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NOTE

# DENSITY AND COMPRESSIBILITY OF WYOMING BENTONITE PARTICLES

**Key Words**—Bentonite, Compressibility, Density, Smectite, Sonic velocity.

Clay mineral densities measured under a variety of conditions provide useful information about chemical and physical properties, because these measurements can be compared with calculated densities based upon crystal structure and chemical models. For example, many clay minerals, especially smectites, contain water molecules that although labile appear to be essential to their crystal structure (Grim, 1968). How this structural water affects the density of smectite is illustrated by average densities of anhydrous bentonite and bentonite containing 4 molecules of structural water per $O_{20}(OH)_4(0.66\ Na)$ calculated by Weaver and Pollard (1973) from the structural formulae for 11 different Wyoming bentonites (actually nine different samples and two color variations). The mean calculated densities from unit-cell dimensions of 5.31 × 9.2 × 9.9 Å and 5.31 × 9.2 × 12.5 Å are, respectively, 2.56 and 2.22 g/cm³. Conversely, measured densities provide information on the number of interlayer molecules present in the mineral (de Wit and Arens, 1950).

The equation (Urick, 1947):

$$V^2 = 1/[FwBw + Sum(FcBc_i)] \cdot [FwRw + Sum(Fc_iRc_i)], \quad (1)$$

where V = the acoustic velocity in a suspension described by the denominator, Fw = volume fraction of water, Fc = the volume fraction of each of the minerals i, Rw = the density of water, Rc = the density of each mineral i, Bw = the compressibility of water, and Bc = the compressibility of each mineral i, provides the basis for an experimental technique for determining the density and compressibility of clay particles. Urick (1947) measured the sonic velocities of an aqueous suspension of pure kaolinite; however, instead of determining the density of kaolinite in the suspension from the sonic velocity, he used the dry density of the clay to calculate volume fractions of his suspensions. He was primarily interested in the shape of the curve of the plot of velocity vs. volume fraction and the value of the kaolinite compressibility $10^{-12}$ cm²/dyne.

The present paper reports results of the determination of the density and compressibility of bentonite particles in aqueous suspension.

## METHODOLOGY

If the sonic velocity of clay-water suspensions is measured at constant temperature and pressure over a range of volume fractions of clay, the density and compressibility of the clay particles can be determined from a nonlinear least-squares fit of the data to Eq. (1). Clay-water suspensions were prepared from pulverized "Western Bentonite" from American Colloid, Skokie, Illinois, dried at 130°C for several days. The volume fraction of inpurities in the clay sample was assumed to be too small to warrant their separation. The volume fraction at which this clay gels in distilled water limited the upper Fc value to about 0.019.

The initial sample was prepared by suspending about 70 g of dried clay in a volumetric flask with distilled water to a total volume of 1000 ml; e.g., in the first sample, the amount of water was measured by titrating 981 ml from a buret giving Fw = .981 and Fc = .019. Each succeeding sample was prepared by titrating about 850 ml of the preceding sample with distilled water to 1000 ml in a volumetric flask. Six samples with a range of clay volume fractions from .019 to .007 were prepared in this manner (Table 1).

The sonic velocities were measured with a model 2007H seismic analyzer manufactured by Structural Behavior Engineering Laboratories, Inc. (SBEL) and two SBEL 200 kHz transducers. The sonic velocities of each clay-water suspension were calculated from time-of-flight measurements in two length-calibrated Pyrex glass cylinders sealed at each end with cylindrical glass plates, each about 3.5 mm thick. The travel time constant for the transducers and two glass plates was 8.0 μs. The lengths of the glass cylinders determined from the sonic velocities of distilled water were 0.3623 ± 0.0005 m and 0.3636 ± 0.0005 m at 27.9 ± 0.2°C and 27.8 ± 0.2°C, respectively, where the values are ± one standard deviation. The values for the sonic velocity of distilled water were calculated with the Greenspan and Tschiegg (1957) polynomial as modified by Lovett (1969).

## RESULTS AND CONCLUSION

The experimental data and calculated velocities are listed in Table 1. The density of the bentonite particles calculated from these data is 2.457 ± 4 × $10^{-7}$ g/cm³ and the compressibility is 0.12 × $10^{-12}$ ± 2 × $10^{-20}$ cm²/dyne. The ± values are asymptotic standard errors. These data indicate that the number of interlayer water molecules tightly bonded to bentonite in dilute suspension is fewer than 4 per unit cell.





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Table 1. Sonic velocity measurements for bentonite.[1]

| Observation | Temp. (°C) | Time (μs) | Fw | Length (m) | V (cm/s) | Vcal (cm/s) | Vcal − V (cm/s) |
|---|---|---|---|---|---|---|---|
| 1 | 22.60 | 244.42 | .981 | 0.3636 | 148,760 | 148,381 | −379.8 |
| 2 | 22.60 | 244.75 | .981 | 0.3636 | 148,560 | 148,381 | −179.2 |
| 3 | 22.60 | 244.15 | .981 | 0.3623 | 148,392 | 148,381 | −11.8 |
| 4 | 22.80 | 244.20 | .981 | 0.3623 | 148,362 | 148,437 | 75.2 |
| 5 | 22.90 | 242.75 | .985 | 0.3636 | 149,784 | 148,588 | −1195.7 |
| 6 | 22.90 | 242.75 | .985 | 0.3636 | 149,784 | 148,588 | −1195.7 |
| 7 | 22.90 | 244.05 | .985 | 0.3623 | 148,453 | 148,588 | 134.9 |
| 8 | 23.10 | 244.10 | .985 | 0.3623 | 148,423 | 148,644 | 221.5 |
| 9 | 22.05 | 245.30 | .985 | 0.3623 | 147,697 | 148,346 | 648.8 |
| 10 | 22.30 | 244.95 | .987 | 0.3636 | 148,438 | 148,480 | 41.6 |
| 11 | 22.40 | 244.95 | .987 | 0.3636 | 148,438 | 148,509 | 70.3 |
| 12 | 22.60 | 244.70 | .987 | 0.3623 | 148,059 | 148,566 | 506.9 |
| 13 | 22.00 | 245.05 | .987 | 0.3623 | 147,847 | 148,394 | 546.2 |
| 14 | 22.00 | 245.25 | .989 | 0.3636 | 148,257 | 148,457 | 200.2 |
| 15 | 22.05 | 245.50 | .989 | 0.3636 | 148,106 | 148,472 | 365.7 |
| 16 | 22.10 | 245.00 | .989 | 0.3623 | 147,878 | 148,486 | 608.5 |
| 17 | 22.20 | 244.75 | .989 | 0.3623 | 148,029 | 148,515 | 486.3 |
| 18 | 21.90 | 244.95 | .989 | 0.3623 | 147,908 | 148,428 | 520.4 |
| 19 | 22.00 | 243.15 | .989 | 0.3623 | 149,003 | 148,457 | −545.6 |
| 20 | 22.00 | 244.35 | .991 | 0.3636 | 148,803 | 148,522 | −281.4 |
| 21 | 22.60 | 244.30 | .991 | 0.3636 | 148,833 | 148,694 | −139.4 |
| 22 | 22.60 | 244.35 | .991 | 0.3636 | 148,803 | 148,694 | −109.0 |
| 23 | 22.75 | 243.85 | .991 | 0.3623 | 148,575 | 148,737 | 161.7 |
| 24 | 22.70 | 243.95 | .991 | 0.3623 | 148,514 | 148,722 | 208.4 |
| 25 | 22.75 | 243.75 | .991 | 0.3623 | 148,636 | 148,737 | 100.7 |
| 26 | 22.80 | 243.95 | .991 | 0.3623 | 148,514 | 148,751 | 236.8 |
| 27 | 22.90 | 243.60 | .993 | 0.3636 | 149,261 | 148,845 | −416.4 |
| 28 | 22.90 | 243.60 | .993 | 0.3636 | 149,261 | 148,845 | −416.4 |

[1] Fw = Water volume fraction; length = cylinder length; V = sonic velocity; Vcal − Sonic velocity, Eq. (1).

Future sonic velocity experiments should be conducted with a sonic interferometer instead of time-of-flight columns. The interferometer requires a smaller sample, and the temperature of the sample can be controlled more precisely by submerging the apparatus in a water bath.

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