

COMMENT

REPORT OF THE CLAY MINERALS SOCIETY NOMENCLATURE COMMITTEE: REVISED CLASSIFICATION OF CLAY MATERIALS

INTRODUCTION

Clay materials commonly contain a considerable fraction of layer silicate minerals that exert a strong influence on the nature of the material. Both the structural and chemical characteristics of the constituent layer silicates play a role in determining the extent of this influence. They are the fundamental features needed to explain the variations in properties of clay materials.

Layer silicate minerals can be classified conveniently on the basis of these characteristics (Tables 1, 2). Structural characteristics include, for example, the type of silicate layer or linkage configuration (for modulated layer silicates). Chemical characteristics include both the magnitude of net layer charge (x) per formula unit and the type of interlayer material. Obviously, structural features are interrelated with chemical character-

istics. Except for the micas, all hydrous layer silicate species are given in the Tables, even if they are not found as clay minerals. The classification scheme is expected to evolve as knowledge of the details of these minerals increases.

PLANAR HYDROUS PHYLLOSILICATES

The planar hydrous phyllosilicate minerals (Table 1) are arranged in seven groups according to (a) the type of silicate layer present (1:1 or 2:1), (b) the magnitude of the net layer charge (x) per formula unit, and (c) the interlayer material that compensates the layer charge. Each group is divided into subgroups on the basis of the octahedral character (dioctahedral or trioctahedral with 2.5 cations as the boundary). Species are distinguished by different compositions or, for the kaolin minerals, by different layer (nacrinite) or octahedral vacancy (kaolinite, dickite) sequences along Z . Addi-

Table 1. Classification of planar hydrous phyllosilicates.

Layer type	Interlayer material ¹	Group	Octahedral character	Species
1:1	None or H ₂ O only ($x \sim 0$)	Serpentine-kaolin	Trioctahedral Dioctahedral Di-trioctahedral	Lizardite, berthierine, amesite, cronstedtite, nepouite, kellyite, fraipontite, brindleyite Kaolinite, dickite, nacrite, halloysite (planar) Odinite
2:1	None ($x \sim 0$)	Talc-pyrophyllite	Trioctahedral Dioctahedral	Talc, willemseite, kerolite, pimelite Pyrophyllite, ferripyrophyllite
	Hydrated exchangeable cations ($x \sim 0.2-0.6$)	Smectite	Trioctahedral Dioctahedral	Saponite, hectorite, saucanite, stevensite, swinefordite Montmorillonite, beidellite, nontronite, volkonskoite
	Hydrated exchangeable cations ($x \sim 0.6-0.9$)	Vermiculite	Trioctahedral Dioctahedral	Trioctahedral vermiculite Dioctahedral vermiculite
	Non-hydrated monovalent cations ($x \sim 0.6-1.0$)	True (flexible) mica	Trioctahedral Dioctahedral	Biotite, phlogopite, lepidolite, etc. Muscovite, illite, glauconite, celadonite, paragonite, etc.
	Non-hydrated divalent cations ($x \sim 1.8-2.0$)	Brittle mica	Trioctahedral	Clintonite, kinoshitalite, bityite, anandite
	Hydroxide sheet ($x = \text{variable}$)	Chlorite	Trioctahedral Dioctahedral Di-trioctahedral	Margarite Clinochlore, chamosite, pennantite, nimite, baileychlore Donbassite Cookeite, sudoite
2:1	Regularly interstratified ($x = \text{variable}$)	Variable	Trioctahedral Dioctahedral	Corrensite, aliettite, hydrobiotite, kulkeite Rectorite, tosudite

¹ x is net layer charge per formula unit.

Table 2. Classification of non-planar hydrous phyllosilicates.

Layer type	Modulated component	Linkage configuration	Unit layer, $c \sin \beta$ value	Traditional affiliation	Species
A. Modulated structures					
1:1 layer	Tet. Sheet	Strips	7 Å	Serpentine	Antigorite, bementite
		Islands	7 Å	Serpentine	Greenalite, caryopilite, pyrosmalite, manganpyrosmalite, ferropyrosmalite, friedelite, mcgillite, schallerite, nelenite
2:1 layer	Tet. Sheet	Other		None	None
		Strips	9.5 Å	Talc	Minnesotaite
		Islands	12.5 Å	Mica	Ganophyllite, eggletonite
	Oct. Sheet		9.6–12.5 Å	Mica/complex	Zussmanite, parsettensite, stilpnomelane, ferrostilpnomelane, ferristilpnomelane, lennilenapeite
		Other	12.3 Å	None	Bannisterite
		Strips	14 Å	Chlorite	Gonyerite
			12.7–13.4 Å	Pyribole	Sepiolite, loughlinite, falcondoite, palygorskite, yofortierite
B. Rolled and spheroidal structures					
1:1 layer	None	Trioctahedral	—	Serpentine	Chrysotile, pecoraite
		Diocahedral	—	Kaolin	Halloysite (nonplanar)

tional details on regularly interstratified species are given in Bailey *et al.* (1982).

Most of these hydrous phyllosilicates occur as clay minerals. The small particle size and high surface areas of clays are a consequence of their conditions of crystallization or subsequent histories, as well as their chemical compositions and crystal structures. The classification scheme for clay minerals ideally is independent of the method of characterization, which may be influenced by several variables. For example, low-charge smectites usually are identified by their ability to incorporate two sheets of glycerol or ethylene glycol molecules in the interlayer during solvation, thereby expanding the basal spacing to 17–18 Å, whereas high-charge vermiculites accept only one such interlayer sheet. Historically, the boundary between smectite and vermiculite has been a net layer charge (x) of 0.6 with Mg ions as the interlayer material. Expansion upon solvation depends upon the net layer charge and the nature of the interlayer material neutralizing that charge. Secondary factors that affect expansion are the distribution of charge between the tetrahedral and octahedral sheets as well as the solvating medium, which includes relative humidity. Because net layer charge is not easily determinable, several methods of characterization are advisable for specimens that lie near the boundary between smectite and vermiculite.

NON-PLANAR HYDROUS PHYLLOSILICATES

Modulated layer silicates are defined (Guggenheim and Eggleton, 1988) as those minerals in which there is a periodic perturbation to the basic silicate structure. The simplest classification scheme for non-planar phyllosilicates (Table 2) can be derived by considering the nature of the periodicity and the relationship of the

perturbation to the basic 1:1 or 2:1 structure. Species are distinguished primarily by both different compositions and further structural variations within the subdivisions.

Rolled forms, such as coils and spheroids, are probably not periodic within the layers over the entire extent of the crystal because of a continuously varying and non-periodic radius. However, these structures clearly do have a periodicity at the unit cell level. In contrast, modulated layer silicates are ideally periodic within the layers. The distinction, therefore, separates Table 2 into two parts.

Within the classification of modulated layer silicates, further distinctions may be made by comparing the basic (substructure) layer configuration to the traditional planar 1:1 or 2:1 structures, by identifying the modulated component (tetrahedral vs. octahedral sheets), and by describing the linkage configuration (strips, islands, or other). The basic layer configuration is readily determined by noting the $c \sin \beta$ value, usually from a measurement of an X-ray diffractometer pattern made from an oriented mount. The linkage configuration type is most readily obtained by electron diffraction powder techniques (see Guggenheim and Eggleton, 1988). Simple identification of known structures listed in Table 2 can be achieved by X-ray random powder diffraction techniques.

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