CLAY MINERALS OF THE ARGILLE SCAGLIOSE OF THE MODENESI APENNINES

By PAOLO GALLITELLI

Mineralogical Institute, University of Modena, Italy.

[Read 5th November, 1954]

ABSTRACT

Samples of the argille scagliose from various localities in the Modenese Apennines have been studied by optical, X-ray and d.t.a. methods as part of an investigation into the composition and origin of this remarkable allochthonous formation. Illite, chlorite and a kaolinitic mineral of "fireclay" type are widespread. Samples from one locality contain also a conspicuous 22-28 Å swelling chlorite, the origin of which is discussed. It is as yet uncertain whether this mineral is confined to clays containing exotic blocks of ophiolite (greenstone) or whether it is more widely distributed.

INTRODUCTION

A programme of work on the allochthonous clays of the Apennines, financed by the National Research Council of Italy, has been undertaken in order to investigate the composition and characteristics of these sediments; and if possible to determine their age and the conditions under which they were originally deposited. This work, started in 1942, has involved two separate lines of research. The palaeontological side has been largely developed by E. M. Gallitelli, the mineralogical-petrological aspects by the author and his co-workers (see Gallitelli and Gallitelli 1949).

The allochthonous formation known as the argille scagliose consists of a shaly matrix in which are enveloped exotic blocks of basic igneous material ("ophiolites"), limestones, sandstone and other rocks. The whole sequence is regarded by Merla (1951) as material which has slid eastwards in gigantic "orogenic landslips" during the elevation of the Apennines. Neither its original position in the geosyncline nor its age are known with certainty.

The investigations described in this paper were made on samples of the argille scagliose from Varana, Sassomorello and Castelvecchio in the Modenese Apennines. They were collected close to enveloped blocks of ophiolite (gabbro, diabase or serpentine) and consist of red and grey clays both of which contain arenaceous foraminifera of Upper Cretaceous age (E. M. Gallitelli 1943 (a) and (b), 1947). These clays have been separated by suspension in water into fractions with a particle size of 30-12μ, 12-5μ, 5-1μ and 1-0.1μ for optical, X-ray and d.t.a. examination.

RESULTS

The grey clays collected from Varana and Castelvecchio appear to be almost alike, being formed of 14 Å, 10 Å and 7 Å minerals. The 14 Å mineral is less abundant in the 5-1μ than in the 1-0.1μ fractions. On X-ray photos obtained from oriented aggregates, the characteristic pattern of a chloritic mineral is seen. After glycerol saturation the
X-ray pattern is not changed and no diffraction pattern typical of montmorillonite appears (see MacEwan 1946). After heating to 540°C, the 001 line is displaced from 14·2Å to 13·8Å, the intensity increasing considerably, in the manner characteristic of chlorite.

X-ray diagrams from powders and oriented aggregates show the following characteristics for the 10Å mineral.

(a) 002, \( d = 9·9 \pm 10\) Å, is sharp at its outer margin and diffuse towards the lower values of \( d \), developed in the 11-11.5Å region. (b) 004, \( d = 5·00 Å \), is always present, though weak. (c) 116, \( d \) is absent, while 025 and 115 seldom appear or are very weak. (d) on heating to

![X-ray patterns of clay from Sassomorello. A and C—fraction 5—1μ, B—fraction 5—1μ, after glycerol treatment.](image)

540°C, 002 and 004 spacings increase in intensity and become sharper. These characteristics lead to the conclusion that the 10Å mineral is a hydrated illite, according to the meaning given to this term by Grim (1953).

The 7Å mineral is quite abundant. The 001 line, with \( d = 7·14 Å \), often intense, is broadened to 7·0Å in fractions containing much chlorite owing to overlapping of the kaolinite 001 and chlorite 002. In clay fractions low or lacking in chlorite, kaolinite 001 broadens to 7·28Å. This increase of \( d \) value indicates both an excess of water in the kaolinite lattice and a random interstratification of mineral layers. On heating to 440°C, 001 intensity is not modified but dis-
appears almost completely at 540°C. A more accurate examination of the pattern between \(d = 4.46\) Å and \(d = 3.75\) Å for the fraction richest in kaolinite shows the marked extension of 002 and 020 that characterises the disordered form of kaolinite frequently found in fireclay. It is worthy of note that the clay contains no antigorite though it has been collected from the neighbourhood of a serpentine mass.

A reflection at 7.7 Å is given by oriented aggregates of the 1-0.1 μ fraction. This may indicate the existence of a mixed-layer structure of illite and fireclay mineral. The evidence is at present inconclusive and further investigations are being carried out.

![Fig. 2—Differential thermal analysis curves of clay of varying grain size from Sassomorello.](image)

D.t.a. curves obtained from the 5-1 μ and 1-0.1 μ fractions are similar. Endothermic peaks at about 130°C and 610-615°C are due to overlapping of the corresponding endothermic effects of the fireclay mineral and illite. The endothermic peak of illite at about 900-920°C is followed by a weak exothermic peak at about 950-980°C, a characteristic of illite and the fireclay mineral. Its rounded character, despite the large amount of the fireclay mineral present, may be an indication of the poor crystallinity of this mineral. A weak endothermic reaction at about 740°C may be attributed to chlorite since the X-ray photographs show montmorillonite to be absent.

Red clays collected at Varana and Castlevecchio show the same mineralogical composition as the grey clays just described. The presence of some haematite and iron hydroxide is indicated by the
X-ray patterns and by the presence in d.t.a. curves of an endothermic peak at about 380-420°C.

X-ray examination of both red and grey clays from Sassomorello (fractions between 5µ and 0.1µ) reveals a strong broad line between 22Å and 28Å (Fig. 1). In oriented aggregates, this band is accompanied by a series of 00l reflections at 14.15, 7.08, 4.72, 3.55, 2.83 and 2.37Å characteristic of chloritic minerals. In order to identify the chloritic mineral, patterns from oriented aggregates treated with glycerol or heated to 540°C were studied. The results, shown in Table 1, give rise to the following conclusions.

(a) On X-ray diagrams of an oriented aggregate saturated with glycerol no 17Å or 8Å spacings appear showing that no montmorillonoid mineral is present in appreciable quantity. (b) After saturation with glycerol the broad band between 22Å and 28Å is displaced to 26-30Å. (c) After heating to 540°C the 14.2Å line is displaced to 13.8Å with increase in intensity and a very weak 11.6Å line appears beside the 9.9Å line.

TABLE 1—Basal reflection from oriented aggregates of Sassomorello clay (1-0.1µ) [I=intensity, s=strong, m=moderate]

<table>
<thead>
<tr>
<th></th>
<th>Untreated</th>
<th>Glycerol saturated</th>
<th>Heated to 540°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>d (Å)</td>
<td>I</td>
<td>d (Å)</td>
<td>I</td>
</tr>
<tr>
<td></td>
<td>I</td>
<td>I</td>
<td></td>
</tr>
<tr>
<td>22-28</td>
<td>s</td>
<td>26-30</td>
<td>s</td>
</tr>
<tr>
<td>14.2</td>
<td>m</td>
<td>14.01</td>
<td>m</td>
</tr>
<tr>
<td>9.90</td>
<td>m</td>
<td>9.95</td>
<td>m</td>
</tr>
<tr>
<td>7.15</td>
<td>s</td>
<td>7.11</td>
<td>s</td>
</tr>
<tr>
<td></td>
<td></td>
<td>13.80</td>
<td>m-s</td>
</tr>
<tr>
<td></td>
<td></td>
<td>11.60</td>
<td>w</td>
</tr>
<tr>
<td></td>
<td></td>
<td>9.90</td>
<td>m</td>
</tr>
<tr>
<td></td>
<td></td>
<td>7.02</td>
<td>vw</td>
</tr>
</tbody>
</table>

Additional experiments were carried out by treating fractions with ammonium nitrate and boiling. The powder and oriented aggregate diagrams showed that the 14.2Å line is slightly affected, the 9.9Å completely unaffected. This demonstrates that the 14Å mineral does not react to ammonium nitrate in the manner of a vermiculite (Brown 1953). The above considerations suggest that the chlorite has a mixed-layer structure but is not interleaved with a montmorillonoid a deduction confirmed by the fact that after heating to 540°C, no 24Å line appears. The properties of the mineral resemble those of a chlorite with alternating swelling and non-swelling layers recorded from the Keuper Marl (Stephen and MacEwan, 1951; Honeyborne; 1951). A swelling chlorite from the neighbourhood of Göttlingen has been described by Lippmann (1954) under the name of Corrensite.

Illite from the Sassomorello grey clay is similar to that from Varana clay. The presence of a band between 10Å and 11Å suggests that it is strongly hydrated. The kaolinitic mineral of fireclay type is rather abundant and shows a weak 7.7Å line. D.t.a. curves of the Sassomorello clay have been made after removal of calcium carbonate with N/10 HCl. Endothermic peaks at about 135-160°C and 600-620°C
are most pronounced in the finest fraction (Fig. 2). The weak peak at about 780-810°C may be attributed to chlorite. The sharpness of the endothermic peak at about 900°C shows that illite is more abundant in Sassomorello clay than in Varana clay. The exothermic peak between 360°C and 400°C is interpreted as due to the organic material. A rounded exothermic maximum at 940-980°C is characteristic of all samples.

The salient feature of the Sassomorello clay is thus the presence of a 22-28 Å chlorite. The conditions under which this mineral are formed are at present unknown. The ophiolites in the argille scagliose contain minerals which on weathering could give rise to chlorite. Caillère and Hénin (1949) have synthesised chlorite (similar in some respects to swelling chlorite) from montmorillonite. The author suggests that minerals with a mixed layer structure are often an intermediate product of a series of transformations, and that their presence in the Apennine clays is perhaps indicative of the fact that these deposits are still in a stage of “evolution” as regards their mineral composition. It is hoped that the present investigation will ultimately show whether the 22-28 Å chlorite is widespread in the clay formations of the Apennines or whether it is restricted to those in which ophiolites occur.

REFERENCES

Gallitelli, E. M. 1943 (b) Ibid.
Gallitelli, E. M. 1947 Ibid.

DISCUSSION

Dr R. C. Mackenzie pointed out that it seemed rather strange to have an illite fire-clay mineral interstratification and such had not yet been reported to occur, especially, that is, 2:1 or 1:1 layering. He also found it rather strange that there was no antigorite in the clays near serpentine. He quoted the experience encountered by soils investigators where antigorite decreased with depth and under poor drainage conditions only illite occurred. While enrichment due to movement of illite had to be considered, it would seem that under wet conditions antigorite was unstable.

Professor J. H. Taylor enlarged on the geological nature of the particular formation investigated which was of unknown age being an allochthonous deposit. Large blocks of serpentine and ophiolites
occurred in the clays, they seemingly had slid from the top of an apennine anticline and the mixed nature of the deposit was further emphasised by the mixture of Cretaceous and Eocene Foraminiferal faunas.

Professor P. Gallitelli (written communication) in reply, stated that the appearance of a 7·7Å line in the X-ray photographs certainly was suggestive at first of an antigorite, but this view could not be held, for after heating to 500°C this line disappeared, whereas Brindley (1951) has shown that the 7·3Å of antigorite remained unaltered after heating to this temperature. X-ray photographs of serpentine from the ophiolites showed a strong 7·25-7·3Å line which remained after heating to 500°C. At other areas than those reported in this paper, admixture of antigorite from the ophiolites with kaolinite had been found, but usually in small amounts and behaving as typical antigorite as regards heating and X-ray patterns. The remark made by Professor Taylor explained why perhaps no trace of antigorite could be found near blocks of serpentine, but the broken topographical relief with its attendant variation in drainage conditions could perhaps also be a contributing factor. It was hoped that the investigations at present in progress would shed more light on the presence and stability of antigorite.

**Reference**