11. Occurrence of Authigenous Illitic Mica in the Sediments of the Central Tyrrhenian Sea

By

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A striking feature of the sediments of the Tyrrhenian Sea as revealed in the long cores (No. 205, 13, 15 and 16) of the bottom deposits collected by the Swedish Deep Sea Expeditions under the leadership of Professor H. PETTERSSON in 1946 and 1948 is the very rare occurrence of any traces of post-depositional, secondary alteration of the primary mineral components. This is most evident in the layers of volcanic tuff which has not previously been exposed to actions of subaerial weathering: the sanidines and the rather calcic plagioclases are usually still perfectly glass clear, so also are the pyroxenes and the sherds of volcanic glass, and even the fragments of extremely porous pumice with its exceedingly thin-walled glass cavities and, thus, enormous surface of reaction, do not usually exhibit any conspicuous traces of attack by the sea water even in the deepest parts of the cores. The absence of any considerable such secondary alteration of the volcanic glass is also evident by the low content of H_2O^+ in the pumice of these layers which, in 6 analyses, fluctuates between the extremes 2.92 and 5.58 % only.

There occur, however, frequently in the sediment-fractions obtained by mechanical analysis of the sediments, aggregate polarizing grains consisting of aggregates of coagulated birefringent clay particles which may be mistaken for decomposed volcanic glass or other decomposition products. This aggregation is hard to avoid because of the unusually high tendency to coagulation exhibited by these sediments. Here the standard methods of mechanical analysis fail; it has taken us long time of experimenting to arrive at an effective method of dispersion which does not also seriously affect the clay minerals chemically.

The biotite, which largely has been derived from the Recent and Sub-Recent volcanics, is also usually quite fresh, but not unfrequently a clearly post-depositional alteration of this mineral is to be observed. It consists in a more or less far advanced exfoliation of the biotite crystals resulting in a vermicular structure (Fig. 1 a and b). The biotite is then strongly paled but still strongly pleochroic with α light yellowish gray, γ greenish gray; $\gamma - \alpha$ = about 0.01.

Apart from these occasional alterations of the biotite the other microscopically distinguishable primary constituents of the sediments seem to have suffered very little post-depositional decomposition. It is therefore rather unexpected to find in slides of the sandy horizons of the core, obtained after metacrylate treatment of the soft sediment (HAGERMANN 1952), an unquestionably post-depositional mineral formation of illitic type in great abundance. The characteristic appearance of this substance is seen on the micrographs Fig. 2—7. In sections perpendicular to the bedding of the strata it forms colourless, strongly birefringent prismatic, vermicular crystals sometimes as much as $^1/_2$ mm broad by a height several times that measure, the long axis often orientated more or less perpendicular to the bedding plane. The prisms are composed of extremely thin lamellae perpendicular to the long axis and, thus, when rotated on the universal stage from the vertical position, the lamellae disappear and the mineral looks like a flake of colourless mica. The prisms are often bended, sometimes into horse shoe shape (Fig. 5) or in an irregular manner. The mineral has also a very distinct parting parallel to the long axis of the prisms, i.e. perpendicular to the lamellae (Fig. 3 and 7) and sometimes the mineral is split along this parting, the pieces gradually diverging (Fig. 2). The development of this parting seems to follow at a later stage after the formation of lamellae (Fig. 6). Thin lenses and veinlets of the matrix often extend between the lamellae, sometimes again these lenses divide the crystal into thinner packets of lamellae which diverge at the ends of the packets (Fig. 4 and 6), or isolated lamellae are scattered in the matrix without order.

A rather peculiar development of the mineral is exhibited by the specimen Fig. 4 from Hor. 357. This is an unusually large aggregate, in part fan-shaped, the isolated parts of which are apparently connected genetically as if the mineral had developed out of some gele-like substance soaking the sediment.

It is a curious fact that no trace of this lamellar structure has ever been seen even in very carefully extracted samples placed on the object glass with immersion liquid directly; as soon as a drop of liquid is placed on the sample, the structure collapses and disintegrates into isolated thin flakes, not to be distinguished from ordinary sericitic mica. This delicate structure is preserved only in such samples, the primary structure of which has been stabilized by means of the metacrylate method.

This circumstance makes the determination of the optical properties of the mineral by the immersion method rather hazardous because of the difficulty to distinguish in the disintegrated samples between the flakes which originate from the mineral in question and those which do not. The birefringence is, however, readily determined in the vertical sections of the plexiglass slides. It amounts to about 0.02. The extinction is parallel to the lamellae, elongation positive. The mineral is faintly but distinctly pleochroic with γ dark gray or bluish gray, α colourless. The mineral is not attacked by hydrochloric acid (1:1).

Samples extracted from the horizons 357 and 257, which are exceptionally rich in the illitic mineral, exhibit in the immersion liquid plenty of thin flakes of colourless mica, pale greenish mica of various shade, and, very sparingly, brownish green and tabac brown biotite. The refractive indices $\beta = \gamma$ of the colourless mica seems to extend between 1.57 and 1.60; the pale greenish mica between 1.60 and about 1.63, and the biotite between 1.63 and 1.65. The biotite is nearly uniaxial. The angle $2V_\alpha$ of the colourless mica was determined in one specimen to 30°, but whether this specimen really represents the illitic mica is, however, uncertain. It is also uncertain whether the colourless mica and the greenish mica are different minerals or if transitions between them exist. The optical properties of the mineral so far ascertained clearly indicate, however, affinity to the illite-muscovite series. The high birefringence excludes the possibility of the mineral being a kaolinite or a chlorite.

Also the X-ray study is hampered by the difficulty of isolating the mineral. For the investigation have been selected the horizons M 257 and M 357 in which the mineral in question constitutes about 20 % of the volume as determined in the plexiglass slides on the integration stage. The granulometrical composition of the perfectly dispersed sample M 257 is the following:

<2 μ	<4 μ	<8 μ	<16 μ	<31 μ	<62 μ	>62 μ
2.5 %	1.3 %	1.3 %	1.9 %	21.3 %	41.1 %	30.6 %

The mineral is, thus, evidently accumulated mainly in the fractions $> 16\mu$ with sizes convenient for microscopic study. Series of X-ray photograms have been taken of these and the smaller fractions. The diffraction data are compiled in Table I. The photograms are all very similar. There are within the low angle region three rather strong lines at about 14, 10 and 7 kX, resp. The 10 kX line represents mainly illite as confirmed by the full representation of the characteristic array of lines of this substance. The contribution of biotite to the intensity of the 10 kX line must be small because not even the strong $(20\bar{2})$ reflection of biotite appears in the photograms.

The 14 kX line evidently represents some mineral of chloritic type; the greenish mica mentioned above may perhaps be of such nature. Thus, the line 1) is not displaced after glycerole treatment; 2) it is not extinguished but

Table I.

	Spec. 257 205.13								Spec. 357 205.25						Ultra clay of ''normal'' sediment 336 IB	
	< 2 μ		4—8 μ		8—16 μ		16—31 μ		< 2 μ		4h 600°		4—8 μ			
	F 279	I	F 281	I	F 285	I	F 292	I	F 284	I	F 287	I	F 277	I	F 252	I
1 a	13.6	2	14.1	2			14.7	3	14.1	5	13.8	5	14.4	1	13.7	2
1 b					14.2	2			14.7						16.5	5
2	10.1	2	10.0	3	9.8	3	9.8	2	10.0	4	10.0	7	10.0	3	10.1	6
3	7.03	4	7.12	3	7.0	4	7.0	3	7.1	5			7.1	3	7.19	3
4					5.6	1							5.6	4		
5	4.48	7	4.46	4	4.45	4	4.44	1	4.46	8	4.48	9	4.46	3	4.47	10
6	4.23	3	4.25	6	4.24	5	4.21	5	4.22	3	4.23	4	4.21	4	4.21	3
7			3.98	1	4.01	1	4.01	2								
8	3.74	<1	3.70	1	3.71	1	3.71	2	3.73	<1	3.66	1	3.78	1		
9	3.52	1	3.47	1	3.48	1			3.52	1	3.51	2			3.53	2
10	3.34	10	3.33	10	3.33	10	3.32	10	3.34	10	3.34	10	3.33	10	3.33	3
11	3.19	1	3.19	1	3.18	2	3.19	5	3.21	2	3.22	2	3.20	3		
12	3.09	1	3.09	3	3.08	2	3.08	4	3.09	2	3.10	2			3.10	1
13	2.98	1	2.98	2	2.96	2	2.97	3	2.97	2					2.99	1
14							2.87	3					2.90	2		
15													2.81	2		
16	2.57	6	2.56	5	2.557	4	2.55	2	2.56	7	2.58	5	2.57	3	2.57	9
17	2.45	1	2.45	4	2.446	4	2.44	3	2.446	2					2.45	4
18	2.38	2	2.38	1	2.377	1			2.38	2	2.40	1			2.37	4
19	2.27	1	2.27	3	2.27	3	2.267	3	2.277	1			2.274	5		
20	2.23	1	2.23	1	2.23	1	2.222	1			2.25	1				
21							2.18	1								
22	2.12	1	2.12	5	2.12	4	2.114	3	2.12	2	2.12	1	2.12	2		
23	1.974	1	1.97	4	1.97	2	1.968	2	1.97	1	1.98	1	1.97	1	1.99	1
24	1.815	3	1.81	7	1.812	5	1.819	5	1.813	3	1.815	3	1.812	2		
25			1.684	1			1.680	1	1.695	1					1.707	2
26	1.662	1	1.663	3	1.662	2	1.663	2	1.665	1					1.63	2
27	1.538	2	1.537	6	1.538	4	1.535	4	1.537	3	1.54	2	1.538	2		
28	1.486	3					1.496	1								
29	1.452	1	1.449	1	1.448	1	1.449	1							1.50	8
30							1.426	1								
31	1.371	2	1.371	6			1.369	4	1.372	2	1.373	2				
															1.295	4
															1.246	1

1 b : spacing of glycerole-treated sample.

rather enhanced after heating 4 hours at 600° C, and 3) it disappears after treatment of the sample with hot 23 % HCl, all features characteristic of the chlorite minerals. But the mineral differs from normal chlorites by the absence or very faint development of higher (0 0 l) orders.

The 7 kX line is due in part to some non-chloritic mineral; it is effaced completely after the heating of the sample but, contrary to the chlorite reflection, it is resistant to even prolonged treatment with boiling 23 % HCl, a feature in common with kaolinite. The strong (002) kaolinite reflection at 3.57 kX is, however, absent (cf. RIVIÈRE, B. Soc. Géol. Fr. 16 (463), 1946). As a matter of fact, the 7 kX line is a prominent feature also of other horizons of the sedimentary sequence in which chlorite is not röntgenographically demonstrable.

It, thus, seems that besides illite two other clay minerals enter as essential constituents in the sediment, viz. one with certain features in common with chlorite, the other with certain features in common with kaolinite without being identic with any of these minerals. Judging by the optical properties of the vermicular mineral, this seems to consist mainly of illite. The peculiar features of the photograms may be due to the presence of complex mixed layer minerals of the group. A large material of data bearing on this problem has been gathered but is not yet ripe for publication.

Concerning the mode of formation of the illitic mica it is quite evident from its appearance that it is a secondary mineral formation, developed *in situ* in the sediment. It is unconceivable that a mineral with such a delicate structure as e.g. that of Fig. 5, could have been transported any considerable distance in water and deposited without disintegrating. The size of the mineral individual is often many times larger than the largest grains of the primary detritus. The eventuality that the mineral might have developed by some kind of alteration of biotite of similar kind as the exfoliation occasionally noticed on this mineral above, is excluded by the fact that e.g. in Horizon 257, the content of illitic mica amounts to not less than 20 % as measured on the integration stage, whereas biotite as a rule enters rather sparingly in the sedimentary sequence, usually with only a fraction of a percent.

There is no relationship between the chemical character of the mineral and rock constituents of the detritus and the appearance of the illitic mica: it is just as common in layers composed of terrigenous detritus as in those consisting only of volcanic glass, neither is the mineral confined to the deeper, older strata of the core, but is found abundantly even in the uppermost sandy bed at a depth of only 1.65 m below the present sea bottom. Its development does, thus, not require any considerable length of time. But, on the other hand, the mineral appears only rarely in the horizons of pure mud or clay, and then as very minute grains only.

The substance from which the illitic mica develops is universally present in the sandy layers throughout the sequence and a very similar substance constitutes by far the main part of the clay and sub-clay fractions of the sediment (cf. Table IV Col. 8).

Mineral formations of a similar kind have been described in fossil sediments long ago by P. TERMIER (1899). M. STORZ (1928 I, pp. 73) has followed various stages of its development in the Pomona Quartzite in South-West Africa. Recently A. SCHÜLLER (1950) has carefully investigated and described as leverrierite a similar vermicular mineral formation in the Lower Carboniferous coal bearing series of Dobrilugk. The optical properties as well as the X-ray data of this substance agree perfectly with the illite of the Tyrrhenian sediments.

Apparently autigenous mineral formations of similar vermicular habit but consisting of kaolinite have been described by C. S. ROSS and P. F. KERR (1931) in various sediments and rocks, by A. ORLOV (1942) in the Palaeozoic coal bearing series in Bohemia, and by M. REINHARD, J. V. STEIGER and E. BRANDENBERGER (1944) in material of unknown origin. It is, thus, evident that the peculiar structural development of the "leverrierite" is not confined to any special mineral of the clay mineral group but that a similar habit can be exhibited by clay minerals of very different composition. It seems therefore most appropriate to retain the conception leverrierite as a morphological term only as suggested by K. JASMUND (1951).

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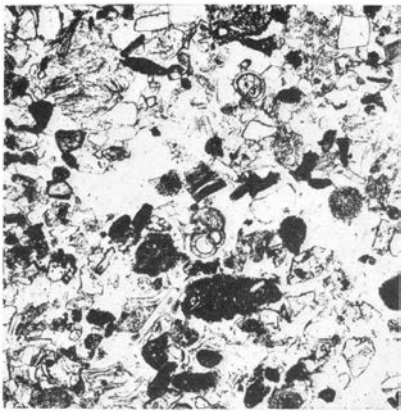
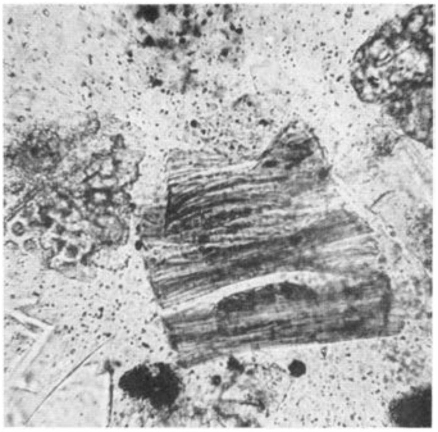


E. Köster photo.

Fig. 1 a. Tuffite. Near center a flake of paled and exfoliated biotite. 205.26: 3. 26 × 1 nic.



A. Strömberg photo.

Fig. 1 b. Detail of Fig. 1 a. 200 × 1 nic.

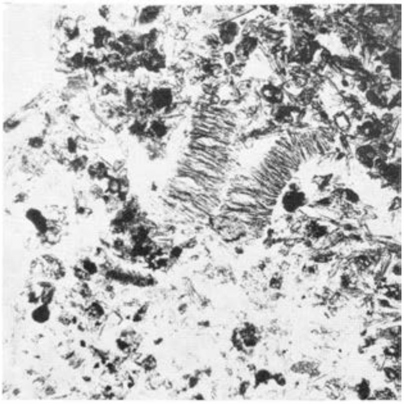
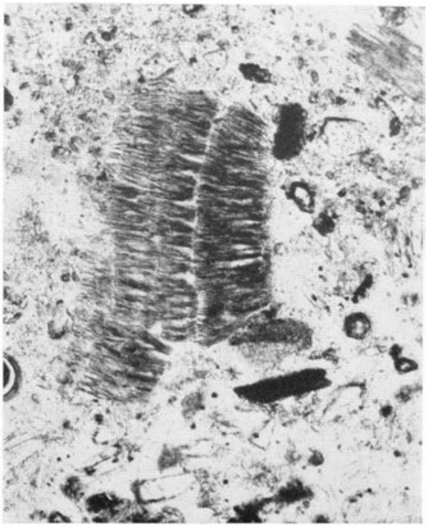


Fig. 2. Crystal of illitic mica split along prismatic parting. 205.27: 2. 28 ×.



E. Köster photo.

Fig. 3. Crystal of illitic mica with parting perpendicular to the basal cleavage. 205.10: 3. 125 ×.

Fig. 4. Part of concretionary aggregate of illitic mica. 205.25: 1. 110×.

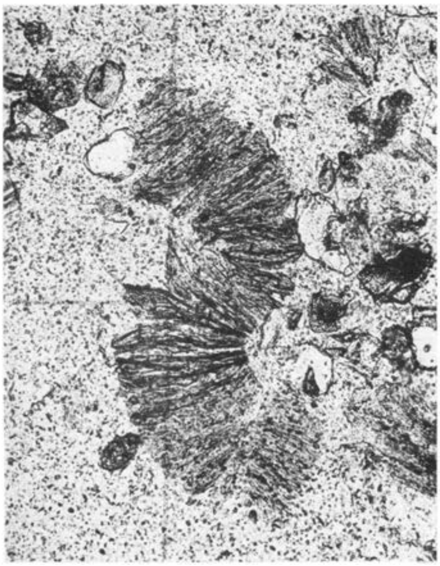


Fig. 5. Vermicular crystal of illitic mica. 205.13: 3. 110×.

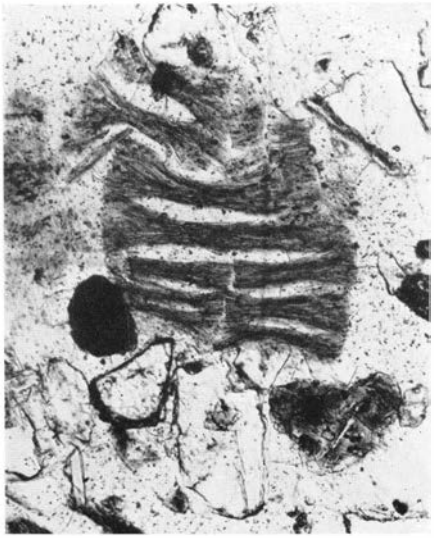


Fig. 6. Crystal of illitic mica with intercalations of the groundmass.
205.26: 3. 110×.

E. Köster photo.

Fig. 7. Crystal of illitic mica with basal cleavage and transverse parting.
205.10: 3. 110× 2 nic.