A STUDY OF MISSOURI GLAUCONITE*

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INTRODUCTION

The conclusions of E. W. Galliher[1] that glauconite is forming from biotite in Monterey Bay, and of John W. Gruner[2] that the molecular structure of Bonneterre glauconite is similar to that of biotite from Mora, Minnesota, led me to test the possibility that Missouri glauconite has formed from biotite. Several years ago I observed[3] that anauxite from the Ione formation of California which had formed from biotite contained rutile needles similar to those in biotite, and studies of clay[4] carried on by the Missouri Geological Survey afford evidence that titanium is concentrated along with aluminum during the change of flint clay to diaspore clay. The titanium content of glauconite, especially that present as rutile, seemed a logical starting point in this study. A survey of the published analyses of glauconite showed that little attention had been given to the titanium of glauconite, for only three or four record even a trace.

GLAUCONITE OF THE BONNETERRE DOLOMITE

Certain layers of the Bonneterre dolomite of Cambrian age contain forty to fifty per cent glauconite. The glauconite of this formation was studied by C. S. Ross[5] and all the constituents except titanium, listed as No. 4 in the accompanying table, were determined by G. V. Brown. Glauconite was separated from an outcrop of the Bonneterre dolomite along U. S. Highway 61 about twelve miles south of Farmington, Missouri, and the titanium determined by R. T. Rolufs, chemist of the Missouri Geological Survey. It contained 0.1 per cent titanium oxide and thin sections showed the absence of rutile needles in the glauconite. Galliher was kind enough to send me what remained of the samples used in his published analyses[6] which are given as 1, 2, 3, in the accompanying table.

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[1] Galliher, E. W., Glauconite genesis: *Bull. Geol. Soc. Am.*, vol. **46**, pp. 1351–66, 1935.

[2] Gruner, John W., The structural relationship of glauconite and mica: *Am. Mineral.*, vol. **20**, pp. 699–714, 1935.

[3] Allen, Victor T., Anauxite from the Ione formation of California, *Am. Mineral.*, vol. **13**, p. 150, 1928.

[4] McQueen, H. S., Geologic relations of the diaspore and flint fire clays of Missouri: *Jour. Am. Cer. Soc.*, vol. **12**, pp. 687–697, 1929.

Allen, Victor T., Mineral composition and origin of Missouri flint and diaspore clays: *Missouri Geological Survey and Water Resources*, 58th Bienn. Report, App. **IV**, pp. 1–24, 1935.

[5] Ross, C. S., The optical properties and chemical composition of glauconite: *Proc. U. S. Nat. Mus.*, vol. **69**, pp. 1–15, 1926.

[6] *Loc. cit.*, p. 1359.

The titanium in these samples was determined by Mr. Rolufs. The spongy glauconite contains three times the titanium, and the firm glauconite six times the titanium present in the glauconite of the Bonneterre

	(1) Biotite Monterey Bay, Calif.	(2) Firm Glauconite Monterey Bay, Calif.	(3) Spongy Glauconite Monterey Bay, Calif.	(4) Glauconite Bonneterre Dolomite, Missouri	(5) Biotite Mora, Minn.
SiO_2	36.25	55.95	51.90	48.66	35.67
Al_2O_3	18.25	11.56	1.52	8.46	14.56
Fe_2O_3	6.35	9.99	27.98	18.80	3.03
FeO	17.09	2.02	1.26	3.98	23.23
MgO	9.01	6.77	4.67	3.56	9.24
CaO	0.79	3.95	0.89	0.62	1.13
Na_2O		0.61	0.53	none	0.49
K_2O	8.68	4.12	4.90	8.31	8.06
H_2O-		1.60	2.10	1.94	0.23
H_2O+	2.70	3.22	4.05	4.62	1.02
Others		0.18	0.11	0.12	0.24
TiO_2*	3.26*	0.59*	0.30*	0.10*	3.32
Refractive Index γ	1.645	1.618	1.618	1.618	1.655

No. 1, 2, 3. Analyses by A. A. Hanks, see E. W. Galliher, *Bull. Geol. Soc. Am.*, vol. **46**, p. 1359, 1935.

No. 4. Analysis by G. V. Brown, see C. S. Ross, *Proc. U. S. Nat. Museum*, vol. **69**, pp. 1–15, 1926.

No. 5. Analysis by F. F. Grout, *Am. Mineral.*, vol. **9**, p. 161, 1924.

* No. 1, 2, 3, 4, TiO_2 determinations by R. T. Rolufs, Chemist, Missouri Geological Survey.

formation, and both contain occasional rutile needles which are more common in the biotite from Monterey Bay. Galliher's evidence[7] of the derivation of Monterey glauconite from biotite is convincing, and the reactions involved seem simpler than those in the formation of glauconite by colloidal silica and ferric hydroxide derived from the decomposition of clay reacting with potassium in sea water.[8] According to Galliher[9] the change of biotite to glauconite involves: oxidation of its iron, retention of its potash, hydration, partial loss of alumina and magnesia. To this must now be added a partial loss of titanium from more than 3 per cent in biotite to .3 or less per cent in glauconite. The oxidation of iron in a black mud environment under anaerobic conditions, where slow sedi-

[7] *Loc. cit.*

[8] Murray, John, and Renard, A. F.: *Report of the Challenger Expedition, Deep Sea Deposits*, p. 385, **1891.**

[9] *Loc. cit.*, pp. 1357–1360.

mentation allows time for the reactions to take place, is explained by Galliher as due to dehydrogenation following hydrolysis. But, in spite of the attractiveness of the method from the chemical side, its application to the glauconite of the Bonneterre formation meets with other difficulties besides a scarcity of titanium. Not the least of these are suitable source rocks to furnish this large quantity of biotite, for the pre-Cambrian granites of Missouri are poor in biotite. If we postulate a buried area of biotite schists as the source material, we would expect that an occasional metamorphic mineral attached to a large biotite flake would be rafted to the site of deposition. Attempts to concentrate the heavy minerals from large samples of the Bonneterre dolomite indicate the absence of metamorphic minerals and a great scarcity of any heavy minerals. Furthermore, the arrangement of the glauconite along the bedding of the dolomite is not that common in micaceous sediments, for clusters of glauconite often end abruptly instead of grading out along the same horizontal layer, due to the ease with which the plates float during deposition.

Glauconite in the St. Peter Sandstone

The same objections apply to the glauconite-like mineral that coats the surface of sand grains in the upper part of the St. Peter sandstone of Missouri. I use the term "glauconite-like mineral" because its greatest refractive index, gamma, is about 1.58 instead of the usual 1.62 or 1.63 of glauconite. But the green mineral of the St. Peter sandstone has the peculiar spotted interference colors that characterize all the glauconite examined. Galliher would term this green film on the quartz grains pigmentary glauconite, which he considers forms by tiny particles breaking off the spongy type. The lack of visible rutile needles and a satisfactory source for the glauconite, or the biotite, stands in the way of accepting this explanation.

Glauconite in Clayton and Porters Creek Formations

In southeastern Missouri at Crowleys Ridge near the town of Ardeola are two Eocene formations that contain glauconite, the Clayton and the overlying Porters Creek. The glauconite of these formations contains occasional rutile needles and the sediments contain a small metamorphic assemblage including such minerals as kyanite, epidote, and garnet that probably came from the Appalachian region to the east. In a published paper[10] I have presented evidence that the Porters Creek formation of Missouri is bentonitic and that the montmorillonite in it formed from the

[10] Allen, Victor T., Petrography and origin of the Fuller's earth of southeastern Missouri: *Econ. Geol.*, vol. **29**, pp. 590–598, 1934.

decomposition of volcanic ash, for relict volcanic textures are common in the lower twenty feet of the formation. Parts of the Porters Creek formation contain 2 or 3 per cent of muscovite which exceeds the glauconite present. If 2 or 3 per cent of muscovite could float in from a distant terrane, it is reasonable to believe that half that amount of biotite could accompany it and later be changed to glauconite according to the reactions described by Galliher.

Conclusions

From this study it appears that the glauconite in the two Eocene formations of Missouri, the Porters Creek and the Clayton, could well have formed from biotite, but similar substantiating evidence is lacking for a like origin of the glauconite in the two older formations of Missouri, the St. Peter sandstone of Ordovician age and the Bonneterre dolomite of Cambrian age.