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GIBBSITE VERMIFORMS IN THE PENSAUKEN FORMATION OF NEW JERSEY

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ABSTRACT

Vermiform aggregates found in seven localities in the coarse sands of the Pensauken formation were identified as composed mostly of gibbsite. Although their appearance is very similar to kaolinite vermiforms and knaeuel described in the literature, all indications are that they are authigenic and formed by direct weathering of feldspar and other silicates to gibbsite, suggesting a near-laterite type of weathering during an interglacial period of the Pleistocene in this area.

INTRODUCTION

Vermiform crystal aggregates of kaolinite, dickite, and anauxite have been reported by Ross and Kerr (1930) and others (Carozzi 1960), usually associated with kaolin deposits. Kulbicki (1954) describes vermicular dickite in a gibbsite matrix. Gordon and Tracey (1952) found accordionlike kaolinite crystals partly replaced by gibbsite in the bauxites of Arkansas.

Vermicular aggregates of appearance strikingly similar to some of these were found by J. H. C. Martens (personal communication) in the Pensauken formation near South Amboy, New Jersey. These vermiforms are much larger in size, however, than those reported elsewhere, and their principal constituent was identified as gibbsite (Lodding 1960).

OCCURRENCE

Vermicular gibbsite aggregates were found since then in six additional localities of the Pensauken formation, as indicated in Table I. They occur in coarse and medium size arkosic sand and gravel. Considering the delicate shapes and little strength of some of these aggregates it is difficult to imagine that they underwent any amount of transportation. It must be assumed that they are authigenic. Gibbsite was also found in the same localities as a whitish cement, filling interstices between the sand grains. Although gibbsite cement is present in some glauconitic sands, no vermiforms were found to date in sands containing glauconite.

Five of the seven localities described lie within a circle of six miles south of the Raritan River estuary. Samples No. 960 and 1081 were found 20 and 30 miles to the south-east of this area. No preferential vertical distribution has been observed.

The thickness of the gibbsite-bearing beds is rather irregular mainly due to cross-bedding. Although it is sometimes possible to follow a horizon for several hundred feet, its thickness may vary from a few inches to several feet. The spans indicated in Table 1 are those encountered at a particular bore hole or channelled exposure.

DESCRIPTION OF SPECIMENS

Vermicular gibbsite aggregates range in size from 1 to 6 mm. in their longest dimension, with length-to-width ratios varying between 1 and 10. (Fig. 1)

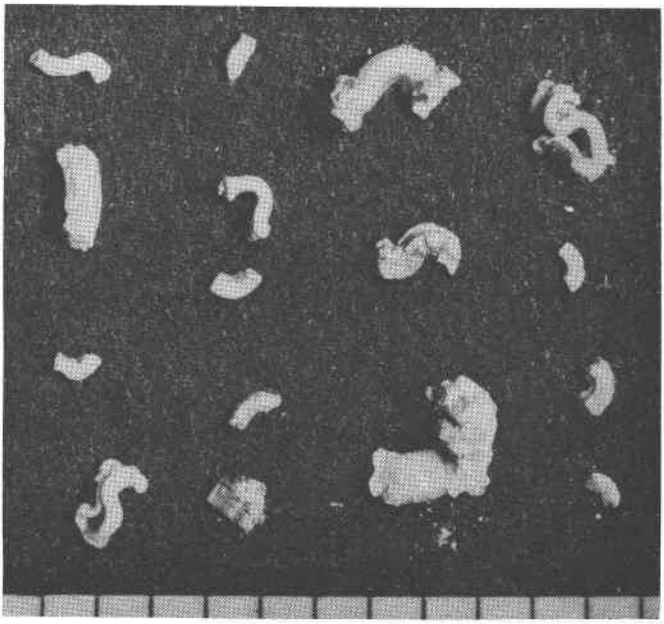

FIG. 1. Vermicular gibbsite. Each scale division = 1 mm.

The color of the aggregates ranges from off-white to light brown. A few specimens show a heavy surface coating and are almost black. Branching along longitudinal cracks is frequent. Some twisted vermicular aggregates very similar to the Kaolinitknaeuel described by Guthörl (1956) are also found. Many vermiforms show brown banding perpendicular to their long axis. Unlike that in the kaolinite vermiforms described by Schüller, the brown banding is not due to organic matter, but to iron oxides.

Vermiform gibbsite shows some cleavage perpendicular to the long axis. Thus mica-like platelets are sometimes obtained by prodding a vermiform with a needle. These platelets have the shape of irregular hexagons, parallelograms, or a composite of these figures, often with reentrant angles.

Delicate water-clear skeletal particles of plagioclase (as identified by J. H. C. Martens) are often found in the coarse sands.

Composition

Chemical and spectrographic analyses were made on hand picked vermiforms of sample 1013. The chemical analysis showed the following:

Al_2O_3	57.0 %	MnO	0.05
SiO_2	7.41	CuO	0.02
Fe_2O_3 (total)	4.32	Na_2O	0.12
TiO_2	1.80	K_2O	traces
MgO	0.14	Loss on ign.	28.7
CaO	0.04		
SrO	0.01	Total	99.61%

X-ray powder photographs show strong reflections for gibbsite and weak lines for kaolinite and quartz. No reflections were found for iron oxides, suggesting poorly crystalline or amorphous compounds. A Laue photograph taken on a single vermiform platelet with the beam perpendicular to the presumed a–b plane showed that the platelet is clearly not a single crystal, although a certain degree of preferred orientation can be observed.

Differential thermal analysis showed the endothermic reaction for the dehydration of gibbsite starting at 250° and the peak at 335° C. A small kaolinite peak is at 550°, and a small amount of quartz is indicated by the α-β inversion at 573°. No evidence of dickite was found in 38 thermograms.

DTA was performed both in dynamic air, or in hydrogen atmosphere followed by oxidation in air. The latter method was used to distinguish between hydrated iron oxides and gibbsite, which both dehydrate in the same temperature range, when heated in air. (Lodding and Hammell 1960.) The approximate amount of gibbsite present was determined by these methods in all vermiform-bearing sands shown in Table I.

From the chemical analyses and DTA the mineral composition of sample 1013 was calculated:

gibbsite	87%
kaolinite	6%
iron and titanium oxides	6%
quartz	1%

Vermiforms from other localities have a similar mineral composition except for the gibbsite-kaolinite ratio, which may vary from 15 to 3. Op-

TABLE 1. OCCURRENCE AND DESCRIPTION OF VERMICULAR GIBBSITE

Sample No.	Thickness Inches	Location	Gibbsite	Vermiforms		Total* Gibbsite	Matrix
			Max. length	Color	Abundance		
951	18	Wright Tract South River	—	—	—	10%	very coarse glauconitic sand, slightly cemented, off-white
1007	18	Wright Tract South River	2 mm.	buff to brown	1%	10%	fine white sand, crumbly buff cement
1013	12	Wright Tract South River	6 mm.	buff to brown	5–10%	20%	medium yellow to brown sand
1019†	12	Wright Tract South Tract	3 mm.	buff to black	1–10%	10%	medium red and yellow sand black and brown crumbly aggregates
961	6–24	Whitehead Ave. East Brunswick	2 mm.	buff	1%	20%	coarse light brown to gray sand, abundant white crumbly cement
982 and 924	10–24	Sayre & Fisher Sand Co. Sayreville	2 mm.	buff	1%	15–20% 3%	white to yellow feldspathic sand, brown yellow or white crumbly cement
992	20	Crossman Co. South Amboy	1.5 mm.	buff	1%	2%	feldspathic coarse sand, colorless to heavily coated by brown and black oxides, white cement
996	10–20	Whitehead Ave. Oldbridge	2 mm.	light buff	1%	3%	medium light sand, much white crumbly cement, black and brown aggregates
1084	6–12	Windsor, N. J.	2 mm.	white to buff	1%	6%	white gravel, feldspathic sand, light brown clay
960†	2×4	Columbus, N. J.	3.5 mm.	white to buff	1–5%	15–20%	medium red brown sand, heavily coated, white crumbly cement

* As determined by DTA
† Collected by James Bowman II.

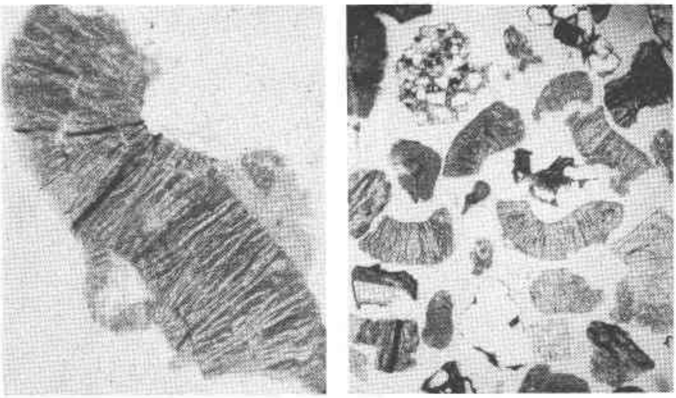

FIG. 2. Vermicular gibbsite; undisturbed thin sections. Left: ×40; right: ×14.

tical Properties: Indices α,β 1.566 ± 0.002; α appr. 1.585 (all except fragments very high in limonite 1.584), 2V estimated 10°, sign positive.

Thin Sections

Undisturbed sections were prepared from slightly consolidated vermiform-bearing sands. See Figs. 2 and 3. Orientation of the gibbsite seems to be random and little relation is apparent between quartz aggregates and vermiforms. Gibbsite vermiforms often split parallel to their long axis, and sometimes these branches double back to the main body (Fig. 2). These branches look like the result of longitudinal cracks, causing a peculiar angular cross section of the vermiform gibbsite platelets described. In Fig. 3 a gibbsite vermiform is seen in polarized light with the extinction boundaries following the rotation of the moving stage. No

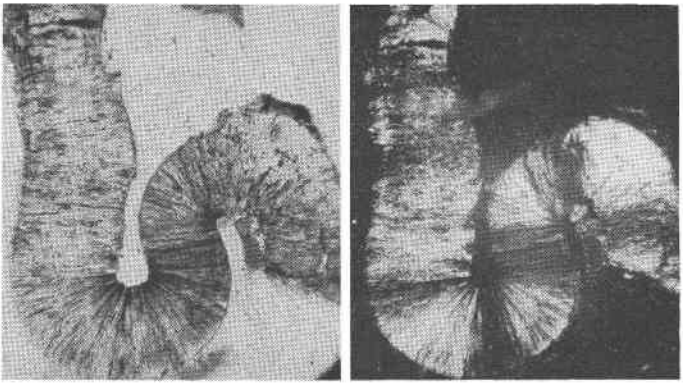

FIG. 3. Vermicular gibbsite. Left: plane polarized light; right: crossed nicols. Both ×40.

evidence of vermiforms growing on muscovite platelets as described by Schüller (1951) was seen. The gibbsite vermiforms seem to be detached from the other mineral grains and aggregates with only point contacts between them.

Genesis of Vermiform Gibbsite

The Pensauken formation is composed of sand, gravel, silt and clay, often deeply eroded and weathered. According to Salisbury and Knapp (1918) and MacClintock (1940) it is interglacial, younger than the Bridgeton and older than the Cape May (Sangamon) formations. It is thought to be a stream deposit laid down by rivers with shifting channels as evidenced by frequent cross bedding. The permeable Pensauken sands are not covered by any other formation and apparently have not had much of any cover in their past history.

Vermiforms are found at depths of three to twenty feet below the present surface. The presence of abundant feldspar in various stages of weathering in the Pensauken points to the source of alumina needed to form gibbsite. Keller (1958) proposes a mechanism of direct weathering of nepheline, amphiboles and feldspars to kaolinite, gibbsite, and iron oxides. Weathering in a pH range of 7 to 9.5 may lead to removal of silica and iron, leaving aluminum hydroxides behind. At higher pH, both alumina and silica are mobile, and at a pH below 7 alumina is immobile and silica has low mobility. Abrasion pH values of 9 to 11 are obtained when nepheline, diopside, or feldspars are ground. In the presence of these minerals, rain and ground water may acquire a pH between 7 and 9.5. Such a condition may produce preferential leaching of silica in the weathering of aluminous silicates. Aluminum hydroxide left behind may partly dehydrate and crystallize to gibbsite on suitable seed crystals.

An alternative possibility would be the formation of kaolinite vermiforms as the result of feldspar weathering, and subsequent transformation of the kaolinite into gibbsite by the removal of silica. This process appears less likely in the present case, because of the absence of kaolinite vermiforms in the Pensauken. It is likely that some of the vermiforms found in seven different localities of the Pensauken would have remained kaolinite, if this had been the starting material. The fact that kaolinite constitutes at most one-fourth of the vermiforms, and usually much less, would indicate the likelihood of direct weathering of pyroxenes and feldspars to gibbsite. Incomplete removal of the silica can then account for the kaolinite present.

Keller (1958) lists the following conditions leading to the formation of gibbsite:

1) parent materials with an abrasion pH of 9 or higher.
2) profuse rainfall throughout the year.
3) high temperature (accelerating rate of hydrolysis).
4) abundant and continuously active microflora of very warm humid climate.
5) high permeability of regolith which allows the removal of dissolved silica.

Conditions corresponding to points one and five are evident in the Pensauken formation. Some evidence is also present for the existence of conditions two, three, and four, which assume a hot and humid climate and rapid weathering and oxidation representing a near-laterite type of weathering. The scarcity of organic matter and the state of oxidation of iron as heavy coatings on sand grains and in the clays point in this direction.

In this connection it should be noted that Krebs and Tedrow (1958) recently identified gibbsite as a major constituent of the clay fractions in certain soil horizons in two widely separated areas of New Jersey. The Annandale loam and silt loam derived from the pre-Wisconsin glacial drift on Schooleys Mountain and the Aura and related sandy loams derived from the Bridgeton formation all contain considerable gibbsite and kaolinite.

Acknowledgments

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