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Comparison of the Fabric of a Sensitive Pleistocene Clay with Laboratory Flocculated Clay using the Scanning Electron Microscope*

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Introduction

This paper reports the results of a scanning electron microscope study of the fabric of a sensitive Pleistocene clay outcropping in the St. Lawrence River Valley. This fabric is compared to that produced in flocculated clay sedimented in distilled water in the laboratory.

The particular clay studied is found at water level, approximately 600 feet downstream from Snell Lock on the St. Lawrence River, near Massena, New York. At this location it is 40 feet thick and lies on Ordovician bedrock; however, nearby the clay is found overlying two distinctive tills. MacClintock (1958) identified them as the Malone and Fort Covington tills. Properties of the clay described in this paper are also very similar to other fine-grained sensitive sediments called "Leda" clay and found in the valleys of the St. Lawrence and Ottawa Rivers.

O'Brien and Harrison (1969) have published a transmission electron micrograph of the sensitive clay which reveals the random arrangement of clay flakes. Their conclusion is that the fabric supports the cardhouse model and that it was produced by deposition in the flocculated state. Electron micrographs by Gillott (1969) and Crawford (1968) also show a general random orientation of clay particles in a similar clay. Crawford (1968) states that the Leda clays, like other sensitive clays, are thought to have a cardhouse fabric because of their environment of deposition. Marine fossils found in some areas demonstrate the clay was deposited in salt water.

Gadd (1962) however, suggests that there may have been redeposition of marine clays into fresh water. Crawford (1968) states that "if these clays were actually deposited in fresh water, some explanation must be found for their open structure and sensitivity". It is the purpose of this paper to present evidence that the open structure may be produced also by flocculation in fresh water. To test this hypothesis, the authors studied the fabric of clay flocculated in distilled water and compared the fabric produced tothat of the Pleistocene clay.

Pleistocene Clay Fabric

Figures 1-2 show the fabric of the bedding plane surface of an air-dried clay sample. The random clay flake orientation or cardhouse structure is quite apparent. Particular attention is called to the cluster of flakes lying perpendicular to the plane of the photograph in Figure 1. Even though the clay sample was air-dried, the open structure can still be observed (Figure 2). The general particle orientation of the air-dried clay appears to be little different from freeze-dried clay. Pusch (1966) studied quick clay in the Gota River Valley and reported "no significant difference between the microstructure of samples from 3 m depth (the dry crust) and 6 m depth (the quick clay)". Although there is a change in volume in the air-dried sample studied, the gross fabric probably does not change.

Fabric of Freeze-dried Flocculated Kaolinite

There seems to be little doubt that the cardhouse structure is produced in flocculated clay deposited in marine water. However, can this structure also result from deposition in fresh water? More basically, what is the actual orientation of clay in a cardhouse, whether formed in marine or fresh water? To answer these questions and to relate the answers to the fabric of a natural clay, experiments were run in which a high concentration (which promoted flocculation) of poorly crystalline kaolinite was sedimented in distilled water. In this case the flocculation was not due to the presence of electrolytes but the clay concentration. Kaolinite was used

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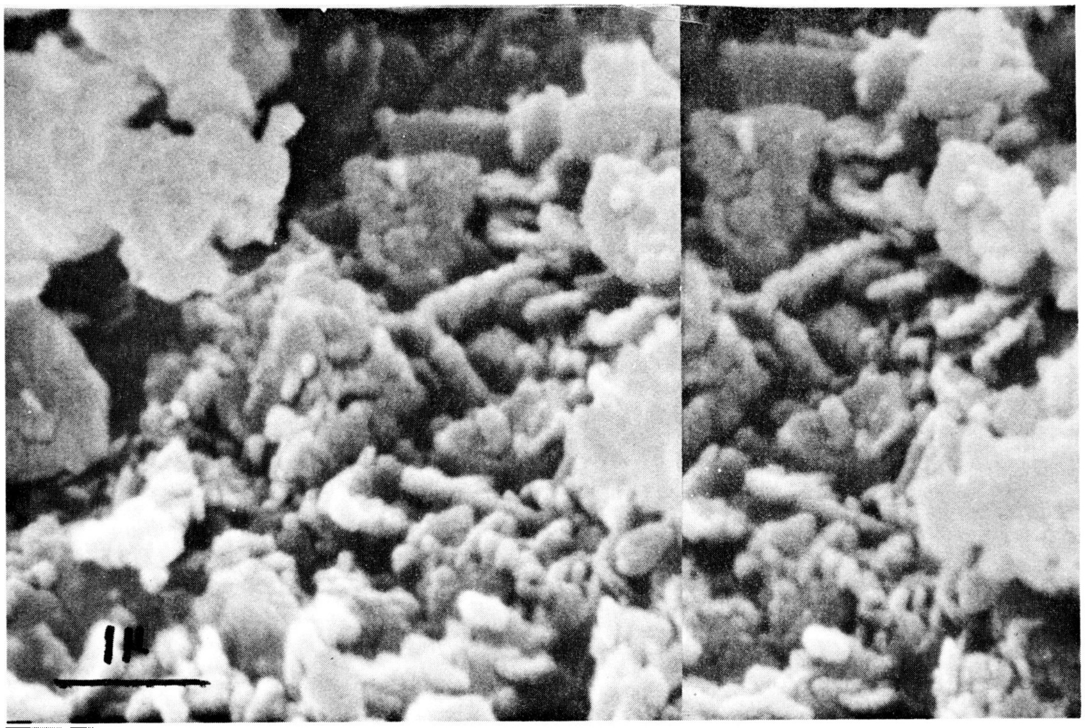

FIGURE 1 - Stereo-pair scanning electron micrograph of the top surface, Pleistocene clay, x 20000.

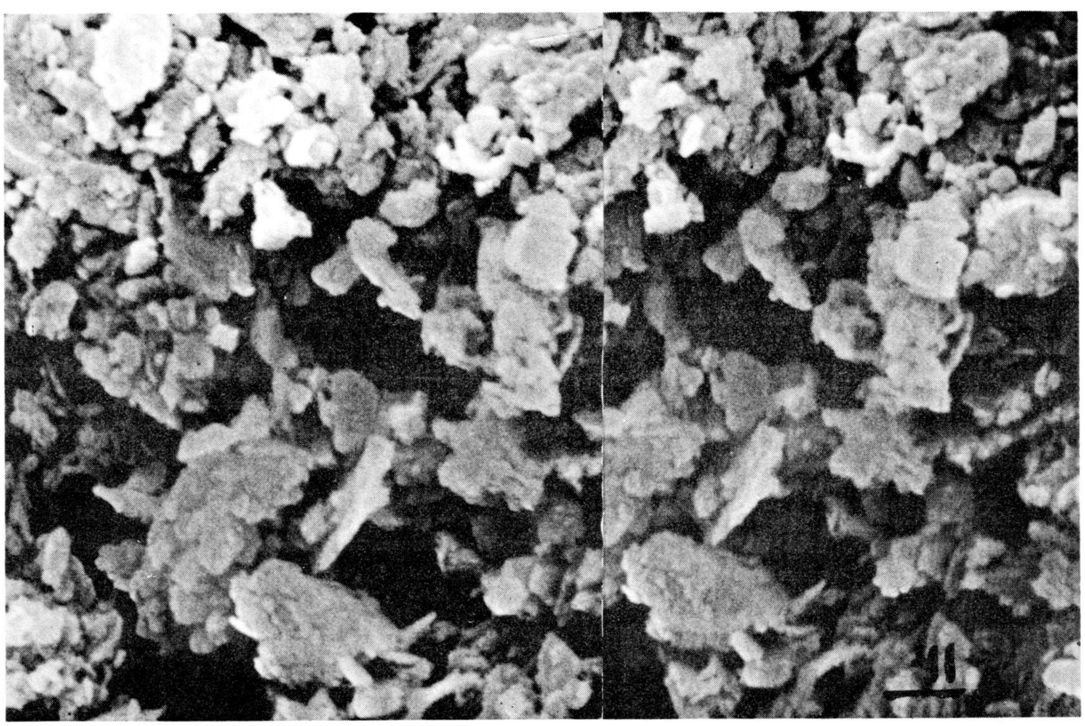

FIGURE 2 - Stereo-pair scanning electron micrograph of the top surface, Pleistocene clay, x 10000.

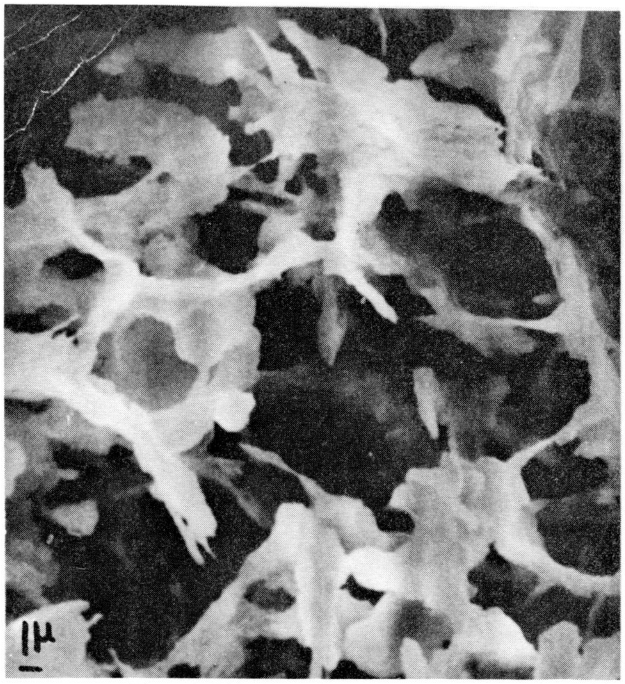

FIGURE 3
Scanning electron micrograph of freeze-dried flocculated kaolinite, x 2000.

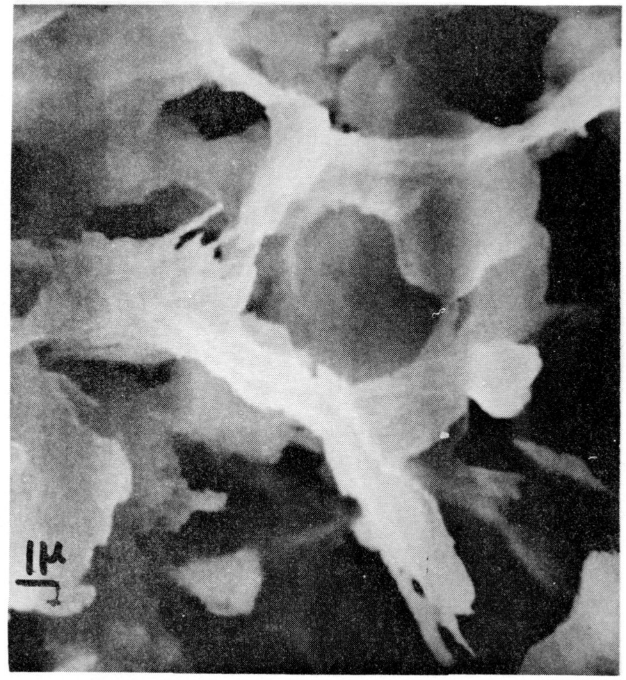

FIGURE 4
Scanning electron micrograph of freeze-dried flocculated kaolinite, x 4000.
(enlargement of Figure 3).

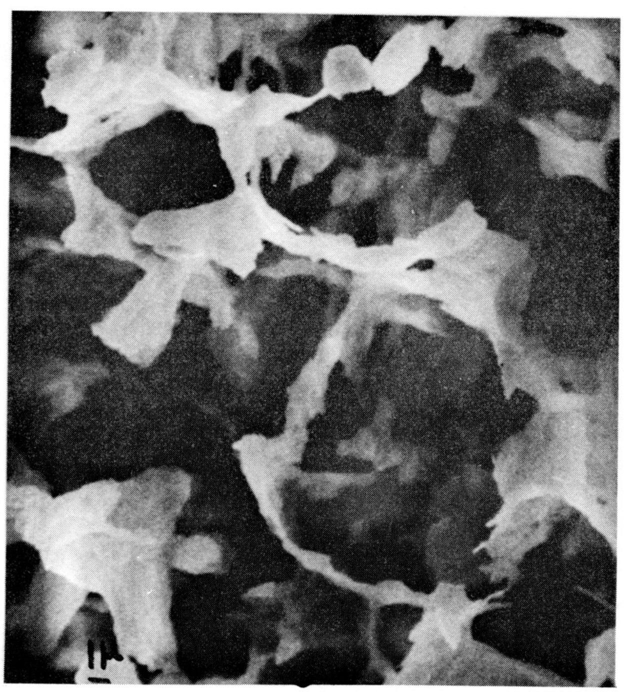

FIGURE 5
Scanning electron micrograph of freeze-dried flocculated kaolinite, x 2000.

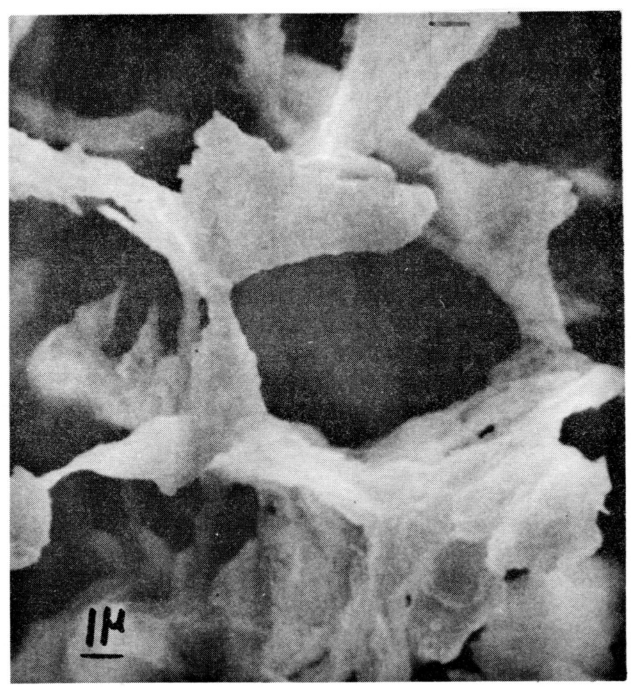

FIGURE 6
Scanning electron micrograph of freeze-dried flocculated kaolinite, x 4000.
(enlargement of Figure 5).

because its flake boundaries are better defined and thus easier to recognize in the microscope. The clay was stirred in distilled water and allowed to settle. Drops of the flocculated suspension were put onto small sample holders, which were then immersed into liquid nitrogen (-160°C) for a few seconds. Ice was then removed by sublimation under a vacuum, leaving a framework of dry clay having approximately the same volume as the moist clay. The samples were kept at a temperature of at least -20°C during sublimation.

Figure 3-6 show the typical fabric produced by the freeze-drying of flocculated kaolinite. The fabric consists of an open network of flakes oriented at various angles. The sides of a typical floccule (Figure 3) consist of a domain of a number of face to face flocculated flakes. These domains then appear to be flocculated in an edge-face or edge-edge manner thus composing the entire floccule. Smalley and Cabrera (1969) studied the fabric of moist compacted kaolinites and observed a particle association which they called "stepped face to face". Others use the term "bookhouse" for the structure of the random packets of clay. The fabric of the clay reported here seems to be a modification of the typical cardhouse model in which the sides of the model are composed of packets of flakes, instead of individual flakes.

Conclusion

The significance of these findings is that there is a similarity between the fabric of clay flocculated in distilled water and that of the sensitive Pleistocene clay. For example, both Figure 1 and Figure 4 show flakes parallel and perpendicular to the plane of the photo. In addition Figure 1 reveals packets composed of parallel flakes; these packets, in turn, appear attached to others composed of parallel flakes. Generally, the random orientation and open texture is apparent in both samples. It seems likely that the fabric of the Pleistocene clay could be produced by deposition in the flocculated state. This state could be produced not only by sedimentation in marine water, but by deposition of a high clay concentration in fresh water. Under the latter conditions, the clay concentration is a major factor in promoting flocculation and hence random clay flake orientation.

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