LONG-TERM SETTLING CHARACTERISTICS OF SOME CLAYS

by

T. J. Tobias and A. P. Ruotsala

Michigan Technological University, Houghton, Michigan

ABSTRACT

A series of experiments was set up, the purpose of which was to determine factors affecting long-term settling characteristics of some suspensions of clay-sized materials. Suspensions of approximately 8 g per l. were prepared using Georgia kaolin, Mississippi bentonite, Wyoming bentonite, Iowa illite and finely ground quartz. In addition, 2 g and 16 g per l. suspensions of kaolinite were prepared. All suspensions were observed for 2-week periods at constant temperatures of 19°C; kaolinite suspensions were also observed at 2°, 10°, 25° and 31°C.

After settling 3–4 days at 19°C, layering formed in all clay suspensions, and all the tops of the layers contained higher concentrations of suspensoid than bottoms. Tops and bottoms of the layers were parallel to liquid top surfaces.

At 2°C, no stratification developed in kaolinite suspensions. At 10°C, layering formed only in 2 g per l. suspensions after 3 months of settling. At higher temperatures, layering formed after 3–4 days of undisturbed settling. Two grams per liter kaolinite suspensions formed five distinct layers; 8 g per l., nine layers; and 16 g per l. suspensions formed a many-layered, banded structure after approximately 2 weeks.

If layered suspensions were cooled, the layers were not disturbed. However, layering was very responsive to heating: they expanded and tilted downward away from the heat source. With prolonged heating, layering disappeared.

These experiments show that temperature and concentration markedly affect long-term settling characteristics of fine-grained suspensions. Layering forms most readily in water with relatively low viscosity and density. If such layered suspensions were formed in nature, such features as graded bedding, lamination, or varving probably would result after complete settling.

INTRODUCTION

If suspensions of unflocculated clay materials are allowed to remain undisturbed for several days at constant temperature, a layered appearance develops in them. In this study, mineralogy, temperature and concentrations of suspensoid are considered as possible factors affecting layering.

The writers thank Professor R. E. Grim, Department of Geology, University of Illinois, for furnishing clay materials.

EXPERIMENTAL PROCEDURE

To test the effect of mineralogy upon layering, the following clay-sized

https://doi.org/10.1346/CCMN.1964.0130136 Published online by Cambridge University Press

materials were dispersed in distilled water: (1) Georgia kaolin; (2) Mississippi bentonite, consisting of montmorillonite with calcium as the dominant exchangeable cation; (3) Wyoming bentonite, consisting of montmorillonite with sodium as the dominant exchangeable cation; (4) illite from Iowa; (5) quartz, very finely ground, locality unknown.

Approximately 8 g per l. suspensions of these minerals were prepared. The addition of sodium hexametaphosphate was necessary to disperse the clay minerals. The suspensions were allowed to remain undisturbed for 4 weeks at a constant temperature of 19°C.

To test the effect of the concentration of a suspensoid upon layering, Georgia kaolin suspensions containing 2 g, 8 g and 16 g per l. were prepared.

To test the effect of temperature, separate Georgia kaolin suspensions of 2 g, 8 g and 16 g per l. were tested at constant temperatures of 2°C, 10°C, 19°C, 25°C and 31°C.

RESULTS

Eight grams per liter suspensions of all materials tested at 19°C produced layering. An example of layering, produced in 2 g per l. kaolinite suspension, is shown in Plate 1. Difficulty in reproduction for publication prevents showing illustrations of all layered suspensions. The layering has the following characteristics:

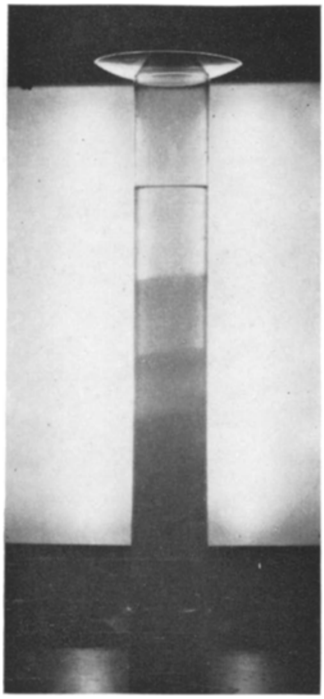
1. Layers are produced after 3–4 days of undisturbed settling.
2. Layers appear to have higher concentrations of suspensoid near the tops of the layers than at the bottoms (see Plate 1).
3. Tops and bottoms of layers are approximately parallel to liquid surfaces.
4. Top layers of suspension settle more slowly than bottom layers. Rates of settling of tops of individual layers in a 2 g per l. suspension are shown in Fig. 1.
5. The sediment settling from kaolinite suspensions has a "varved" appearance. Such an appearance is shown in Plate 2.

Concentration affects layering in kaolinite suspensions in two ways:

1. The higher the concentration of suspensoid, the greater the number of layers formed. The effect of concentration upon layering is shown in Table 1.
2. Layering seems to form only in relatively dilute suspensions. Although no measurements of exact times were made, 2 g per l. suspensions seemed to layer more quickly than more concentrated suspensions.

Layering is affected by temperature. At 2°C, layering did not form in kaolinite suspensions. At 10°C, layering formed only in the 2 g per l. kaolinite suspension after 3 months. In suspensions tested at 19°C, 25°C and 31°C, layering developed after 3–4 days.

Cooling a layered suspension produced no noticeable effect upon layering. However, layering is very sensitive to heat. Heating caused layer surfaces to



ATE 1. Layering developed in a 2 g per l. suspension of kaolinite at 19°C

https://doi.org/10.1346/CCMN.1964.0130136 Published online by Cambridge University Press

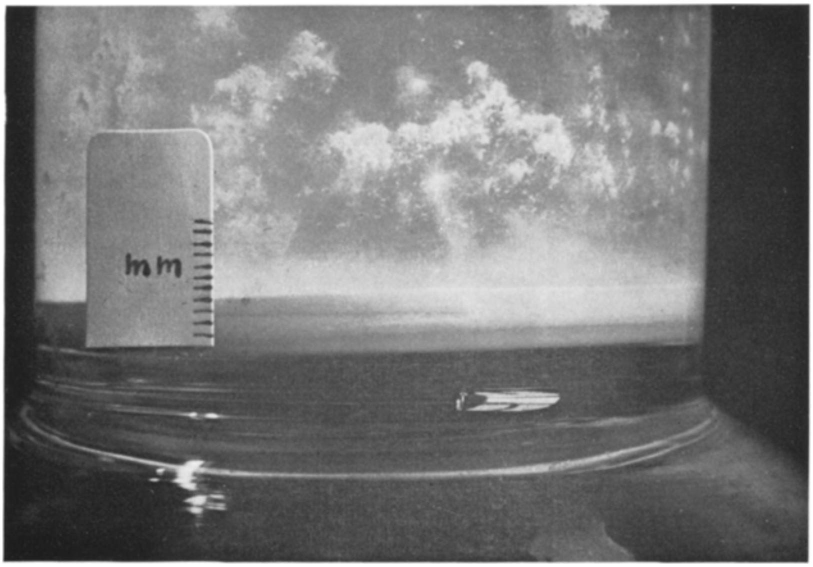


PLATE 2. Layered structure developed in sediment completely settled from 8 g per l. kaolinite suspension at 19°C

be tilted downward away from the heat source. The tilted layers in Plate 1 resulted from heat from photoflood lamps approximately 1 ft from the suspension. If heating is continued, the layers disappeared apparently owing to convection.

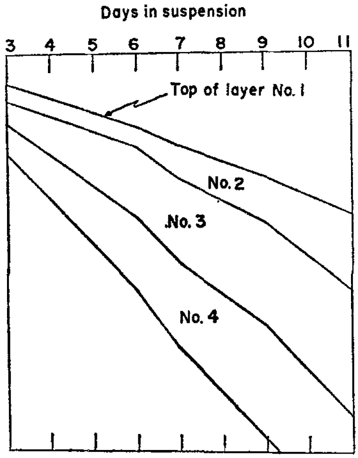


FIG. 1. Relative positions of tops of layers during settling. Number 1 is the uppermost layer. Vertical scale is equal to column height in Plate 1.

TABLE 1.—NUMBERS OF LAYERS FORMED IN KAOLINITE SUSPENSIONS (198°C)

Concentration, g/l.	Number of layers
2	5
8	9
16	Approximately 10 per in. in upper 2 in. of column

DISCUSSION

Long-term settling of unflocculated fine-grained suspensions are controlled to a great extent by temperature and concentration. In suspensions tested in this series of experiments, cool and warm suspensions settled in a different manner. Suspensions below 10°C appear uniform throughout, while those above 10°C take on a layered appearance after several days in suspension. An inverse relationship seems to exist between temperature and time required for the onset of layering.

The time required for layering to develop also seems directly related to the concentration of the suspensoid. The number of layers formed seems directly proportional to concentration. The fact that upper layers settle more slowly than lower layers (Fig. 1) suggests that upper layers consist of smaller particles.

To the extent that different materials were tested in these experiments, layering developed regardless of mineralogy. However, banding in kaolinite suspensions was more distinct than in other suspensions. This would suggest some mineralogical effect.

Bradley (1948, p. 636) graphically illustrated the relationships among temperature, viscosity and density of water. At low temperatures, water is considerably more viscous and dense. Apparently, layering is greatly favored by low viscosity and density. It is not clear why layering develops or why layers have a higher concentration of suspensoid at the top than at the bottom. A fairly constant temperature favors their development.

These experiments suggest the possibility that lamination, graded bedding, or " varving " might develop while fine-grained sediments are settling. Wood (1946), for example, has described " varving " in sediments deposited in a short period of time.

REFERENCES

BRADLEY, W. H. (1948) Limnology and the Eocene Lakes of the Rocky Mountain Regions, *Bull. Geol. Soc. Am.* **59**, 635–48.

WOOD, A. E. (1946) Multiple banding of sediments deposited during a single season, *Bull. Geol. Soc. Am.* **57**, 1245.