

Nomenclature for regular interstratifications

S. W. BAILEY¹

Department of Geology and Geophysics
University of Wisconsin
Madison, Wisconsin 53706

It is now generally accepted that species names can be given to regularly interstratified clay minerals, in accordance with the recommendation of the International Association for the Study of Clays (AIPEA) Nomenclature Committee (Brindley and Pedro, 1970). In Part A of this report we suggest (1) criteria for defining the degree of regularity of alternation of different layer types that should be required to merit a name, (2) data that should be provided for documentation of a regular interstratification, and (3) some examples of interstratifications that do not merit names. In Part B of the report we apply the suggested criteria to the analysis of regular interstratifications previously reported in the literature, and make recommendations regarding the usage of existing names.

Part A

The Nomenclature Committee makes the following recommendations regarding the usage of species names for regular interstratifications.

1. Names should be restricted to regular interstratifications where the kinds of layers, their relative proportions, chemical compositions, and regularity of interstratification have been well documented. In determining the kinds of layers present, it is important that the swelling-shrinking behavior of each layer type be demonstrated relative to water, organic solvates, and heat.

2. In order to merit a name, an interstratification of two layer types A and B should have sufficient regularity of alternation to give a well defined series of at least ten 00l summation spacings $d_{AB} = d_A + d_B$, for which the suborders are integral and the

even and odd suborders have closely similar diffraction breadths. If any odd 00l suborders are absent, calculations must be given to show that their intensities are too small to be observed. The coefficient of variation of the d(00l) values should be less than 0.75 to demonstrate adequate regularity of alternation. The coefficient of variation is defined as $CV = 100s/\bar{X}$, where the standard deviation for a small sample is

$$s = \left[\frac{\sum(X_i - \bar{X})^2}{n - 1} \right]^{1/2},$$

X_i is an individual observed $l \times d(00l)$ value, \bar{X} is the mean of the X_i values, and n is the number of observed X_i values.

3. Names should not be used for less regular interstratifications, for specimens that deviate from the ideal mixing ratio or chemistry, or for less well documented specimens. Instead, such specimens should be characterized according to the information available, e.g. mica-smectite irregular interstratification or [1:1 dioctahedral mica-dioctahedral smectite]_{P(A,B)=0.7}, etc.

4. Interstratifications incorporating imperfect types of layers, which could not qualify for names by themselves in the non-interstratified state (e.g. "swelling chlorite" and "labile chlorite") do not merit names. Interstratifications with considerable inhomogeneity of layer charge do not merit names. Interstratifications with only a single summation peak $d(001) = d_A + d_B$ and no other odd suborders do not merit names, because a single peak could result from a short-range association of layers.

5. It is not certain that single layers of smectite or of vermiculite sandwiched between layers of a different type in an interstratification react in the same way as the non-interstratified minerals would react to solvation, hydration, and dehydration tests. MacEwan and Wilson (1980) stated that glycerol solvation of a Mg-saturated clay gives the best differentiation between nonswelling vermiculite and

¹Chairman of the AIPEA Nomenclature Committee. Other members A. Alietti (Italy), G. W. Brindley (USA), M. L. L. Formosa (Brazil), K. Jasmund (FRG), J. Konta (Czechoslovakia), R. C. Mackenzie (UK), K. Nagasawa (Japan), R. A. Rausell-Colom (Spain), and B. B. Zvyagin (USSR). This report, originally prepared by the Nomenclature Committee of The Clay Minerals Society (U.S.), was approved by the AIPEA Nomenclature Committee at its meeting of September 9, 1981.

swelling smectite, as defined according to the present boundary between these clay mineral types of 0.6 layer charge per formula unit. We suggest, for interstratifications where the distinction between vermiculite and smectite may be critical, that both glycerol and ethylene glycol solvation be used in connection with several saturating cations.

6. Because of the difficulty in determination, the species of smectite involved should not be specified in the definition of the species of a regular interstratification, beyond its dioctahedral or trioctahedral nature. Names so defined are apt to be of more widespread and practical usage than would be the case for a more restrictive definition. Where feasible, however, the smectite species may be noted by the investigator and used to characterize a particular occurrence in more detail.

Part B

We have applied our criteria to examples of regular interstratifications cited in the literature. We conclude that the criteria are not unduly restrictive, and we use our evaluations to make recommendations regarding acceptance or modification of existing species names.

Aliettite

The name aliettite was given by Veniale and van der Marel (1969) to a 1:1 regularly interstratified talc-saponite. Three occurrences have been reported: (1) in serpentized rocks from Monte Chiaro in the Taro Valley of Italy (Alietti and Mejsner, 1980, and earlier reports by Alietti), (2) in weathered serpentine from Ferriere in the Nure Valley of Italy (Veniale and van der Marel, 1968, 1969), and (3) in Precambrian dolomites in the Congo (Guenot, 1970).

The study of Alietti and Mejsner (1980) for the Monte Chiaro sample is the most rigorous. It is shown that 10 orders of basal reflections occur in the untreated sample with equal diffraction breadths for the even and odd values. Although three of the ten orders were unobserved, calculation of theoretical structure amplitudes shows that they are too weak to be observed. The coefficient of variation for untreated material is 0.04. The bulk chemical compositions and the d values for natural, solvated, and heated specimens are consistent with the authors' interpretation. The diagnostic treatments and d values are: $d(001)$ untreated 24.80Å, glycerol solvated 27.10Å, heated at 600°C 9.34Å.

Recommendations: The name aliettite is justified according to our criteria. We suggest that trioctahedral smectite be substituted for saponite in the definition.

Corrensite

Corrensite was defined by Lippmann (1954) as a regular 1:1 interstratification of trioctahedral chlorite and trioctahedral swelling chlorite. The swelling chlorite component was characterized as expanding from 14Å in thickness to about 18Å upon solvation with glycerol but resistant to collapse to 10Å upon heating. Because swelling chlorite is believed to be a defect form of chlorite that would not merit a species name if it occurred by itself, we do not consider this definition of corrensite as valid. In subsequent articles, Lippmann (1956, 1960) has referred to the swelling component in corrensite as vermiculite (swelling chlorite) and as montmorillonite. Because different specimens were involved in these latter cases, it is not certain that the same swelling component was involved in each.

Our analysis of over 30 literature citations of corrensite, selected from a comprehensive bibliography and data compilation by Hauff, Hayhurst, and Hanatani (in preparation) for the U.S. Geological Survey, shows that the predominant current usage of the name corrensite is for a 1:1 regular interstratification of trioctahedral chlorite and trioctahedral smectite. Documentation in many cases is poor, and the swelling component has been variously identified as smectite, montmorillonite, saponite, and vermiculite. Several of the samples have coefficients of variation below 0.75 with the even and odd 00 l orders of equal diffraction breadth. The data of Schlenker (1971) for corrensite from the Middle Keuper shales and marls in Germany are the best encountered in our survey for documentation of the smectitic component. It was shown that the mineral expands to 31–32Å not only with ethylene glycol but also with 100% relative humidity. Most other studies used only ethylene glycol solvation or used glycerol without Mg-saturation. The Middle Keuper corrensite has a mean $d(001)$ value of 29.1Å air dried with CV = 0.57 and a mean $d(001)$ of 31.05Å glycolated with CV = 0.61. Corrensite collapses to 23.5–24.0Å upon heating at 550°C.

Regular 1:1 interstratifications of trioctahedral chlorite and trioctahedral vermiculite also are known to exist. Well documented examples have been provided by Johnson (1964) from a soil in Pennsylvania and by Gradusov (1969) from an as-

bestos deposit in the southern Ural Mountains. The material from Pennsylvania gives 13 observed orders of a 28.52\AA repeat in the air dried state with all orders equally sharp and a coefficient of variation of 0.23. The Mg-saturated material does not expand further upon ethylene glycol solvation, the K-saturated material air-dried shrinks to 24.36\AA , and collapses to 24.06\AA upon heating at 475°C . Mg-saturated material from the Ural Mountains does not expand beyond 28.5\AA upon solvation with glycerol or ethylene glycol. A calculated Fourier transform and a one-dimensional electron density projection both indicate regularity of alternation of the two components for the Ural's specimen. The diffraction patterns of both chlorite-smectite and chlorite-vermiculite are characterized by very low intensities for all odd orders of $00l$ except the first order for untreated material. Johnson (1964) has calculated that the intensities of these odd orders should be very small.

Recommendations: The definition of corrensite should be changed to a 1 : 1 regular interstratification of trioctahedral chlorite with either trioctahedral smectite or trioctahedral vermiculite, the former constituting low-charge corrensite and the latter high-charge corrensite. Glycerol solvation of Mg-saturated material and other methods of determining layer charge can be used for differentiation of the two types. A different name for high-charge corrensite may be appropriate if further research establishes the feasibility of reliable distinction of the smectite and vermiculite components.

Kulkeite

Abraham *et al.* (1980) defined kulkeite as a 1 : 1 regular interstratification of trioctahedral chlorite and talc. The mineral occurs as single crystals in a metamorphosed evaporite sequence in Algeria. The ideal formula is listed as $\text{Mg}_8\text{Al}(\text{Si}_7\text{Al})\text{O}_{20}(\text{OH})_{10}$, but a small substitution of $\text{NaAl} \rightarrow \text{Si}$ (about 0.40 atoms) takes place in the actual mineral. The NaAl is assumed to be in the talc component, similar to analyzed discrete talc in the same rock. The authors say the chlorite-talc 1:1 interstratification also can be pictured as a 2:1 regular alternation of talc and brucite units.

The mean $d(001)$ value for ten basal reflections is 23.715\AA , with $\text{CV} = 0.12$. No solvation or heating tests are mentioned. Optical properties and cell dimensions are listed.

Recommendations: The name kulkeite appears to be justified for a 1:1 regular interstratification of

trioctahedral chlorite and talc, but further documentation of the material's behavior with respect to organic solvates and heating is desirable.

Rectorite

From chemical analyses, cation exchange measurements, X-ray examination, electron microscopy, and IR absorption spectra, Brown and Weir (1963) established, in general agreement with previous work by Bradley (1950), Caillère *et al.* (1950), Brindley (1956), and others, that rectorite and allevardite are the same mineral. The name rectorite has priority over allevardite. The structure consists of pairs of dioctahedral 2:1 layers; alternate interlayers are mica-like and montmorillonite-like. The non-swelling, mica-like interlayers contain about 0.85 univalent cations per mica formula unit and the swelling interlayers about 0.35 univalent cations per smectite formula unit.

X-ray basal reflections up to 0,0,26 for air-dry material, 0,0,22 for material heated to 500° and 900°C for 24 hrs., and 0, 0, 22 for ethylene glycol saturated material were given by Brindley (1956) together with one-dimensional electron density projections. Basal spacings for the mineral from Alleward, France, under various conditions were as follows: immersed in water 28.36\AA , air dry natural state 24.63\AA , after 450°C for 24 hrs. 19.09\AA , after 900°C for 24 hrs. 19.40\AA , after ethylene glycol treatment 26.41\AA . The even and odd $00l$ orders have similar diffraction breadths, and the coefficient of variation for the air dry material is 0.50. More detailed study of the component layers of rectorite from Baluchistan by Kodama (1966) led to the conclusion that the mineral consists of paragonite-like layers and expansible layers having beidellitic and montmorillonitic compositions. Similar regular interstratifications in which K is the dominant cation in the mica component have been reported by Pevear *et al.* (1980) in bentonites from British Columbia, and in which Ca is the dominant cation by Matsuda *et al.* (1981) from the Sano mine, Japan.

Recommendations: The name rectorite is justified for a 1:1 regular interstratification of a dioctahedral mica and dioctahedral smectite. The kind of smectite should not be specified in the definition. A prefix Na-, K-, or Ca- can be used to specify the dominant interlayer cation in the mica component.

Tarasovite

The name tarasovite was given by Lazarenko and Korolev (1970) to a 2:1 regular interstratification of

mica layers and rectorite, which also can be described as a 3:1 alternation of mica and smectite layers MMMS. The mean $d(001)$ repeat is 43.81Å for 11 observed orders in the original state, with $CV = 1.73$, and 46.10Å glycolated for 20 observed orders, with $CV = 1.08$ (omitting 0,0,18 as a printing error). The material collapses to 19.5Å with loss of the higher periodicity on heating at 600°C, but rehydrates with time to 42Å. The authors presented chemical analyses, a Fourier transform, a one-dimensional electron density projection, and calculation of $00l$ structure amplitudes to propose that the two mica layers contain $K_{0.6}Na_{0.4}$ in the interlayer regions and have the muscovite $2M_1$ stacking sequence; the mica layer in the rectorite portion contains $Na_{0.5}(H_3O)_{0.5}$, with Na and Ca as exchangeable cations in the smectitic layer of the rectorite.

Recommendations: Although the sample has been documented well, the degree of regularity is not sufficient to warrant a species name (coefficients of variations of 1.73 and 1.08 relative to the desired 0.75). The name can be reserved pending discovery of a more regular interstratification of the same type.

Tosudite

The name tosudite was given by Frank-Kamenetskii *et al.* (1965) to a 1:1 regularly interstratified dioctahedral chlorite-smectite. At least 14 occurrences have been reported, and six of these samples give 10 or more orders of basal reflections. Only the two samples from Tooho, Japan (Nishiyama *et al.*, 1975), and Huy, Belgium (Brown *et al.*, 1974), meet the requirements that the coefficient of variation should be less than 0.75 (0.33 and 0.55, respectively). Both samples give $d(001)$ values of 31.1Å on glycolation and $d(001)$ of 23.3Å on heating at 500–650°C, although the mean $d(001)$ of the Tooho specimen under air-dry conditions is 0.65Å larger than that of Huy (29.47Å and 28.82Å, respectively). With glycerol solvation the Huy sample expands to 32.2Å. The $d(060)$ values are 1.492Å for the Tooho specimen and 1.506Å for the Huy specimen.

Recommendations: The name tosudite is valid for a 1:1 regular interstratification of chlorite and smectite that is dioctahedral on average. Dioctahedral is defined for this purpose as a total octahedral population between 6.0 and 7.0 on the basis of $O_{20}(OH)_{10}$ for the assemblage and a $d(060)$ value between about 1.49Å and 1.506Å. This allows combination

of di,dioctahedral chlorite (donbassite) with either dioctahedral or trioctahedral smectite and of dioctahedral smectite with either di, trioctahedral chlorite (sудоite or cookeite) or tri,dioctahedral chlorite (unknown to date). (In di, trioctahedral, *etc.*, the first designator refers to the octahedral sheet in the 2:1 layer of chlorite and the second designator to the interlayer sheet.)

References

- Abraham, K., Schreyer, W., Medenbach, O., and Gebert, W. (1980) Kulkeit, ein geordnetes 1:1 Mixed-Layer-Mineral zwischen Klinochlor und Talk (abstr.). *Fortschritte der Mineralogie, Beiheft 1*, 58, 4–5.
- Alietti, A. and Mejsner, J. (1980) Structure of a talc/saponite mixed-layer mineral. *Clays and Clay Minerals*, 28, 388–390.
- Bradley, W. F. (1950) The alternating layer sequence of rectorite. *American Mineralogist*, 35, 590–595.
- Brindley, G. W. (1956) Allevardite, a swelling double-layer mica mineral. *American Mineralogist*, 41, 91–103.
- Brindley, G. W. and Pedro, G. (1970) Report of the AIPEA Nomenclature Committee. *AIPEA Newsletter No. 4*, 3–4.
- Brown, G., Bourguignon, P. and Thorez, J. (1974) A lithium-bearing aluminian regular mixed layer montmorillonite-chlorite from Huy, Belgium. *Clay Minerals*, 10, 135–144.
- Brown, G. and Weir, A. H. (1963) The identity of rectorite and allevardite. *Proceedings of the International Clay Conference, Stockholm*, 1, 27–35 and 2, 87–90.
- Caillère, S., Mathieu-Sicaud, A., and Hénin, S. (1950) Nouvel essai d'identification du minéral de la Table près Allevard, l'allevardite. *Bulletin de Société Française de Minéralogie et des Cristallographie*, 73, 193–201.
- Frank-Kamenetskii, V. A., Logvinenko, N. V., and Drits, V. A. (1965) Tosudite—a new mineral, forming the mixed-layer phase in alushtite. *Proceedings of the International Clay Conference, Stockholm*, 2, 181–186.
- Gradusov, B. P. (1969) An ordered trioctahedral mixed-layer form with chlorite and vermiculite packets. *Doklady Akademii Nauk, SSSR*, 186, 140–142 (English translation).
- Guenot, B. (1970) Etude d'un minéral argileux du type interstratifié talc-saponite trouvé dans le Précambrien du Congo Kinshasa. *Bulletin du Groupe Français des Argiles*, 22, 97–104.
- Johnson, L. J. (1964) Occurrence of regularly interstratified chlorite-vermiculite as a weathering product of chlorite in a soil. *American Mineralogist*, 49, 556–572.
- Kodama, H. (1966) The nature of the component layers of rectorite. *American Mineralogist*, 51, 1035–1055.
- Lazarenko, E. K. and Korolev, Yu. M. (1970) Tarasovite, a new dioctahedral ordered interlayered mineral. *Zapiski Vsesoyuzhogo Mineralogicheskogo Obshchestva*, 99, 214–224.
- Lippmann, F. (1954) Über einen Keuperton von Zaisersweiher bei Maulbronn. *Heidelberger Beiträge zur Mineralogie und Petrographie*, 4, 130–134.
- Lippmann, F. (1956) Clay minerals from the Röt Member of the Triassic near Göttingen, Germany. *Journal of Sedimentary Petrology*, 26, 125–139.
- Lippmann, F. (1960) Corrensit: In *Handbuch der Mineralogie* by C. Hintze, *Ergänzungsband II, Neue Mineralien und Neue Mineralnamen* by K. F. Chudoba, Teil III, p. 688–691.
- MacEwan, D. M. C. and Wilson, M. J. (1980) Interlayer and

- intercalation complexes of clay minerals. In G. W. Brindley and G. Brown, Eds., *Crystal Structures of Clay Minerals and their X-ray Identification*, chapter 3, Monograph 5 of Mineralogical Society, London.
- Matsuda, T., Nagasawa, K., Tsuzuki, Y., and Henmi, K. (1981) Regularly interstratified dioctahedral mica-smectite from Roseki deposits in Japan. *Clay Minerals*, 16, 91-102.
- Nishiyama, T., Shimoda, S., Shimosaka, K., and Kanaoka, S. (1975) Lithium-bearing tosudite. *Clays and Clay Minerals*, 23, 337-342.
- Pevear, D. R., Williams, V. E., and Mustoe, G. E. (1980) Kaolinite, smectite, and K-rectorite in bentonites: relation to coal rank at Tulameen, British Columbia. *Clays and Clay Minerals*, 28, 241-254.
- Schlenker, B. (1971) Petrographische Untersuchungen am Gipskeuper und Lettenkeuper von Stuttgart. *Oberrheinische Geologische Abhandlungen*, 20, 69-102.
- Veniale, F. and van der Marel, H. W. (1968) A regular talc-saponite mixed-layer mineral from Ferriere, Nure Valley (Piacenza Province, Italy). *Contributions to Mineralogy and Petrology*, 17, 237-254.
- Veniale, F. and van der Marel, H. W. (1969) Identification of some 1:1 regular interstratified trioctahedral clay minerals. *Proceedings of the International Clay Conference, Tokyo I*, 233-244.

*Manuscript received, October 15, 1981;
accepted for publication, December 4, 1981.*