Gorceixite-Goyazite in Kaolinite Rocks of the Sydney Basin

F. C. LOUGHNAN and C. R. WARD

Abstract—Occurrences of the phosphate mineral, gorceixite-goyazite (Ba,Sr)Al₃(PO₄)₃(OH)₉, in a claystone from the Illawarra Coal Measures and in two dyke clays from the southern part of the Sydney Basin are described. The phosphate mineral is associated with abundant well-ordered kaolinite and minor amounts of anatase. The concentration of the phosphate mineral in parts of the claystone could be attributed to its high specific gravity compared with that of the associated kaolinite. However, no explanation can be given for the origin of the mineral in the dyke clays.

Introduction

Renewed interest in the nature of soil phosphate minerals in recent years has shown that members of the plumbogummite group with the general formula RAl₃(PO₄)₃(OH)₉ (Palache et al., 1951) including gorceixite (R=Ba), goyazite (R=Sr), crandallite (R=Ca) and florencite (R=Ce) have widespread distribution. Thus, Coetzee and Edwards (1959), Wolfenden (1965), Trueman (1965) and Schellmann (1966) have recorded the presence of these minerals in tropical soils, while Norrish (1957, 1968), who examined a range of soil types, concluded that they are common in the "less-weathered" terra rossas and rendzinas as well as the highly-leached laterites and krasnozens, and that in all these occurrences the associated clay mineral is kaolinite. Since both kaolinite and the phosphate minerals are resistant to chemical breakdown, it would be expected that their association would persist in detrital sediments derived from these soils. However, there has been only a limited number of references to the presence of plumbogummite minerals in kaolinite-rich rocks. In the occurrences of these minerals cited by Palache et al. (1951) no mention is made of their association with kaolinite, while according to Milton et al. (1959) the gorceixite nodules in the Bashi Marl, Alabama, are accompanied by glauconite. Nevertheless, Stadler and Werner (1962), Burger (1964) and Wilson et al. (1966) have described crandallite in kaolinite tonsteins of Carboniferous age from Germany and England, and Loughman (1970) has recognized gorceixite-goyazite in the kaolinite-rich Garie member of the Narrabeen Group in the southern part of the Sydney Basin and in a kaolinite claystone (flint clay) of the basal Pennsylvanian at Olive Hill, Kentucky. The kaolinite in each of these deposits is particularly well-ordered.

Recently, gorceixite-goyazite has been found in relative abundance, associated with well-ordered kaolinite, in three separate deposits within the Sydney Basin. One of these is a kaolinite claystone of Permian age that crops out at Fitzroy Falls, and the remaining two are completely kaolizined igneous dykes that intersect Permian and Triassic strata at Fitzroy Falls and at Bullio, approximately 30 miles north-west of Fitzroy Falls.

Occurrence

At Fitzroy Falls toward the southern end of the Sydney Basin, an indurated claystone, approximately 4 ft. thick, forms the uppermost unit of the Permian Illawarra Coal Measures. The Narrabeen Group has been overlapped in this area, and the claystone is separated from the overlying Hawkesbury Sandstone by an eroded surface. Angular blocks of the claystone up to a foot across occur sporadically in the lower few feet of the sandstone. Below the claystone the succession is obscured by talus but, according to Shiels (private communication), coal occurs within 20 ft. of the base of the Hawkesbury sandstone in this area.

In structure, texture and mineralogy the claystone is similar to many of the kaolin coal tonsteins described by Burger et al. (1962) from the Westphalian Coal Measures of the Ruhr Basin and also to many of the flint clays of the Pennsylvanian of North America, particularly those occurring in the Olive Hill area, Kentucky (Patterson and Hosterman, 1958). The claystone is remarkably indurated, lacks bedding, and breaks with a pronounced conchoidal fracture. The texture of the rock varies from dense to brecciated and oolitic with the angular fragments and oolites ranging up to 1 mm. across. However, vermicular kaolinite crystals, a common feature of the European tonsteins and of similar kaolinite claystones observed elsewhere in the Sydney Basin.
Well-ordered kaolinite is the dominant constituent of all textural types of the Fitzroy Falls claystone and in some samples it comprises more than 90% of the mineral content. On the other hand, quartz rarely exceeds 10% and frequently is absent, while clay minerals other than kaolinite have not been detected. Siderite in the form of oolites or pseudoolites is abundant in some thin sections, and all samples examined by X-ray diffraction showed a reflection at 3.51 Å attributable to anatase (Figure 1). Gorceixite-goyazite comprises as much as 15% of the claystone. The presence of the mineral was detected by X-ray diffraction and chemical analysis but, because of either a very fine particle size or the masking effect of the associated kaolinite, it was not recognizable in thin sections under the petrological microscope.

The dyke clay at Fitzroy Falls, where sampled, has a width of 18 in. and that at Bullio 2 ft. Although the parent material is not evident in either deposit, residual igneous textures can be observed in thin sections of these clays. Basalt and dolerite dykes are prevalent in the Sydney Basin, and where permeable sandstones form the host rocks they are generally completely altered down to the level of the water-table. Control of the depth of the clay by the level of the water-table suggests that the alteration of the igneous rocks is the result of low-temperature leaching.
This map was inadvertently omitted from the article by Hamilton, Hall and Roberts in Volume 187 (394) and should be inserted between pages 78 and 79 of that issue.
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and not hydrothermal activity. As Loughnan and Golding (1957) have shown, kaolinite is the dominant alteration product in these dyke clays, but illite and/or mixed layer clay minerals may also be present. In the dyke clays at Fitzroy Falls and at Bullio well-ordered kaolinite was the only clay mineral detected, and gorceixite-goyazite is present to the extent of 10% and 15% respectively.

Composition of the Phosphate Minerals

For the specific identification of the phosphate mineral in the Fitzroy Falls claystone and the Bullio dyke clay, concentrates were obtained using the technique described by Norrish (1957, 1968). The rocks were treated with a 20% solution of hydrofluoric acid for two minutes and, after dilution and washing, the residue was neutralized with a normal solution of caustic soda. Examination of the residue by X-ray diffraction showed that the kaolinite had been completely destroyed and that gorceixite-goyazite and anatase (Figure 1) were the only minerals present. An elemental analysis of the residue was made by X-ray fluorescence through the courtesy of the Australian Atomic Energy Commission and the results converted to the oxide forms are given in Table 1. On the basis of these results, the phosphate mineral in the Fitzroy Falls claystone consists of approximately 60% gorceixite, 25% goyazite, 10% crandallite and 5% florencite, whereas that in the Bullio dyke clay is composed of 45% gorceixite, 40% goyazite, 10% crandallite and 5% florencite. Other metals detected in the residues of the clay rocks in amounts less than 1% are magnesium, lead, copper, zinc and, to a lesser extent, tin, chromium, manganese and boron. The residues also contained some free silica released from the kaolinite but not dissolved by the caustic soda.

Table 1

<table>
<thead>
<tr>
<th></th>
<th>Fitzroy Falls Claystone</th>
<th>Bullio Dyke Clay</th>
</tr>
</thead>
<tbody>
<tr>
<td>SrO</td>
<td>2·09</td>
<td>5·20</td>
</tr>
<tr>
<td>CaO</td>
<td>0·58</td>
<td>0·62</td>
</tr>
<tr>
<td>BaO</td>
<td>7·37</td>
<td>8·37</td>
</tr>
<tr>
<td>CeO</td>
<td>0·50</td>
<td>1·06</td>
</tr>
<tr>
<td>TiO₂(a)</td>
<td>8·47</td>
<td>23·27</td>
</tr>
<tr>
<td>Al₂O₃</td>
<td>11·22</td>
<td>30·03</td>
</tr>
<tr>
<td>P₂O₅(b)</td>
<td>8·32</td>
<td>13·74</td>
</tr>
<tr>
<td>Fe₂O₃</td>
<td>19·81</td>
<td>0·21</td>
</tr>
</tbody>
</table>

Remainder undissolved silica.

(a) Present mostly as anatase.
(b) Present as free iron oxides.

Discussion

The origin of the gorceixite-goyazite in these clay rocks is not fully understood. From the study of their distribution in soils Norrish (1968) concluded that they do not represent residuals of the parent rock that have resisted chemical breakdown but rather, that they have formed during weathering. This would imply that the igneous rocks which formed the parent materials for the dyke clays at Bullio and at Fitzroy Falls contained appreciable quantities of phosphorus, barium and strontium, in addition to aluminium, and that these elements were concentrated through the loss of more mobile constituents such as the alkalis, magnesium and much of the calcium, iron and silicon. However, in published chemical analyses of igneous dyke rocks from the Sydney Basin (e.g. White and Mingaye, 1904) there is no suggestion of the presence of unusually high concentrations of phosphorus, barium or strontium. Moreover, since strontium and to a lesser degree barium behave in a manner similar to calcium and magnesium during weathering, it is difficult to understand the preferential retention of these ions in the resulting clay. Possibly the early release of aluminium and phosphorus during weathering initiated development of the gorceixite-goyazite structure and strontium and barium became entrapped or "fixed" within this structure.

The origin of the phosphate mineral in the Fitzroy Falls claystone does not present the difficulties encountered with the dyke clays. In the Sydney Basin there is much evidence to support a detrital origin for these claystones. The common occurrence of conglomeratic and brecciated textures, perfectly preserved fossil leaves and sharply defined lower boundaries in these claystones negates the possibility that they developed in situ through the intense leaching of a pre-existing rock. Presumably, they represent accumulations of detritus that were derived from highly-leached, kaolinite-rich soils which also contained gorceixite-goyazite. Local concentrations of the phosphate mineral in the sediment probably resulted from its greater specific gravity (3·1-3·3) compared with that of the accompanying kaolinite (2·6).

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References


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