

RELATION OF VISCOSITY OF KAOLIN-WATER SUSPENSIONS TO MONTMORILLONITE CONTENT OF CERTAIN GEORGIA CLAYS

by

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ABSTRACT

THE viscosity of certain kaolin-water systems was correlated with natural montmorillonite content of the kaolin, as determined quantitatively by the Hinckley-Bates (1960) strontium-exchange technique. Transition from low viscosity to high viscosity occurred when montmorillonite content of the Georgia clays studied exceeded 5%.

INTRODUCTION

OVER half of the three million tons of kaolin consumed annually in the United States is sold under rigid viscosity specifications. These require a refined clay having a viscosity no greater than 1000 centipoises—usually less than 200 centipoises—as measured on a Brookfield viscometer in completely deflocculated suspensions of 70% solids. However, extensive reserves of kaolin will not meet these limits. These are loosely termed plastic clays. Natural variations of many thousand fold in viscosity of kaolin samples from the same district and sometimes from the same mine are not uncommon, even though these clays appear to be substantially pure kaolin based on chemical analysis. These variations are believed due to variation in composition, particle size, particle shape, and particle size distribution.

Within limits, it is possible to control the viscosity of kaolin by processing techniques such as shear, fractionation, blending, and use of chemical reagents (Millman, 1951, 1964). However, the range of useful modification that can be produced by such techniques is restricted to certain clays. Extensive reserves of plastic clays remain beyond the scope of useful beneficiation by these processes.

There are numerous indications that variation in mineral composition, such as the amount of montmorillonite present, is a basic cause of high viscosity in kaolin suspensions (Woodward, 1955). The qualitative effects of montmorillonite content on viscosity of kaolin-water systems are well known (Swanson and Hemstock, 1956; Langston, Jenne, and Pask, 1965). More precise relationships have not been established because standard

mineralogical techniques (including DTA and X-ray diffraction) and wet chemical methods are not adequately precise for small amounts (5% or less) of montmorillonite in kaolin.

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RELATIONSHIP OF MONTMORILLONITE CONTENT OF KAOLIN CLAYS TO BROOKFIELD VISCOSITY AT 50% SOLIDS

We have found that viscosity of deflocculated kaolin-water systems at high solids contents can be correlated quantitatively with the amount of montmorillonite present in kaolin as measured by the Hinckley-Bates technique. As a result, viscosity of kaolin-water systems can be used as an indication of the montmorillonite content of a kaolin. Alternatively, determination of the montmorillonite content of a kaolin by the Hinckley-Bates method provides an excellent prediction of the viscosity of the kaolin.

VISCOSITY TESTS

Viscosity determinations were made on a Brookfield Synchro-lectric Rotational Viscometer (Model LVF) at 20 RPM. Determinations were made on each slurry to which increments of TSPP (0.05% based on clay) had been added until minimum viscosity was attained. Spindles 1, 2, 3, and 4 were used, depending on the viscosity range. Other determinations were made on a Hercules High Shear Viscometer (Model No. HV 2000). Determinations were made at a shear rate of 4540 reciprocal seconds.

MONTMORILLONITE DETERMINATIONS

Montmorillonite determinations were made at Tem-Pres Research, University Park, Pennsylvania, according to the procedure of Hinckley and Bates. This technique uses the difference in base-exchange capacity of kaolin and montmorillonite. It consists of exchanging strontium ion into the clay, removing the excess strontium by dialysis, analyzing the exchanged sample for strontium by X-ray fluorescence, and computing the percentage of montmorillonite from results according to a curve derived from known standards. Precision of this method is reported to be $\pm 0.5\%$ montmorillonite in the 0.5–8.0% range. This method makes the following assumptions:

1. The base-exchange capacity of the sample is due primarily to montmorillonite, i.e. the base-exchange capacity of the kaolinite is negligible in comparison to that of the montmorillonite.
2. The base-exchange capacity of the montmorillonite in the standards (Wyoming bentonite) is the same as that of montmorillonite in the sample.

CORRELATION OF MONTMORILLONITE CONTENT AND VISCOSITY

Ten crude clays from the Huber, Georgia, area (15 miles south of Macon) were selected to provide extreme variations in location, overburden, and geological history. An additional sample (J) from Eastern Georgia was also included. Crude clays were dried and broken up. No washing or fractionation was performed in an effort to preserve the original composition. Samples were analyzed for montmorillonite content by the Hinckley-Bates technique. Properties of these clays are summarized in Table 1.

TABLE 1.—PHYSICAL PROPERTIES OF CLAYS

Code	Particle size, % < 2 μ	Surface area, m ² /g	Minimum viscosity at 50% solids		Montmorillonite, %
			Brookfield, 20 RPM, CPS	Hercules, dyne-cm $\times 10^5$	
68-50 B	65.5	15.2	61,800	16.2	16.8
F	58.4	22.8	400	2.4	8.1
C	73.0	23.4	770	2.1	7.1
E	52.0	22.4	156	1.8	6.4
D	61.3	20.8	31	0.7	5.7
H	64.2	20.0	28	0.5	4.3
I	65.2	18.8	16	0.3	2.9
J	83.5	21.6	20	0.3	2.2
K	59.2	11.3	15	0.2	1.0
A	50.8	9.8	15	0.3	0.65
G	65.8	10.9	13	0.3	0.65

When Brookfield viscosity at 50% solids (Fig. 1) is plotted against montmorillonite content, a sharp break in the curve is obtained when montmorillonite content exceeds 5%. Above 5% montmorillonite, viscosity of kaolin is extremely sensitive to variations in montmorillonite content and this relationship is nearly linear to 10% montmorillonite. Below 5% montmorillonite, Brookfield viscosity measured at 50% solids is very low and not sensitive to variations in montmorillonite content. In this low viscosity range other kaolin parameters such as particle shape, presence and amount of soluble salts or organic matter, and processing variables override effects due to montmorillonite content. The 5% montmorillonite level thus clearly delineates low-viscosity from high-viscosity kaolin. This classification is of great practical significance as only those clays having viscosities corresponding to 0-5% montmorillonite are suitable for paper-coating applications. Results obtained by a high-shear, Hercules viscometer (Fig. 2) at 50% solids corroborate results obtained with a low shear Brookfield viscometer.

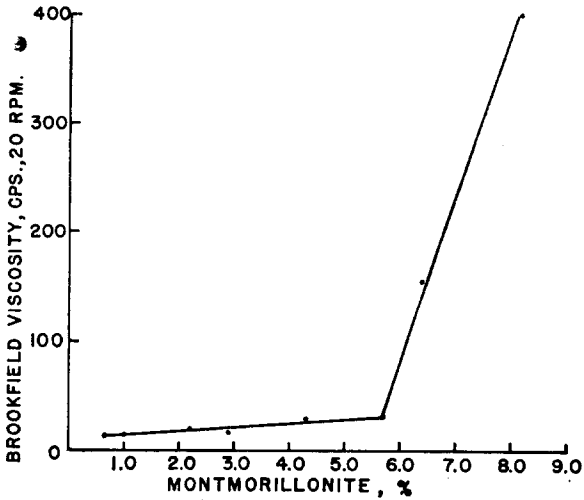


FIG. 1. Effect of montmorillonite on Brookfield viscosity of kaolin-water suspensions 50% solids.

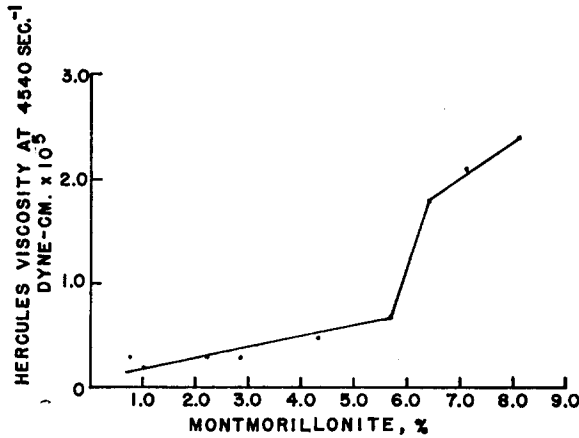


FIG. 2. Effect of montmorillonite on Hercules viscosity of kaolin-water suspensions 50% solids.

LACK OF CORRELATION OF MONTMORILLONITE CONTENT WITH PARTICLE SIZE OF KAOLIN

To insure that the observed effect of montmorillonite content on viscosity was not significantly affected by variations in the particle size of the kaolin samples, plots of montmorillonite content versus BET surface area (Fig. 3)

and montmorillonite content versus particle size (Fig. 4) were made. Correlation of surface area and particle size with montmorillonite content is weak—especially in the range between 5 and 10% montmorillonite. This range is precisely where viscosity is indicated to be most affected by montmorillonite content. Thus it is concluded that montmorillonite content, not particle size or surface area, is the controlling factor affecting viscosity.

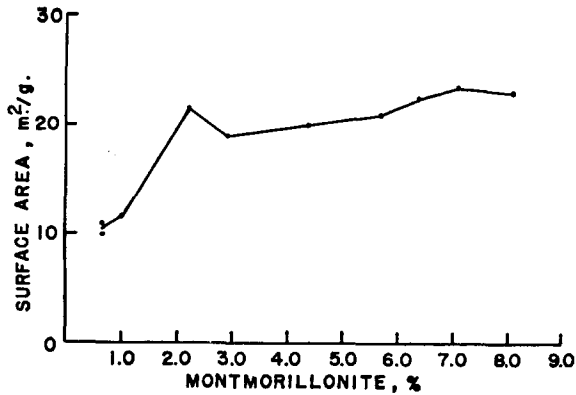


FIG. 3. Effect of montmorillonite on surface area of kaolin.

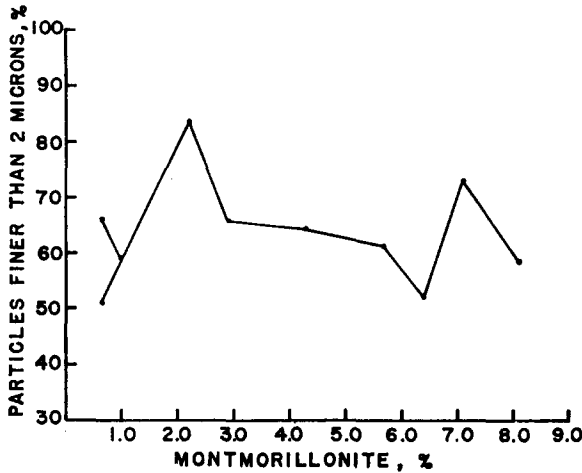


FIG. 4. Effect of montmorillonite on particle size of kaolin.

EFFECT OF ADDING CRUDE MONTMORILLONITE
TO KAOLIN

A strong relationship between viscosity and montmorillonite content was also found in the range of 0–5% montmorillonite, *provided* other clay parameters such as particle size, particle shape, and composition are held constant. This was demonstrated by adding small amounts of a crude montmorillonite to a low-viscosity kaolin and measuring viscosity at 70% total solids. Figure 5 shows variation of Brookfield viscosity with amount of added crude montmorillonite. The original kaolin sample contained about 1% montmorillonite. It can be seen that addition of 4% crude montmorillonite to this kaolin rapidly raised viscosity to the limit of the low-viscosity range. Since the total montmorillonite content of this clay was about 5%, this experiment confirmed that the line of demarcation between high- and low-viscosity clays occurs near the 5% montmorillonite content. The relationship shown in Fig. 5 also indicates that the maximum montmorillonite content for clays meeting *preferred* paper-coating specifications is about 3% montmorillonite. This value is supported from viscosity data of natural kaolin samples shown in Table 2.

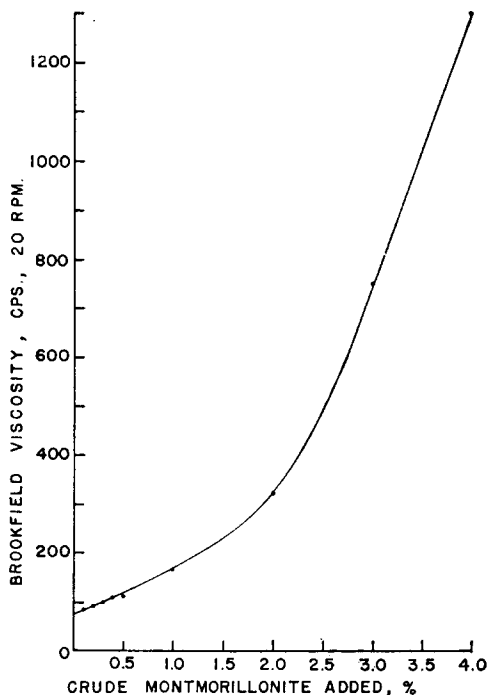


FIG. 5. Effect of montmorillonite additions on viscosity of clay-water suspensions 70% solids.

TABLE 2.—VISCOSITY OF 70% KAOLIN SLURRIES
VERSUS MONTMORILLONITE CONTENT

Code	Minimum Brookfield (70% solids)	Montmorillonite, %
H	3500	4.3
I	145	2.9
J	360	2.2
K	67	1.0
A	60	0.65
G	57	0.65

RELATION OF MONTMORILLONITE CONTENT
AND CALCIUM CONTENT

As a further test of the validity of the Hinckley-Bates technique for determining montmorillonite, the values obtained were compared with calcium content of these clays as determined by X-ray fluorescence analysis. Fair agreement was obtained in correlating montmorillonite content with CaO content according to the relationship, % montmorillonite = $(44.5 \times \% \text{CaO})$.

SUMMARY

It was found that viscosity of kaolin-water systems is closely related to montmorillonite content of certain Central Georgia kaolins.

A clear line of demarcation occurs between low- and high-viscosity clays at a montmorillonite content of 5%.

In the range of 5-10% montmorillonite, montmorillonite content is the dominant factor controlling viscosity and there is a good quantitative correlation between montmorillonite content and minimum Brookfield viscosity measured at 50% solids.

Below 5% montmorillonite, the relation between viscosity and montmorillonite content of natural kaolins is masked by variations in other kaolin parameters.

A relation between viscosity and montmorillonite content can be clearly shown when montmorillonite content is the only variable and viscosity is measured in a high-solids suspension of a clay having 1-5% montmorillonite.

For a given low-viscosity kaolin, Brookfield viscosity at 70% solids bears a direct relationship to amount of montmorillonite added.

In most cases, low-viscosity kaolin meeting the standard viscosity specifications (measured at 70%) for coating clays has a montmorillonite content below 3.0%.

These conclusions are based on a limited study of Central Georgia kaolin and depend on the assumptions implicit in use of Hinckley-Bates method of determining montmorillonite content of a kaolin.

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