 6-fold. The generalized formula is ideally:  $M_{3m-3}T_{2m}O_{5m}(\text{OH})_{4m-6}$  where *M* = six-coordinated cations, *T* = Si, Al, and *m* = tetrahedral repeat along the superstructure direction, usually the [100]. *M* is predominantly Mg, but may have Fe (mostly  $\text{Fe}^{2+}$ ), Ni, Cr, and Al. Because each superstructure type affects the composition, these forms are not *sensu stricto* polymorphs of each other or between lizardite and chrysotile. Each half wave has a curvature, either concave up (+ *c* axis) or concave down (- *c* axis). The interlayer in an ideal serpentine is occupied by hydrogen bonds, which link adjacent 1:1 layers. In antigorite, linkage across this region is by tetrahedra, and polytypism cannot describe the stacking structure. For *m* = 17, the space group symmetry is *Pm*, for *m* = 16, the space group is *C2/m*. Antigorite is commonly found in igneous or metamorphic serpentinites. Serpentine rock is mostly comprised of antigorite and lizardite. *Cf.*, carlosturanite, chrysotile, lizardite

**antrophyllite** a poorly defined material, possibly a mica

**aphrosiderite** an obsolete term for chlorite filling cavities in igneous rocks, possibly chamosite

**armbrusterite** a modulated 2:1 layer silicate with a continuous octahedral sheet containing Mn and Na and tetrahedral sheets having 5-, 6-, 7-, and 8-fold tetrahedral rings (Yakovenchuk et al.,

2007). One symmetry-unique Si tetrahedron is inverted relative to the others in the sheet and this tetrahedron links two adjacent tetrahedral sheets. The other tetrahedra link to the octahedral sheets. The ideal chemical composition is  $K_5Na_6Mn^{3+}Mn^{2+}_{14}(Si_9O_{22})_4(OH)_{10} \cdot 4H_2O$ .

Armbrusterite is found in the Khibiny alkaline massif, Kola Peninsula, Russia. *Cf.*, bementite, parsettensite, pyrosmalite, innsbruckite, varennite

**asbestos** see Part 1 of Glossary

**aspidolite** a trioctahedral member of the true mica group. The end-member formula is  $NaMg_3AlSi_3O_{10}(OH)_2$  and it occurs most commonly as the 1*M* polytype. Aspidolite is rare and can occur in meta-evaporates, in chromite sequences of mafic/ultramafic layered intrusions, gabbroic xenoliths, and metapelites. In older literature, aspidolite is referred to as sodium phlogopite (a term now considered obsolete).

**astrolite** an obsolete term for muscovite

**astrophyllite** see astrophyllite group

**astrophyllite group** The general formula (as given by Sokolova and Hawthorne, 2016) for the astrophyllite group minerals is  $A_{2p}B_rC_7D_2(T_4O_{12})_2[X^{OD2}X^{OA4}X^{PDn}W_{A2}]$  where *C* represents cations at the *M*(1-4) sites in the O sheet and are commonly  $Fe^{2+}$ , Mn, Na, Mg, Zn,  $Fe^{3+}$ , Ca, Zr, Li; *D* represents cations in the *H* sheet and are either in 6 or 5 coordination and are Ti, Nb, Zr,  $Sn^{4+}$ ,  $Fe^{3+}$ , Mg, Al; *T* = Si, Al;  $A_{2p}B_rW_{A2}$  (I block) with *p* = 1, 2; *r* = 1, 2; *A* = K, Rb, Cs, Ba,  $H_2O$ , Li,  $Pb^{2+}$ , Na, □ where □ = vacancy; *B* = Na, Ca, Ba,  $H_2O$ , □;  $X^o$  refers to anions in the O sheet not bonded to *T* sites,  $X^{OD}$  = oxygen anions in common at the 3*M* and *D* vertices;  $X^{OA}$  = OH, F anions at the common vertices of 3*M* polyhedra;  $X^{PD}$  = F, O, OH,  $H_2O$ , □, apical anions of *D* cations at the edges of the *HOH* block;  $W_A$  =  $H_2O$ , □; and for  $X^{PDn}$ , *n* = 0, 1, 2.

The astrophyllite group minerals form 2:1 phyllosilicate-type structures with portions of the structure described as *HOH* (analogous to *TOT* in 2:1 phyllosilicates) with  $T_4O_{12}$  ribbons comprising the *H* (heterogeneous, *hetero*- meaning “extra”) sheet. Alternating with *HOH* blocks are intermediate (I) blocks along the *c* axis. Sokolova and Hawthorne (2016) described the astrophyllite group as a “supergroup” with three divisions (groups): the astrophyllite group, the kupletskite group and the devitoite group. *HOH* blocks may link directly (as in astrophyllite group, with  $Fe^{2+}$  dominant) or do not link (as in devitoite group) or direct linkage with  $Mn^{2+}$  dominant (as in kupletskite group). The linkages involve “bridges” of D- $X^{PD}$ -D. These titanosilicates have similar *a* axial lengths to phyllosilicates (both near 5.4 Å) and *d*(001) values (~10.9 Å, although somewhat variable vs 10.0 Å in 2:1 phyllosilicates). The supergroup divisions are:

Astrophyllite Group,  $Fe^{2+}$  dominant, direct *HOH* linkage

astrophyllite  $K_2NaFe^{2+7}Ti_2(Si_4O_{12})_2O_2(OH)_4F$

iobophyllite  $K_2NaFe^{2+7}(Nb,Ti)(Si_4O_{12})_2O_2(OH)_4(F,O)$

zircophyllite  $K_2NaFe^{2+7}Zr_2(Si_4O_{12})_2O_2(OH)_4F$

bulgakite  $Li_2(Ca,Na)Fe^{2+7}Ti_2(Si_4O_{12})_2O_2(OH)_4(F,O)(H_2O)_2$

nalivkinitite  $\text{Li}_2\text{NaFe}^{2+7}\text{Ti}_2(\text{Si}_4\text{O}_{12})_2\text{O}_2(\text{OH})_4\text{F}(\text{H}_2\text{O})_2$

tarbagataite  $(\text{K}^\ominus)\text{CaFe}^{2+7}\text{Ti}_2(\text{Si}_4\text{O}_{12})_2\text{O}_2(\text{OH})_5$

Kupletskite Group,  $\text{Mn}^{2+}$  dominant, direct *HOH* linkage

kupletskite-1A  $\text{K}_2\text{NaMn}_7\text{Ti}_2(\text{Si}_4\text{O}_{12})_2\text{O}_2(\text{OH})_4\text{F}$

kupletskite-2M  $\text{K}_2\text{NaMn}_7\text{Ti}_2(\text{Si}_4\text{O}_{12})_2\text{O}_2(\text{OH})_4\text{F}$

kupletskite-(Cs)  $\text{Cs}_2\text{NaMn}_7\text{Ti}_2(\text{Si}_4\text{O}_{12})_2\text{O}_2(\text{OH})_4\text{F}$

niobokupletskite  $\text{K}_2\text{NaMn}_7(\text{Nb},\text{Ti})(\text{Si}_4\text{O}_{12})_2\text{O}_2(\text{OH})_4(\text{O},\text{F})$

Devitoite group

devitoite  $\text{Ba}_6\text{Fe}^{2+7}\text{Fe}^{3+2}(\text{Si}_4\text{O}_{12})_2(\text{PO}_4)_2(\text{CO}_3)\text{O}_2(\text{OH})_4$

sveinbergeite  $(\text{H}_2\text{O})_2[\text{Ca}(\text{H}_2\text{O})](\text{Fe}^{2+6}\text{Fe}^{3+})\text{Ti}_2(\text{Si}_4\text{O}_{12})_2\text{O}_2(\text{OH})_4(\text{OH},\text{H}_2\text{O})$

lobanovite  $\text{K}_2\text{Na}(\text{Fe}^{2+4}\text{Mg}_2\text{Na})\text{Ti}_2(\text{Si}_4\text{O}_{12})_2\text{O}_2(\text{OH})_4$

*HOH* blocks are found in other (heterophyllosilicate) titanosilicates, and these minerals have been described by Ferraris and co-workers (e.g., for a partial summary, see Ferraris, 1997, Sokolova, 2006, Jin et al., 2018). These include:

nafertisite  $[\text{Na},\text{K},^\ominus]_4(\text{Fe}^{2+},\text{Fe}^{3+},^\ominus)_{10}(\text{Ti}_2\text{O}_3\text{Si}_{12}\text{O}_{34})(\text{O},\text{OH})_6]$ ,

bafertisite  $[(\text{Ba}_2(\text{Fe},\text{Mn})_4\text{Ti}_2(\text{Si}_2\text{O}_7)_2\text{O}_2(\text{OH})_2\text{F}_2,$

jinshajiangite  $(\text{Na},\text{Ca})(\text{Ba},\text{K})\text{Fe}_4\text{Ti}_2(\text{Si}_2\text{O}_7)_2\text{O}_2(\text{OH})_2\text{F},$

perraultite  $(\text{Na},\text{Ca})(\text{Ba},\text{K})\text{Mn}_4\text{Ti}_2(\text{Si}_2\text{O}_7)_2\text{O}_2(\text{OH})_2\text{F},$

lamprophyllite  $\text{Na}_2(\text{Sr},\text{Ti},\text{Na},\text{Fe})_4(\text{Ti}_2\text{O}_2\text{Si}_4\text{O}_{14})(\text{O},\text{F})_2,$

seidozerite  $\text{Na}_{1.6}\text{Ca}_{0.275}\text{Mn}_{0.425}\text{Ti}_{0.575}\text{Zr}_{0.925}(\text{Si}_2\text{O}_7)\text{OF},$

and many others. The titanosilicates are found in hyperagpaitic (highly peralkaline nepheline syenites) rocks.

**attapulgitite** 1) refers to the mineral, palygorskite, and should not be used in the mineralogic or geologic literature. See Guggenheim *et al.* (2006) and references therein. 2) Attapulgitite is a common, globally used industrial term synonymous with palygorskite; especially, where mined and processed in the Florida-Georgia region of the United States or other commercial deposits around the world (e.g., China, Spain, Senegal, India, Australia, Greece, Turkey and Ukraine).

**augite** a common clinopyroxene with wide ranges of solid solutions,  $(\text{Ca},\text{Mg},\text{Fe}^{2+},\text{Fe}^{3+},\text{Ti},\text{Al})_2(\text{Si},\text{Al})_2\text{O}_6$ . Si may be replaced by Al (~ 2 to 10 mole %). Ti-bearing augite may develop sector zoning (or hourglass zoning). Exsolution lamellae of Ca-poor pyroxene in augite crystals are common. Augite occurs in mafic or ultramafic igneous rocks and in high-grade metamorphic rocks. See pyroxene group for additional details.

**avalite** a poorly defined material, possibly chromian illite or a mineral mixture

**baddeckite** a poorly defined material, possibly muscovite and hematite

**bafertisite** see astrophyllite group

**baileychlore** the trioctahedral Zn-rich member of the chlorite group. Also, see Part 1. General terms: group names, chlorite

**balestraitite** a member of the mica group characterized by octahedral vanadium and lithium and free from Al and OH, with a chemical composition of ideally  $\text{KLi}_2\text{VSi}_4\text{O}_{12}$ . Balestraitite occurs in subgroup *C2* symmetry because of octahedral ordering and as a *1M* polytype. Balestraitite occurs in Mn-rich beds within metacherts of an ophiolite sequence and was located between carbonate-rich and hematite bands at the Cerchiara mine, Eastern Liguria, Italy.

**baltimorite** see picrolite

**bannisterite** a modulated, trioctahedral, mica-like layer silicate with cross-linked inverted tetrahedra with an idealized formula of  $\text{Ca}_{0.5}\text{K}_{0.5}\text{M}_{10}(\text{Si}_{14.5}\text{Al}_{1.5})\text{O}_{38}(\text{OH})_8 \cdot n\text{H}_2\text{O}$  where *M* is medium-size divalent cations, such as Fe, Mn, Zn, Mg, and *n* = 2 - 6 (Heaney et al., 1992). The tetrahedral sheet consists of 5-, 6-, and 7-fold rings. Important localities for bannisterite include Franklin, New Jersey (USA), Broken Hill, Australia, and Nyberget, Sweden; localities with abundant Mn silicates.

**barbertonite** see hydrotalcite group

**bardolite** a poorly defined material, possibly interstratified biotite and vermiculite

**basonite** a poorly defined material, possibly interstratified biotite and vermiculite

**barium phlogopite** an obsolete varietal term for phlogopite

**barytbiotite** an obsolete varietal term for phlogopite

**bastite** an obsolete term describing a pseudomorph comprised of serpentine altered from a Mg-rich pyroxene

**bastonite** a poorly defined material, possibly interstratified biotite and vermiculite

**baumite** discredited name because it is a mixture of several phases; see caryopilite

**bauxite** see Part 1 of Glossary

**bavalite** an obsolete term for oolitic chlorite, possibly chamosite

**bayerite** a polymorph of  $\text{Al}(\text{OH})_3$  that occurs rarely in nature. The gibbsite  $\text{Al}(\text{OH})_3$  octahedral layer is similar to the dioctahedral layer in bayerite, but the stacking of the layers differs. Small distortions in the bayerite octahedra produce an overall two-layer structure. A notable occurrence for bayerite is in sedimentary rocks from Hartrurim, Israel, where bayerite is in association with calcite, gypsum, portlandite, and ettringite. *Cf.*, gibbsite, nordstrandite

**beidellite** a dioctahedral member of the smectite group. An important characteristic of this member is that isomorphous substitution occurs primarily in the tetrahedral sites to produce the net negative charge on the 2:1 layer (Güven, 1988). An idealized formula for beidellite is  $R^{+0.33}Al_2(Si_{3.67}Al_{0.33})O_{10}(OH)_2 \cdot nH_2O$ , where  $R$  is an exchangeable cation, in this case univalent, but other valences are possible. The iron ( $Fe^{3+}$ ) analogue is known as nontronite and intermediate compositions are known. Beidellite is found abundantly as weathering products of volcanic ash, in association with hydrothermal environments, and as diagenetic products. An especially pure end-member beidellite comes from the Black Jack Mine, Idaho, USA. *Cf.*, smectite.

**bementite** a modulated 1:1 layer silicate with octahedral sheets interlayered by a continuous tetrahedral sheet with double 6-fold tetrahedral rings (Heinrich et al., 1994). The 6-fold rings are interconnected and have tetrahedra pointing up and down, and adjacent octahedral sheets are connected with 5- and 7-fold tetrahedral rings. The ideal chemical composition is  $M_7Si_6O_{15}(OH)_8$ , where  $M$  are medium size cations, such as Mn, Fe, Mg, Zn. Small amounts of Al are known to enter the tetrahedral site for Si. Important localities include Franklin, New Jersey, USA in a metamorphosed, zinc stratiform ore body, and the Olympic peninsula, Washington, USA. *Cf.*, armbrusterite, parsettensite, pyrosmalite, innsbruckite, varenesite

**bentonite** see Part 1 of Glossary

**bergseife** see “bole”, halloysite

**berthierine** a member of the serpentine group with an ideal composition of approximately  $(Fe^{2+}, Mn^{2+}, Mg)_{3-x}(Fe^{3+}, Al)_x(Si_{2-x}Al_x)O_5(OH)_4$ . Berthierine is commonly found in unmetamorphosed sedimentary iron formations. Berthierine occurs more commonly as either an apparent trigonal (possibly  $1T$ ) or less commonly as an apparent monoclinic (possibly  $1M$ ) polytype, and both polytypes are generally intergrown. Berthierine is often confused in the older literature with chamosite, a member of the chlorite group, but not to be confused with berthierite, a sulfide mineral. *Cf.*, brindleyite, chamosite

**biaxial mica** an obsolete term for muscovite

**bildstein** an obsolete term for pyrophyllite or a mixture with dominant pyrophyllite

**biotite** defined by Rieder et al. (1998) as a trioctahedral mica between, or close to, the annite-phlogopite (i.e., ferrous iron and magnesium substitutions) and siderophyllite-eastonite (i.e., Al rich) joins. The term grandfathered the use of “biotite” in the field, when a chemical analysis is unavailable to describe a dark mica, presumably without Li.

**birnessite** a layered manganese oxide mineral (phyllomanganate) similar in structure to chalcophanite. The formula of a synthetic sample used in a structure determination (Post and Veblen, 1990) is  $Mg_{0.29}Mn^{4+}_{1.42}Mn^{3+}_{0.58}O_4 \cdot 1.7H_2O$ , assuming no Mn vacancies and an analysis

total of 100%. Chalcophanite has a sheet of edge sharing Mn-O octahedra where one in seven octahedra is vacant. Zn cations are located above and below the vacant sites, also in octahedral coordination, with oxygen atoms from the octahedral sheet and from a plane of H<sub>2</sub>O molecules between the Mn-O sheets. Interlayer cations in birnessite, Mg, Na, K, Ca, etc., may occupy the Zn site and/or H<sub>2</sub>O sites (as found in chalcophanite). However, distributions of the interlayer cation and H<sub>2</sub>O sites in birnessite may also differ for various compositions (e.g., Na- vs Mg-rich birnessite), and the occupancy of the interlayer cation/H<sub>2</sub>O sites is believed to produce observed superstructures. Cation exchange and redox reactions can occur in birnessite. Ranceite is the (interlayer cation) Ca end member of birnessite and takanelite has Mn<sup>2+</sup> as the interlayer cation. “Buserite” is a hydrated form of birnessite with a 10-Å spacing instead of the 7-Å value of birnessite. “Buserite” has not been found in nature and is not a mineral, but is a common phase during synthesis of birnessite. Birnessite is a major Mn-rich phase in many soils, in desert varnish, in ocean manganese nodules, and as an alteration product in Mn-rich ore deposits. Australian soils containing birnessite may be related to neutral to slightly alkaline conditions, but this result is not universal and the presence of birnessite may instead be related to a paucity of Ca and Mg of these soils.

**bityite** A trioctahedral member of the brittle mica group. The end-member formula is: CaLiAl<sub>2</sub>(BeAlSi<sub>2</sub>)O<sub>10</sub>(OH)<sub>2</sub>. Compositional range restriction includes <sup>vi</sup>Li > <sup>vi</sup>□, where □ = vacancy (i.e., <sup>vi</sup>Li < <sup>vi</sup>□ is defined as margarite). Bityite forms in the 2M<sub>1</sub> polytype and has been found in pegmatites from Madagascar, Zimbabwe, and the Urals, and in a tin vein in Uganda. Like margarite, bityite (Lin and Guggenheim, 1983) has nearly complete tetrahedral ordering of Al,Be vs Si, and thus is non-centric in symmetry (C<sub>c</sub> space group). *Cf.*, margarite

**bixbyite** Bixbyite, alpha-(Mn<sup>3+</sup>,Fe<sup>3+</sup>)<sub>2</sub>O<sub>3</sub>, is structurally comprised of edge sharing and corner sharing (Mn,Fe)O<sub>6</sub> octahedra. Bixbyite has been reported from non-metamorphosed sediments where it had transformed from todorokite-birnessite, and from hydrothermal and low grade metamorphic deposits.

**boehmite** Boehmite, or gamma-AlO(OH), is a hydrous aluminum oxide comprised of corrugated sheets of double edge-sharing octahedra of Al–O,OH. Boehmite is isostructural with lepidocrocite, the Fe analogue. Bauxite is a mixture of diaspore, gibbsite, and boehmite, and any one of the three may dominate. *Syn.*, böhmite

**böhmite** see boehmite

**bole** an obsolete term for a greasy clay with iron oxide impurities that produce a red, yellow and/or brown color and with about 24% water, possibly primarily halloysite. *Syn.* “bergseife” for “mountain soap”, also obsolete

**borocookeite** a boron-rich member of chlorite with an ideal chemical composition of Li<sub>1+3x</sub>Al<sub>4-x</sub>(BSi<sub>3</sub>)O<sub>10</sub>(OH,F)<sub>8</sub> where x = 0.0 to 0.33 atoms per formula unit (Zagorsky et al., 2003). Borocookeite occurs as the 1a polytype. Borocookeite has been found in miarolitic cavities at

temperatures greater than 240-265 °C in pegmatite deposits, such as in the Krasny Chikoy district, Chita region, Russia. *Cf.*, manandonite, boromuscovite

**boromuscovite** a dioctahedral member of the true mica group. The end-member formula is  $\text{KAl}_2\Box\text{BSi}_3\text{O}_{10}(\text{OH})_2$ , where  $\Box$  = vacancy. Boromuscovite occurs as  $2M_1$  and  $1M$  polytypes and has been found in pegmatites at the Řečice pegmatite dikes, Czech Republic, where it occurs as fine-grained masses, and Little Three Mine pegmatite dike, San Diego County, California, USA, where it occurs as coatings from late-stage hydrothermal fluids. *Cf.*, borocookeite, manandonite, muscovite

**bowenite** a transparent, yellow green variety of massive serpentine (antigorite?), used as an alternative for jade. Bowenite is not a mineral name and should not be used in the scientific literature. *Syn.* tangiwaite or tangawaite (from New Zealand)

**bowleyite** an obsolete term for bityite

**bowlingite** an obsolete term for a saponite-rich material from near Bowling, Dumbarton, Scotland

**brammallite** an aluminum-rich dioctahedral mica that shows interlayer deficiency and limited substitutions of Al in the tetrahedral sites. It is a series name (Rieder et al., 1998) with a generalized composition of  $\text{Na}_{0.65}\text{Al}_2\Box\text{Al}_{0.65}\text{Si}_{3.35}\text{O}_{10}(\text{OH})_2$ . Series names designate that additional research may be warranted.

**brandisite** an obsolete varietal term for clintonite

**bravaisite** a poorly defined material, possibly illite and montmorillonite

**brindleyite** a platy serpentine with an ideal composition of  $(\text{Ni}_{1.75}\text{Al}_{1.0})(\text{Si}_{1.5}\text{Al}_{0.5})\text{O}_5(\text{OH})_4$ . Crystals are generally poorly crystalline mixtures of hexagonal and monoclinic polytypes. Poorly described, Al-rich material similar to a Ni analogue of amesite (referred to as “nimesite”) was redefined as brindleyite. Brindleyite is compositionally similar to berthierine because of the tetrahedral Si/Al ratio and structurally similar owing to the hexagonal and monoclinic polytype intergrowths. Brindleyite has been found in the Marmara bauxite deposit, Greece. *Cf.*, amesite, berthierine, garnierite, nepouite, pecoraite, pimelite, willemseite

**brinrobertsite** a regularly ordered interstratification of a pyrophyllite-like layer and dioctahedral smectite-like layer in a ratio of 1:1 (Dong et al., 2002) *Cf.*, interstratification

**bronzite (Finch)** an obsolete varietal term for clintonite

**brown mica** an obsolete name for astrophyllite

**brucite** Brucite is a hydroxide mineral with the composition of  $Mg(OH)_2$ . Also, brucite has been used as a group name for  $M^{2+}(OH)_2$  where  $M = Fe, Mg, Mn, Ni$ . Brucite is comprised of a plane of Mg cations, with each Mg octahedrally coordinated by edge-sharing OH groups, thus forming an infinite two-dimensional sheet. Brucite primarily occurs as a contact metamorphic mineral in dolomites and Mg-rich limestones from the alteration of periclase, and in serpentinites and chlorite schists.

**brunsvigite** an obsolete varietal term for manganoan zincian chamosite. See chlorite

**buddingtonite** an ammonia-dominated feldspar mineral,  $NH_4(Si_3Al)O_8$ . . *Cf.*, alkali feldspar, feldspar, plagioclase feldspar

**buldymite** a poorly defined material, possibly biotite and vermiculite or interlayer-deficient biotite

**bulgakite** see astrophyllite group

**buserite** a synthetic phase, see birnessite

**bytownite** see plagioclase feldspar

**caesium-biotite** an obsolete varietal term for biotite

**cairncrossite** see reyerite group

**calciobiotite** an obsolete varietal term for biotite

**calciotalc** an obsolete varietal term for clintonite

**carlostanite** Carlosturanite is a rare antigorite-like mineral that apparently contains vacant tetrahedral sites which interrupt the continuity of the tetrahedral sheet without affecting the continuity of the octahedral sheet (Mellini et al., 1985). The structure is thus similar to a modulated serpentine. To maintain charge balance, OH groups substitute for O atoms. The generalized formula is  $M_{21}[T_{12}O_{28}(OH)_4](OH)_{30}H_2O$ , where  $M = Mg, Fe^{3+}, Mn^{2+}, Ti^{4+}$ , and  $Cr^{3+}$ , and  $T = Si, Al$ . Alberico (1998) showed that there are problems with the model of Mellini et al. (1985), and suggested the need to reexamine the structure. Important occurrences are related to low grade metamorphic (serpentinite) environments. *Cf.*, antigorite

**carrboydite** see hydrotalcite group

**caryopilite** a modulated layer silicate based on the serpentine structure, with an approximate ideal composition of  $Mn^{2+}_3Si_2O_5(OH)_4$ . Fe, Mg, and Al can substitute for Mn. There is an apparent excess of Si and an apparent deficiency in octahedral composition on the basis of 7

oxygen atoms. Earlier literature sometimes described caryopilite as bementite, but it has been shown that they are separate species. A monoclinic polytype is dominant and small amounts of a trigonal phase are often intergrown. Caryopilite, like greenalite, is an “island” structure where Si-rich tetrahedra of a given layer have apical oxygen atoms coordinate to one octahedral sheet and others to the adjacent sheet (Guggenheim and Eggleton, 1998). The islands are saucer-shaped with some islands inverted, and the islands are domed. Island diameters depend on composition with larger-diameter islands having smaller average octahedral cation sizes (4 tetrahedral-ring diameters in greenalite, 3 rings in caryopilite). Island domains are randomly displaced within layers. “Baumite”, a mixture of several phases, contains a phase, probably Zn,Mg-rich, that is intermediate in domain structure to greenalite and caryopilite. Caryopilite is commonly found in bedded manganese deposits, such as those at the North Chichibu belt in the Shikoku region, SW Japan. *Cf.*, greenalite

**caswellite** a poorly defined material, possibly mica and manganooan andradite

**cat gold** an obsolete term for muscovite

**cat silver** an obsolete term for muscovite

**cataspilite** a poorly defined material, possibly alteration product with dominant muscovite

**cathkinite** an obsolete term for a chocolate-brown saponite-rich material from Cathkin Hills, Scotland

**catlinite** a poorly defined material, possibly muscovite and pyrophyllite

**celadonite** a dioctahedral member of the true mica group. The ideal end-member formula is  $\text{KFe}^{3+}(\text{Mg}, \text{Fe}^{2+})_{\square}\text{Si}_4\text{O}_{10}(\text{OH})_2$ , where  $\square$  = vacancy. The typical range in composition is:  ${}^{\text{vi}}\text{R}^{2+}/({}^{\text{vi}}\text{R}^{2+} + {}^{\text{vi}}\text{R}^{3+}) \geq 0.25$ ,  ${}^{\text{vi}}\text{Al}/({}^{\text{vi}}\text{Al} + {}^{\text{vi}}\text{Fe}^{3+}) < 0.5$ ,  $\text{Mg}/(\text{Mg} + {}^{\text{vi}}\text{Fe}^{2+}) > 0.5$  (Rieder et al., 1998). Celadonite is commonly an alteration product of pyroxenes and other Fe,Mg minerals found in basalts either during low-grade metamorphism or hydrothermal activity.

**celsian** a Ba-dominated feldspar mineral,  $\text{Ba}(\text{Si}_2\text{Al}_2)\text{O}_8$ . *Cf.*, alkali feldspar, feldspar, plagioclase feldspar

**cerolite** equivalent to kerolite, see kerolite

**chabazite** see zeolite

**chacaltaite** a poorly defined material, possibly an illite pseudomorph after cordierite

**chacaltocite** an obsolete term for muscovite

**chalcedony** Chalcedony is a rock term to describe a mixture of a fibrous  $[11\bar{2}0]$  variety of microcrystalline (length fast) quartz and moganite. *Cf.*, quartzine

**chalcodite** an obsolete varietal term for stilpnomelane

**chalcophanite** see birnessite

**chamosite** the Fe-rich member of the chlorite group with a composition of ideally  $\text{Fe}^{2+}_5\text{Al}(\text{Si}_3\text{Al})\text{O}_{10}(\text{OH})_8$ . There may be considerable substitutions of Mg,  $\text{Fe}^{3+}$ , and Al for  $\text{Fe}^{2+}$ . The common polytype is the *I**b*** form, a one-layer form. Chamosite is an important constituent in oolitic and sedimentary iron formations and may be found as grain coatings in sandstones. See chlorite

**chernykhite** a dioctahedral member of the brittle mica group. The end-member formula is:  $\text{BaV}_2\text{Al}_2\text{Si}_2\text{O}_{10}(\text{OH})_2$ , where  $\square$  = vacancy, but known samples are deficient in Ba (or K). Typical site substitutions primarily occur in the octahedral site by Al, Fe, and/or Mg. The  $2M_1$  polytype is the common polytype. Chernykhite is only known from southern Kazakhstan. *Cf.*, roscoelite

**chert** Chert is a rock term to describe an authigenic species of  $\text{SiO}_2$  which consists of nanoscale intergrowths of quartz and moganite, a metastable  $\text{SiO}_2$  polymorph (Heaney, 1994). *Cf.*, moganite, quartz

**chlorite** a group name for phyllosilicates with the general formula of  $(R^{2+}_{6-y-z}R^{3+}_y\square_z)(\text{Si}_{4-x}R^{3+}_x)\text{O}_{10}(\text{OH})_8$  where  $\square$  represents vacancies,  $x$  is the number of tetrahedral  $R^{3+}$  cations,  $y$  is the number of octahedral  $R^{3+}$  cations, and  $z$  is the number of vacancies. The common structure consists of negatively charged trioctahedral 2:1 layers alternating regularly with positively charged trioctahedral interlayer sheets. Ideal composition of the 2:1 layer is  $(R^{2+}, R^{3+})_3(\text{Si}_{4-x}R_{3+x})\text{O}_{10}(\text{OH})_2$  and that of the interlayer is  $(R^{2+}, R^{3+})_3(\text{OH})_6$ . Bayliss (1975) defined trioctahedral end members based on the dominant cation, e.g., Fe-rich, chamosite; Mg-rich, clinochlore; Mn-rich, pennantite; Ni-rich, nimite; Zn-rich, baileychlore. The trioctahedral chlorites are commonly found in metamorphic rocks and are the diagnostic mineral of the greenschist facies. Chlorite is also a common alteration product. Eggleton and Bailey (1967) combined composition and structure characteristics to define dioctahedral chlorite species. Cookeite is the Li-rich chlorite, whereas sudoite is essentially Li-free. Cookeite and sudoite occur in pegmatite, hydrothermal deposits, and ore deposits. Both have a dioctahedral 2:1 layer and a trioctahedral interlayer (di, trioctahedral chlorite). Donbassite has two dioctahedral sheets (di, dioctahedral chlorite) and is Al-rich. For trioctahedral chlorite, the common polytype is the one-layer, *I**b*** form, although cookeite, commonly forms in the one-layer *I**a*** form (*cf.*, *I**a*** polytype, *I**b*** polytype). See also Part 1 of the Glossary.

**chlorite/smectite (or chlorite-smectite)** terminology commonly used to denote the interstratification of chlorite or chlorite-like layers with smectite or smectite-like layers.

Alternatively, this interstratification can be described as chlorite/corrensite. It may be abbreviated as C/S or C-S. Because the interstratification is not regular, it is not recognized as a unique phase. *Cf.*, chlorite, corrensite, smectite

**chlormagaluminite** see hydrotalcite group

**chloropal** an obsolete term for nontronite

**chlorophanerite** an obsolete term for glauconite

**chlorophœite** a poorly defined material, found as infillings in cavities in basic igneous rocks, possibly an altered chlorite

**chrombiotite** an obsolete varietal term for biotite

**chromceladonite** a dioctahedral member of the true mica group. The ideal end-member formula is  $\text{KCrMg}_{\square}(\text{Si}_4\text{O}_{10})(\text{OH})_2$  where  $\square$  = vacancy. First discovered at the Srednyaya Padma U-V deposit, chromceladonite was described from southern Karelia, Russia, in occurrences relating to apparent metasomatism and in association with dolomite, calcite, hematite, quartz, roscoelite, chromphyllite, uraninite, zincochromite, vanadium oxides and selenides (Pekov et al., 2000). Chromceladonite occurs as a  $1M$  polytype. *Cf.*, chromphyllite

**chrome mica** an obsolete term for chromian muscovite, chromian phengite

**chromglimmer** an obsolete term for chromian muscovite, chromian phengite

**chromochre** an obsolete term for chromian muscovite

**chromphyllite** a dioctahedral member of the true mica group. The ideal end-member formula is  $\text{KCr}_2_{\square}\text{AlSi}_3\text{O}_{10}(\text{OH},\text{F})_2$ , where  $\square$  = vacancy. Chromphyllite, like muscovite, occurs as the  $2M_1$  polytype in  $C2/c$  symmetry, and the Cr forms a solid solution series with Al in muscovite. Chromphyllite is known from the Lake Baikal region, Russia, Outokumpu, Finland, and elsewhere, and is believed to occur in association with metasomatism. *Cf.*, muscovite

**chrysophane** an obsolete term for clintonite

**chrysotile** a member of the serpentine group with textures showing packets of cylinders, scrolls, and tubes, as well as helical or spiral fibers. Chrysotile, ideally  $\text{Mg}_3\text{Si}_2\text{O}_5(\text{OH})_4$ , crystallizes in monoclinic symmetry (clinochrysotile) with the fiber axis parallel to  $X$  and orthorhombic symmetry with the fiber axis along  $X$  (orthochrysotile) or  $Y$  (parachrysotile). Polytype stacking for clinochrysotile is either  $2M_{c1}$  or  $1M_{c1}$ , where the number of layers (e.g., 1 or 2) precedes  $M$  = monoclinic, subscript c = cylindrical, and subscript 1 is used to distinguish the form from another cylindrical polytype that would otherwise have the same symbol. The orthochrysotile polytype is

$2O_{c1}$ . Cylindrical structures do not have consistent hydrogen bonding between layers that would be observed in an ideal platy structure, and thus do not conform to the standard polytypes. Fiber dimensions are variable with inner diameters near 70-80 Å and outer diameters reported at 220-270, >350, and 490 Å (the latter value involves synthetic samples). Al, Fe<sup>2+</sup>, and Fe<sup>3+</sup> may substitute for Mg, and Fe<sup>3+</sup> may substitute for Si; all substitutions are very limited, but greater than in lizardite. The differences between these substitutions in lizardite vs. chrysotile suggest that in natural systems, lizardite and chrysotile are not *sensu stricto* polymorphs. Chrysotile, or “white asbestos”, is the asbestosform serpentine and is mined in Russia near the Ural Mountains and in Asbestos, Quebec, Canada.

**clingmanite** an obsolete term for margarite

**clinocllore** the trioctahedral Mg-rich member of the chlorite group. See chlorite

**clinoenstatite** a monoclinic ( $P2_1/c$ ) polymorph of enstatite. It is a product of fast cooled protoenstatite. Clinoenstatite occurs in Mg-rich basaltic rocks.

**clinoptilolite** see zeolite

**clinopyroxene** a pyroxene subgroup of Ca-,Na-bearing pyroxenes with monoclinic ( $C2/c$ ,  $P2_1/c$ ) symmetry. See pyroxene group for additional details.

**clinobermorite** see tobermorite

**clintonite** a trioctahedral member of the brittle mica group. The end-member formula is:  $CaMg_2Al(Al_3Si)O_{10}(OH)_2$ . Typical site substitutions include: Ca > Na,K; Fe<sup>2+</sup>, Al, Fe<sup>3+</sup>, Mn for Mg; and Al and Fe<sup>3+</sup> for Si or <sup>iv</sup>Al. The common polytype is  $1M$ , and the  $2M_1$ ,  $1M_d$ , and  $3T$  are rare. The Loewenstein Al avoidance rule is violated in that the tetrahedral content of  $Al_3Si$  requires that Al tetrahedra share bridging oxygen atoms with other Al tetrahedra, which is unusual in aluminosilicate minerals. Clintonite occurs in metasomatically altered limestones, which involves thermal metamorphism coupled with a restrictive bulk composition undersaturated in silica.

**coalingite** see hydrotalcite group

**colomite** an obsolete term for roscoelite

**common mica** an obsolete term for muscovite

**confolensite** an obsolete, local term for montmorillonite from Confolens, Charente, France

**connarite** an obsolete varietal term for willemseite

**cookeite** a Li-bearing member of the chlorite group, with an ideal composition of  $(\text{Li},\text{Al}_4)(\text{Si}_3\text{Al})\text{O}_{10}(\text{OH})_8$ . The octahedral sheet of the 2:1 layer is dioctahedral and the interlayer is trioctahedral, therefore this is a di, trioctahedral chlorite. The common polytype is based on the *Ia* structure. *Cf.*, chlorite

**coombsite** see zussmanite

**coronadite** see hollandite

**corrensite** a regular interstratification of trioctahedral chlorite-like layers with either trioctahedral smectite-like or trioctahedral vermiculite-like layers, the former being “low-charge corrensite” and the latter “high-charge corrensite”. The ratio of chlorite-like layers to smectite-like or vermiculite-like layers is 1:1 (Guggenheim et al., 2006). Corrensite occurrences are from low temperature environments, such as evaporites, saline deposits, sedimentary rocks, weathering zones, hydrothermal systems, burial diagenesis, low grade metamorphic regimes, and some contact metamorphic zones. Beaufort et al. (1997) discussed corrensite possibly as a regular mixed-layer structure involving a continuous series from smectite (or vermiculite) to chlorite or alternatively, as a single phase with a regular alteration of chlorite and smectite (or vermiculite) layers, with a stability field. If the latter, mixtures that deviate from 1:1 ratios of interstratified layers would require physical mixtures of appropriate layers of corrensite and chlorite.

**corundellite** an obsolete term for margarite

**corundophilite** an obsolete term for low-Si (and variable amounts of  $\text{Fe}_2\text{O}_3$ ) chlorite

**cossaite** an obsolete varietal term for paragonite

**crystalite** Beta-cristobalite, a high temperature (above 1470 °C, but below liquid at 1727 °C at 1 bar) polymorph of  $\text{SiO}_2$ , has an ideal basic structure that is polytypic with tridymite. Like tridymite, beta cristobalite has sheets of hexagonal tetrahedral rings with alternate tetrahedra around a ring with apices pointing in opposite directions from adjacent tetrahedra. These sheets have an ABCABC... stacking sequence, which creates an offset such that no channels form as they do in tridymite. Cristobalite is found in volcanic rocks, primarily in a fine groundmass, but also as a lining of cavities and as a devitrification of volcanic glasses. *Cf.*, opal, tridymite, quartz

**cronstedtite** Cronstedtite is the Fe-rich serpentine of composition  $(R^{2+}_{3-x}\text{Fe}^{3+}_x)(\text{Si}_{2-x}\text{Fe}^{3+}_x)\text{O}_5(\text{OH})_4$ . Divalent cations ( $R^{2+}$ ) may include Fe, Mg, Mn, and possibly Ca. It is *assumed* that the value of *x* in the formula is equal (and near 0.5 to 1.0) for both the tetrahedral and the octahedral sites. Cronstedtite has a large number of polytypes, with the *1T* (space group *P31m*) most common. The lateral dimensions of the iron-rich tetrahedral sheet are large, but the lateral dimensions of the octahedral sheet are large also, and thus tetrahedral rotation ranges only up to ~8°. Because most (possibly all) of the iron is ferric, the tetrahedral-octahedral misfit is limited.  $\text{Fe}^{3+}$  and Si segregate to different *T* sites in the *2H*<sub>2</sub> polytype, but not in the *1T*, *3T*, *2H*<sub>1</sub>, and *6R*<sub>2</sub>

polytypes. Amesite- $2H_2$  also shows tetrahedral ordering, but between Al and Si. Cronstedtite forms in low-temperature hydrothermal veins with other iron rich minerals, such as siderite, and in low-temperature metamorphosed iron formations. It is also known to occur in carbonaceous chondrites. The Mn analogue of cronstedtite is guidottiite. *Cf.*, amesite, greenalite, guidottiite

**cryophyllite** an obsolete varietal term for zinnwaldite, ferroan trillithionite, and ferroan polyolithionite

**cryptomelane** see hollandite

**culsageeite** an obsolete name for altered material, probably vermiculite

**cymatolite** a poorly defined material, possibly muscovite and albite

**damourite** an obsolete term for muscovite

**daphnite** an obsolete term for a low-Si chlorite

**de saulesite** a discredited term for pimelite

**delessite** an obsolete term for a chlorite material, rich in ferric iron, probably a Mg-rich chamosite

**desautelsite** see hydrotalcite group

**devitoite** see astrophyllite group

**deweylite** an obsolete term for a mixture of poorly crystalline phyllosilicates (1:1 and 2:1 types). When red, “deweylite” was called “eisengymnite”, and when found at Bare Hills, Maryland, USA, “deweylite” was called “gymnite”.

**diabantite** a discredited term for a Si- and Fe-rich (clinochlore) chlorite

**diaspore** a polymorph of hydrous aluminum oxide,  $\alpha$ -AlO(OH), and isostructural with goethite,  $\alpha$ -FeO(OH). The structure is comprised of double chains of edge-sharing octahedra of  $\text{AlO}_3(\text{OH})_3$  along the *c* axis, and the chains are offset along the *b* axis. Diaspore occurs with corundum, often in chlorite schists and in dolomite, and as a major constituent as fine-grained matrix in bauxite.

**dickite** a member of the kaolin group, which consists of the dioctahedral and aluminous rich 1:1 phyllosilicates. Dickite has a chemical composition of  $\text{Al}_2\text{Si}_2\text{O}_5(\text{OH})_4$ . Dickite is distinguished from the other polymorphs, kaolinite and nacrite, by the vacant octahedral site regularly alternating from layer to layer across “B” and “C” sites. Thus, the polytype is a two layer form

with monoclinic symmetry, *Cc*. The “B” and “C” sites would be related by a mirror plane if both sites were occupied identically within the same layer, whereas the “A” site resides on the mirror plane (Bish and Johnston, 1993). Dickite has a widespread occurrence and often is believed to be transformed from kaolinite (and therefore dickite is the more stable phase) by higher temperature (various temperatures have been suggested depending on origin, e.g., ~120 °C, 290 - 300 °C, 80 - 160 °C), but dissolution-precipitation of kaolinite to dickite has been suggested also, as well as direct precipitation. Dickite has been described from hydrothermal and diagenetic environments. Examples of hydrothermal dickite include those of Japan and Nayarit, Mexico. *Cf.*, halloysite, kaolin, kaolinite, nacrite

**didrimite** an obsolete term for muscovite

**didymite** an obsolete term for muscovite

**diopside** a clinopyroxene with an end-member composition of  $\text{CaMgSi}_2\text{O}_6$ . A continuous solid-solution series exists between diopside and hedenbergite,  $\text{CaFeSi}_2\text{O}_6$ . Diopside occurs in metamorphic rocks, alkali basalts, and nodules in kimberlite. Near end-member diopside occurs in metasomatic rocks, such as skarns formed through contact metamorphism between siliceous carbonate and granitic intrusion. See pyroxene group for additional details

**diphanite** an obsolete term for margarite

**disterrite** an obsolete varietal term for clintonite

**donbassite** a member of the chlorite group, with an ideal formula of  $(\text{Al}_{4+x/3}\text{Si}_{4-x}\text{Al}_x)\text{O}_{10}(\text{OH})_8$ , where *x* represents excess Al. Both octahedral sheets are dioctahedral, therefore this is a di,dioctahedral chlorite. *Cf.*, chlorite

**dozyite** a regular interstratification of trioctahedral serpentine with trioctahedral (i.e., tri, trioctahedral) chlorite. The ratio of chlorite layers (i.e., one 2:1 layer and one interlayer) to serpentine (i.e., one 1:1 layer) is 1:1. The name applies to any composition of interstratified trioctahedral serpentine or trioctahedral chlorite regardless of the structure type (i.e., stacking) of the chlorite. Variations in chemical composition other than Mg and Al may be noted by descriptive adjectival modifiers (Bailey et al., 1995).

**dudleyite** a poorly defined material, possibly smectite or vermiculite

**dysintribite** an obsolete term for muscovite

**eastonite** a trioctahedral member of the true mica group. The ideal end-member formula is  $\text{KMg}_2\text{Al}(\text{Al}_2\text{Si}_2)\text{O}_{10}(\text{OH})_2$ , although such a chemical composition has not been reported. The original eastonite occurrence from Easton, Pennsylvania, USA, was shown to be a mixture of phlogopite and lizardite-1*T* with some “antigorite-like offsets”. The eastonite composition is

useful to describe solid solution series where there are Mg + Al substitutions. *Cf.*, presiwerkite, siderophyllite

**eggletonite** see ganophyllite

**eisengymnite** see “deweylite”

**ekmanite** a 2:1 modulated phyllosilicate having an ideal chemical composition of  $KM_{20}Si_{32}O_{76}(OH)_{17}$ , where  $M = Fe^{2+}, Mg, Mn^{2+}$ . Analyses show that Ca and Na substitutes for K,  $Fe^{3+}$  substitutes for  $M$ , and Al substitutes for Si. Ekmanite has a highly disordered layer-stacking. The proposed model (Ferrow et al, 1999), based on TEM analysis, has strips of tetrahedra attached to the continuous octahedral sheet, with the strips along the  $a$  axis. The basic layer is 2:1 with inverted tetrahedra linking across the interlayer through apical oxygen atoms, with three of eight tetrahedra linking the 2:1 layers and inverted relative to adjacent octahedral sheets, similar to bannisterite. All tetrahedral rings are 6-fold, unlike bannisterite. Ekmanite is known from the magnetite ore body and skarns at Brunnsjögruvan, Sweden, in rocks metamorphosed to greenschist facies.

**elhuyarite** an obsolete term for allophane associated with lignite from Friesdorf, Germany

**emerylite** an obsolete term for margarite

**endellite** a redundant term for halloysite and its use should be discontinued

**enstatite** an orthorhombic (space group  $Pbca$ ) pyroxene, with an end-member composition of  $Mg_2Si_2O_6$ . Enstatite and ferrosilite,  $Fe_2Si_2O_6$ , form a continuous solid solution series (with <5 mole % of  $CaSiO_3$ ). Enstatite commonly occurs in mafic and ultramafic igneous rocks and some high-grade metamorphic rocks (granulite facies). Polymorphs of enstatite include a low-temperature, monoclinic form (clinoenstatite) and a high-temperature, orthorhombic form (protoenstatite) that may also occur naturally in nanocrystallite form. Ca-rich exsolution lamellae in enstatite crystals are common. See pyroxene group for additional details.

**ephesite** a trioctahedral member of the true mica group. The end-member formula is  $NaLiAl_2(Al_2Si_2)O_{10}(OH)_2$ . Ephesite occurs as the  $1M$  and  $2M_1$  polytypes. Ephesite has been identified in pegmatite as a hydrothermal alteration product with analcime and natrolite from the Ilimaussaq intrusion, Greenland, and in manganese ore from Postmasburg, South Africa.

**epichlorite** a poorly defined material, possibly an altered chlorite

**epileucite** a poorly defined material, possibly a muscovite and K-rich feldspar pseudomorph after cordierite

**episericite** a poorly defined material, possibly illite

**erionite** see zeolite

**errite** an obsolete (light green) variety of parsettensite

**ettringite** see calcium silicate hydrate (CSH) in Part 1

**eukamptite** a poorly defined material, possibly altered biotite

**euchlorite** an obsolete term for biotite

**euphyllite** a poorly defined material, possibly paragonite and muscovite or paragonite

**euralite** a poorly defined material, possibly an altered chlorite found as infillings in cavities in basic igneous rocks

**falcondoite** a member of the palygorskite-sepiolite group with a composition of approximately  $(\text{Ni}_{8-y-z} \text{R}^{3+}_y \square_z) (\text{Si}_{12-x} \text{R}^{3+}_x) \text{O}_{30} (\text{OH})_4 (\text{OH}_2)_4 \cdot \text{R}^{2+}_{(x-y+2z)2} (\text{H}_2\text{O})_8$ , where  $R$  is a cation,  $\square$  are vacancies, and  $x$ ,  $y$ , and  $z$  are compositional parameters. See palygorskite-sepiolite group

**faratsihite** a poorly defined material, probably a mixture of kaolin and nontronite

**Fe muscovite** an invalid name for a hypothetical end member

**fedorite** see reyerite group

**feitknechtite** see groutite

**feldspar** The group name for a set of anhydrous framework silicate minerals. The most common feldspar minerals belong to the ternary system of end members of albite [Ab:  $\text{Na}(\text{Si}_3\text{Al})\text{O}_8$ ], anorthite [An:  $\text{Ca}(\text{Si}_2\text{Al}_2)\text{O}_8$ ], and orthoclase [Or:  $\text{K}(\text{Si}_3\text{Al})\text{O}_8$ ]. Si and Al atoms are in tetrahedral sites of the aluminosilicate framework. Large monovalent or divalent cations (Na, K, Ca, Ba) occupy interstices of the framework to maintain charge balance. In general, cleavage along the  $\{001\}$  is perfect and good on the  $\{010\}$  planes. The feldspar group minerals are separated into two series, alkali (K- to Na-rich) feldspars and plagioclase (Na- to Ca-rich) feldspars. At high temperature, solid solutions are common in both alkali feldspar (between K and Na) series and plagioclase feldspar (between Na and Ca, and Si and Al) series, but not between K- and Ca-rich feldspars. During cooling, homogeneous compositions may exsolve to form perthite (alkali feldspar with plagioclase exsolution) or antiperthite (albite with “orthoclase” exsolution). Feldspar minerals readily weather near the surface of the earth to produce clay minerals. In addition, ground feldspar and quartz may be mixed with clays and/or clay minerals (e.g., kaolin) and fused to create porcelain and glazes, with the feldspar acting as a binder material. *Cf.*, alkali feldspar

**feroxyhite** a poorly defined, fine grained, poorly crystalline, and non-magnetic form of gamma-FeO(OH). Feroxyhite transforms in air to goethite, but it has been found in ocean-floor iron-manganese concretions and in some soils with high iron hydroxide content. Drits et al. (1993) examined several structural models and suggested from X-ray data that iron atoms occupy octahedral sites with distributions of face-sharing octahedral pairs alternating with vacant octahedral pairs along the *c* axis. *Syn.*, feroxyhyte

**ferri-phengite** an obsolete varietal term for ferrian muscovite

**ferriannite** an obsolete term for tetra-ferri-annite

**ferribiotite** an obsolete varietal term for biotite

**ferrihollandite** see hollandite

**ferrihydrate** Ferrihydrate is metastable, fine grained, and poorly crystalline and occurs as brown gel-like precipitates and as friable crusts in soil matrix in podzols or lithosols, and in environments associated with acid mine drainage. The chemical composition of ferrihydrate is very approximately  $\text{Fe}_2\text{O}_3 \cdot 2\text{FeO}(\text{OH}) \cdot 2.6\text{H}_2\text{O}$ , and it is believed to be a precursor of hematite and possibly goethite (by dissolution). Surface adsorption of organic molecules and (heavy and other foreign) metals may occur and affect ferrihydrate stability. The gel-like forms, when studied by powder X-ray diffraction, produces patterns with two broad diffraction peaks (“two line ferrihydrate”) and the crust produces five or more lines (“five line ferrihydrate” and sometimes as “six line ferrihydrate”). Ageing promotes formation of the “five line ferrihydrate” from the two line form. Michel et al. (2007) suggested a single-phase model for ferrihydrate that is based on a cluster of 13 Fe and 40 oxygen atoms: central  $\text{FeO}_4$  tetrahedra surrounded by 12  $\text{FeO}_6$  octahedra, with an ideal chemical composition of  $\text{Fe}_{10}\text{O}_{14}(\text{OH})_2$ . The model is affected by surface bound  $\text{H}_2\text{O}$ , surface effects, strain and defects, particle size and shape, etc.

**ferrimuscovite** an invalid name for a hypothetical end member

**ferriphlogopite** an obsolete varietal term for ferrian phlogopite, tetra-ferriphlogopite

**ferripyrophyllite** the ferric iron analogue of pyrophyllite

**ferrisepiolite** a member of the palygorskite-sepiolite group with a composition of approximately  $(\text{Fe}^{3+}, \text{Fe}^{2+}, \text{Mg})_4 (\text{Si}, \text{Fe}^{3+})_6 \text{O}_{15}(\text{O}, \text{OH})_2 \cdot 6\text{H}_2\text{O}$ . See palygorskite-sepiolite group

**ferristilpnomelane** see stilpnomelane

**ferrititanbiotite** an obsolete varietal term for biotite

**ferriwodanite** an obsolete varietal term for biotite

**ferriwotanite** an obsolete varietal term for biotite

**ferro-aluminoceladonite** a dioctahedral member of the true mica group. The end-member formula is  $\text{K Al}(\text{Fe}^{2+}, \text{Mg})\square\text{Si}_4\text{O}_{10}(\text{OH})_2$ . Typical range in composition is:  ${}^{\text{vi}}\text{Al}/({}^{\text{vi}}\text{Al} + {}^{\text{vi}}\text{Fe}^{3+}) = 0.5 - 1.0$ ,  $\text{Mg}/(\text{Mg} + {}^{\text{vi}}\text{Fe}^{2+}) \leq 0.5$  (Rieder et al., 1998). Li et al. (1997) described ferro-aluminoceladonite-1M from tuffs in the Murihiku Supergroup, Hokonui Hills, Southland, New Zealand.

**ferro-ferri-muscovite** an obsolete term for ferrian annite

**ferro-phlogopite** an obsolete varietal term for ferroan phlogopite

**ferroceladonite** A dioctahedral member of the true mica group. The end-member formula is  $\text{K Fe}^{3+}(\text{Fe}^{2+}, \text{Mg})\square\text{Si}_4\text{O}_{10}(\text{OH})_2$ . Typical range in composition is:  ${}^{\text{vi}}\text{Al}/({}^{\text{vi}}\text{Al} + {}^{\text{vi}}\text{Fe}^{3+}) < 0.5$ ,  $\text{Mg}/(\text{Mg} + {}^{\text{vi}}\text{Fe}^{2+}) \leq 0.5$  (Rieder et al., 1998). Li et al. (1997) described ferroceladonite-1M from tuffs in the Murihiku Supergroup, Hokonui Hills, Southland, New Zealand.

**ferroferrimargarite** an obsolete varietal term for margarite

**ferrokinoshitalite** a trioctahedral member of the brittle mica group with an ideal chemical composition of  $\text{BaFe}^{2+}_3\text{Si}_2\text{Al}_2\text{O}_{10}(\text{OH})_2$ . Ferrokinoshitalite occurs as a 1M polytype from the silicate-rich bands of high-grade metamorphic rocks in banded iron formation at the Broken Hill massive sulfide deposit, Namaqualand metamorphic complex, northern Cape Province, South Africa (Guggenheim and Frimmel, 1999). The Si and Al are disordered in the tetrahedral sites.

**ferromuscovite** an obsolete varietal term for biotite

**ferrophengite** an invalid name for a hypothetical end member

**ferrophlogopite** an obsolete varietal term for ferroan phlogopite

**ferropyrosmalite** see pyrosmalite

**ferrosilite III** see pyroxenoid group

**ferrosilite** an orthorhombic (space group *Pbca*) pyroxene, with an end-member composition of  $\text{Fe}_2\text{Si}_2\text{O}_6$ . End-member ferrosilite does not occur under normal pressure conditions, with the assemblage of fayalite and quartz thermodynamically more stable than ferrosilite. Ferrosilite is thus rare, but it has been found in mafic rocks and some high-grade metamorphosed banded iron formations. See pyroxene group for additional details.

**ferrostilpnomelane** see stilpnomelane

**flogopite** an obsolete term for phlogopite

**fluortainiolite** an obsolete term for tainiolite

**foshagite** see tobermorite

**fraipontite** the Zn-rich, platy serpentine defined ideally as  $Zn_3(Si,Al)_2O_5(OH)_4$ . Cu, Al, and vacancies are known to substitute for Zn. Occurrences include Gleeson, Arizona, USA, and Laurion, Greece (both Cu-rich), Defiance, Belgium, and Tsumeb, Namibia.

**franklinfurnaceite** an intermediate structure between chlorite and brittle micas (Peacor et al., 1988). The franklinfurnaceite structure is similar to chlorite-IIa-1 polytype with a trioctahedral 2:1 layer, but with a dioctahedral interlayer (thus, tri-dioctahedral). It differs from chlorite and is more mica-like because Ca cations occupy octahedral sites between the tetrahedral sheets and the dioctahedral interlayers. Franklinfurnaceite is ideally  $Ca_2Fe^{3+}Mn^{2+}_3Mn^{3+}[Zn_2Si_2O_{10}](OH)_8$  and occurs at Franklin, New Jersey, USA.

**franklinphilite** the Mn analogue of stilpnomelane, see stilpnomelane

**frauenglas** an obsolete term for muscovite

**friedelite** see pyrosmalite

**fuchsite** an obsolete term for chromian muscovite

**gaebhardtite** an obsolete term for chromian muscovite

**galapectite** an obsolete term for a halloysite from Angleur, Belgium

**ganophyllite** a modulated 2:1 layer silicate with a continuous octahedral sheet and a tetrahedral sheet that involves triple chain strips linked by pairs of inverted tetrahedra that connect the strips and adjacent layers (Eggleton and Guggenheim, 1986). The ganophyllite chemical composition is approximately  $(K,Na,Ca)_6(Mg,Fe,Mn)_{24}(Si_{32.5}Al_{7.5})O_{96}(OH)_{16} \cdot 21H_2O$ . The large cations (K, Na, Ca) are exchangeable and occur associated near the undersaturated inverted tetrahedra that connect adjacent layers. Eggletonite is the Na analogue of ganophyllite. Ganophyllite occurs in low-grade metamorphic, silicate-rich manganese deposits, such as those found at the Harstig mine, Pajsberg, near Persberg, Vermland, Sweden.

**ganterite** a dioctahedral member of the true/brittle mica group with the ideal chemical composition of  $[Ba_{0.5}(Na,K)_{0.5}]Al_2(Si_{2.5}Al_{1.5}O_{10})(OH)_2$ . Ganterite may be described as a Ba-dominant analogue of muscovite-2M<sub>1</sub> that crystallizes, like most muscovite crystals, in space

group  $C2/c$ . Ganterite was originally described from basement rocks of the Berisal Complex, Simplon Region, Switzerland (Graeser et al., 2003). but it has also been found from Oreana, Nevada, and Ba-rich muscovite-like phases have been reported from West Greenland; Ontario, Canada; and Franklin/Sterling Hill, New Jersey, USA.

**garnet** a group of orthosilicate (= nesosilicate) minerals with stoichiometry of  $A_3B_2(\text{SiO}_4)_3$ , where divalent cations occur in the large-size (8-coordinated)  $A$  site and trivalent cations occur in the medium-size (6-coordinated octahedron)  $B$  site. Common garnet minerals are pyrope  $[\text{Mg}_3\text{Al}_2(\text{SiO}_4)_3]$ , almandine  $[\text{Fe}_3\text{Al}_2(\text{SiO}_4)_3]$ , spessartine  $[\text{Mn}_3\text{Al}_2(\text{SiO}_4)_3]$ , uvarovite  $[\text{Ca}_3\text{Cr}_2(\text{SiO}_4)_3]$ , grossular  $[\text{Ca}_3\text{Al}_2(\text{SiO}_4)_3]$ , and andradite  $[\text{Ca}_3\text{Fe}_2(\text{SiO}_4)_3]$ . These garnets are separated into two series, pyralspite (the Mg, Fe, and Mn Al-rich members) and ugrandite (the Ca-rich members). Solid solution is common in the  $A$  site of pyralspite and in the  $B$  site of ugrandite, but little substitution between the two series. Grandite is a generic name for the grossular-andradite series. Garnet minerals commonly occur in metamorphic rocks, and are believed to be stable in the lower mantle of the earth. The minerals are generally cubic (= isometric) in symmetry. Garnet minerals are generally hard (Mohs hardness H: 6.5 to 7.5) and dense (specific gravity G: 3.5 to 4.5) and are used commercially as an abrasive. *Syn.*, silicate garnet

**garnierite** Although not a valid mineral name, garnierite is often used as a field term for nickel-bearing ( $\pm$  magnesium) hydrous phyllosilicates.

**gavite** an obsolete term for a variety of talc that apparently deviates from the (OH) content of talc as determined in old literature, from Gava valley, Italy

**genthite** a discredited term, a mixture of pimelite and Ni-rich serpentine

**gibbsite** a polymorph of  $\text{Al}(\text{OH})_3$  where one third of the octahedral sites are vacant and each OH group is coordinated by two Al cations. Although each layer is approximately closest packed, the stacking of layers is not closest packed, and OH groups in adjacent layers superpose. The interlayer OH to OH distance is relatively small (at  $\sim 2.78 \text{ \AA}$ ), indicating a strong hydrogen bond that is enhanced by strong polarization caused by the highly charged  $\text{Al}^{3+}$  cation. *Cf.*, bayerite, nordstrandite

**gibbsite-like** a term that is synonymous with the dioctahedral interlayer sheet in chlorite. This sheet is analogous to gibbsite in that gibbsite consists of two (intralayer) planes of closest packed oxygen atoms with two out of three of the octahedral sites between the two planes occupied by trivalent cations, in this case Al. In the gibbsite-like sheet, some of the oxygen atoms are replaced by hydroxyl groups, (OH). This term is only for chlorite. The dioctahedral sheet in a 2:1 layer silicate, such as mica, is very different from gibbsite, whereas the interlayer in a chlorite is quite “gibbsite-like”. For example, in a 2:1 layer octahedral sheet, two thirds of the oxygen anions are apical oxygen atoms whereas only one third are OH groups—very different from a gibbsite-like sheet.

**gigantolite** a poorly defined material, possibly muscovite and cordierite

**gilbertite** an obsolete term for muscovite

**glagolevite** a chlorite-like mineral containing Na in seven-fold coordination located between the interlayer octahedral sheet and the 2:1 layer. The ideal chemical composition is  $\text{Na}(\text{Mg,Al})_6(\text{Si}_3\text{Al})\text{O}_{10}(\text{OH},\text{O})_8$ . Glagolevite was described by Krivovichev et al. (2004) in analogy to chlorite as a tri-trioctahedral chlorite with polytypes *Iib-6*, *Iib-2* and *Iib-4*. The mineral occurs at the Kovdor Phlogopite quarry, Kovdor massif, Kola peninsula, Russia.

**glauconite** an iron-rich dioctahedral mica that shows K deficiency and limited substitutions of Al in the tetrahedral sites. Glauconite is a series name (Rieder et al., 1998) with a generalized composition of  $\text{K}_{0.8}\text{R}^{3+}_{1.33}\text{R}^{2+}_{0.67}(\text{Al}_{0.65}\text{Si}_{3.87})\text{O}_{10}(\text{OH})_2$ , where  ${}^{\text{vi}}\text{R}_{2+}/({}^{\text{vi}}\text{R}_{2+} + {}^{\text{vi}}\text{R}^{3+}) \geq 0.15$ , and  ${}^{\text{vi}}\text{Al}/({}^{\text{vi}}\text{Al} + {}^{\text{vi}}\text{Fe}^{3+}) \leq 0.5$  and shows no compositional overlap with celadonite. Often interstratified with smectite as the mixed-layered mineral glauconite/smectite. When mixed with other minerals or when referring to morphological features, the term “glauconitic” is appropriate. The mode of origin is not a criterion for identification.

**goethite** see diaspore

**goeschwitzite** an obsolete term for illite

**gonyerite** a poorly known, modulated 2:1 layer silicate (Guggenheim and Eggleton, 1987). Although superficially resembling chlorite, gonyerite has a two-layer structure with structurally different types of interstratified layers. Inverted tetrahedra occur between the 2:1 layer and linked to the what would be the brucite-like interlayer in an ideal chlorite. Samples of gonyerite are generally impure, although an analysis by Frondel (1955) reported an approximate composition of  $(\text{Mn}_{3.25}\text{Mg}_{1.95}\text{Fe}^{3+}_{0.64})(\text{Si}_{3.75}\text{Fe}^{3+}_{0.17}\text{Al}_{0.08})\text{O}_{10.2}(\text{OH})_{7.8}$  and is based on the assumption that gonyerite is a chlorite and all iron is ferric. Gonyerite occurs in low-grade metamorphic, silicate-rich manganese deposits, such as that at the Harstigen Mine, Pajsberg, Värmland, Sweden.

**graminite** an obsolete term for nontronite

**grandite** see garnet

**greenalite** a modulated 1:1 layer silicate based on the serpentine structure, with an approximate ideal composition of  $\text{Fe}^{2+}_3\text{Si}_2\text{O}_5(\text{OH})_4$ . Mn, Mg, and Al can substitute for Fe. There is an apparent excess of Si and an apparent deficiency in octahedral composition on the basis of 7 oxygen atoms. Earlier literature erroneously described greenalite as an iron serpentine, similar to the structure of lizardite. The *1T* polytype (space group *P31m*) is dominant and the *1M*

polytype (space group *Cc*) is often intergrown. Greenalite is an “island” structure where Si-rich tetrahedra of a given layer have apical oxygen atoms coordinate to one octahedral sheet and others to the adjacent sheet (Guggenheim and Eggleton, 1998). The islands are saucer-shaped with some islands inverted, and the islands are domed. Island diameters depend on composition with larger-diameter islands having smaller average octahedral cation sizes (4 tetrahedral-ring diameters in greenalite, 3 rings in the Mn analogue, caryopilite). Island domains are randomly displaced within layers. Greenalite is commonly found in Precambrian iron formations. *Cf.*, caryopilite

**griffithite** a poorly described material, possibly chlorite, from Griffith Park, Los Angeles, California, USA

**groutellite** “Groutellite” is a poorly defined phase that had been found in heating experiments as an intermediate phase from ramsdellite to groutite with a possible composition of  $\text{Mn}_2\text{O}_3\text{OH}$ . The phase is a synthesis product only, although it has been anticipated that it may occur in nature.

**groutite** Groutite is a manganese oxyhydroxide,  $\alpha\text{-MnO(OH)}$ , and is isostructural with diaspore. The manganese is trivalent and coordinated with O to form edge-sharing  $\text{Mn}^{3+}\text{O}_6$  octahedra, which are linked three-dimensionally by sharing vertices. The three dimensional structure is comprised of tunnels, with the sizes of these tunnels determined by the chain widths. In groutite, the edge-sharing octahedra form double chains, whereas in manganite ( $\gamma\text{-MnO(OH)}$ ; isostructural with rutile) the edge-sharing octahedra form single chains. Jahn-Teller distortions (Kohler et al., 1997) affect the octahedral shape with four short and two long Mn-O bond lengths and determine partially where the hydrogen links the octahedral chains to form the overall topologies. Groutite may be described as a distorted derivative of ramsdellite ( $\text{MnO}_2$ , with  $\text{Mn}^{4+}$  and a double octahedral chain; isostructural with gibbsite) and manganite as a distorted derivative of pyrolusite,  $\beta\text{-MnO}_2$  (and a single octahedral chain with  $\text{Mn}^{4+}$ ; isostructural with rutile). Feitknechtite,  $\beta\text{-MnO(OH)}$ , has not been well described. Pyrolusite occurs in low temperature hydrothermal deposits and as replacement after other Mn oxide minerals. Groutite and ramsdellite are rare, often altering to pyrolusite, and occur in low temperature hydrothermal deposits. Feitknechtite occurs as fine-grained mixtures with hausmannite.

**grovesite** a discredited name, now known to be a Mn-rich chlorite, pennantite

**grundite** an obsolete term for illite

**grüner Chrysopraserde** an obsolete term for poorly described Ni- and Mg-rich phyllosilicates, generally characterized as “garnierite”

**guidottiite** the Mn-analogue of cronstedtite, a serpentine. Guidottiite has an ideal composition of  $(\text{Mn}_2\text{Fe}^{3+})(\text{SiFe}^{3+})\text{O}_5(\text{OH})_4$ . Guidottiite- $2H_1$  and - $2H_2$  were reported by Wahle et al. (2010)

with random interstratified polytype intergrowths and stacking disorder common. The sample comes from the Kalahari Manganese field, South Africa, and forms from hydrothermal solutions.

**gumbellite** an obsolete term for illite- $2M_2$

**gymnite** see “deweylite”

**gyrolite** see reyerite group

**hallerite** a poorly defined material, possibly paragonite and lithian muscovite

**hallite** an obsolete name for altered material, probably vermiculite

**halloysite** a member of the kaolin group, with a chemical composition of ideally  $\text{Al}_2\text{Si}_2\text{O}_5(\text{OH})_4 \cdot x(\text{H}_2\text{O})$ . Varying amounts ( $x$ ) of  $\text{H}_2\text{O}$  may be present in the interlayer, and the terms halloysite (7 Å) and halloysite (10 Å) were recommended for general usage to quantify the amount of  $\text{H}_2\text{O}$  present between layers. Values of  $x \sim 0$  [halloysite (7 Å)] are near kaolinite and  $x \sim 2$  is halloysite (10 Å). Gentle heating of the halloysite (10 Å) phase will produce halloysite (7 Å), and this is a non-reversible reaction. Halloysite (10 Å) requires storage in water to prevent (partial) dehydration. Halloysite commonly has considerable stacking disorder although a “well crystallized” sample may have an approximate two-layer ( $2M_1$ ) structure for halloysite (7 Å) for a limited stacking sequence of 6-7 layers. Atomic coordinates for interlayer  $\text{H}_2\text{O}$  are not known, although  $\text{H}_2\text{O}$  within the silicate ring and  $\text{H}_2\text{O}$  in a discontinuous plane between the layers have been suggested. Halloysite layers may be planar, curved, rolled (tubular), and partly spherical to spherical, and these morphologies appear to be related to crystallization conditions and chemical composition. There is no way to conclusively differentiate between halloysite and kaolinite without knowing the history of the sample, although suggestions have included the evidence of the  $2M_1$  polytype and various treatments involving intercalation as ways to identify halloysite (7 Å). *Cf.*, dickite, kaolin, kaolinite, nacrite

**haughtonite** an obsolete varietal term for biotite

**hausmannite** Hausmannite,  $\text{Mn}_3\text{O}_4$ , is tetragonal and has a deformed cubic spinel structure. Each Mn cation (Jarosch, 1987) in octahedral coordination is affected by Jahn-Teller distortions with two long Mn-O distances and four short distances. The Mn-O<sub>4</sub> tetrahedra have equal Mn-O bond lengths. Hausmannite is isostructural with the  $\text{Fe}_3\text{O}_4$  inverse spinel structure (magnetite). Hausmannite occurs in metamorphic manganese deposits, for example at Langban, Sweden, and Postmasburg, South Africa.

**hectorite** Hectorite is the Mg- and Li-rich trioctahedral member of the smectite group. It has the ideal chemical composition of  $(M^+_y \cdot n\text{H}_2\text{O})(\text{Mg}_{3-y}\text{Li}_y)\text{Si}_4\text{O}_{10}(\text{OH})_2$  where  $M$  is the exchangeable cation,  $y$  is the Li content, and  $n$  is variable. The  $M$  (interlayer) cation is assumed here as univalent, but it may have other valence states also. F substitution for (OH) has been

documented. Stacking of natural samples is generally turbostratic. Fluorohectorite, with  $M = \text{Na, K, Rb, and Cs}$  and with  $y = 0.5$  was synthesized by Breu et al. (2003), and the well-ordered, one-layer structure of the Cs phase was determined (space group  $C2/m$ ,  $1M$  polytype). Cf., swinefordite

**hedenbergite** a clinopyroxene (monoclinic space group  $C2/c$ ) with an end-member formula of  $\text{CaFeSi}_2\text{O}_6$ . Hedenbergite and diopside,  $\text{CaMgSi}_2\text{O}_6$ , form a continuous solid solution series. Hedenbergite primarily occurs in metamorphic rocks and skarns. See pyroxene group for additional details.

**helvetan** a poorly defined material, possibly decomposed biotite

**hendricksite** a trioctahedral member of the true mica group. The end-member formula is  $\text{KZn}_3\text{AlSi}_3\text{O}_{10}(\text{OH})_2$ . The Zn content must be greater than or equal to 1.5 for the specimen name to be valid. Reported polytypes are  $1M$ ,  $2M_1$ , and  $3T$ . It forms in skarns of Zn deposits and occurs at Franklin Furnace, New Jersey, U.S.A.

**henrymeyerite** see hollandite

**heterophyllite** an obsolete varietal term for biotite

**hexagonal mica** a poorly defined material, possibly a mica

**hisingerite** Hisingerite is a natural ferric kaolin, analogous to halloysite, that forms partly spherical to spherical morphologies approximately 60-200 Å in diameter.

**hollandite** Hollandite (Post et al., 1982) is a manganese oxide mineral within the hollandite supergroup (Biagioni et al., 2012) with a general chemical composition of  $A_{0-2}B_8(\text{O,OH})_{16}$ , where  $A = \text{Ba}^{2+}$  and  $B = (\text{Mn}^{4+}_6\text{Mn}^{3+}_2)$  in hollandite. The  $B$  cations form edge sharing double chains of  $B$ -O octahedra, with each double chain forming a wall of a four-sided tunnel. The large  $A$  cations, in ideally eight-coordinated sites, reside in the tunnel and offset any undersaturated charge on the octahedra. The supergroup is divided further into the coronadite group ( $\text{Mn}^{4+}$  dominates the  $B$  cations and includes hollandite) and the priderite group ( $\text{Ti}^{4+}$  dominates). Other minerals in the coronadite group include ( $A$  cations)  $\text{K}^+$  in cryptomelane [ideally  $B = (\text{Mn}^{4+}_7\text{Mn}^{3+})$ ],  $\text{Sr}^{2+}$  in strontiomelane [ideally  $\text{Sr}(\text{Mn}^{4+}_6\text{Mn}^{3+}_2)\text{O}_{16}$ ],  $\text{Pb}^{2+}$  in coronadite [ideally  $B = (\text{Mn}^{4+}_6\text{Mn}^{3+}_2)$ ], and  $\text{Na}^+$  in manjiroite [ideally  $B = (\text{Mn}^{4+}_7\text{Mn}^{3+})$ ]. Ferrihollandite is  $\text{BaMn}^{4+}_6\text{Fe}^{3+}_2\text{O}_{16}$ . Other  $B$  cations in natural samples can include  $\text{Ti}^{4+}$ ,  $\text{Fe}^{3+}$ ,  $\text{Al}^{3+}$ ,  $\text{Si}^{4+}$ ,  $\text{Mg}^{2+}$  or additionally, in synthetic phases,  $\text{Zn}^{2+}$ ,  $\text{In}^{4+}$ ,  $\text{Ni}$ ,  $\text{Cr}$ , and many others. Likewise,  $A$ -cation substitutions include  $\text{Ca}$ ,  $\text{Sr}$ ,  $\text{H}_2\text{O}$ , vacancies, etc. Priderite is  $(\text{K,Ba})_{0-2}(\text{Ti}^{4+}_7\text{Fe}^{3+})_8\text{O}_{16}$  and other members of the priderite group are redledgeite [ $\text{Ba}(\text{Ti}^{4+}_6\text{Cr}^{3+}_2)\text{O}_{16}$ ], mannardite [ $\text{Ba}(\text{Ti}^{4+}_6\text{V}^{3+}_2)\text{O}_{16} \cdot \text{H}_2\text{O}$ ], henrymeyerite [ $\text{Ba}(\text{Ti}^{4+}_7\text{Fe}^{2+})\text{O}_{16}$ ]. The presence or absence of  $\text{H}_2\text{O}$  does not define a hollandite-like species. Hollandite-supergroup mineralization occurs in oxidized zones of

manganese ores, in hydrothermal deposits, and in some soils. The tunnel topology allows for these minerals to be good ionic conductors for batteries.

**holmesite** an obsolete term for clintonite

**holmite** an obsolete term for clintonite

**honessite** see hydrotalcite group

**hormite** a term used in industry referring to palygorskite and/or sepiolite. This term should not be used in the scientific literature.

**hullite** a poorly defined material, found as infillings in cavities in basic igneous rocks, possibly an altered chlorite or a chlorite + smectite mixture

**hyalite** see opal

**hydrobiotite** a regular interstratification of biotite-like layers with vermiculite-like layers. The ratio of vermiculite-like layers (i.e., one 2:1 layer and one interlayer capable of limited swelling) to biotite (i.e., one 2:1 layer) is 1:1 (Brindley et al., 1983).

**hydrohausmannite** a discredited term for a mixture of hausmannite and feitknechtite (beta-MnOOH)

**hydrohonessite** see hydrotalcite group

**hydromicas** an obsolete term for interlayer-deficient micas

**hydromuscovite** an obsolete term for illite

**hydroparagonite** an obsolete term for brammallite

**hydrophlogopite** a poorly defined material, possibly interstratified phlogopite and vermiculite

**hydropolyolithionite** a poorly defined material, possibly altered lepidolite

**hydrotalcite group** Hydrotalcite-like and manasseite-like minerals occur as polytypes in rhombohedral and hexagonal forms, respectively. The general formula is  $[\text{Mg}_{1-x}\text{Al}_x(\text{OH})_2]^{x+} [(\text{CO}_3)_{x/2} \cdot n\text{H}_2\text{O}]^{x-}$ , where  $x = 0.25$  to  $0.33$  (Drits et al., 1987). In general, the structure is a brucite-like positively charged layer separated by  $\text{CO}_3$  anions and  $\text{H}_2\text{O}$  as interlayer material, but substitutions are common. The International Mineralogical Association recognizes different species (below), based primarily on chemical differences, although there are many other unnamed forms. These minerals occur in saline deposits, pegmatites, and serpentinites.

Hydrothermal synthesis is relatively easy, as is anion exchange. *Cf.*, anionic clay (Part A), double metal hydroxides (Part A)

barbertonite  $\text{Mg}_6\text{Cr}_2(\text{OH})_{16}\text{CO}_3 \cdot 4(\text{H}_2\text{O})$

carrboydite  $(\text{Ni,Cu})_{5.90}\text{Al}_{4.48}(\text{OH})_{21.69}(\text{SO}_4,\text{CO}_3)_{2.78} \cdot 3.67(\text{H}_2\text{O})$

chlormagaluminite  $(\text{Mg}_{3.55}\text{Fe}^{2+}_{0.27}\text{Na}_{0.05})(\text{Al}_{1.93}\text{Fe}^{3+}_{0.07}\text{Ti}_{0.01})(\text{OH})_{12} \cdot \text{Cl}_2\text{CO}_3 \cdot 2(\text{H}_2\text{O})$

coalingite  $\text{Mg}_{10}\text{Fe}^{3+}_2(\text{OH})_{24}\text{CO}_3 \cdot 2(\text{H}_2\text{O})$ ;  $\text{Mg}_{16}\text{Fe}^{3+}_2(\text{OH})_{36}\text{CO}_3 \cdot 2(\text{H}_2\text{O})$

desautelsite  $\text{Mg}_6\text{Mn}_2(\text{OH})_{16}\text{CO}_3 \cdot 4(\text{H}_2\text{O})$

honestite  $[\text{Ni}_{5.55}\text{Mg}_{0.10}\text{Fe}^{3+}_{2.35}(\text{OH})_{16}](\text{SO}_4)_{1.18} \cdot n\text{H}_2\text{O}$

hydrohonestite  $[\text{Ni}_{5.43}\text{Fe}^{3+}_{2.57}(\text{OH})_{16}](\text{SO}_4)_{1.28}6.95\text{H}_2\text{O} \cdot 0.98\text{NiSO}_4$

hydrotalcite  $\text{Mg}_6\text{Al}_2(\text{OH})_{16}\text{CO}_3 \cdot 4(\text{H}_2\text{O})$ ;  $\text{Mg}_4\text{Al}_2(\text{OH})_{12}\text{SO}_4 \cdot 3(\text{H}_2\text{O})$

iowaite  $\text{Mg}_{4.63}\text{Fe}^{3+}_{1.32}(\text{OH})_{12}\text{Cl}_{1.33} \cdot 1.95(\text{H}_2\text{O})$

manasseite  $\text{Mg}_6\text{Al}_2(\text{OH})_{16}\text{CO}_3 \cdot 4(\text{H}_2\text{O})$ ;  $\text{Mg}_4\text{Al}_2(\text{OH})_{12}\text{CO}_3 \cdot 3(\text{H}_2\text{O})$

meixnerite  $\text{Mg}_6\text{Al}_2(\text{OH})_{16}(\text{OH})_2 \cdot 4(\text{H}_2\text{O})$

motukoreaite  $[\text{Mg}_{1.82}\text{Mn}_{0.03}\text{Zn}_{0.02}\text{Al}_{1.12}(\text{OH})_{5.15}] \cdot [\text{Na}_{0.07}\text{K}_{0.07}(\text{CO}_3)_{0.40}(\text{SO}_3)_{0.41} \cdot 2.7(\text{H}_2\text{O})]$

mountkeithite  $[(\text{Mg}_{8.15}\text{Ni}_{0.85})(\text{Fe}^{3+}_{1.31}\text{Cr}_{1.02}\text{Al}_{0.65})(\text{OH})_{24}](\text{CO}_3)_{1.11}(\text{SO}_4)_{0.38}(\text{Mg}_{1.76}\text{Ni}_{0.18})(\text{SO}_4)_{1.94}(\text{H}_2\text{O})_{9.39}$

pyroaurite  $\text{Mg}_6\text{Fe}^{3+}_2(\text{OH})_{16}\text{CO}_3 \cdot 4.5(\text{H}_2\text{O})$ ;  $\text{Mg}_4\text{Ni}^{2+}_2\text{Fe}^{3+}_2(\text{OH})_{16}\text{CO}_3 \cdot 4(\text{H}_2\text{O})$

reevesite  $\text{Ni}_6\text{Fe}^{2+}_2(\text{OH})_{16}\text{CO}_3 \cdot 4(\text{H}_2\text{O})$

sjögrenite  $\text{Mg}_6\text{Fe}^{3+}_2(\text{OH})_{16}\text{CO}_3 \cdot 4.5(\text{H}_2\text{O})$

stichtite  $\text{Mg}_6\text{Cr}_3(\text{OH})_{16}\text{CO}_3 \cdot 4(\text{H}_2\text{O})$ ;  $[\text{Mg}_{5.94}(\text{Cr}_{1.29}\text{Al}_{0.51}\text{Fe}^{3+}_{0.25})(\text{OH})_{15.1}][(\text{CO}_3)_{1.47}3.7(\text{H}_2\text{O})]$

takovite  $\text{Ni}_6\text{Al}_2(\text{OH})_{16}\text{CO}_3\text{OH} \cdot 4(\text{H}_2\text{O})$ ;  $[\text{Ni}_5\text{Mg}_{0.10}\text{Fe}^{3+}_{0.13}\text{Al}_{2.81}(\text{OH})_{14.42}](\text{CO}_3)_{2.27} \cdot 5.4(\text{H}_2\text{O})$ ;

$\text{Ni}_6\text{Al}_2(\text{OH})_{16}\text{SO}_4\text{OH} \cdot n\text{H}_2\text{O}$

wermlandite  $[\text{Mg}_{3.55}(\text{Al}_{0.57}\text{Fe}^{3+}_{0.41})_2(\text{OH})_{18}](\text{Ca}_{0.6}\text{Mg}_{0.4})(\text{SO}_4)_2 \cdot 12(\text{H}_2\text{O})$

woodwardite  $\text{Cu}_4\text{Al}_2(\text{OH})_{12}\text{SO}_4 \cdot 2-4\text{H}_2\text{O}$

**hydrotalcite** see hydrotalcite group

**hydroxyl-annite** an obsolete term for annite

**hydroxyl-biotite** an obsolete term for biotite

**iberite** a poorly defined material, possibly altered cordierite and zeolite

**illite** Illite was a term proposed in 1937 by Grim et al. as a “group” name for the mica-like, clay-size mineral constituents in argillaceous sediments. Bailey et al. (1984) indicated that illite, as a species, must meet the following characteristics: (1) the structure is not expansible, (2) the 2:1 layer is dioctahedral, and (3) there are compositional criteria. Rieder et al. (1998) gave a representative formula and typical ranges as:  $\text{K}_{0.65}\text{Al}_2\text{O}^{\square}(\text{Al}_{0.65}\text{Si}_{3.35})\text{O}_{10}(\text{OH})_2$  where  ${}^{\text{vi}}\text{R}^{2+}/({}^{\text{vi}}\text{R}^{2+} + {}^{\text{vi}}\text{R}^{3+}) \leq 0.25$  and  ${}^{\text{vi}}\text{Al}/({}^{\text{vi}}\text{Al} + {}^{\text{vi}}\text{Fe}^{3+}) \geq 0.6$  and this differs from muscovite, a closely related mica with an end-member formula and ranges of  $\text{KAl}_2(\text{AlSi}_3)\text{O}_{10}(\text{OH})_2$  where  ${}^{\text{iv}}\text{Si}$ : 3.0 – 3.1,  ${}^{\text{vi}}\text{Al}$ : 1.9 – 2.0, K: 0.7 – 1.0 (interlayer cations  $\geq 0.85$ ),  ${}^{\text{vi}}\text{R}^{2+}/({}^{\text{vi}}\text{R}^{2+} + {}^{\text{vi}}\text{R}^{3+}) < 0.25$ , and  ${}^{\text{vi}}\text{Al}/({}^{\text{vi}}\text{Al} + {}^{\text{vi}}\text{Fe}^{3+})$ : 0.5 – 1.0. The interlayer deficiency observed in illite is considered an important part of the definition. Rieder et al. defined illite as a “series” name, and series names designate that

additional research may be warranted. The clay-size aspects and an occurrence in argillaceous sediments are not considered acceptable criteria to define a mineral. When illite is being referred to as a mineral species, it is advisable to make a clear statement to that effect. Non-pure illite, i.e., material containing an expansible component, is referred to as “illitic”.

**illite/smectite or illite-smectite** a phase or mixture of two phases (the status remains unknown) generally showing a non-regular interstratification of illite-like layers with smectite-like layers. The ratio of smectite-like layers (i.e., one 2:1 layer and one interlayer capable of swelling) to illite-like layers (i.e., one 2:1 layer) may vary. Regularity in stacking may be found at specific ratios of layers (I = illite-like, S=smectite-like), for example, ISISIS... or IISIIISIIIS..., but these patterns of regularity are not of a sufficient long-range nature to designate a separate species. Commonly abbreviated as “I/S” or “I-S”.

**imogolite** a poorly crystallized (i.e., lacks long-range atomic order) hydrous aluminosilicate of approximate composition of  $(\text{OH})_3\text{Al}_2\text{O}_3\text{SiOH}$ , with a natural-samples range of  $\text{Al}_2(\text{OH})_3(\text{SiO}_2)_{1.0-1.2}(\text{H}_2\text{O})_{2.3-3.0}$ . The Si/Al ratio is near 0.5. The structure consists of nanotubes, often occurring in closest packing arrangements about 2nm in diameter and to several micrometers in length, typically forming bundles 10 to 30 nm across. The morphology makes imogolite potentially useful in industry for contaminant sorption, gas storage, as an oxidation catalyst, and as an electron emitter. Imogolite has a gibbsite-like structure with Si tetrahedra spanning the vacant octahedral sites, and because of the mismatch in size between the vacant site and the tetrahedron, the gibbsite-like sheet rolls. Imogolite forms from weathered volcanic ash, but may also occur in podzolized soils and in pumice. *Cf.*, allophane

**indianaite** an obsolete, local term for a halloysite from Lawrence County, Indiana, in beds to 3 meters thick; may have been used as a rock name for these beds

**innsbruckite** a modulated 1:1 layer silicate with a continuous edge-sharing, Mn-rich octahedral sheet, and an interstratified continuous tetrahedral sheet consisting of 8-, 6-, 5-, and 4-member tetrahedral rings that cross link the octahedral sheet (Krüger et al., 2014). The chemical composition is ideally  $\text{Mn}_{33}(\text{Si}_2\text{O}_5)_{14}(\text{OH})_{38}$ . The type locality, near Tyrol, Austria, is located between a serpentinite and chert body, and it appears that the Mn-rich sediments were deposited in deep water and metamorphosed. *Cf.*, bementite, pyrosmalite, varennesite

**ionite** an obsolete, local term for a kaolin forming crusts in the Ione sandstone, California, USA

**iowaite** see hydrotalcite group

**iron mica** an obsolete term for annite, siderophyllite, biotite, and hematite

**iron muscovite** an invalid name for a hypothetical end member

**iron-sericite** an obsolete varietal term for ferrian illite

**irvingite** an obsolete varietal term for lithian muscovite

**isinglas** an obsolete term for muscovite

**ivigtite** a poorly defined material, possibly muscovite or sodian ferruginous mica

**jadeite** a pyroxene with chemical formula of  $\text{NaAlSi}_2\text{O}_6$ . Jadeite occurs in high-pressure, low temperature metamorphic rocks and is the primary mineral in jade. See pyroxene group for additional details.

**jefferisite** an obsolete name for altered material, probably vermiculite

**jennite** see tobermorite and see calcium silicate hydrate (CSH) in Part 1

**kalifersite** a member of the palygorskite-sepiolite group with a composition of  $(\text{K},\text{Na})_5\text{Fe}^{3+}_7(\text{Si}_{20}\text{O}_{50})(\text{OH})_6 \cdot 12(\text{H}_2\text{O})$ . The kalifersite shows a regular alternation of structural components of sepiolite and palygorskite Ferraris et al. (1998). See palygorskite-sepiolite group

**kaliglimmer** an obsolete term for muscovite

**kandite** a name previously proposed for the kaolin/serpentine group. The name has not been approved for use by any mineralogical nomenclature committee and its use should be discontinued.

**kaolin** (1) Mineralogically, a group name for Al-rich minerals of layer type 1:1 which are dioctahedral and planar (i.e., not modulated). Species include kaolinite, dickite, nacrite, halloysite (planar). (2) Petrologically, a soft, dispersible, usually white or nearly white claystone composed primarily of minerals of the kaolin group, principally kaolinite. Sometimes described as non-plastic. The mixture often contains a variable proportion of, e.g., mica, quartz. Kaolin is white or nearly white on firing; a porcelain clay or natural (unwashed) china clay; and used in the manufacture of ceramics, refractories, and paper. Type locality: Kao-ling (meaning "high hill"), a hill in Kiangsi province, SE China. See also Part 1 of the Glossary. *Syn.*, kaoline, white clay, bolus alba, *Cf.*, dickite, halloysite, kaolinite, nacrite

**kaolinite/smectite or kaolinite-smectite** a non-regular interstratification of kaolinite-like layers with smectite-like layers. Alternatively, the smectite-like layer may be replaced with other expandable layers (e.g., vermiculite). Found in paleosols. May be abbreviated K/S or K-S, and has been referred to as an "kaolinite/expandable" interstratification, K/E (Hughes et al., 1993).

**kaolinite** a member of the kaolin group (1:1 layer, dioctahedral), and polymorphic with dickite and nacrite. The chemical composition is  $\text{Al}_2\text{Si}_2\text{O}_5(\text{OH})_4$ . In kaolinite, the vacant octahedral site is located in the "B" site in each layer to form a triclinic structure. The "B" and "C" sites

would be related by a mirror plane if both sites were occupied identically within the same layer, whereas the “A” site resides on the mirror plane (Bish and Von Dreele, 1989). Kaolinite forms under diagenetic and hydrothermal conditions, and may transform to dickite at higher temperatures. At very high temperatures, kaolinite transforms to “metakaolinite”. In early publications, kaolinite was used as the group name, now known as kaolin. *Cf.*, dickite, halloysite, kaolin, nacrite

**kellyite** a platy serpentine mineral of ideal composition of  $Mn_2Al(Si,Al)O_5(OH)_4$ , and thus, the  $Mn^{2+}$  analogue of amesite. Mg and  $Fe^{2+}$  have been found to substitute for Mn and Al. Natural occurrences are rare; the type locality is Bald Knob, North Carolina, USA. Stacking disorder is common but, two-layer ( $2H_2$ ) and six-layer polytypes are known to occur. *Cf.*, amesite, zinalsite

**kenyaite** see magadiite

**kerolite** a variety of talc, but with  $H_2O$  either in the interlayer or associated with the broken bonds at the edges of the particles. As a variety of talc, “kerolite” should not be used as a mineral name in a strict sense. Brindley et al. (1977) reported the composition as  $Mg_3Si_4O_{10}(OH)_2 \cdot nH_2O$  with  $n = 0.8 - 1.2$ . Stacking is turbostratic and particle size is  $< 5$  layers. After weeks under ethylene glycol, kerolite swells slightly, whereas talc does not. Kerolite occurs in weathering profiles (Brindley et al., 1977), in palustrine environments (Pozo and Casas, 1999), and in microbial mats in Hawaiian caves (Léveillé et al., 2002), and may be derived from sepiolite (Stoessell, 1988). Older literature may use the spelling of “Cerolite”. *Cf.*, pimelite, talc

**kerrite** an obsolete term for a local variety name of vermiculite

**killinite** an obsolete term for illite

**kimolite** an obsolete term for a kaolin, but probably a mixture, described from Kimolos, Greece. *Syn.* cimolite, pelikanite (from Kiev, Russia, also obsolete)

**kinoshitalite** a trioctahedral member of the brittle mica group. The end-member formula is:  $BaMg_3Al_2Si_2O_{10}(OH)_2$ . Typical site substitutions include:  $Ba > K$ ;  $Mn^{2+}$ ,  $Mn^{3+}$ , Al, Fe, Ti for Mg; and F for OH. Kinoshitalite forms  $1M$  and, less commonly,  $2M_1$  polytypes. In general, kinoshitalite occurs in metamorphic deposits in amphibolite- to granulite-facies, in marbles and calc-silicate rocks, and in kimberlites (group I) and in volcanic rocks that are K undersaturated. *Cf.*, ferrokinoshitalite

**klementite** an obsolete term for chamosite (chlorite)

**kmaite** an obsolete term for celadonite, ferrian celadonite

**kotschubeite** an obsolete term for a Cr-containing chlorite from the Ural mountains

**kryptotile** a poorly defined material, probably not a mica

**kulkeite** a regular interstratification of talc-like layers and trioctahedral (tri, trioctahedral) chlorite in a ratio of 1:1 (Abraham et al., 1980). The ideal formula is  $Mg_8Al(Si_7Al)O_{20}(OH)_{10}$ , although substitutions of  $NaAl = Si$  to about  $Si_{0.4}$  are known.

**kupletskite** see astrophyllite group

**labradorite** see plagioclase feldspar

**lamprophyllite** see astrophyllite group

**larvikite** syenite (an igneous rock) dominated by anorthoclase with iridescent colors

**lassallite** an obsolete name for a poorly defined material from Haute-Loire, France, possibly palygorskite-sepiolite

**laumontite** see zeolite

**ledikite** a poorly defined material, possibly interstratified biotite and vermiculite

**lebergite** an obsolete varietal term for  $Fe^{2+}$ -rich saponite

**lennilenapeite** Mg analogue of stilpnomelane, see stilpnomelane

**lennilite** an obsolete name for altered material, probably vermiculite

**lepidocrocite** see boehmite

**lepidolite** a series name for trioctahedral micas on or close to the trilithionite-polyolithionite join. Also used to describe light-colored micas with a significant amount of lithium. Lepidolite is useful as a field term for micas that have not been completely analyzed compositionally, that are commonly found in pegmatite, that have a pink or whitish color. In general, lepidolite, as distinguished from muscovite, commonly crystallizes as the  $1M$  polytype, whereas muscovite is commonly the  $2M_1$  polytype. Lithium is not a chromophore and does not impart the pink color to lepidolite; the presence of Mn probably imparts the pink color to lepidolite.

**lepidomelane** an obsolete varietal term for annite, siderophyllite, tetra-ferri-annite, and biotite

**lepidomorphite** an obsolete term for phengite

**leptochlorite** an obsolete term for an iron-rich chlorite

**lesleyite** a poorly defined material, possibly margarite or a mineral mixture

**leuchtenbergite** an obsolete term for a near iron-free chlorite from the Ural mountains

**leucophyllite** an obsolete term for aluminoceladonite

**leverrierite** a poorly defined material, probably not a mica, possibly containing halloysite

**lilalite** an obsolete term for lepidolite

**lilalith** an obsolete term for lepidolite

**lime mica** an obsolete term for margarite

**lime** see calcium silicate hydrate (CSH) in Part 1

**lithia mica** an obsolete term for lepidolite, zinnwaldite

**lithioneisenglimmer** an obsolete term for zinnwaldite

**lithionglimmer** an obsolete term for lepidolite

**lithionit** an obsolete term for lepidolite

**lithionite** an obsolete term for lepidolite

**lithionitesilicat** an obsolete term for lepidolite

**lithiophorite** Lithiophorite,  $\text{LiAl}_2(\text{Mn}^{4+}_2\text{Mn}^{3+})\text{O}_6(\text{OH})_6$ , has a structure that contains alternating sheets of (Al,Li)(OH)<sub>6</sub> octahedra and sheets of (Mn<sup>3+</sup>,Mn<sup>4+</sup>)O<sub>6</sub> octahedra. The Al,Li sheet chemistry has an ideal ratio of Al:Li of 1:2, but may vary with charge balance being maintained by the Mn oxidation state. Sheets are held together by hydrogen bonding. Lithiophorite occurs in oxidized zones of Mn ore deposits, acidic soils, and low-temperature hydrothermal environments. Lithiophorite has been identified in nodules from Hawaiian soils.

**lithium muscovite** an obsolete term for trilithionite, lithian muscovite

**lithium phengite** an obsolete varietal term for lithian muscovite

**lithomarge** an obsolete term for a massive, compact, often impure kaolin

**lizardite** a platy trioctahedral member of the serpentine group. The ideal, end-member formula is:  $\text{Mg}_3\text{Si}_2\text{O}_5(\text{OH})_4$ . Typical site substitutions include Al and Fe<sup>3+</sup> for Si and Mg. The most

common form of lizardite is the  $1T$  polytype (space group  $P31m$ ), followed by the  $2H_1$  polytype (space group  $P6_3cm$ ). Lizardite is the most abundant serpentine and forms from the weathering (hydration) of ultramafic rocks, primarily composed of olivine and pyroxene.

**lobanovite** see astrophyllite group

**loughlinite** a member of the palygorskite-sepiolite group with a composition of approximately  $\text{Na}_4\text{Mg}_6(\text{Si}_{12}\text{O}_{30})(\text{OH})_4(\text{OH}_2)_4$ . See palygorskite-sepiolite group

**lucianite** a poorly described material originally thought to be a “swelling” talc in old literature, but probably saponite, and now considered as an obsolete term

**luogufengite** Luogufengite is an Al-bearing iron oxide ( $\epsilon\text{-Fe}_2\text{O}_3$ ) polymorph that occurs as a nanomineral with large magnetic coercivity (resistant to be affected by an external magnetic field). The structure is orthorhombic with doubled hexagonal (i.e., ABAC) packing of oxygen atoms. Luogufengite occurs as an oxidation product of Fe-bearing basaltic lava or glass at high temperature, and is associated with maghemite and hematite (Xu et al., 2017). The mineral transforms into hematite ( $\alpha\text{-Fe}_2\text{O}_3$ ) when the crystal size reaches  $\sim 100$  nm or larger (Lee and Xu, 2016). Luogufengite may affect high-remnant magnetization of some igneous and metamorphic rocks.

**lussatine** see opal

**lutécine** an obsolete name for opal, see opal

**lutécite** an obsolete name for opal, see opal

**mackensite** an obsolete term for an iron-rich chlorite

**maconite** an obsolete term for a poorly defined material perhaps related to vermiculite

**macrolepidolite** an obsolete term for lepidolite

**magadiite** a platy, hydrous alkali silicate of composition approximating  $\text{Na}_2\text{O} \cdot 14\text{SiO}_2 \cdot 9\text{H}_2\text{O}$  with exchange properties, and which forms by precipitation from alkaline lakes rich in carbonate/bicarbonate brines, such as that found at Lake Magadi, Kenya. Suggested formulae include  $\text{NaSi}_7\text{O}_{13}(\text{OH})_3 \cdot 3\text{H}_2\text{O}$  and  $\text{NaSi}_6\text{O}_{12}(\text{OH})$ . The latter formula, which differs somewhat from the chemical ratio (due to supposed impurities), is derived from a proposed structure model (Garcés et al., 1988) based on the zeolites in the mordenite group: the model consists of continuous sheets of six-fold  $\text{SiO}_4$  rings of tetrahedra and adjacent five-fold rings pointing away from the sheet surfaces. Other structure models are possible. Kenyaite, with an approximate formula of  $\text{NaSi}_{11}\text{O}_{20.5}(\text{OH})_4 \cdot \text{H}_2\text{O}$ , forms under a similar environment as magadiite and is probably a layer structure also.

**magnesia mica** an obsolete term for phlogopite

**magnesiomargarite** an obsolete varietal term for clintonite

**magnesium sericite** an obsolete varietal term for magnesian illite

**mahadevite** a poorly defined material, possibly Al-rich biotite

**manandonite** a boron-rich serpentine (Ranoroosa et al., 1989), often confused with a boron-rich chlorite in older literature. Manandonite has an ideal chemical composition of  $\text{Li}_2\text{Al}_4(\text{Si}_2\text{AlB})\text{O}_{10}(\text{OH})_8$  and occurs in the  $2H_2$  polytype. Manandonite occurs in the Antandrokomby pegmatite, Manadona River, near Antsirabe, Madagascar. *Cf.*, borocookeite, boromuscovite

**manasseite** see hydrotalcite group

**mangan-muscovite** an obsolete term for manganoan muscovite

**manganarsite** see pyrosmalite

**manganese mica** an obsolete varietal term for biotite

**manganese muscovite** an obsolete term for manganoan muscovite

**manganoglauconite** an obsolete varietal term for glauconite

**manganite** see groutite

**manganmuscovite** an obsolete term for manganoan muscovite

**manganophyll** an obsolete varietal term for biotite

**manganophyllite** an obsolete varietal term for biotite

**manganosite** Manganosite,  $\text{Mn}_{1-x}\text{O}$ , is a wustite-type oxide, isostructural with NaCl occurring in low-temperature hydrothermal environments.

**manganphlogopite** an obsolete varietal term for manganoan phlogopite

**manganpyrosmalite** see pyrosmalite

**manjiroite** see hollandite

**mannardite** see hollandite

**margarite** a dioctahedral member of the brittle mica group. The end-member formula is:  $\text{CaAl}_2\text{Al}_2\text{Si}_2\text{O}_{10}(\text{OH})_2$ . Typical site substitutions include:  $\text{Ca} > \text{Na}, \text{K}$ ;  $\square > \text{Li}$ ;  ${}^{\text{iv}}\text{Al} \approx \text{Si}$ ;  ${}^{\text{iv}}\text{Al} > \text{Be}$ . Margarite is a rock-forming mineral and occurs in low- and medium-grade metamorphic rocks and at nearly all pressure grades. In addition, margarite commonly occurs as pseudomorphs, indicating retrograde reactions and/or polymetamorphism. Margarite most commonly is a  $2M_1$  polytype and, less often, as  $1M$  and  $1M_d$ . Tetrahedral site occupancies alternate with Si and Al around the tetrahedral ring, thereby producing a non-centric structure in space group  $Cc$ . *Cf.*, bityite

**margarodite** an obsolete term for muscovite

**marienglas** an obsolete term for muscovite

**mariposite** an obsolete term for chromian phengite and chromian muscovite

**marmolite** an obsolete varietal term for a thinly foliated form of green-white serpentine

**marsjatskite** an obsolete term for Mn-bearing glauconite from the Urals

**marsyatskite** an obsolete term for glauconite

**masutomilite** a trioctahedral member of the true mica group. The end-member formula is  $\text{KLiAlMn}^{2+}\text{AlSi}_3\text{O}_{10}\text{F}_2$ . Typical ranges in composition are:  $\text{Mn}^{2+} = 1.0 - 0.5$ ,  $\text{Li} = 1.0 - 1.5$ ,  $\text{Si} = 3.0 - 3.5$ ,  ${}^{\text{iv}}\text{Al} = 1.0 - 0.5$  (Rieder et al., 1998). Masutomilite occurs as a  $1M$  polytype with octahedral ordering, which reduces the ideal space group of  $C2/m$  to the acentric subgroup of  $C2$ . Masutomilite occurs in granitic pegmatites rich in Li. *Cf.*, zinnwaldite

**maufite** a discredited term describing a randomly interstratified Ni-bearing lizardite and clinocllore

**mcGillite** see pyrosmalite

**medmontite** discredited name for a copper-rich smectite, now known to be a mixture of chrysocolla and mica

**meerscham** an older term for a variety of sepiolite often used to make pipes. Some meerscham samples may contain amorphous material of similar composition to sepiolite. *Cf.*, sepiolite

**meixnerite** see hydrotalcite group

**melanglimmer** a poorly defined material, possibly biotite, stilpnomelane, or cronstedtite

**melanolite** an obsolete term used for an iron chlorite

**meroxene** an obsolete varietal term for biotite

**metabiotite** a poorly defined material, possibly a weathering product of biotite

**metahalloysite** obsolete term for less hydrated form of halloysite, now halloysite (7 Å)

**metajennite** see tobermorite

**metasericite** an obsolete term for muscovite

**Mg-illite-hydromica** a poorly defined material, possibly interstratified phlogopite and vermiculite

**mica** see Part 1 of the Glossary

**microcline** see alkali feldspar

**microlepidolite** an obsolete term for lepidolite

**miloschite** an obsolete term for a Cr-bearing kaolinite

**minehillite** see reyerite group

**minguetite** (or minguétite) a poorly defined material, possibly interstratified biotite and vermiculite

**minnesotaite** a modulated 2:1 layer silicate with a continuous octahedral sheet and a tetrahedral sheet that forms linked hexagonal 6-fold tetrahedral rings along strips along the [010] direction (Guggenheim and Eggleton, 1986). Some of the tetrahedra are partially inverted to form a chain along the [010], and this chain links adjacent 2:1 layers. There are two varieties of minnesotaite that are based on strip widths and chemical composition: a *P* cell is Mg-rich and is formed where 10 tetrahedra span 9 octahedra along the [010] whereas a *C* cell, which is Fe-rich, forms with 9 tetrahedra spanning 8 octahedra. The ideal chemical composition for the *P* cell is  $(\text{Fe},\text{Mg})_{30}\text{Si}_{40}\text{O}_{96}(\text{OH})_{28}$  and  $(\text{Fe},\text{Mg})_{27}\text{Si}_{26}\text{O}_{86}(\text{OH})_{26}$  for the *C* cell. Early workers incorrectly considered minnesotaite as the Fe analogue of talc. Minnesotaite occurs in low grade metamorphic silicate iron formations.

**modified chlorite structure** a Fe-,Mg-rich chlorite, heat treated in air for one-hour at 550 °C to produce a chlorite-like structure (Guggenheim and Zhan, 1999) with a strong  $d(001)$  peak (14 Å) and weak or absent higher order  $00l$  peaks. The chlorite-to-modified chlorite reaction allows the identification of mixtures of 7 Å phases (e.g., kaolin minerals) and Fe-,Mg-rich chlorite after heating samples of clay mixtures that may contain chlorite with moderate to high amounts of Fe by revealing the possible presence of 7Å peaks in an oriented clay mineral aggregate.

**moganite** Moganite, a polymorph of quartz, has lower symmetry than quartz ( $I2/a$ ) and a triclinic superstructure commonly occurs. The structure was described by Miede and Graetsch (1992) as comprised of sections of right- and left-handed quartz alternating at the unit cell level to form a framework of corner sharing tetrahedra. The framework has 4-, 6- and 8-fold rings, and there is no open tunnel as found in alpha quartz. The nanoscale alternation follows the Brazil twin law, but because it is periodic at the unit cell level, moganite represents a (metastable) mineral phase. Moganite occurs as intergrowths with (alpha) quartz in chert, quartzine, flint, and chalcedony, thus indicating that these latter varieties are not minerals, but rock names. Any H<sub>2</sub>O present in moganite is not structurally required.

**monrepite** an obsolete term for ferrian annite

**montdorite** a trioctahedral member of the true mica group. The ideal formula is  $KFe^{2+}_{1.5}Mn^{2+}_{0.5}Mg_{0.5}Si_4O_{10}F_2$  and this formula does not represent an end-member species. A typical range in composition is:  $Fe^{2+} > Mn^{2+} + Mg$  (Rieder et al., 1998). Robert and Maury (1979) originally described montdorite-1M from a peralkaline rhyolite of the Mont-Dore massif, France, in space group  $C2/m$ .

**montmorillonite** a dioctahedral member of the smectite group of minerals. A representative formula is:  $R_{0.33}(Al_{1.67}Mg_{0.33})Si_4O_{10}(OH)_2 \cdot nH_2O$ . Montmorillonite is Al-rich and capable of cation exchange (the exchangeable cation is depicted as  $R$  in the formula,  $n$  is a rational number, not necessarily an integer). The origin of the layer charge is in the octahedral sheet. In older literature, montmorillonite was used as a group name, which is replaced by the group name, smectite. See also Part 1 of the Glossary for terms that are obsolete: Wyoming-type, Otay-type, Chambers-type, Tatatila-type, beidellite-type (ideal and non-ideal), and non-ideal montmorillonite. *Cf.*, smectite

**mordenite** see zeolite

**morencite** an obsolete term for nontronite from Morenci, Arizona, USA

**motukoreaite** see hydrotalcite group

**mountkeithite** see hydrotalcite group

**muscovite** a dioctahedral member of the true mica group. The end-member formula is  $KAl_2 \square AlSi_3O_{10}(OH)_2$  (where  $\square$  = vacancy). Typical range in composition is: Si = 3.0 - 3.1,  $^{iv}Al = 1.9 - 2.0$ ,  $K = 0.7 - 1.0$  (although the interlayer site is defined in true micas as  $I \geq 0.85$ ),  $^{vi}R^{2+}/(^{vi}R^{2+} + ^{vi}R^{3+}) < 0.25$ ,  $^{vi}Al/(^{vi}Al + ^{vi}Fe^{3+}) = 0.5 - 1.0$  (Rieder et al., 1998). Muscovite commonly occurs in the  $2M_1$  polytype, and less commonly in  $1M$ ,  $3T$ ,  $1M_d$ , and  $2M_2$  forms. Muscovite is a common rock forming mineral and occurs in igneous, metamorphic, diagenetic, and weathering environments. *Cf.*, nanpingite, paragonite

**Na brittle mica** an obsolete term for preiswerkite

**Na-eastonite** an obsolete term for preiswerkite

**nacrite** a member of the kaolin group, which consists of the dioctahedral and aluminous rich 1:1 phyllosilicates. Nacrite has a chemical composition of  $Al_2Si_2O_5(OH)_4$ . Nacrite is distinguished from the other polymorphs, kaolinite and dickite, by the vacant octahedral site regularly alternating from layer to layer across “B” and “C” sites and by a different stacking sequence of layers (Zheng and Bailey, 1994). The “B” and “C” sites would be related by a mirror plane if both sites were occupied identically within the same layer, whereas the “A” site resides on the mirror plane. Dickite and nacrite have a similar alteration of vacant sites, but kaolinite does not. Nacrite differs from dickite by the different stacking sequence. In nacrite the stacking is similar to the  $6R$  polytype, but the vacancy produces monoclinic symmetry. The choice of axes produces a two-layer, monoclinic structure. Nacrite is considered the high-temperature kaolin form, occurring in hydrothermal and pneumatolytic environments. *Cf.*, dickite, halloysite, kaolin, kaolinite

**nacrite (Thomson)** an obsolete term for muscovite

**nafertisite** see astrophyllite group

**nalivkinite** see astrophyllite group

**nanpingite** a dioctahedral member of the true mica group. The ideal end-member formula is  $CsAl_2 \square AlSi_3O_{10}(OH)_2$  (where  $\square$  = vacancy) and forms as a  $2M_2$  polytype. Nanpingite is the Cs analogue of muscovite and occurs at one locality, the Nanping pegmatite field, Fujian, China.

**natrum illite** an obsolete term for brammallite

**natro-alumobiotite** an obsolete varietal term for biotite and sodian siderophyllite

**natro-ferrophlogopite** an obsolete varietal term for biotite and sodian phlogopite

**natronbiotite** an obsolete varietal term for biotite

**natronmargarite** an obsolete term for calcic paragonite, calcic ephesite

**natronphlogopite** an obsolete varietal term for sodian phlogopite

**nelenite** see pyrosmalite

**nemalite** an obsolete, varietal name for fibrous brucite, possibly brucite intergrown with chrysotile

**nemaphyllite** a poorly described material, possibly a finely divided mixture of serpentine and a Na-containing phase, from Tyrol, Austria

**népouite** a Ni-rich, planar serpentine where Ni is greater than 50% of the octahedral substitution (Brindley and Wan, 1975), typically  $\text{Ni}_x\text{Mg}_{3-x}\text{Si}_2\text{O}_5(\text{OH})_4$ . Nepouite forms a series with lizardite, the Mg (platy) end member. Stacking disorder dominates, but specimens may approach monoclinic and orthorhombic stacking sequences. Occurrences are complex, but generally involve weathered ultramafics that produce serpentinites followed by lateritic weathering, as is the case for the Ni deposits of New Caladonia. *Syn.*, nepouite.

**nickel phlogopite** an obsolete varietal term for nickeloan phlogopite

**nickel-gymnite** a discredited term, a mixture of pimelite and Ni-rich serpentine

**nimesite** an obsolete name, see brindleyite

**nimite** the Ni-rich trioctahedral member of the chlorite group. See chlorite

**niobokupletskite** see astrophyllite group

**niobophyllite** see astrophyllite group

**nontronite**  $\text{Fe}^{3+}$ -bearing and dioctahedral member of the smectite group of minerals. A representative formula is:  $R_{0.33}\text{Fe}^{3+}_2(\text{Si}_{3.67}\text{Al}_{0.33})\text{O}_{10}(\text{OH})_2n\text{H}_2\text{O}$ , where  $R$  refers to the exchangeable cation, commonly Na, Ca and Mg, and  $n$  is a rational number, not necessarily an integer. The layer charge originates by substitution primarily in the tetrahedral sheet. One of the dominant minerals along mid-ocean ridges. *Cf.*, smectite

**nordstrandite** a polymorph of  $\text{Al}(\text{OH})_3$  that occurs in bauxites and soils and rarely in dolomitic marls. Nordstrandite is a two-layer, dioctahedral structure of Al octahedra (similar to layers found in gibbsite), but with displacements between the layers. Ideally, adjacent layers are superposed in bayerite, offset in nordstrandite, and reversed in gibbsite, presumably because of strong polarization effects of the OH. *Cf.*, gibbsite, bayerite

**norrishite** a trioctahedral member of the true mica group. The end-member formula is  $\text{KLiMn}^{3+}_2\text{Si}_4\text{O}_{12}$ . The chemical composition of norrishite is noteworthy because it is Li- and Mn-rich and anhydrous, oxygen-rich, and fluorine-poor content. Norrishite forms as the *1M* polytype (space group *C2/m*), and the octahedral sites show Jahn-Teller distortions (Tyrna and Guggenheim, 1991). Norrishite occurs at the (now-filled) Hoskins manganese mine, near Grenfell, New South Wales, Australia.

**nsutite** Nsutite was originally described as one in a series of similar manganese oxide phases called "gamma  $\text{MnO}_2$ ". Zwicker et al. (1962) showed that the samples they studied have a chemical formula more typical of a hydrous component, e.g.,  $\text{Mn}(\text{O},\text{OH})_2$ . S. Turner (1982), in a PhD. thesis (Arizona State University), as described in Post (1999), showed that the samples he studied are comprised of random intergrowths of pyrolusite ( $\text{MnO}_2$ ) and ramsdellite ( $\text{MnO}_2$ ) or a ramsdellite-like phase and, therefore, classification of nsutite as a mineral is questionable. Samples have numerous structural defects and grains commonly have crystallite boundaries. Large deposits occur near Nsuta, Ghana; it has been noted in marine nodules and as residual oxidation products of Mn-rich carbonates. *Cf.*, vernadite

**odinite** a  $\text{Fe}^{+3}$ -rich, green, 1:1 serpentine type clay mineral that is intermediate between dioctahedral and trioctahedral, approximately  $(\text{Fe}^{3+}, \text{Fe}^{2+}, \text{Mg}, \text{Al}, \text{Ti}, \text{Mn}^{2+})_{2.5}(\text{Si}, \text{Al})_2\text{O}_5(\text{OH})_4$ . Odinite forms primarily as *1M* (space group *Cm*) with lesser amounts of *1T* (trigonal or hexagonal) polytypes. Octahedral cation totals range from 2.30 to 2.54 cations per 3.0 sites for samples described. Apparently forms in association with organic material on shallow marine shelves and reef lagoonal areas in tropical latitudes.

**oblique mica** an obsolete term for muscovite

**odenite** an obsolete term for biotite

**odinit** an obsolete term for biotite

**odith** an obsolete term for biotite

**oellacherite** an obsolete term for barian muscovite

**omphacite** a clinopyroxene (space group *P2/n* or *C2/c*) with an ideal chemical composition of  $(\text{Ca}, \text{Na})(\text{Mg}, \text{Al})\text{Si}_2\text{O}_6$  and this represents the solid solution between augite and jadeite. Ordering and resulting symmetry occurs between Ca and Na (in *M2* sites) coupled with ordering between Mg (+Fe) and Al (in *M1* sites). Omphacite commonly occurs in high-pressure, high temperature metamorphic rocks, such as eclogite which forms by subduction of oceanic crust. See pyroxene group for additional details.

**oncophyllite** an obsolete term for muscovite

**oncosine** a poorly defined material, possibly muscovite with quartz and/or other phases

**onkophyllit** an obsolete term for muscovite

**onkosin** a poorly defined material, possibly muscovite with quartz and/or other phases

**onkosine** a poorly defined material, possibly with muscovite, quartz and/or other phases

**opal** Opals are microcrystalline or noncrystalline forms (Graetsch, 1994) of  $\text{SiO}_2$  or  $\text{SiO}_2 \cdot n\text{H}_2\text{O}$ . The  $\text{H}_2\text{O}$  is not structurally required. Opal-C (synonym: lussatine) refers to a form with a disordered cristobalite (C) structure, opal-CT (synonym: lussatite, common opal) refers to disordered cristobalite/tridymite intergrowths (CT), and opal-AG (synonym: precious opal) is comprised of cubic- or hexagonal-stacking of closest-packed silica spheres (amorphous spheres of equal size,  $\sim 0.0003$  mm), where A = amorphous, G = gel-like. Precious opal exhibits opalescence or play of colors in reflected, white light. Opal-AG (synonym: potch opal) lacks opalescence because of disorder in the stacking of planes of the closest-packed spheres. Opal-AN (synonym: hyalite) occurs as botryoidal masses, where N = network or glass-like forms.

**opal, common** an obsolete term for opal-CT, see opal

**opal, potch** see opal

**opal, precious** see opal

**orlovite** a trioctahedral member of the true mica group. The end-member, ideal formula is  $\text{KLi}_2\text{Ti}^{4+}\text{Si}_4\text{O}_{10}(\text{O},\text{F})$ , and orlovite occurs as the *1M* polytype. Orlovite is from the Darai-Pioz alkaline massif of the Garmskii district, northern Tajikistan. Ti occurs in two positions in what is normally the *M1* site in a mica (the *M1* site is typically on a center of symmetry, but in orlovite each of the positions is displaced along the *m* plane away from the center) separated by  $0.432 \text{ \AA}$ , indicating short range order where Ti is occupied in one domain in one of these positions and in the other domain by the other (Sokolova et al., 2018). Charge balance to offset the 4+ charge of the Ti cation occurs by the substitution of an oxygen anion for fluorine.

**orlymanite** see reyerite group

**orthoclase** see alkali feldspar

**orthopyroxene** a pyroxene subgroup of Mg-Fe pyroxenes in the enstatite-ferrosilite solid-solution series with orthorhombic (*Pbca*, *Pbcn*) symmetry. See pyroxene group for additional details. *Cf.*, enstatite

**owenite** a poorly defined material, possibly an altered iron-rich chlorite, from near Harper's Ferry, West Virginia, USA

**oxykinoshitalite** a member of the brittle mica group, with an ideal chemical composition of  $\text{Ba}(\text{Mg}_2\text{Ti}^{4+})\text{Si}_2\text{Al}_2\text{O}_{12}$ . Oxykinoshitalite is the Ti and oxygenian dominant analogue of kinoshitalite. Oxykinoshitalite-1M forms in the  $C2/m$  space group with Ti primarily in the  $M2$  site. It occurs in an olivine nephelinite from Fernando de Noronha Island, Pernambuco, Brazil (Kogarko et al., 2005).

**pagodite** an obsolete term for pyrophyllite or a mixture with dominant pyrophyllite

**palygorskite** a member of the palygorskite-sepiolite group with a composition of approximately  $(\text{Mg}_{5-y-z}\text{R}^{3+}_y\text{□}_z)(\text{Si}_{8-x}\text{R}^{3+}_x)\text{O}_{20}(\text{OH})_2(\text{OH}_2)_4 \cdot \text{R}^{2+}_{(x-y+2x)/2}(\text{H}_2\text{O})_4$ , where  $R$  are cations,  $\square$  are vacancies, and  $x$ ,  $y$ , and  $z$  are compositional parameters. See palygorskite-sepiolite group

**palygorskite-sepiolite group** The palygorskite-sepiolite group consists of palygorskite, sepiolite, falcondoite, kalifersite, loughlinitite, raite, tuperssuatsiaite, yofortierite, windhoekite, and an un-named species,  $\sim\text{NaCa}(\text{Fe}^{2+}, \text{Al}, \text{Mn})_5[\text{Si}_8\text{O}_{19}(\text{OH})](\text{OH})_7 \cdot 5\text{H}_2\text{O}$ . Palygorskite and yofortierite are dioctahedral and all others are trioctahedral. The palygorskite-sepiolite group has infinitely extending tetrahedral sheets involving 6-fold rings of tetrahedra. Tetrahedral sheets have a continuous basal oxygen-atom plane, but the palygorskite-sepiolite group has apical oxygen atoms pointing in opposing directions within a continuous sheet. Each section of like-pointing tetrahedra form a strip or ribbon pattern, and each ribbon consists of a tetrahedral ring (or two pyroxene-like chains) in palygorskite and 1.5 rings (or three pyroxene-like chains) in sepiolite. In palygorskite and sepiolite, the octahedra, which are linked via edge sharing, form strips that are not continuous sheets. In sepiolite, the octahedral strips are eight octahedra wide, whereas strips that are five octahedra in width occur in palygorskite. The terminal anion at the edges of the octahedral strip involves four  $\text{OH}_2$  groups per formula unit and are required for charge balance. Because these groups are well bonded to the octahedral metal cation and not isolated, they are not referred to as  $\text{H}_2\text{O}$ . Vacant regions, zeolitic  $\text{H}_2\text{O}$ , and exchangeable cations may reside in the channels formed at the edges of the octahedral strips in palygorskite and sepiolite. Exchange reactions with organic molecules are possible if the size of the organic cations is appropriate, because steric constraints control what can enter this channel. Larger molecules also may be adsorbed by the structure, but this is probably because of defects. Environments of formation range from low-temperature aqueous solutions to high-temperature hydrothermal ( $< 350\text{ }^\circ\text{C}$ ) conditions, and natural solutions tend to be alkali-rich with  $(\text{Na} + \text{K})/\text{Al} > 1$ . See individual species for chemical compositions.

**palysepiole** a name introduced to replace palygorskite-sepiolite. This name has not been accepted by the International Mineralogical Association (or any nomenclature committee) and therefore should not be used.

**paragonite** a dioctahedral member of the true mica group. The end-member formula is  $\text{NaAl}_2\text{AlSi}_3\text{O}_{10}(\text{OH})_2$ , where  $\square$  = vacancy, and thus paragonite is the Na analogue of muscovite. The typical range in composition is:  $\text{K} < 0.5$ ,  $\text{Ca} \leq 0.11$ . (Rieder et al., 1998). Paragonite occurs

as  $2M_1$ ,  $3T$ , and  $1M$  polytypes. Paragonite is found in low- and medium-grade metapelites and at variable pressures near those of greenschist and blueschist facies. It commonly occurs with muscovite/phengite and margarite. *Cf.*, muscovite

**parsettensite** a modulated 2:1 layer silicate with continuous Mn-rich octahedral sheets and 6-fold tetrahedral rings forming islands three rings wide. These islands have inter-island linkages, some of which have inverted tetrahedra, involving 12-fold tetrahedral rings and double four-member rings, which act to link adjacent tetrahedral sheets (Eggleton and Guggenheim, 1994). A structural formula for parsettensite is  $M_{7.5}(\text{Mn,Mg})_{49}(\text{Si}_{64.5}\text{Al}_{7.5})_{\Sigma=72}\text{O}_{168}(\text{OH})_{50} \cdot n\text{H}_2\text{O}$ . Parsettensite occurs in (low grade to very low grade) metasedimentary manganese ore deposits in Val d'Err, Oberhalbstein, Graubünden, Switzerland and on surfaces of pegmatite minerals by either hydrothermal or pneumatalytic processes at the Foote mine, Kings Mountain, North Carolina, USA, and in a very low grade metagraywacke and argillite near Otago, New Zealand. *Cf.*, stilpnomelane

**partridgeite** an obsolete term for the Fe-free variety of bixbyite,  $\alpha\text{-(Fe,Mn)}_2\text{O}_3$

**pattersonite** a poorly defined material, possibly interstratified biotite and vermiculite

**paucilithionite** an obsolete term for trilithionite

**pearl-mica** an obsolete term for margarite

**pecoraite** the nickel analogue of chrysotile

**pectolite** see pyroxenoid group

**pelikanite** an obsolete term for a kaolin, but probably a mixture, described from Kiev, Russia. *Syn.* kimolite (from Kimolos, Greece, also obsolete), cimolite

**pennantite** the Mn-rich trioctahedral member of the chlorite group. See chlorite

**pennine** an obsolete varietal term for clinochlore

**penninite** a discredited trioctahedral Mg- and Si-rich chlorite, now referred to as clinochlore. See chlorite

**perlglimmer** an obsolete term for margarite

**perlite** see Part 1 of the Glossary.

**perraultite** see astrophyllite group

**pimelite** a kerolite-like phase where Ni > Mg

**phengite** a series name to describe potassium-rich dioctahedral micas between or close to the muscovite-aluminoceladonite join and the muscovite-celadonite join (i.e., Al,Mg,Fe-containing).

**philadelphite** a poorly defined material, possibly a decomposition product of biotite and vermiculite

**phillipsite** see zeolite

**phlogopite** a trioctahedral member of the true mica group. The end-member formula is  $\text{KMg}_3\text{AlSi}_3\text{O}_{10}(\text{OH})_2$ .  $\text{Fe}^{2+}$  for Mg substitution is common nearly to the Fe end member (annite). Mn and Ti and minor V and Cu substitution is less common. Octahedral vacancies are more prevalent in Fe-containing phlogopite. Phlogopite is defined as having <50% Fe substitution for Mg along the Mg/Fe join. When Fe and Mg content have not been determined, the series name, biotite, is appropriate. Tetrahedral Al substitution tends to be limited to <1.5 cations per formula unit (Fleet, 2003) and  $\text{Fe}^{3+}$  and Ti can occupy the tetrahedral site if there is a deficiency in Si. Phlogopite commonly occurs as the  $1M$  and  $1M_d$  polytypes, although the  $3T$  and  $2M_1$  forms are less common.

**pholerite** an obsolete and poorly defined term describing material from Fins, France, similar to kaolin but with apparently excess  $\text{H}_2\text{O}$

**pholidolite** a poorly defined material, possibly phlogopite or saponite

**picrolite** an obsolete varietal term for a fibrous to columnar form of green serpentine, often referring to antigorite. The original locality is from Taberg, Sweden, and this material was shown to be carlosturanite. The material from Bare Hills, Maryland, USA, was called baltimorite and is considered an obsolete term also.

**picrophengite** an obsolete varietal term for magnesian muscovite

**pigeonite** a clinopyroxene (monoclinic,  $C2/c$  space group) with a chemical composition of  $(\text{Mg,Fe,Ca})(\text{Mg,Fe})\text{Si}_2\text{O}_6$  where Ca is between about 5 to 15 mole % of  $\text{CaSiO}_3$  (wollastonite component). Pigeonite forms where the basaltic melt is relatively quickly cooled in, for example, minor shallow intrusions.

**pimelite** not a valid mineral species, but is often used to describe Ni-rich, 2:1 layer silicates with additional structural  $\text{H}_2\text{O}$ . *Cf.*, kerolite

**pinguite** an obsolete term for nontronite

**pinite** a poorly defined material, possibly a pseudomorph mostly of mica after cordierite,

nepheline, or scapolite

**piotine** an obsolete term for saponite

**plagioclase feldspar** Plagioclase feldspar minerals occur in the solid solution series between albite [Ab:  $\text{Na}(\text{Si}_3\text{Al})\text{O}_8$ ] and anorthite [An:  $\text{Ca}(\text{Si}_2\text{Al}_2)\text{O}_8$ ] end-members. Ordering between Al and Si is very sluggish in the plagioclase feldspars and requires a coupled substitution between (Si + Na) and (Al + Ca). The plagioclase feldspar minerals are the most abundant minerals in the earth's crust. Plagioclase mineral names are divided into albite ( $\text{An}_{0-10}$ ), oligoclase ( $\text{An}_{10-30}$ ), andesine ( $\text{An}_{30-50}$ ), labradorite ( $\text{An}_{50-70}$ ), bytownite ( $\text{An}_{70-90}$ ), and anorthite ( $\text{An}_{90-100}$ ), but it is increasingly common to designate molecular percentages (i.e.,  $\text{Or}_{10}\text{Ab}_{60}\text{An}_{30}$ , where Or = orthoclase and Ab and An are defined above). Labradorite feldspar may show iridescent colors at compositions of  $\text{An}_{50-60}$  and with  $\text{Or}_{2-5}$  where semi-periodic exsolution lamellae occur with periodicity of ~100 nm to ~300 nm. Labradorite commonly occurs in gabbroic rocks or anorthosites (plagioclase-dominated rocks) that experienced extremely slow cooling history. Plagioclase feldspars are used in glass making and ceramics, paints, rubber, and plastics, although the alkali feldspars are more commonly used in industry. *Cf.*, alkali feldspar

**plombièreite** see tobermorite 14Å

**polianite** The obsolete term "polianite" was once used to refer to crystalline pyrolusite, which was assumed to be a different species than earthy to "crusty" pyrolusite.

**poly-irvingite** an obsolete varietal term for lepidolite

**polyolithionite** a trioctahedral member of the true mica group. The end-member formula is  $\text{KLi}_2\text{AlSi}_4\text{O}_{10}\text{F}_2$ , and polyolithionite forms a series with siderophyllite. Polyolithionite forms as 1*M*, 2*M*<sub>2</sub>, 3*T*, and 2*M*<sub>1</sub> polytypes and occurs in granitic pegmatites, including pegmatites at Mont St. Hilaire, Quebec, Canada, and the Kola Peninsula, Russia.

**potash mica** an obsolete term for muscovite

**potash margarite** an obsolete varietal term for margarite

**pregrattite** an obsolete term for paragonite

**preiswerkite** a trioctahedral member of the true mica group. The end-member formula is  $\text{NaMg}_2\text{Al}(\text{Al}_2\text{Si}_2)\text{O}_{10}(\text{OH})_2$ . The first occurrence of preiswerkite is from a metamorphosed basic dike in the Geisspfad ultramafic complex in the Penninic Alps. The 1*M*, 2*M*<sub>1</sub> and 1*M*<sub>d</sub> polytypes have been identified. *Cf.*, aspidolite, eastonite

**priderite** see hollandite

**prochlorite** a discredited name for an often iron-rich, but Si-poor chlorite

**protoenstatite** a high-temperature, orthorhombic (*Pbcn*) polymorph of enstatite. Protoenstatite has been thought to be unquenchable, and commonly transforms to clinoenstatite at low temperature in experiments. However, natural nanoparticle-size protoenstatite has been reported in gem quality “watermelon” sunstones from Oregon, U.S.A. and are apparently quenchable from high-temperature and high-pressure conditions as nanoparticles (Xu et al., 2017).

**protolithionite** an obsolete varietal term for zinnwaldite, lithian annite, and lithian siderophyllite

**pseudo-lussatine** an obsolete name for opal, see opal

**pseudo-quartzine** an obsolete name for opal or quartzine

**pseudobiotite** a poorly defined material, possibly interstratified biotite and vermiculite or interlayer-deficient biotite

**pseudophite** an obsolete term for a compact, massive chlorite that resembles serpentine

**pseudosteatite** an obsolete term for poorly defined material, impure halloysite

**pseudothuringite** an obsolete term for low-Si chlorite

**psilomelane** an obsolete manganese oxide name, now known as cryptomelane, see hollandite. Also, a term used to describe any massive, gray to black, hard, fine-grained manganese oxide material. Often, the latter material is romanechite. *Cf.*, wad, romanechite

**pteralite** a poorly defined material, possibly a decomposition product of hornblende consisting of mica and alkali pyroxene

**pycnochlorite** a poorly defined material, found as infillings in cavities in basic igneous rocks, possibly an altered chlorite or an iron-rich clinochlore

**pycnophyllite** an obsolete term for fine-grained muscovite or illite

**pyknophyllit** an obsolete term for fine-grained muscovite or illite

**pyroaurite** see hydrotalcite group

**pyrochroite** Pyrochroite,  $Mn(OH)_2$ , structurally forms sheets of  $Mn(OH)_6$  octahedra and is isostructural with brucite. The structure is hexagonal closest packed. Pyrochroite occurs in low-temperature hydrothermal environments. *Cf.*, brucite

**pyrolusite** see groutite

**pyrophyllite** the dioctahedral member of the talc-pyrophyllite group. The ideal composition is  $\text{Al}_2\text{Si}_4\text{O}_{10}(\text{OH})_2$ . Pyrophyllite forms as a prominent *1A* polytype (where *A* = anorthic, older literature refers to this polytype as *1Tc*) and a less prominent, poorly crystalline *2M* polytype. The stacking of 2:1 layers in pyrophyllite (Lee and Guggenheim, 1981) is not constrained by an interlayer cation as in the micas, but is related to  $\text{Si}^{4+}$  to  $\text{Si}^{4+}$  repulsions across the vacant interlayer region. Thus Si tetrahedra between adjacent layers are shifted by  $\sim a/3$  so that there are no six-fold or twelve-fold interlayer sites available for interlayer cations, as in mica. Ferripyrophyllite is the ferric iron analogue of pyrophyllite. Pyrophyllite occurs in highly Al-rich metapelites, including metabauxites and metaquartzites, and under hydrothermal conditions. *Cf.*, talc

**pyrosclerite** an obsolete name for altered material, probably vermiculite

**pyrosmalite** a modulated 1:1 layer silicate with a continuous, planar octahedral sheet and a general chemical composition of  $M^{2+}_8T_6\text{O}_{15}(\text{OH},\text{Cl})_{10}$ . Pyrosmalite is the *M* = Mn, Fe series, manganopyrosmalite is *M* for Mn > Fe, and ferropyrosmalite is *M* for Fe > Mn. Friedelite is the Mn end member and a disordered (polytypic) equivalent of mcGillite. In addition, mcGillite has several additional polytypes. The pyrosmalite structure has an equal number of tetrahedra coordinating to two adjacent octahedra sheets via tetrahedral apical oxygen atoms (Kato and Takéuchi, 1983). Each tetrahedral sheet is composed of 4-, 6-, and 12-fold tetrahedral rings linked laterally, with half of the tetrahedra in the 4- and 12-fold rings inverted. Schallerite and nelenite are polymorphs and similar to friedelite, but apparently with  $\text{As}_3\text{O}_6$  molecules within the 12-fold rings. Arsenite analogues of pyrosmalite-type minerals (*T* = As) occur: manganarsite (analogue manganopyrosmalite), and unnamed arsenite equivalents of schallerite and friedelite. Phase assemblages and occurrences are complex. Pyrosmalite occurs in greenschist facies manganiferous rocks. A near Fe-rich end member was reported from low-grade Fe- and Mn-rich sulfide deposits near Mt. Isa, Queensland, Australia. Friedelite occurs in low-grade metamorphic rocks and is Cl bearing.

**pyroxene group** The pyroxene group minerals are single-chain silicates with repeat units of two  $\text{SiO}_4$  tetrahedra ( $\sim 5.2\text{\AA}$ ) along the chain direction (*c*-axis). Chemical formulae, using site nomenclature, are given by:  $M_2M_1T_2\text{O}_6$ , where *M2* represents medium- to large-size cations, commonly  $\text{Ca}^{2+}$ ,  $\text{Na}^+$ ,  $\text{Fe}^{2+}$ ,  $\text{Mg}^{2+}$ ,  $\text{Mn}^{2+}$ , and  $\text{Li}^+$ ; *M1* represents small- to medium-size cations like  $\text{Fe}^{2+}$ ,  $\text{Mg}^{2+}$ ,  $\text{Al}^{3+}$ ,  $\text{Fe}^{3+}$ , and  $\text{Ti}^{4+}$ ; and *T* represents  $\text{Si}^{4+}$  and  $\text{Al}^{3+}$  in tetrahedral sites. The minerals develop good {110} cleavage, with cleavage angles near 90 degrees. The pyroxene group is divided further to subgroups according to composition (and symmetry). The common pyroxenes form solid solutions of the Ca-Mg-Fe pyroxenes and are compositionally described (e.g., Morimoto et al., 1988) in the pyroxene quadrilateral with end-members diopside (Di:  $\text{CaMgSi}_2\text{O}_6$ ), hedenbergite (Hd:  $\text{CaFeSi}_2\text{O}_6$ ), enstatite (En:  $\text{Mg}_2\text{Si}_2\text{O}_6$ ), and ferrosilite (Fs:  $\text{Fe}_2\text{Si}_2\text{O}_6$ ). The enstatite-ferrosilite solid solution series forms orthopyroxenes (OPX) with orthorhombic (*Pbca*) symmetry, whereas, the diopside-hedenbergite solid solution series forms

clinopyroxenes (CPX) with monoclinic ( $C2/c$ ) symmetry. Weathering reactions of pyroxene group minerals often produce clay minerals. Pyroxene end-members are: enstatite  $Mg_2Si_2O_6$  (polymorphs clinoenstatite, orthoenstatite, protoenstatite); ferrosilite  $Fe_2Si_2O_6$ ; diopside  $CaMgSi_2O_6$ ; hedenbergite  $CaFeSi_2O_6$ ; jadeite  $NaAlSi_2O_6$ ; aegirine  $NaFeSi_2O_6$ ; spodumene  $LiAlSi_2O_6$ ; pigeonite  $(Mg,Fe,Ca)(Mg,Fe)Si_2O_6$ ; augite  $(Ca,Mg,Fe^{2+},Fe^{3+},Ti,Al)_2(Si,Al)_2O_6$ ; omphacite  $(Ca,Na)(Mg,Al)Si_2O_6$ ; grossmanite  $CaTiSiAlO_6$ . Refer to individual end members for further descriptions.

**pyroxenoid group** single-chain silicate minerals with Si-tetrahedral repeats of 3 (e.g., in wollastonite,  $CaSiO_3$ ), 5 (e.g., in rhodonite,  $MnSiO_3$ ), 7 (e.g., in pyroxmangite,  $FeSiO_3$ ), or 9 (e.g., in ferrosilite III). In contrast, the pyroxene tetrahedral repeat is 2. However, both the pyroxenoids and the pyroxenes have octahedrally coordinated cations connecting to the tetrahedral chains in similar ways. Hydrous pyroxenoids exist also, where Na + H substitute for one of the divalent cations, e.g., pectolite,  $Ca_2NaH(SiO_3)_3$ . Wollastonite occurs as a contact metamorphic mineral of siliceous dolomites and is used in the manufacture of tile and in glazes. Rhodonite and pyroxmangite occur in manganese deposits and metamorphosed Mn-rich iron formations. Pectolite, commonly associated with zeolites, forms in cavities in basalts as a secondary mineral formed by hydrothermal activity.

**pyroxmangite** see pyroxenoid group

**quartz** Quartz,  $SiO_2$ , is comprised of two chains, both spirals of  $SiO_4$  tetrahedra parallel to the  $c$  axis. In the alpha-quartz structure (low temperature form to  $573\text{ }^\circ\text{C}$  at 1 bar), these chains are kinked and the structure has trigonal symmetry. In the beta-quartz structure (high temperature form, above  $574.3\text{ }^\circ\text{C}$ ), the chains expand (the tetrahedra are not twisted) and the symmetry is hexagonal with a more open structure than the alpha form. The beta form is non-quenchable and not found under ambient conditions. An intermediate phase between  $573 - 574.3\text{ }^\circ\text{C}$  is known to exist. Quartz is a common associated phase in clay, but generally forms grains larger than clay particles (about 0.2 - 0.4 micrometers) and therefore quartz particles can be removed by size separation.

**quartzine** Quartzine is a rock term to describe a mixture of a fibrous [0001] variety of microcrystalline (length slow) quartz and moganite. *Cf.*, chalcedony

**rabenglimmer** an obsolete term for zinnwaldite

**raite** a member of the palygorskite-sepiolite group with a composition of approximately  $Na_3Mn_3Ti_{0.25}(Si_8O_{20})(OH)_2 \cdot 10(H_2O)$ . See palygorskite-sepiolite group

**ramesdellite** see groutite

**ranceite** see birnessite

**rastolyte** a poorly defined material, possibly an altered biotite or interlayer-deficient biotite

**rectorite** a regular interstratification of dioctahedral mica-like layers and dioctahedral smectite-like layers in a ratio of 1:1 (Brown and Weir, 1963). The structure may be described more completely as pairs of dioctahedral 2:1 layers with alternate interlayers that are mica-like and montmorillonite-like. Mica-like layers may be paragonite-like and the smectite-like layers may be beidellitic. The non-swelling mica interlayers contain about 0.85 univalent cations per mica formula unit and the swelling interlayers about 0.35 univalent cations (e.g., Na, K, but divalent Ca is known also) per smectite formula unit (Bailey, 1982). In the older literature, the name “allevardite” has been used (Bailey, 1982), but the term rectorite has priority.

**redledgeite** see hollandite

**reedmergnerite** an albite-like mineral with B in the tetrahedral site,  $\text{Na}(\text{Si}_3\text{B})\text{O}_8$ . *Cf.*, alkali feldspar, feldspar, plagioclase feldspar

**reevesite** see hydrotalcite group

**rensselaerite** an obsolete, local term for talc pseudomorphic after pyroxene from northern New York state and Canada

**retinalite** an obsolete term for a resinous, massive, yellow to green serpentine

**revdanskite** a discredited name of a material that is primarily pimelite

**reyerite group** Reyerite is comprised of a sheet of edge-sharing Ca octahedra with adjacent tetrahedral sheets of  $\text{Si}_8\text{O}_{20}$  and a double tetrahedral sheet of  $\text{Si}_{14}\text{Al}_2\text{O}_{38}$ , and an overall chemical composition of  $(\text{Na},\text{K})_2\text{Ca}_{14}\text{Si}_{22}\text{Al}_2\text{O}_{58}(\text{OH})_8 \cdot 6\text{H}_2\text{O}$  (Merlino, 1988a). The tetrahedral sheets are formed from 6-fold rings of tetrahedra with some tetrahedra pointing up and some down. Na, K, and  $\text{H}_2\text{O}$  occupy partially filled sites within the double tetrahedral sheet network. Truscottite,  $\text{Ca}_{14}(\text{Si}_{24}\text{O}_{58})(\text{OH})_8 \cdot 2\text{H}_2\text{O}$ , is similar to reyerite, but with alkali and aluminum generally absent, although a limited amount of K and Al can be present and the composition can approach reyerite. Gyrolite,  $\text{Ca}_{16}\text{Si}_{24}\text{O}_{60}(\text{OH})_8 \cdot (14+x)\text{H}_2\text{O}$ , has a Ca octahedral sheet bounded by  $\text{Si}_8\text{O}_{20}$  tetrahedral sheets as a unit (layer charge may vary from -4 to -5 depending on Al content) separated from other similar units by an interlayer of 2Ca + Na octahedra (Merlino, 1988b). Fedorite,  $\text{K}_2(\text{Ca}_5\text{Na}_2)\text{Si}_{16}\text{O}_{38}(\text{OH},\text{F})_2 \cdot \text{H}_2\text{O}$ , has a sheet of edge-sharing Ca octahedra with double tetrahedral sheets,  $\text{Si}_{16}\text{O}_{38}$ , on adjacent sides. Minehillite,  $(\text{K},\text{Na})_2\text{Ca}_{28}\text{Zn}_5\text{Al}_4\text{Si}_{40}\text{O}_{112}(\text{OH})_{16}$ , has a central edge sharing Ca octahedral sheet with a single tetrahedral sheet on one side (similar to reyerite), but a complex slab that differs from reyerite on the other. The structure of cairncrossite,  $\text{Sr}_2\text{Ca}_{7-x}\text{Na}_{2x}(\text{Si}_4\text{O}_{10})_4(\text{OH})_2(\text{H}_2\text{O})_{15-x}$ , where x is between 0 and 1, forms a unit consisting of edge-sharing Ca octahedral sheets with adjacent Si tetrahedral sheets. These units are cross linked by  $\text{SrO}_8$  polyhedra. The structure of orlymanite (chemical composition approximately  $\text{Ca}_4\text{Mn}_3\text{Si}_8\text{O}_{20}(\text{OH})_6 \cdot 2\text{H}_2\text{O}$ ), which has not been determined, is believed related

to reyerite. Synthetic (“K-phase”, “Z-phase”) phases with structural similarities to reyerite are known. Reyerite group minerals are potentially important in cements used to case geothermal wells where phases form at elevated temperatures and pressures in a steam-rich environment.

**reyerite** see reyerite group

**rhodonite** see pyroxenoid group

**rhombenglimmer** an obsolete varietal term for phlogopite, biotite

**rhombic mica** an obsolete varietal term for phlogopite, biotite

**ricolite** an obsolete varietal term for a banded form of green serpentine

**riemannite** a discredited name for allophane from Gräfental, Thuringia, Germany

**ripidolite** a discredited name for an iron-rich, Si-poor chlorite. See chlorite

**riversideite** see tobermorite

**romanechite** The structure of romanechite,  $(\text{Ba}, \text{H}_2\text{O})_2(\text{Mn}^{4+}, \text{Mn}^{3+})_5\text{O}_{10}$ , forms large, rectangular-shaped tunnels bounded by double- and triple-chains of edge sharing  $\text{MnO}_6$  octahedra. The  $\text{Mn}^{3+}$  cations are located in the octahedra at the edges of the triple chains, and the Ba and  $\text{H}_2\text{O}$  are located in the tunnels, often in a ratio of 1 to 2. Romanechite occurs in oxidized zones in Mn-rich ore deposits.

**roscoelite** a dioctahedral member of the true mica group. The end-member formula is  $\text{KV}_2\text{AlSi}_3\text{O}_{10}(\text{OH})_2$ . Roscoelite occurs as a *1M* polytype and more rarely as *2M*<sub>1</sub>. Roscoelite is found in sedimentary rocks where V has been remobilized from black shales and mafic rocks. Roscoelite is known from the Colorado Plateau district (Colorado, also Utah, Arizona, New Mexico, USA) in U-bearing sandstones. It is also known from Gabon, Western Australia, and Ontario, in the latter occurrence, the V was introduced from metasomatic fluids.

**röttisite** a discredited name for material primarily containing pimelite

**rubellan** a poorly defined material, possibly altered biotite or interlayer-deficient biotite, and/or vermiculite

**rumpfite** a poorly defined term, possibly for a Si-poor chlorite

**saliotite** Saliotite is a regular interstratification (mixed layer) of cookeite-like and paragonite-like layers in a ratio of 1:1 (Goffé et al., 1994). The ideal chemical composition is

$\text{Na}_{0.5}\text{Li}_{0.5}\text{Al}_3(\text{Si}_3\text{Al})\text{O}_{10}(\text{OH})_5$  and it occurs in high-pressure, low-temperature metamorphic rocks (estimated at 280-330 °C, 8 kbar) in Andalusia, Spain. *Cf.*, interstratification

**sandbergite** an obsolete term for barian muscovite

**sanidine** see alkali feldspar

**saponite** Saponite is ideally  $(M^{+}_{x-y} \cdot n\text{H}_2\text{O})(\text{Mg}_{3-y}\text{R}^{3+}_y)(\text{Si}_{4-x}\text{Al}_x)\text{O}_{10}(\text{OH})_2$  where  $M$  is the exchangeable cation in the interlayer (univalent example given here),  $\text{R}^{3+}$  are  $y$  trivalent cation substitutions in the octahedral site,  $x$  is the number of substitutions for Si by Al in the tetrahedral sites, and  $n$  is variable. Natural samples (Moore and Reynolds, 1997) may show < 0.66 Al tetrahedral atoms per asymmetric unit [ $\text{O}_{10}(\text{OH})_2$ ] to produce a large negative charge in the tetrahedral sheet which is balanced by positive charge in the octahedral sites ( $\text{R}^{3+}$  cations) and interlayer exchangeable ( $M$ ) cations. Octahedral site vacancies may also occur (Newman and Brown, 1987). Suquet et al. (1975) determined that the two-layer hydrate structure (two planes of  $\text{H}_2\text{O}$ ) of a Na-saturated sample is  $C$  centered with  $a = 5.333$ ,  $b = 9.233$ ,  $c = 15.42 \text{ \AA}$ ,  $\beta = 96.66^\circ$ . The sample approximates a  $1a-2$  polytype. The  $d(001)$  values of saponite commonly range from 13.5 (air dry) to 16.8  $\text{Å}$  (ethylene glycol treatment). Dehydrated K-exchanged saponite shows a mica-like structure with stacking described as either a  $1M$  or  $3T$  structure. Saponite with a Mg-rich octahedral sheet is usually, but not limited to, a weathering product involving volcanic rocks (see Guggenheim, 2011 for a literature review of natural and synthetic saponite). Ferrian saponite (e.g., Kodama et al., 1988) with a composition of  $(M^{+}_{0.61} \cdot n\text{H}_2\text{O})(\text{Mg}_{1.39}\text{Fe}^{3+}_{0.85}\text{Al}_{0.17}\text{Mn}_{0.03})(\text{Si}_{3.49}\text{Al}_{0.51})\text{O}_{10}(\text{OH})_2$  and ferrosaponite (Chukanov et al., 2003),  $(\text{Ca}_{0.31}\text{Na}_{0.04}\text{K}_{0.01} \cdot 4\text{H}_2\text{O})(\text{Fe}^{2+}_{1.54}\text{Mg}_{0.85}\text{Fe}^{3+}_{0.45})_{\Sigma=2.84}(\text{Si}_{2.87}\text{Al}_{1.01}\text{Fe}^{3+}_{0.12})\text{O}_{9.67}(\text{OH})_{2.33}$ , occur in a gabbro saprolite and as a hydrothermal mineral in basaltic pillow lavas, respectively. *Cf.*, smectite

**sarospatakite** an obsolete term for illite

**sauconite** The  $\text{Zn}^{2+}$ -rich trioctahedral smectite (Ross, 1946) with the ideal composition of  $(M^{+}_x \cdot n\text{H}_2\text{O})\text{Zn}_3(\text{Si}_{4-x}\text{Al}_x)\text{O}_{10}(\text{OH})_2$  where  $M$  is the exchangeable cation in the interlayer (univalent example given here),  $x$  is the number of substitutions for Si by Al in the tetrahedral sites, and  $n$  is variable. Zn content may vary commonly from 1.48 to 2.89 atoms per  $\text{O}_{10}(\text{OH})_2$ , and the octahedral site may contain vacancies. Mg,  $\text{Fe}^{3+}$ , and Al are known to replace Zn (Faust, 1951).

**scale stone** an obsolete term for lepidolite

**schallerite** see pyrosmalite

**schernikite** an obsolete term for muscovite

**schrötterite** an obsolete term for what is believed to be a mixture of opal and allophane

**schuchardite** an obsolete term, probably a nickel-bearing chlorite

**schuppenstein** an obsolete term for lepidolite

**seidozerite** see astrophyllite group

**seladonite** an obsolete term for celadonite

**sepiolite** A member of the palygorskite-sepiolite group with a composition of approximately  $(\text{Mg}_{8-y-z}\text{R}^{3+}_y\text{□}_z)(\text{Si}_{12-x}\text{R}^{3+}_x)\text{O}_{30}(\text{OH})_4(\text{OH}_2)_4 \cdot \text{R}^{2+}_{(x-y+2z)2}(\text{H}_2\text{O})_8$ , where *R* are cations, □ are vacancies, and *x*, *y*, and *z* are compositional parameters. See palygorskite-sepiolite group

**sepiolite-palygorskite group** see Part 1 of the Glossary

**sericite** a poorly defined term, commonly used in the past to describe an optical microscopic fine-grained aggregate of mica-like phases

**serpentine** see serpentine-kaolin group

**serpentine/chlorite (or serpentine-chlorite)** a general term used to describe randomly interstratified layers (= “mixed layers”) of two types: 1:1 layers (i.e., serpentine-like, 7-Å spacing) and 2:1 layers + interlayer (i.e., chlorite-like, 14-Å spacing). The “random” (non-periodic) aspect is important because such a structure will not produce basal X-ray reflections expected by the Bragg equation. A non-periodic structure, i.e., a structure with random interstratifications, is not defined as a mineral (and cannot be given a mineral name). Serpentine-chlorite structures form most commonly under diagenetic conditions as authigenic material associated with pore-linings and fillings, peloids, and replacement phases.

**serpentine/kaolin** see Part 1 of the Glossary

**seybertite** an obsolete varietal term for clintonite

**shafranovskite** a 2:1 hydrous phyllosilicate with continuous sheets of Mn and Na octahedra between two types of tetrahedral sheets. One sheet has isolated  $\text{Si}_{13}(\text{O},\text{OH})_{37}$  islands whereas the other has similar islands with  $\text{SiO}_3(\text{OH})$  tetrahedra linkages between islands. The 2:1 layers are apparently not cross linked. The ideal chemical composition is  $\text{K}_2\text{Na}_3(\text{Mn},\text{Fe},\text{Na})_4[\text{Si}_9(\text{O},\text{OH})_{27}(\text{OH})_2 \cdot n\text{H}_2\text{O}]$ , with  $n \sim 2.33$ . Shafranovskite occurs in the pegmatites of the Khibiny and Lovozero alkaline complexes, Kola peninsula, Russia.

**sheridanite** a discredited name for a trioctahedral Mg-rich (Fe-poor), Si-poor chlorite. See chlorite

**shilkinite** an obsolete varietal term for ferroan muscovite, ferroan illite

**shirokshinite** a trioctahedral member of the mica group characterized by Na occurring in the octahedral sheet in the *M1* site. The ideal chemical composition is  $K(\text{NaMg}_2)\text{Si}_4\text{O}_{10}\text{F}_2$ . It is found in the apatite mine, Kukisvumchorr Mountain, Khibiny massif, Kola Peninsula, Russia, as a late hydrothermal phase in a small hyperalkaline pegmatite and it forms in the *1M* polytype (Pekov et al., 2003).

**siderischer-fels-glimmer** an obsolete term for lepidolite

**siderophyllite** a trioctahedral member of the true mica group. The ideal end-member formula is  $\text{KFe}^{2+}_2\text{Al}(\text{Al}_2\text{Si}_2)\text{O}_{10}(\text{OH})_2$ , although such a chemical composition has not been reported. The siderophyllite composition is useful to describe solid solution series where there are  $\text{Fe}^{2+} + \text{Al}$  substitutions, whereas eastonite components involve  $\text{Mg} + \text{Al}$  substitutions. A Tschermak type substitution, which is common in some biotites, involves  $\text{Al}_{\text{oct}} + \text{Al}_{\text{tet}} = \text{R}^{2+} + \text{Si}$ . *Cf.*, eastonite

**silica** Silica refers to the chemistry only,  $\text{SiO}_2$ , and not a specific structure or phase. *Cf.*, silica, amorphous; cristobalite, tridymite, opal

**sinopite** an obsolete term for an iron-rich red clay used as a pre-history ocher in the Black sea region

**sjögrenite** see hydrotalcite group

**skolite** an obsolete term for glauconite

**smectite** The group name for the 2:1 phyllosilicate minerals with a net negative layer charge between approximately -0.2 and -0.6 per formula unit on the layer. A generalized formula is  $X_{0.3}Y_{2-3}Z_4\text{O}_{10}(\text{OH})_2 \cdot n\text{H}_2\text{O}$ , where *X* is the exchangeable cation (e.g.,  $\text{Ca}/2$ , Na, K,  $\text{Mg}/2$ ), *Y* is a small to medium size cation (e.g., Al,  $\text{Cr}^{3+}$ ,  $\text{Fe}^{2+}$ ,  $\text{Fe}^{3+}$ , Li, Mg, Ni, Zn), *Z* = Si, Al, and *n* is a rational number, not necessarily an integer). Smectite is often characterized by solvating polar organic molecules into the interlayer causing pronounced swelling between the layers [perpendicular to the (001) plane]. Smectite is commonly referred to as a “swelling clay”, as is vermiculite. The rock term, bentonite, refers to a smectite-rich material. See further discussion under Part 1, smectite and obsolete terms: Wyoming-type, Otay-type, Chambers-type, Tatatila-type, beidellite-type (ideal and non-ideal), and non-ideal montmorillonite. *Cf.*, bentonite, swelling clay, beidellite, hectorite, montmorillonite, nontronite, saponite, sauconite, stevensite, swinefordite, volkonskoite, yakhontovite

**soda mica** an obsolete term for paragonite

**soda glauconite** an obsolete varietal term for glauconite

**soda margarite** an obsolete term for calcic paragonite, calcic ephesite

**sodium illite** an obsolete term for brammallite

**sodium phlogopite** an obsolete term for aspidolite

**spodiophyllite** a poorly described material, possibly a mica related to tainiolite

**sterlingite** an obsolete term for muscovite

**stevensite** Stevensite is a trioctahedral smectite with an ideal composition of  $(M^{+}_{2y} \cdot nH_2O)(Mg_{3-y} \square_y)Si_4O_{10}(OH)_2$  where  $M$  is the exchangeable cation in the interlayer (given here as univalent),  $\square$  represents  $y$  vacancies, and  $n$  is variable. Stevensite is poorly defined, but the lack of Al, some octahedral vacancies, the high Si content, and the high Mg content are important characteristics. Brindley (1955) described the stevensite structure as two-layer with talc and saponite interstratifications, Faust et al. (1959) suggested that stevensite is a defect structure with two components of talc and talc-like domains, and Shimoda (1971) found stevensite to be composed only of swelling components like smectite minerals. Christidis and Mitsis (2006) studied a Ni-rich stevensite that appeared to confirm the smectite character of one layer type with turbostratic stacking and ethylene glycol intercalation capabilities. Stevensite has been shown to commonly alter from sepiolite, and a Ni-rich stevensite is reported from a supergene alteration of an ophiolite complex in Greece. A significant Al content would allow such a phase to be defined as saponite.

**stichtite** see hydrotalcite group

**stilbite** see zeolite

**stilpnochlorane** an obsolete term, possibly for nontronite or chlorite from Moravia

**stilpnomelane** a modulated 2:1 layer silicate with a continuous octahedral sheet and a modulated tetrahedral sheet (Eggleton, 1972). The tetrahedral sheet forms approximately hexagonal islands with 6-fold tetrahedral rings and island connectors are formed by an inverted single 6-fold ring with a near trigonal configuration. The islands are comprised of seven near-hexagonal tetrahedral 6-fold rings. The inverted rings also link adjacent layers across the interlayer. Trigonal rings also form by paired trigonal rings joined by the apical oxygen atoms along  $Z$ . The primarily ferrous form of stilpnomelane, often informally referred to as “ferrostilpnomelane”, has a structural formula of  $K_5Fe^{2+}_{48}(Si_{63}Al_9)O_{168}(OH)_{48} \cdot 12H_2O$ , whereas the analogous “ferristilpnomelane” has a structural formula of  $K_5Fe^{3+}_{48}(Si_{63}Al_9)O_{216} \cdot 36H_2O$ , although neither end-member forms have been found. The Mg-rich stilpnomelane is called lennilenapeite and the Mn-rich mineral is franklinphilite. Older literature incorrectly equates parsettensite as the Mn-rich version. Stilpnomelane occurs in many geological environments, including greenschist facies rocks, iron deposits, metal sulfide deposits, and in weathering profiles.

**stolpenite** an obsolete local name for a mixture of smectite and a Ca-rich phase(?), or Ca-montmorillonite, from Stolpen, Saxony, Germany

**strigovite** an obsolete term for an iron-rich chlorite from Striegau, Silesia (now Poland)

**strontiomelane** see hollandite

**sudoite** a member of the chlorite group with a composition of  $\text{Mg}_2(\text{Al}, \text{Fe}^{3+})_3(\text{Si}_3\text{Al})\text{O}_{10}(\text{OH})_8$ . The octahedral sheet of the 2:1 layer is dioctahedral, whereas the interlayer is trioctahedral; therefore this is a di, trioctahedral chlorite. It differs from cookeite in that it is essentially Li-free. *Cf.*, chlorite, cookeite, donbassite

**suhailite** a trioctahedral member of the true mica group with an approximate chemical composition of  $(\text{NH}_4, \text{K})(\text{Fe}_{1.33}\text{Mg}_{0.71}\text{Al}_{0.42}\text{Ti}_{0.22})\text{Si}_{2.67}\text{Al}_{1.33}\text{O}_{10}(\text{OH})_2$ . The characterizing feature is the  $\text{NH}_4$  ( $\text{NH}_4 > \text{K}$ ) in the interlayer site and the trioctahedral sheet; the composition suggests that suhailite may be described as an ammonium-rich biotite. Difficulties in separating suhailite from impurity phases, stacking disorder and a high numbers of defects prevented structural characterization. Impurity phases and volatility of  $\text{NH}_4$  limited the accuracy of the chemical analysis. Suhailite occurs in gneisses from the Betic Cordillera, Spain, and formed from primary annite during the annite to fibrolite transformation, probably at temperatures up to  $\sim 500$  °C (Ruiz Cruz et al., 2009). *Cf.*, tobelite

**sveinbergeite** see astrophyllite group

**svitalskite** an obsolete varietal term for celadonite

**swelling chlorite** see corrensite and chlorite/smectite

**swinefordite** Swinefordite is the Mg- and Li-rich trioctahedral member of the smectite group, with the original workers (Tien et al., 1975) determining that the location of Li of the natural sample was split with  $\sim 33\%$  in the interlayer and the remainder in the octahedral sheet, and with vacancies in the octahedral site, thereby making this a dioctahedral-trioctahedral intermediate. Köster (1982) redetermined the chemistry based on the cation exchange capacity and determined the composition to be  $(M^{+0.4} \cdot n\text{H}_2\text{O})(\text{Li}_{1.06}\text{Al}_{0.99} \text{Mg}_{0.7}\text{Fe}^{3+}_{0.10})_{\Sigma=2.85} (\text{Si}_{3.87}\text{Al}_{0.13})\text{O}_{10}(\text{OH})_2$  where  $M$  is the exchangeable cation and  $n$  is variable. The  $M$  (interlayer) cation is assumed here as univalent, but it may have other valence states also. The vacancy content in the octahedral site (0.15) is consistent with other trioctahedral smectites (Güven, 1988). Swinefordite occurs as a pseudomorph after spodumene. *Cf.*, hectorite

**taeniolite** an obsolete term for tainiolite

**tainiolite** a trioctahedral member of the true mica group. The end-member formula is  $\text{KLiMg}_2\text{Si}_4\text{O}_{10}\text{F}_2$ , and tainiolite occurs as  $1M$ ,  $2M_1$ , and  $3T$  polytypes. Tainiolite is found in alkaline and peralkaline rocks, especially syenites and metasomatites. *Syn.*, taeniolite

**takanelite** see birnessite

**takizolite** a poorly described term for material from Yanokami Hill, Omi Province, Japan, possibly a kaolin or smectite

**takovite** see hydrotalcite group

**talc** Talc is a 2:1 layer silicate and ideally  $\text{Mg}_3\text{Si}_4\text{O}_{10}(\text{OH})_2$  with layers linked via van der Waals interactions (for a summary, see Evans and Guggenheim, 1988). Layer stacking is controlled by the avoidance of Si to Si electrostatic interactions across the interlayer to form a talc- $1A$  polytype (where  $A$  = anorthic, older literature refers to this polytype as  $1Tc$ ). There are no six- or twelve-fold sites within the interlayer region as in the micas. The talc- $2M$  polytype is poorly crystalline and rare. Talc is commonly near end-member compositions with more major substitutions of  $\text{Fe}^{2+}$  and more minor substitutions of Al and F, with trace substitutions of Mn, Ti, Cr, and Ni. The mineral willemseite is defined for  $\text{Ni} > \text{Mg}$ . Talc occurs in Mg-rich rocks in metamorphosed ultramafic rocks and siliceous dolomites. Talc has also been rarely reported from evaporites, limestones, in beach sands, low-temperature hydrothermal environments, and seafloor sediments. *Cf.*, kerolite, pyrophyllite, willemseite

**talc-pyrophyllite** see Part 1 of the Glossary

**talcite** an obsolete term for muscovite

**tarasovite** originally defined as a regular 3:1 interstratification of (three) dioctahedral mica and (one) smectite layers, but the material is insufficient in regularity to warrant a formal mineral name. The name is in reserve in case a sufficiently regular interstratification of the same type is found.

**tarbagataite** see astrophyllite group

**termierite** an obsolete term for a clay of unknown composition resembling halloysite, from Haute-Loire, France

**tetra-ferri-annite** a trioctahedral member of the true mica group. The end-member formula is  $\text{KFe}^{2+}_3\text{Fe}^{3+}\text{Si}_3\text{O}_{10}(\text{OH})_2$  and the known polytype is  $1M$ . The ferri-iron component is found in the tetrahedral site. Tetra-ferri-annite is commonly associated with stilpnomelane. Stilpnomelane, when coexisting with tetra-ferri-annite, often appears to be replaced by tetra-ferri-annite. Therefore, tetra-ferri-annite occurs in very low-grade metamorphosed iron formations.

**tetra-ferriphlogopite** a trioctahedral member of the true mica group. The end-member formula is  $\text{KMg}_3\text{Fe}^{3+}\text{Si}_3\text{O}_{10}(\text{OH})_2$ , and the occurrence of tetra-ferriphlogopite is from Al-poor, ultrabasic magmas under oxidizing (typically late-stage) environments, such as in alkaline-carbonatites and in some mica kimberlites. Tetra-ferriphlogopite occurs as a 1*M* polytype.

**thermophyllite** an obsolete term for a poorly defined serpentine phase, from Hoponsuo, Finland

**thuringite** a poorly defined material, found as infillings in cavities in basic igneous rocks, possibly an altered chlorite

**titanbiotite** an obsolete varietal term for biotite

**titanglimmer** an obsolete varietal term for biotite

**titanmica** an obsolete varietal term for biotite

**titanobiotite** an obsolete varietal term for biotite

**tobelite** a dioctahedral member of the true mica group. The end-member formula is  $(\text{NH}_4)\text{Al}_2\text{Si}_3\text{O}_{10}(\text{OH})_2$ , where  $\square$  are vacancies. Tobelite-1*M* (space group *C2/m*) was first described from Tobe, Japan by Higashi (1982). Single crystal X-ray analysis of tobelite showed the polytype to be 2*M*<sub>2</sub> in space group *C2/c* (Mesto et al., 2012). Other polytypes (e.g., 2*M*<sub>1</sub>, 3*T*, 2*O*) are known. Tobelite and most NH<sub>4</sub>-rich micas form from diagenesis or in low grade metamorphic or hydrothermal environments, although suhailite is believed to occur at much higher temperatures, in gneisses. *Cf.*, suhailite

**tobermorite** a mineral and mineral group name for a class of hydrated calcium silicate minerals with a strong resemblance to clay minerals, including variability of basal spacing with H<sub>2</sub>O content, specific surface area, crystallinity, cation exchange (especially with Al substitutions), and polytypism. For example, tobermorite 9Å (chemical composition of  $\text{Ca}_5\text{Si}_6\text{O}_{16}(\text{OH})_2$ ), tobermorite 11Å (general formula of  $\text{Ca}_{4+x}\text{Si}_6\text{O}_{15+2x}(\text{OH})_{2-2x} \cdot 5\text{H}_2\text{O}$ ), and tobermorite 14Å ( $\text{Ca}_5\text{Si}_6\text{O}_{16}(\text{OH})_2 \cdot 7\text{H}_2\text{O}$ ; = plombièreite) refer to variations in basal spacings (*d*(002) values) and different degrees of hydration, which by successive heat treatments ultimately result in progressive dehydration (= “normal” tobermorite) to tobermorite 9Å. Some tobermorite 14Å samples do not dehydrate and are referred to as “anomalous”. Clinotobermorite also topotactically dehydrates upon heating to tobermorite 9Å. Tobermorites have sheets of 7-fold coordinated Ca polyhedra parallel to the (001) and silicate wollastonite-like tetrahedral chains, which link adjacent sheets in tobermoreite 9Å, forming parallel to the *b* axis (Merlino et al., 1999). The tetrahedral chains form double-width chains in tobermorite 11Å and clinotobermorite, and the double-width chains form zeolitic-type sites for Ca and H<sub>2</sub>O. Tobermorite is found in hydrothermal altered carbonates (skarns) and basalt vesicles. The tobermorite group is important in cement hydration. Other hydrated calcium silicate phases are also important in cement formation, including an amorphous cement gel (e.g.,  $\text{Ca}_3\text{SiO}_5$  and

cation substituted forms). Other hydrated calcium silicate minerals include jennite ( $\text{Ca}_9\text{Si}_6\text{O}_{18}\text{H}_2(\text{OH})_8 \cdot 6\text{H}_2\text{O}$ ) and metajennite, riversideite ( $?\text{Ca}_5\text{Si}_6\text{O}_{16}(\text{OH})_2$ ), and foshagite ( $\text{Ca}_4\text{Si}_3\text{O}_9(\text{OH})_2$ ). Also see calcium silicate hydrate (CSH) in Part 1

**todorokite** Todorokite,  $(\text{Ca},\text{Na},\text{K})_{0.3-0.5}(\text{Mn}^{4+},\text{Mn}^{3+},\text{Mg})_6\text{O}_{12} \cdot 3-4.5\text{H}_2\text{O}$ , is comprised structurally of edge-sharing triple chains of  $\text{MnO}_6$  octahedra which form tunnels of widths of three octahedra per wall (Post and Bish, 1988). The triple chains are connected by corner sharing. In addition to the 3 by 3 square tunnels, defects are common with tunnel sizes of 3 x 4, with variations to 3 x 9. Octahedra at the edges of the triple chains contain medium size cations, such as Mg or  $\text{Mn}^{3+}$ , whereas tunnel cations are the larger cations,  $\text{H}_2\text{O}$ , and impurity cations. Todorokite occurs commonly in marine nodules, natural coatings, in oxidized portions in Mn ore deposits, and less commonly, in soils.

**tosalite** an obsolete varietal term for manganoan greenalite (or magnesian caryopilite)

**tosudite** a regular interstratification of dioctahedral chlorite-like layers and smectite-like layers in a ratio of 1:1. Tosudite must be dioctahedral *on average*, although tosudite may refer to smectite-like components that are of dioctahedral or trioctahedral character. Dioctahedral chlorite may be of the type di,dioctahedral or di,trioctahedral interstratified with either dioctahedral smectite-like or trioctahedral smectite-like layers. (Bailey, 1982; Frank-Kamenetskii et al., 1965).

**tridymite** Tridymite, a high temperature polymorph of  $\text{SiO}_2$ , has many structural modifications and these are described by Heaney (1994). Ideally, the basic structure is comprised of sheets of hexagonal tetrahedral rings with alternate tetrahedra around a ring with apices pointing in opposite directions from adjacent tetrahedra. Adjacent tetrahedral sheets are related by a mirror plane to form channels normal to the sheets. Stacking of the sheets follow ABAB... stacking with A representing the initial sheet and B relating to its mirror image. Tridymite rarely occurs upon heating of  $\text{SiO}_2$  without the presence of a flux. Tridymite occurs as a devitrification phase of obsidian. *Cf.*, cristobalite, quartz

**trilithionite** a trioctahedral member of the true mica group. The formula is  $\text{KLi}_{1.5}\text{Al}_{1.5}\text{AlSi}_3\text{O}_{10}\text{F}_2$ . This formula does not represent an end-member composition. Trilithionite occurs in Li-rich, late stage, granitic pegmatites and aplites as  $1M$ ,  $2M_1$  and  $3T$  polytypes.

**trioctahedral illite** a poorly defined material, possibly interstratified biotite and vermiculite

**truscottite** see reyerite group

**tuperssuatsiaite** a member of the palygorskite-sepiolite group with a composition of approximately  $\text{Na}_{1.87}\text{Fe}_{2.14}\text{Mn}_{0.48}\text{Ti}_{0.14}(\text{Si}_8\text{O}_{20})(\text{OH})_2 \cdot n(\text{H}_2\text{O})$ . See palygorskite-sepiolite group

**unghwarit** an obsolete term for nontronite or a mixture of nontronite and silica (opal-C?)

**uniaxial mica** a poorly defined material, possibly biotite

**vaalite** a poorly defined material, possibly vermiculite

**valuevite** an obsolete varietal term for clintonite

**vanadimplimmer** an obsolete term for roscoelite

**vanadium mica** an obsolete term for roscoelite

**varenesite** a modulated layer silicate with a continuous Na and Mn octahedra sheet interstratified with a continuous tetrahedral sheet with pairs of 6-fold tetrahedral rings (Grice and Gault, 1995). Each pair of rings is linked to another pair with tetrahedra pointing in opposing direction so that adjacent sheets of octahedra are cross linked. Connecting pairs of tetrahedra are linked such that 4-fold tetrahedral rings and 10-fold rings are formed. The ideal chemical composition is  $\text{Na}_8\text{Mn}_2\text{Si}_{10}\text{O}_{25}(\text{OH},\text{Cl})_2 \cdot 12\text{H}_2\text{O}$ . The mineral is extremely rare and occurs at the Demix-Varenes Quarry, Quebec, Canada in a peralkaline sill. *Cf.*, bementite, innsbruckite, pyrosmalite

**voigtite** a poorly defined material, possibly a weathering product of biotite or interlayer-deficient biotite

**verdite** an obsolete term for chromian muscovite

**vermiculite** Vermiculite refers to a mineral group and an industrial commodity (see part A for a description of both) and a mineral species. As a mineral species, the basic structure is a 2:1 layer [ideally  $\text{Mg}_3(\text{Si}_3\text{Al})\text{O}_{10}$ ] regularly interstratified with a partially completed interlayer [ $\text{Mg}_{0.5}(\text{H}_2\text{O})_4$ ], thus with an overall composition of  $\text{Mg}_3(\text{Si}_3\text{Al})\text{O}_{10} \cdot \text{Mg}_{0.5}(\text{H}_2\text{O})_4$  in either space group *Cc* or *C2/c*. Vermiculites are generally alteration products of (trioctahedral) mica or chlorite and form in soils, with most vermiculite species being trioctahedral, although fine-grained soil varieties may be either dioctahedral or trioctahedral. The 2:1 layer has a net layer charge of -0.6 to -0.9 per formula unit, which is offset by the interlayer to achieve overall neutrality. Like smectite minerals, vermiculite has swelling capabilities. Stacking sequences depend on the  $\text{H}_2\text{O}$  and cation configurations of the interlayer. See vermiculite and intumescence in Part 1 of the Glossary.

**vernadite** Vernadite,  $\text{MnO}_2 \cdot \text{H}_2\text{O}$ , is poorly crystalline and not well studied (Post, 1999). It is a mixture of nano-plates of birnessite, busserite, and interstratified birnessite / busserite. Vernadite occurs in the oxidized zone of Mn ore deposits, as buried manganese nodules on the sea floor, and ferromanganese crusts on seamounts. In soils (Chukhrov et al., 1980), vernadite is believed to be related to microbial oxidation of  $\text{Mn}^{2+}$ .

**verona earth** an obsolete term for celadonite

**veronite** an obsolete term for celadonite

**viridite** an obsolete term for an iron-rich chlorite

**viterbite** an obsolete term for a mixture of allophane and wavellite from Santa Rosa de Viterbo, Colombia

**volkhonskoite** see volkhonskoite

**volkhonskoite** a dioctahedral member of the smectite group with the dominant octahedral cation of Cr. The layer charge may originate by either tetrahedral or octahedral substitutions. *Syn.*, volkhonskoite

**voron'ya slyuda** an obsolete varietal term for zinnwaldite, lithian annite, lithian siderophyllite ('Raven mica' or 'crow mica' in Russian).

**vredenburgite** a discredited term for oriented intergrowths of hausmannite + jacobsite

**wad** a general term, now obsolete, to describe any poorly defined, fine grained manganese oxide with black or dark brown earthy, dull luster. *Cf.*, psilomelane

**waddoite** a poorly defined material, possibly a mica

**walouewite** an obsolete varietal term for clintonite

**waluewite** an obsolete varietal term for clintonite

**walujewit** an obsolete varietal term for clintonite

**wermlandite** see hydrotalcite group

**white mica** a field term used to describe a light-colored, mica, usually in metamorphic rocks, such as muscovite and margarite, and also illite, phengite, and celadonite

**willemseite** Willemseite is the Ni-rich ( $Ni > Mg$ ) member of the talc group. Willemseite occurs at Barberton Mountain Land, Transvaal.

**williamsite** an obsolete local, varietal term for antigorite serpentine of various colors, but typically green, from West Chester, Chester County, Pennsylvania, USA

**windhoekite** a member of the palygorskite-sepiolite group with a composition of approximately  $(Ca_{1.68}Mn_{0.32})Fe^{3+}_{2.96}(Si_{7.87}Al_{0.08})O_{20}(OH)_4 \cdot 10H_{1.98}O$ . See palygorskite-sepiolite group

**wodanite** an obsolete varietal term for biotite

**wollastonite** see pyroxenoid group

**wonesite** a trioctahedral mica that shows interlayer deficiency. It is a series name (Rieder et al., 1998) with a generalized composition of  $Na_{0.5}\square_{0.5}Mg_{2.5}Al_{0.5}(AlSi_3)O_{10}(OH)_2$ . The formula indicates that it is not an end-member composition. Series names designate that additional research may be warranted.

**woodwardite** see hydrotalcite group

**wotanite** an obsolete varietal term for biotite

**xanthophyllite** an obsolete varietal term for clintonite

**yakhontovite** a copper-bearing, approximately dioctahedral, smectite with a chemical composition of  $Ca_{0.20}K_{0.01}(Fe^{3+}_{0.83}Cu_{0.84}Mg_{0.67}Zn_{0.02}Al_{0.01})_{\Sigma=2.37}Si_4O_{10}(OH)_2$ . Yakhontovite occurs in highly oxidized sulfide-cassiterite ores at the Pridorozhnoye deposit of the Komsomolsk district, Khabarovskiy Kray, Far-Eastern Region, Russia (Postnikova et al., 1986).

**yangzhumingite** a member of the true mica group with an ideal composition of  $KMg_{2.5}Si_4O_{10}F_2$ , with possible substitution of 30% Li in the interlayer site. It is characterized by the Mg dominance over Fe, which is characteristic of montdorite. Material suitable for single crystal study has not been found. The type locality is in metamorphosed carbonate rock from Bayan Obo, Inner Mongolia, China (Miyawaki et al., 2011).

**yofortierite** a member of the palygorskite-sepiolite group with a composition of approximately  $\sim(R^{2+}, R^{3+}, \square)_5 Si_8O_{20}(OH, H_2O)_2(H_2O)_7$ , where  $Mn^{2+}$  dominates;  $R$  represents a cation and  $\square$  are vacancies. See palygorskite-sepiolite group

**zebedassite** a poorly defined term, fibrous in habit, possibly a serpentine or chlorite

**zeolite** In general, zeolite structures are fine grained and are comprised of negatively charged, three dimensional  $(Si,Al)O_4$  corner-sharing tetrahedral networks (“framework”) which form structural cavities and “extraframework sites”. The tetrahedra, with Al substituting Si, have a negative charge that is balanced by exchangeable cations in the extraframework sites.  $H_2O$ , which is polar, interacts with both the exchangeable cations and the framework, varying in number depending on relative humidity. Hydration and dehydration is generally continuous and reversible, and quite dynamic, although laumontite exhibits non-continuous behavior. Zeolites occur authigenically, in low-temperature secondary alterations, such as in soils, as hydrothermal

alteration products, in altered volcanics, in sediments, and many other environments. See also Part 1 of the Glossary. There are about 75 natural zeolites, and the more common species are given here:

chabazite  $(\text{Ca}_{0.5}, \text{Na}, \text{K})_4(\text{Al}_4\text{Si}_8\text{O}_{24}) \cdot 12(\text{H}_2\text{O})$

clinoptilolite  $(\text{Na}, \text{K}, \text{Ca}_{0.5})_6(\text{Al}_6\text{Si}_{30}\text{O}_{72}) \cdot 20(\text{H}_2\text{O})$

erionite  $\text{K}_2(\text{Ca}_{0.5}, \text{Na})_7(\text{Al}_9\text{Si}_{27}\text{O}_{72}) \cdot 28(\text{H}_2\text{O})$

laumontite  $\text{Ca}_4(\text{Al}_8\text{Si}_{16}\text{O}_{48}) \cdot 16(\text{H}_2\text{O})$

mordenite  $\text{Na}_3\text{Ca}_2\text{K}(\text{Al}_8\text{Si}_{40}\text{O}_{96}) \cdot 28(\text{H}_2\text{O})$

phillipsite  $\text{K}_2(\text{Na}, \text{Ca}_{0.5})_3(\text{Al}_5\text{Si}_{11}\text{O}_{32}) \cdot 12(\text{H}_2\text{O})$

stilbite  $\text{NaCa}_4(\text{Al}_9\text{Si}_{27}\text{O}_{72}) \cdot 30(\text{H}_2\text{O})$

**zinalsite** a platy serpentine mineral of ideal composition of  $\text{Zn}_2\text{Al}(\text{Si}, \text{Al})\text{O}_5(\text{OH})_4$ . Zinalsite is the Zn analogue of amesite. Natural occurrences are rare. The type locality is from the oxidation zone of the Akdzhai deposit, Kazakhstan, and it is also known from Sterling Hill, New Jersey, USA. *Cf.*, amesite, kellyite

**zinnwaldite** a series name for trioctahedral micas on or close to the siderophyllite-polyolithionite join. Also used to describe dark micas with significant amounts of lithium.

**zircon** an orthosilicate (= nesosilicate) mineral  $\text{Zr}(\text{SiO}_4)$  that commonly occurs as an accessory mineral in igneous and metamorphic rocks. The mineral may be used for dating the age of its host rock because it contains radioactive U and Th.

**zircophyllite** see astrophyllite group

**zussmanite** a modulated trioctahedral 2:1 phyllosilicate with an ideal chemical composition of  $RM_{13}T_{18}O_{42}(\text{OH})_{14}$ , with  $R = \text{Na}$  and  $\text{K}$ ,  $M = \text{Mg}$ ,  $\text{Mn}$ ,  $\text{Fe}^{2+}$ ,  $\text{Fe}^{3+}$ ,  $\text{Al}$ , and  $\text{Ti}$ , and  $T = \text{Si}$  and  $\text{Al}$ . The structure of zussmanite (Lopes-Vieira and Zussman, 1969) has a continuous octahedral sheet with islands of tetrahedral 6-fold rings on both sites of the octahedral sheet. Each island of 6-fold rings is laterally linked to other islands of six-fold rings by inverted three-fold rings, and these three-fold rings are linked also to the six-fold island tetrahedral rings of the adjacent 2:1 layer. The 6-fold rings align across the interlayer region and form a mica-like interlayer site where the large  $R$  cation can reside. Coombsite is the Mn analogue of zussmanite. Zussmanite occurs in blueschist facies metamorphic regimes at the Laytonville Quarry, Mendocino County, California.

**zweiaxiger glimmer** an obsolete term for muscovite

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