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LATH-SHAPED UNITS IN FINE-GRAINED MICAS AND SMECTITES

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Abstract—Transmission electron images of fine-grained micas in bentonites exhibit lath-shaped units. These units seem to be associated along the (110) planes—referred to $2M_1$ mica cell—with perfect registry of their individual lattices. In doing so, they seem to provide lateral growth in the (001) plane. These lath-shaped units are arranged in the [001] direction in modes similar to the stacking of layers in mica polymorphs. Aggregations of lath-shaped units with polycrystalline montmorillonite particles are also observed in several bentonites. From the SAD pattern these laths are inferred to be dioctahedral layer silicates. However, they cannot be exactly identified any further. It is an open question whether these laths have grown from the montmorillonite or are simply entangled with it.

INTRODUCTION

Formation of lath-shaped units has been observed in fine-grained micas by Weaver (1953), Beutelspracher and van der Marel (1963), Rex (1966), Jasmund *et al.* (1969), Suito and Nakahira (1971) and Güven (1972) among others. Laths have also been found as a prominent habit for smectites. These units have been observed in the several bentonite samples mentioned below. In the following, the crystallographic nature of these lath-shaped units and their modes of association will be described. These observations seem to relate to a possible crystal growth mechanism in the mica-type layer silicates.

LATH-SHAPED UNITS IN FINE-GRAINED MICAS

The following clays contain micas which are detectable by a 10 Å reflection in the X-ray diffraction patterns. The sample numbers in this report refer to Grim's Bentonite Collection at Texas Tech University. Bentonite (No. 275A) from Akly Deposit, Rajastran, India; Wrens Fuller's Earth (No. 467–7) from Georgia, U.S.A.; Marblehead Illite from Fond du Lac County, Wisconsin, U.S.A.

The $<2\,\mu$m fractions of these clays were separated and a drop of suspension was added to a mixture of water and *t*-butylamine so that the final concentration of clay was a few ppm. Electron microscope grids were prepared by drying a drop of this suspension on a formvar film. The grids were subsequently shadowed with gold or a gold–palladium alloy at an angle of 26°, and examined using a JEM-7 electron microscope operated at 80 kV. The microscope was equipped with a completely variable field limiting aperture.

Fine-grained micas in Wrens Fuller's Earth show two sets of parallel laths (Fig. 1) which are oriented at an angle of 120° to each other. The superimposed SAD pattern shows sharp spots, indicating that the laths have strict crystallographic orientation with respect to each other. The intensity distribution of the pattern is very similar to that of $2M_1$ dioctahedral micas. The observed intensity relationship, $I_{02} \ll I_{11} \cong I_{1\bar{1}}$ forms a diagnostic criterion for $2M_1$ dioctahedral micas as

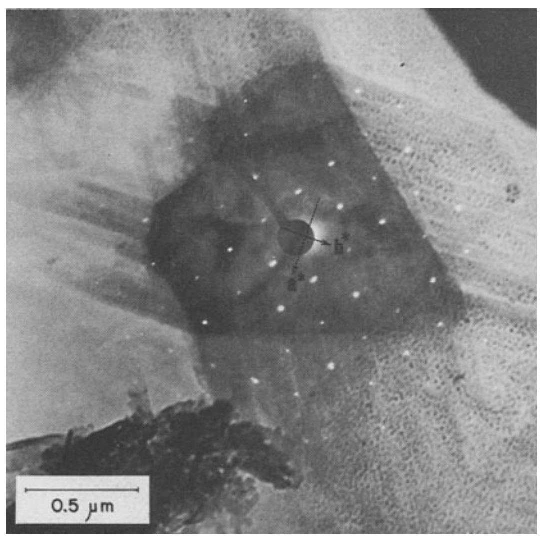

Fig. 1. A mica in Wrens Fuller's Earth (Georgia, U.S.A.) displaying two sets of parallel laths. The SAD pattern is superimposed.

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shown with experimental and theoretical data by Güven (1974).

The widths of these laths vary between 0·03 and 0·2 μm. The thickness and length of the laths have been measured on the separate single laths occurring in the sample. It is rather difficult to follow these dimensions when the laths are aggregated in the form of the aforementioned mica. The lengths of these laths are then not possible to follow in the mica since the laths are only visible at the edges. The thickness of the individual laths, as measured by Au–Pd shadowing, varies between 10 and 50 Å and their lengths between 1 and 3 μm.

The inner portion of the mica (Fig. 1) resembles an ordinary mica with no discontinuities. It displays the usual extinction contours arising from bending and thickness variations. The mica had developed two well-defined forms at an angle of 60°. However, these forms are not parallel to the laths. Crystallographic orientation of the laths can be easily determined from the superimposed selected area electron (SAD) pattern. When corrected properly for the relative rotation between image and diffraction pattern it was found that one set of laths makes an angle of 30° with the b^* direction of Fig. 1. The laths therefore lie parallel to the [$\bar{1}$10] direction as referred to the $2M_1$ mica cell (Fig. 2). This set of laths becomes parallel to the a-axis if referred to the $1M$ mica cell.

As seen in Fig. 2 the laths are bounded by (110) planes of the $2M_1$ cell passing through hydroxyl groups, oxygens, and vacant sites in dioctahedral micas. The (110) plane then forms the contact plane between the laths. Association between laths over the OH's and oxygens in Fig. 2 will provide exact registry between the individual lattices of the laths. The associated laths will then grow into a crystal with larger lateral dimension. The boundary between the laths in this case will not cause any phase change for the electrons passing through both sides. Therefore, no contrast will be created for these boundaries and they will be invisible. This is the case in the inner portion of the mica. However, some slip in the (110) plane will cause a phase difference for the transmitted electrons in both parts of the boundary and the resulting contrast may make the boundary visible. This may be the case for the laths in the periphery of the mica.

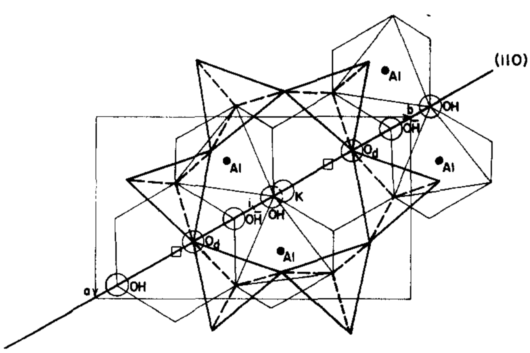

Fig. 2. The projection of a $2M_1$ mica structure (muscovite) on the (001) plane. The contact plane between two laths is (110) and it passes through the ions designated in the figure.

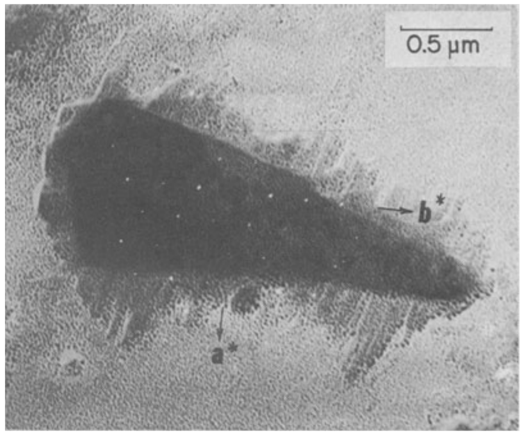

Fig. 3. A mica in Akly bentonite (India), displaying one prominent set of laths.

Whether these laths are to be considered as twin individuals or as ribbons of unit-cell thickness is another question. This may be resolved by the SAD pattern since we can only measure the thickness of the superimposed laths in the mica. For a twinned association the SAD pattern would be expected to have hexagonal symmetry only if both twin sets are of equal volume. In the second case, the laths of unit-cell thickness will form a truly $2M_1$ sequence and the SAD pattern will show the above intensity relationship between the (02), (11), and (1$\bar{1}$) spots, as was observed for the above mica.

The fine-grained micas in the India bentonite sample show a different arrangement of laths (Fig. 3). There is one prominent set of parallel laths oriented nearly parallel to the a^* direction of the superimposed SAD pattern (after appropriate correction for the relative rotation of the image). There is another less conspicuous set visible near the left edge of the flake, forming an angle of 120° with the first set. Again, the central portion of the figure gives the appearance of an ordinary mica and the laths are only visible at the edges. The SAD pattern was taken from the central portion of the flake containing only the prominent set of laths. The intensities of the (02), (11) and ($\bar{1}$1) reflections ($I_{02} \ll I_{11} < I_{\bar{1}1}$) are different from those of the $2M_1$ mica in the previous sample (Fig. 1). The observed SAD pattern (Fig. 3) is similar to that of one layered biotites.

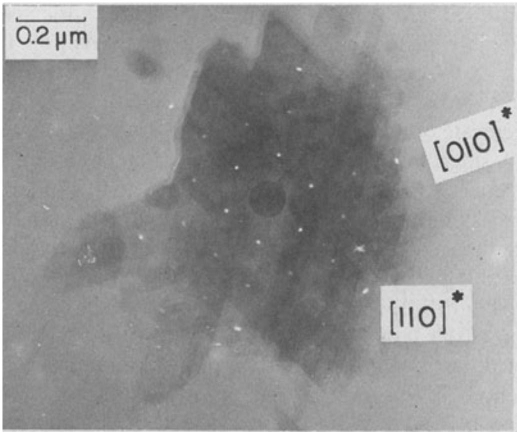

Fig. 4. A hexagonal arrangement of laths in micas from Marblehead illite. The reciprocal lattice directions [010]* and [110]* are tentatively assigned with respect to the $2M_1$ mica cell.

Micas with similar arrangements of laths were previously described from the Marblehead illite (Güven, 1972). Some of th se display a trigonal arrangement of three sets of laths, giving a hexagonal SAD pattern (Fig. 4). A similar image from another illite aggregate was previously interpreted (Güven, 1972) as the disintegration mechanism of micas leading to the formation of illites. This possibility can also be considered for the formation of lath-shaped units in Wrens Fuller's Earth and in India bentonite. There is, of course, a close and often reciprocal relationship between growth and disintegration mechanisms. At least one may shed light on the other.

In conclusion, transmission electron images of the above fine-grained micas in clay deposits display geometrical arrangements of laths, which indicate:

(a) Lath-shaped units can associate with each other in a way to form a perfect registry between their individual lattices. By doing so, they may laterally grow into layers. Thus, laths may be considered as 'building blocks' for one mode of crystal growth in these layer silicates.

(b) Parallel sets of these laths can form arrangements in three dimension similar to the stacking of layers in mica polymorphs. The mica in Wrens Fuller's Earth has two sets of laths arranged at 120° to each other similar to the stacking of layers in $2M_1$ micas. Fine-grained micas in the India bentonite display one set of parallel laths with no rotation between them, similar to the arrangement of layers in $1M$ micas. Finally, some of the Marblehead illite exhibits a trigonal arrangement of laths similar to that of single layers in a $3T$ mica.

The strict geometrical alignment of laths during their association may be referred to as a reticulated arrangement. The growth of the above micas may therefore be attributed to the 'reticulation' of the lath-shaped units.

LATH-SHAPED UNITS IN SMECTITES

Méring and Oberlin (1971) have provided a number of references in which laths are described as the prominent crystal habit for beidellite, nontronite, hectorite, and saponite. If the width of a lath becomes very small, it may be considered as a fiber. This is often the case in hectorite. Since detailed descriptions of these smectites have been given in the literature, we will only mention a few samples in which we have observed lath-shaped units which seem to form intergrowths with

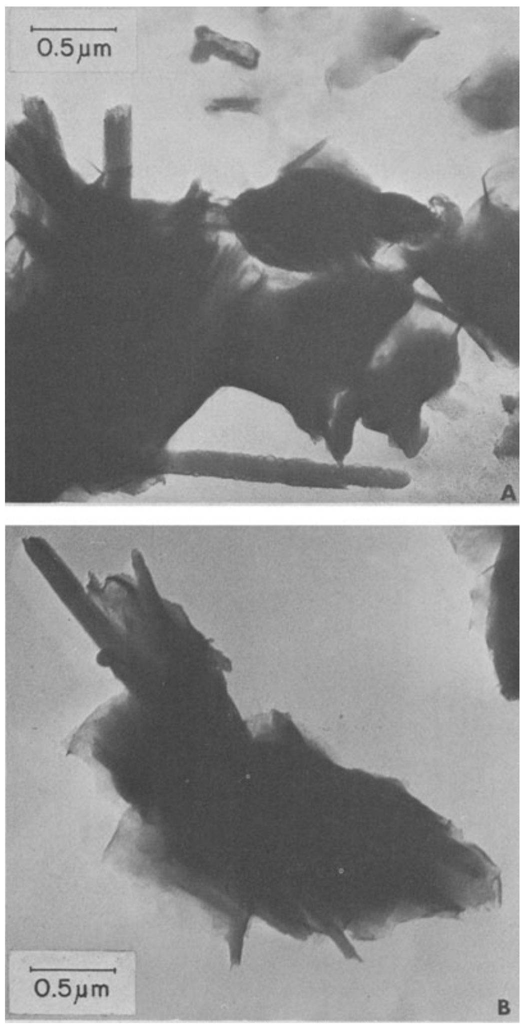

Fig. 5(a) and (b). Aggregations of lath-shaped units with montmorillonite in a bentonite from North Africa.

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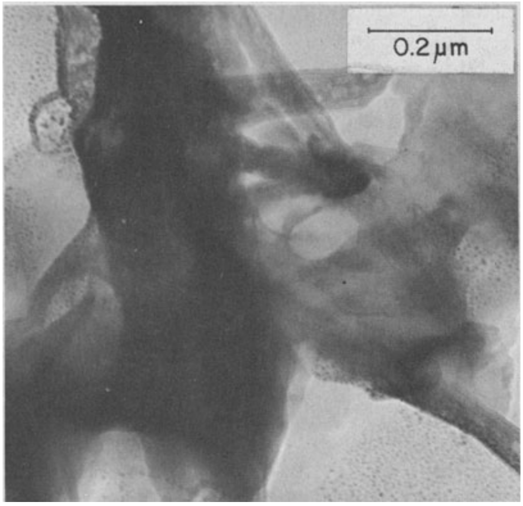

Fig. 6. Aggregation of lath-shaped units with montmorillonite at an original magnification of × 80,000 in a bentonite from North Africa.

montmorillonite aggregates. These samples are: Bentonite (No. 340–12) obtained from CECA, North Africa; Bentonite (No. 467–C) from Helms (Gonzales), Texas, U.S.A.; Bentonite (No. 164) from Cabana de la Sagra, Spain.

In the bentonite from North Africa typical lath-shaped units are seen in Figs. 5(a and b) 6 and 7. These units seem to be intergrown with smectite in Figs. 5(a and b) and 6. The latter micrograph had an original magnification of about × 80,000. The smectite had a basal spacing of 14·4 Å for an air dried oriented sample, which expanded to 16·7 Å upon glycolation. It is difficult to say from the above micrographs whether these laths have grown from the montmorillonite aggregate or are simply entangled with it.

A single lath in the same sample is shown in Fig. 7 together with its superimposed SAD pattern. The lath has a width varying between 0·12 and 0·14 μm. Its length is about 1·0 μm. From the SAD pattern it was possible only to determine the b-cell parameter: $b = 9{\cdot}04 \pm 0{\cdot}02$ Å. It is interesting to note that the elongation of this lath is approximately parallel to the indicated b-axis of Fig. 7 (after the proper rotational correction). In this regard, this lath is different from those described in fine-grained micas. The SAD data indicate that the lath is a dioctahedral layer silicate. However, we cannot be positive at this stage whether it is a mica or another layer silicate.

Similar laths are present in Helms bentonite from Gonzales, Texas. These laths may occur both as separate units or as aggregates with montmorillonite (Fig. 8). Again, it is difficult to say whether the laths have grown from the montmorillonite or are entangled (mechanically) with it. The first case may represent one mode of transformation between these two phases.

In the bentonite from Cabana de la Sagra, Spain, laths occur in intergrowths with montmorillonite (Fig. 9). The montmorillonite had a basal spacing of 13·9 Å for an air-dried oriented aggregate, which expanded up to 16·8 Å upon glycolation. Figure 10 shows, in the same sample, an aggregation of laths which seem to fuse with each other. These laths vary between 0·1 and 0·2 μm in width and 0·25 and 1·0 μm in length up to the

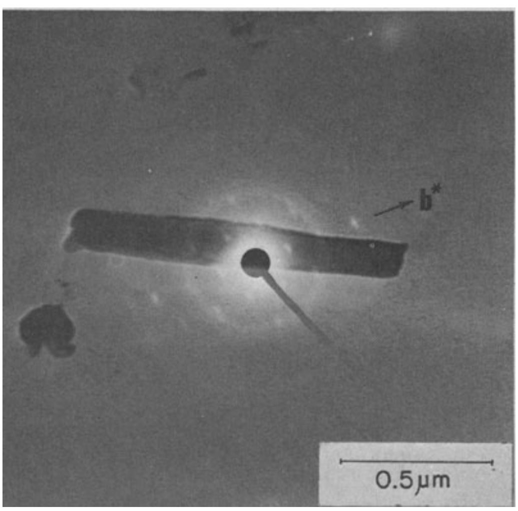

Fig. 7. A single lath with its superimposed SAD pattern in a bentonite from North Africa. The diffraction ring is from gold coating.

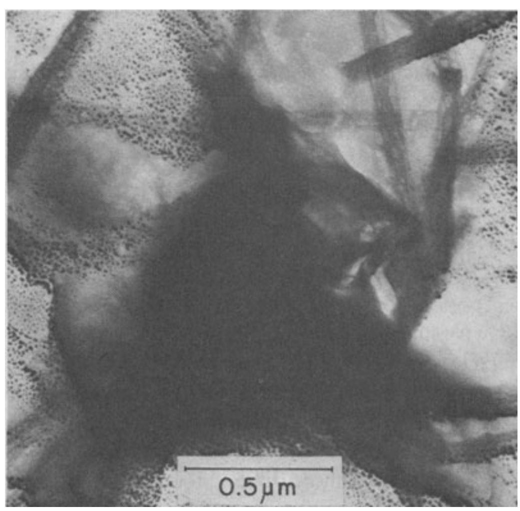

Fig. 8. Aggregation of lath-shaped units with montmorillonite in Helms bentonite (Gonzales), Texas.

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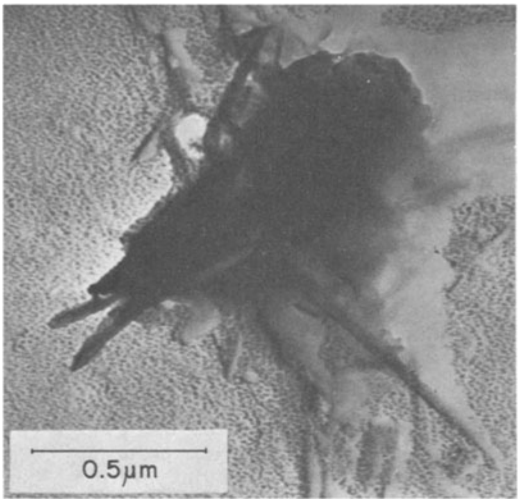

Fig. 9. Aggregation of lath-shaped units with montmorillonite in a bentonite from Cabana de la Sagra, Spain.

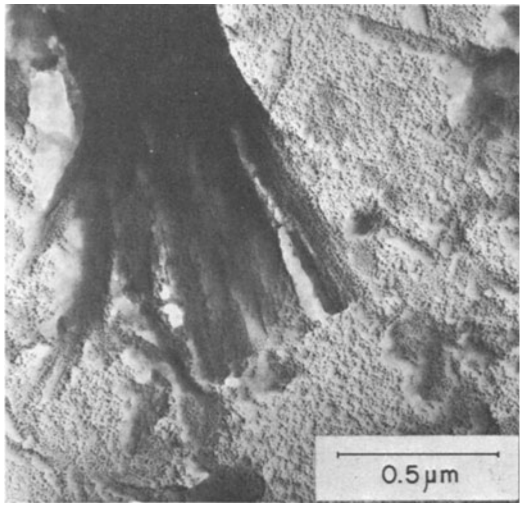

Fig. 10. Association of lath-shaped units in a bentonite from Cabana de la Sagra, Spain. Note that the laths themselves consist of a bundle of fibrous units.

point of fusion. The laths themselves seem to consist of a bundle of fibrous units.

In conclusion, lath-shaped dioctahedral layer silicates are present in several bentonites. It has not been possible to identify these laths exactly. Although some seem to be intergrown with montmorillonite, other laths occur as separate units. The possibility of a mechanical entanglement of laths with montmorillonite films cannot be disregarded.

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Résumé—Les images obtenues par microscopie électronique en transmission sur des petites particules de micas présentes dans les montmorillonites montrent des unités en forme de latte. Ces unités semblent associées le long des plans (110)—en prenant comme référence la maille $2M_1$ du mica—avec une concordance parfaite de leurs réseaux individuels. De la sorte, elles semblent montrer une croissance latérale dans le plan (001). Ces unités en forme de latte sont arrangées dans la direction [001] selon des modes similaires à l'empilement des feuillets dans les polytypes des micas. Des agrégations d'unités en forme de latte avec des particules polycristallines de montmorillonite sont également observées dans plusieurs bentonites. D'après les diagrammes de microdiffraction électronique on peut penser que ces lattes sont des phyllosilicates dioctaédriques. Cependant, on ne peut pas les identifier avec plus de précision. C'est encore un problème non résolu que de savoir si ces lattes se sont développées à partir de la montmorillonite ou sont simplement mélangées avec elle.

Kurzreferat—Transmissionselektronenmikroskopische Bilder feinkörniger Glimmer in Bentoniten weisen lattenförmige Einheiten auf. Diese Einheiten scheinen entlang den (110) Ebenen—bezogen auf die $2M_1$-Glimmerzelle—mit perfekter Regelmäßigkeit ihrer individuellen Gitter vergesellschaftet zu sein. Hierdurch scheinen sie laterales Wachstum in der (001)-Ebene zu ermöglichen. Diese lattenförmigen Einheiten sind in der [001]-Richtung in einer Weise angeordnet, die der Zuordnung von Schichten bei Glimmerpolymorphen ähnlich ist. Aggregierung von lattenförmigen Einheiten mit polykristallinen Montmorillonitteilchen ist ebenfalls in mehreren Bentoniten zu beobachten. Aus den Feinbereichsbeugungsmustern ist zu schließen, daß diese Latten dioktaedrische Schichtsilikate sind. Ihre weitere genaue Bestimmung ist jedoch nicht möglich. Es bleibt eine offene Frage, ob diese Latten aus dem Montmorillonit gewachsen oder einfach mit diesem vermischt sind.

Резюме — Трансмиссия электронных изображений тонко-зернистых слюд в бентонитах обнаруживает сеткообразные группы. Эти группы как будто ассоциируются вдоль плоскостей (110) — в отношении к ячейке слюды $2M_1 - c$ совершенным изображением своих индивидуальных сеток. При этом они как бы сообщают латеральный рост в плоскости (001). Эти сетчатые образования собираются в (001) направлении способом подобным укладке столбиками слоев в полиморфных образованиях слюды. Агрегаты этих сеточных образований с поликристаллическими частицами монтмориллонитов наблюдаются также в нескольких бентонитах. Система SAD относит эти сетчатые образования к диоктаэдрическим слоистым силикатам. Однако, дальше этого их нельзя точно идентифицировать. Вопрос, образовались ли эти сетки из монтмориллонита, или они просто захвачены им, остается открытым.