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SUMMARY OF RECOMMENDATIONS OF THE AIPEA NOMENCLATURE COMMITTEE

S. W. BAILEY, *Chairman**
Department of Geology and Geophysics, University of Wisconsin – Madison,
Madison, Wisconsin 53706, U.S.A.

INTRODUCTION

Because of their small particle-size and variable degree of crystal perfection, it is not surprising that clay minerals proved extremely difficult to characterize adequately prior to the development of modern analytical techniques. Problems in characterization led quite naturally to problems in nomenclature, undoubtedly more so than for the macroscopic, more perfectly crystalline minerals. The popular adoption in the early 1950s of the powder X-ray diffractometer for clay studies helped to solve some of the problems of identification. Improvements in electron microscopy, electron diffraction and oblique texture electron diffraction, infrared and DTA equipment, plus the development of nuclear and isotope technology, high-speed electronic computers, Mössbauer spectrometers and most recently, the electron microprobe and scanning electron-microscope all have aided in the accumulation of factual information on clays. This, in turn, should facilitate eventual agreement on the nomenclature of clays.

Probably the earliest attempt by clay scientists to reach agreement on nomenclature and classification on an international basis occurred at the International Soil Congress held in Amsterdam in 1950 (Brindley *et al.* 1951). Since that time national Nomenclature Committees have been established in many countries. Recommendations from these national groups have been considered every three years at the International Clay Conference, first by the Nomenclature Subcommittee of CIPEA (Comité International pour l'Etude des Argiles) and since 1966 by the Nomenclature Committee of AIPEA (Association Internationale pour l'Etude des Argiles). These international committees in turn have worked closely with the Commission on New Minerals and Mineral Names of the I.M.A. (International Mineralogical Association).

This summary of the recommendations made to date by the international nomenclature-committees has been prepared in order to disseminate more widely the decisions reached and to aid clay scientists in the correct usage of clay nomenclature. Some of the material in the present summary has been taken from an earlier summary by Bailey *et al.* (1971a).

CLASSIFICATION

Agreement was reached early in the international discussions that a sound nomenclature is necessarily based on a satisfactory classification scheme. For this reason, the earliest and most extensive efforts of the several national committees on nomenclature have been expended on classification schemes. Existing schemes were collated and discussed (*e.g.*, Brown 1955, Mackenzie 1959, Pedro 1967), symposia were held at national meetings, and polls were taken of clay scientists in 32 countries as to their preferences. Armed with these data, the international representatives have been able to agree upon most features of a broadly based scheme for the phyllosilicates as a whole (Mackenzie 1965a,b, Brindley 1967).

Table 1 gives the classification scheme in its present form. The phyllosilicates are divided into groups, each containing dioctahedral and trioctahedral subgroups. Each subgroup in turn is divided into mineral species. This subdivision corresponds to successive stages of refinement in the identification process. It is anticipated that the precise definitions of the groups and subgroups and their names will evolve and change with time. This table differs from previously published versions in two respects. *Smectite* has now been accepted as the group name for clay minerals with layer charge between 0.2 and 0.6 *per* formula unit. This decision, made at the 1975 Mexico City meeting (Brindley & Pedro 1976), was based on an

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*for the AIPEA (Association Internationale pour l'Etude des Argiles) Nomenclature Committee: A. Alietti (Italy), G. W. Brindley (U.S.A.), M. L. L. Formosa (Brazil), K. Jasmund (F.R.G.), J. Konta (Czechoslovakia), R. C. Mackenzie (U.K.), K. Nagasawa (Japan), R. A. Rausell-Colom (Spain) and B. B. Zvyagin (U.S.S.R.).

TABLE 1. CLASSIFICATION SCHEME FOR PHYLLOSILICATES RELATED TO CLAY MINERALS

Layer Type	Group (x=charge per formula unit)	Subgroup	Species*
1:1	Kaolinite-serpentine $x \sim 0$	Kaolinite Serpentine	Kaolinite, dickite, halloysite Chrysotile, lizardite, amesite
2:1	Pyrophyllite-talc $x \sim 0$	Pyrophyllite Talc	Pyrophyllite Talc
	Smectite $x \sim 0.2\text{-}0.6$	Dioctahedral smectite Trioctahedral smectite	Montmorillonite, beidellite Saponite, hectorite, sauconite
	Vermiculite $x \sim 0.6\text{-}0.9$	Dioctahedral vermiculite Trioctahedral vermiculite	Dioctahedral vermiculite Trioctahedral vermiculite
	Mica# $x \sim 1$	Dioctahedral mica Trioctahedral mica	Muscovite, paragonite Phlogopite, biotite, lepidolite
	Brittle mica $x \sim 2$	Dioctahedral brittle mica Trioctahedral brittle mica	Margarite Clintonite, anandite
	Chlorite x variable	Dioctahedral chlorite Di,trioctahedral chlorite Trioctahedral chlorite	Donbassite Cookeite, sudoite Clinochlore, chamosite, nimite

* Only a few examples are given. # The status of illite (or hydromica), sericite, etc. must be left open at present, because it is not clear whether or at what level they would enter the table: many materials so designated may be interstratified.

increased world-wide usage of this name as opposed to the alternate dual name *montmorillonite–saponite* for the group. Dual names still exist for the *kaolinite–serpentine* and *pyrophyllite–talc* groups. Suggested names of *kandite* and *septechlorite* for the kaolin and serpentine minerals, respectively, have not been approved by the AIPEA Committee and should not be used. The second change is to treat chlorite as consisting of a 2:1 layer plus an interlayer hydroxide sheet, rather than as a 2:1:1 or 2:2 layer type. This emphasizes the similarity of chlorite with other clay minerals containing interlayer material (Brindley & Pedro 1972).

DEFINITION OF PHYLLOSILICATE

Table 1 assumes a specific definition of a phyllosilicate (or layer silicate). This definition was discussed most recently at the AIPEA Nomenclature Committee meeting held in Madrid in 1972, at which a 1969 definition was modified. The present definition (Brindley & Pedro 1972) states: "Clay minerals belong to the family of phyllosilicates and contain continuous two-dimensional tetrahedral sheets of composition T_2O_5 (T = Si, Al, Be, . . .) with tetrahedra linked by sharing three corners of each, and with the fourth corner pointing in any direction. The tetrahedral sheets are linked in the unit structure to octahedral sheets, or to groups of coordinated cations, or individual cations." The present definition is based on the nature of the silicate parts of the structure, and does not include previous requirements of weaker interlayer bonding or of certain resultant physical properties. Thus, it does not require a category of "pseudolayer silicates" for minerals such as palygorskite and sepiolite that do not possess marked basal cleavages. The criterion of a continuous tetrahedral sheet does exclude "quasilayer silicates" such as astrophyllite, lamprophyllite, bafertisite and haradaite, in which 5- or 6-fold coordinated groups interrupt the continuity of the tetrahedral net.

STANDARDIZATION OF STRUCTURAL TERMS

At the 1975 Mexico City meeting the AIPEA Nomenclature Committee noted that *lattice* and *structure* continue to be misused by authors and speakers. A *lattice* is not synonymous with *structure;* it is a uniform distribution of points in space (*e.g.*, the 14 Bravais lattices). The terms "layer lattice" and "Schichtgitter" are incorrect and should not be used. *Layer structure, layer silicate* and *phyllosilicate* are acceptable terms (Brindley 1967, Brindley & Pedro 1976).

In 1972 the Committee agreed upon usage of the terms *plane, sheet, layer, unit structure* and their equivalents in other languages (Brindley & Pedro 1972). Recommended usage of these is: a single *plane* of atoms, a tetrahedral or octahedral *sheet* and a 1:1 or 2:1 *layer.* Thus, *plane, sheet* and *layer* refer to increasingly thicker arrangements. A sheet is a combination of planes and a layer is a combination of sheets. In addition, layers may be separated from one another by various *interlayer* materials, including cations, hydrated cations, organic molecules and hydroxide octahedral groups and sheets. The total assembly of a layer plus interlayer

TABLE 2. STRUCTURAL TERMS OF REFERENCE AND THEIR EQUIVALENTS IN DIFFERENT LANGUAGES

English	French	German	Russian	Spanish	Italian
plane	plan	Ebene	плоскость	plano	plano
sheet	couche	Schicht	сетка	capa	strato
layer	feuillet	Schichtpaket	слой	estrato o paquete (de capas)	pacchetto
interlayer	espace interfoliaire	Zwischenschicht	межслоево промежуток (межслой)	material interlaminar	interstrato
unit structure	unité structurale	Struktur Einheit	пакет	unidad estructural	unita strutturale

material is referred to as a *unit structure*. Table 2 lists the equivalent terms in other languages, as modified at the 1978 Oxford meeting.

The terms "talc layer" and "brucite sheet" are not suitable descriptions of the component parts of the chlorite structure because the minerals talc and brucite permit very little substitution of Mg by Al, and such substitution is an essential feature of trioctahedral chlorites. It is recommended that *2:1 layer* be used in place of "talc layer" and *hydroxide sheet* or *interlayer sheet* in place of "brucite sheet" (Brindley & Pedro 1972). It is permissible to write *brucite-like* or *brucitic* or *gibbsite-like* or *gibbsitic* if one wishes to specify the trioctahedral or dioctahedral nature of the interlayer.

Attention is drawn also to the report of the I.M.A.–I.U.Cr. Joint Committee on Nomenclature (Bailey 1978); the following recommendations, approved by the AIPEA Nomenclature Committee, will be of special interest to clay scientists.

1. *Polytypism* is defined as "the phenomenon of the existence of an element or compound in two or more layer-like crystal structures that differ in layer stacking sequences. The layers need not be crystallographically identical, but should be similar. Polytypism differs from polymorphism (in the present and strict definition of the latter term) in permitting small differences in chemical composition between structures, not to exceed 0.25 atoms *per* formula unit of any constituent element. Layer structures that differ from one another by more than this amount are to be called *polytypoids* rather than *polytypes*."

2. "In general, polytypes should not receive individual mineral names. Instead, a set of related polytypes should be designated by a single name followed by a structural symbol suffix that defines the layer stacking differences." A recommended system of structural symbols is described in the report.

3. "Polytype mineral names already in existence that have international acceptance and serve a useful function need not be discarded. Decision on retention of individual names should be the responsibility of the I.M.A. Commission on New Minerals and Mineral Names."

4. "It is recommended that *X*, *Y*, *Z* or [100], [010], [001] be used for directions of crystallographic axes and *a*, *b*, *c* for the repeat distance along these axes."

INTERSTRATIFICATIONS AND NONCRYSTALLINE MATERIALS

No general agreement has been reached yet regarding the preferred terminology for interstratified minerals, except that (1) the material should be characterized fully as to degree of regularity or irregularity of the interstratification and (2) it should be described in terms of the nature and ratios of the component layers. The best descriptive terms for those layers are still in question. At the 1972 Madrid meeting the Committee recommended that specific names not be given to poorly defined materials such as irregularly interstratified systems, to imperfect structures (*e.g.*, deweylite and aquacreptite) or to noncrystalline constituents. Special names can be given to regularly interstratified minerals subject to acceptance by the AIPEA Nomenclature Committee and the I.M.A. Commission on New Minerals and Mineral Names (Brindley & Pedro 1972). Names already in the literature at that time were *rectorite* for a regular 1:1 interstratification of dioctahedral paragonite–smectite (Brown & Weir 1963), *corrensite* for a regular 1:1 interstratification of trioctahedral chlorite–"swelling chlorite" (Lippmann

1954), *tosudite* for a regular 1:1 interstratification of dioctahedral chlorite–smectite (Frank-Kamenetskii *et al.* 1963, Shimoda 1969) and *aliettite* for a regular 1:1 interstratification of trioctahedral talc–saponite (Veniale & van der Marel 1969). The I.M.A. Commission on New Minerals and Mineral Names has disapproved the name *sangarite* for a regular 1:1 interstratification of trioctahedral chlorite–vermiculite (Drits & Kossovskaya 1963), and has approved the name *tarasovite* for a regular 3:1 interstratification of dioctahedral mica–smectite (Lazarenko & Korolev 1970). The AIPEA Nomenclature Committee has not yet taken action on specific names for regular interstratifications.

At its Jerusalem meeting (Brindley 1967) the CIPEA Nomenclature Subcommittee agreed unanimously that the term "noncrystalline" is preferable to the commonly used term "amorphous". It was recommended strongly that specific names not be given to newly discovered noncrystalline minerals, but that they be described so far as possible in terms of their chemical composition. Names may be chosen later if it becomes apparent that particular ranges of chemical composition exist for these minerals.

SPECIFIC PHYLLOSILICATE NAMES

Dioctahedral chlorite

The Committee has recommended (Brindley & Pedro 1970) that the chlorite group be subdivided into the three subgroups dioctahedral chlorite, di,trioctahedral chlorite and trioctahedral chlorite (Table 1). *Dioctahedral chlorite* is dioctahedral in both the 2:1 layer and the interlayer hydroxide sheet. An example is *donbassite* (Lazarenko 1940). *Trioctahedral chlorite* is trioctahedral in both octahedral sheets. A *di,trioctahedral chlorite* is dioctahedral in the 2:1 layer but trioctahedral in the interlayer sheet. *Cookeite* and *sudoite* are examples, with cookeite being Li-rich and sudoite Li-poor. No examples are yet known of chlorites with trioctahedral 2:1 layers but dioctahedral interlayers.

Trioctahedral chlorite

At the 1978 Oxford meeting the AIPEA Nomenclature Committee adopted the suggestion of Bayliss (1975) for simplification of chlorite nomenclature. Trioctahedral chlorites should be named according to the dominant divalent octahedral cation present. Recommended species-names are *clinochlore* [Mg dominant, end member $(Mg_5Al)(Si_3Al)O_{10}(OH)_8$], *chamosite* [$Fe^{2+}$ dominant end member $(Fe^{2+}{}_5Al)(Si_3Al)O_{10}(OH)_8$], *nimite* [Ni dominant, end member $(Ni_5Al)(Si_3Al)O_{10}(OH)_8$] and *pennantite* [$Mn^{2+}$ dominant, end member $(Mn^{2+}{}_5Al)(Si_3Al)O_{10}(OH)_8$]. All other species and varietal names should be discarded, because arbitrary subdivisions according to octahedral and tetrahedral compositions have been shown to have little or no structural significance. Tetrahedral compositions and trivalent octahedral cations are not considered in the recommended species-names, nor is the distribution of octahedral cations between the 2:1 layer and the interlayer. Adjectival modifiers, such as those of Schaller (1930), may be used to indicate either important octahedral cations other than the dominant cation or unusual tetrahedral compositions. Bayliss (1975) gives modifiers appropriate for many of the chlorite species listed in other nomenclature systems.

Imogolite

At its 1969 Tokyo meeting (Brindley & Pedro 1970) the Committee approved the name *imogolite* for a hydrous aluminosilicate having a fine, thread-like morphology and the diffraction characteristics described by Wada & Yoshinaga (1969) and others.

Halloysite

The 1975 AIPEA Nomenclature Committee reviewed the several terminologies in use for the less hydrous and the more hydrous forms of halloysite. The terms *halloysite(7Å)* and *halloysite(10Å)* were recommended for general usage as being least ambiguous (Brindley & Pedro 1976). The term *endellite* should not be used.

Celadonite

The 1978 AIPEA Nomenclature Committee has defined *celadonite* as a dioctahedral mica of ideal composition $KMgFe^{3+}Si_4O_{10}(OH)_2$ but allowing a range in tetrahedral Al (or Fe^{3+}) of 0 to about 0.2 atoms *per* formula unit. Substantial octahedral variations from this formula can be described by adjectival modifiers, such as aluminian celadonite or ferroan celadonite. Further characteristics of celadonite are *d*(060) < 1.510 Å and sharp infrared spectra, as described by Buckley *et al.* (1978). There is an area of potential overlap between celadonite and glauconite in the range of $Al^{IV} = 0.17$ to 0.20 atoms. For compositions near this boundary and for cases in which analytical errors or impurities are suspected, application of the other identification criteria are especially important.

Glauconite

Buckley *et al.* (1978) have shown that with careful purification and modern analytical techniques there is little or no overlap between celadonite and glauconite compositions and that the two minerals also can be differentiated by $d(060)$ values and infrared spectra. The 1978 AIPEA Nomenclature Committee has defined glauconite as an Fe-rich dioctahedral mica with tetrahedral Al (or Fe^{3+}) usually greater than 0.2 atoms *per* formula unit and octahedral R^{3+} correspondingly greater than 1.2 atoms. A generalized formula is $K(R^{3+}{}_{1.33}R^{2+}{}_{0.67})(Si_{3.67}Al_{0.33})O_{10}(OH)_2$ with $Fe^{3+} \gg Al$ and $Mg > Fe^{2+}$ (unless altered). Further characteristics of glauconite are $d(060) > 1.510$ Å and, usually, broader infrared spectra than celadonite, as described by Buckley *et al.* (1978). The species glauconite is single-phase and ideally is not interstratified. Mixtures containing an iron-rich mica as a major component can be called *glauconitic.* Specimens with expandable layers can be described as randomly interstratified glauconite–smectite. Mode of origin is not a criterion, and a green fecal pellet in a marine sediment that meets the definition for celadonite should be called celadonite.

Miscellaneous

Attention is drawn here to recommendations made by other nomenclature committees, although not specifically considered by the AIPEA Nomenclature Committee.

The name *berthierine* has priority for the Fe-rich 1:1-type layer silicate having appreciable tetrahedral Al and commonly found in ironstones and iron formations. *Brindleyite* is the Ni-analogue of berthierine. The name *chamosite* has priority for a 2:1 chlorite of composition similar to berthierine (Orcel *et al.* 1949).

The name *clintonite* has priority over other species names (xanthophyllite, seybertite, brandisite, valuevite) for the Li-poor, Ba-poor trioctahedral brittle mica. All of these are so similar in crystallography, chemical composition and mode of origin that only a single species name is justified (Forman *et al.* 1967). *Bityite* (Li, Be-rich), *anandite* (Ba, Fe-rich) and *kinoshitalite* (Ba, Mg-rich) appear to be other valid trioctahedral brittle-mica species (Schaller *et al.* 1967, Pattiaratchi *et al.* 1967, Yoshii *et al.* 1973). *Ephesite,* described originally as a Li–Na brittle mica (Schaller *et al.* 1967), is more accurately described as a true mica with a layer charge *per* formula unit of unity.

The name *palygorskite* has priority over *attapulgite* for the mineral with a ribbon-like structure in which the ribbons have a width of two pyroxene-like chains (Bailey *et al.* 1971b).

The name *anauxite* has been discredited. It is a mixture of components, of which the kaolin component is true kaolinite (Langston & Pask 1968, Allen *et al.* 1969, Bailey & Langston 1969).

Medmontite is a mixture of chrysocolla and mica; the name should be discarded (Chukhrov *et al.* 1968, 1969, Fleischer 1969a).

Nimite is the preferred term for the trioctahedral chlorite with Ni dominant (Hiemstra & de Waal 1968a). Specimens previously termed *schuchardtite* have Ni < Mg (Fleischer 1969b) and should be called nickeloan clinochlore. Brindley & De Souza (1975) also have shown that some "schuchardtites" are transitional between chlorite and vermiculite.

Caryopilite is the preferred term for a 1:1 layer-type mineral that is the Mn^{2+} analogue of greenalite. The name *bementite,* sometimes used for the former mineral, has priority for a Mn-rich mineral that belongs to the friedelite group of minerals and is not a layer silicate (Kato 1963).

The name *rectorite* has priority over *allevardite* for a regular 1:1 interstratification of paragonite–smectite (Brown & Weir 1963).

Sungulite and *kolskite* are mixtures of lizardite and sepiolite; the names should be discarded (Ivanova *et al.* 1973).

Alushtite is a mixture of dickite and hydrous mica; the name should be discarded (Logvinenko & Frank-Kamenetskii 1955). Some specimens that have been called alushtite have been identified later as tosudite (Frank-Kamenetskii *et al.* 1963).

Deweylite is a mixture in variable proportions of a disordered form of talc (kerolite) and a disordered form of serpentine. Both components have excess water, probably associated with unbalanced surface bonds. The name is useful only as a field term (Bish & Brindley 1978).

Kerolite is a varietal name for a mineral close to talc in composition and structure but with highly random layer-stacking and an enlarged basal spacing of about 9.6 Å due to misfitting layers; $R^{2+}{}_3(Si_2O_5)_2(OH)_2 \cdot nH_2O$ with $n \sim 0.8$–1.2 (Brindley *et al.* 1977).

Pimelite is a Ni-analogue of kerolite with Ni > Mg (Maksimović 1966, Brindley *et al.* 1979).

Nepouite is a Ni-analogue of lizardite (Glasser 1907, Maksimović 1973, Brindley & Wan 1975).

New names for layer silicate minerals approved recently by the I.M.A. Commission on New Minerals and Mineral Names are listed below:

hendricksite, a trioctahedral Zn-rich mica (Frondel & Ito 1966, Frondel & Einaudi 1968)

willemseite, a Ni-analogue of talc (Hiemstra & de Waal 1968b)

pecoraite, a Ni-analogue of clinochrysotile (Faust *et al.* 1969)

Mn–sepiolite, Mn–palygorskite, Mn–ferrisepiolite, Mn–ferropalygorskite (Semenov 1969)

chernykhite, a dioctahedral V, Ba, Na-rich mica (Ankinovich *et al.* 1972)

kellyite, a Mn^{2+}-analogue of amesite (Peacor *et al.* 1974)

swinefordite, a Li,Al,Mg-rich smectite intermediate between dioctahedral and trioctahedral (Tien *et al.* 1975)

baumite, a Mn,Fe,Zn-rich serpentine (Frondel & Ito 1975)

masutomilite, a Mn^{2+}-analogue of zinnwaldite (Harada *et al.* 1976).

yofortierite, a Mn^{+2}-analogue of palygorskite (Perrault *et al.* 1975)

falcondoite, a Ni-analogue of sepiolite with Ni > Mg (Springer 1976)

ferripyrophyllite, a Fe^{3+}-analogue of pyrophyllite (Chukhrov *et al.* 1979).

Several layer silicates incorporating interlayer metallic elements have been recognized recently. *Chapmanite* and *bismutoferrite* have 1:1 layers with Si in the tetrahedral sheet and Fe^{3+} in the octahedral sheet. The surface hydroxyl groups of the octahedral sheet are replaced by oxygens, and Sb and Bi (in chapmanite and bismutoferrite, respectively) are in the interlayer space (Zhukhlistov *et al.* 1974, Zhukhlistov & Zvyagin 1977). *Surite* is a smectite having a defect, cerussite-like lead carbonate interlayer (Haysase *et al.* 1978).

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