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NON-DESTRUCTIVE WET WEIGHING OF MARINE SEDIMENTS

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SUMMARY

A rapid Archemedian technique is presented for determining the weight of a marine sediment sample which: (*1*) maintains to a greater degree during treatment the natural marine sedimentary environment; and (*2*) eliminates the ambiguities produced by conventional washing, deflocculating, and drying of a marine sample.

The weight of the mineral solids in the sample is determined from the density of the mineral solids and the density and volume of a mixture of solids and interstitial water measured with: (*a*) a tared top loading analytical balance; (*b*) graduated cylinder; and (*c*) sea water with a known density determined by the formula:

$$w_s = \frac{w_{mix}\,\rho_s}{\rho_s - \rho_{sw}}\left(1 - \frac{\rho_{sw}}{\rho_{mix}}\right)$$

INTRODUCTION

Standard laboratory techniques used in the analyses of size parameters in the silt and finer fractions of recent marine sediments such as: (*1*) washing the sample in distilled water to remove salt; (*2*) dispersing the sample with a deflocculant (KRUMBEIN and PETTIJOHN, 1938, pp.56–75); and (*3*) weighing an air dried sample produce misleading results and render the sample useless for many other analytical techniques. The above mentioned techniques are adequate for the investigations of terrestrial sediments in fresh water where the natural aqueous environment has a low ionic strength and the clay particles are naturally dispersed.

For recent marine sediments this, obviously, is not the case. The natural aqueous environment for marine sediments is sea water with a relatively high ionic strength in which clay particles are flocculated rather than dispersed. Knowledge of the size distribution of the individual clay platlets, of course, is of great interest. However, it is misleading to say that the dispersed distribution is the natural size distribution or to determine or conjecture hydraulic properties of the marine sediment from a dispersed size distribution. In particular:

(*1*) Prolonged washing in fresh or distilled water of a marine sample will modify the ion exchange capacity of the clays and also tend to disperse the clays.

(*2*) Addition of a deflocculant destroys the natural marine floccule composed of clay platlets.

(*3*) Finally, drying the sample also destroys the natural size distribution of the marine floccules as PETELIN and ALEKSINA (1961) have shown that continued resuspension and drying will give non-reproducible grain-size distribution curves. Thus, either washing with distilled water, adding deflocculant, or air drying a marine sediment modifies or destroys the natural grain-size distribution of the marine sediment.

The following procedure illustrates a method by which marine sediment samples can be separated initially for sedimentological or paleontological purposes without destroying any of the fundamental natural properties of the fine silt and clay fractions.

The following methods require only: (*1*) a tared top loading analytical balance; (*2*) relatively large volume graduates (polycarbonate is preferred as this material produces an easily read flat meniscus); and (*3*) sea water, in addition to a set of sieves.

PROCEDURES

The following steps were carried out:

(*a*) Wash sample with sea water through appropriate size sieves to separate the sand fractions from the finer fractions. The sand and coarser fractions caught on the sieves can be treated by standard size-grading methods as, in general, this fraction is composed of mineral grains whose properties, such as grain-size and exchange capacities, are not modified significantly by washing with fresh water or repeated drying.

(*b*) Retain the sea water wash water, which contains the fine fractions. For convenience the sample should be washed into a large polycarbonate graduate (1 l is usually adequate) whose dry weight is known, to eliminate repeated transfer of wash water and sediment from vessel to vessel. Allow the clays to flocculate and decant off excess water as needed.

(*c*) Determine the weight and thus the density of a known volume of the sea water used in the washing in a graduate on an analytical balance with the weight of the tared graduate by the formula:

$$\text{density } (\rho_{sw}) = \frac{\text{weight of sea water } (w_{sw})}{\text{volume of sea water } (v_{sw}) \cdot \text{g}}$$

(*d*) Place graduate with wash water and flocculated clays on tared analytical balance. Read total weight of water plus sediment (w_t).

(*e*) Determine the volume of clear sea water (v_{sw}) and volume of flocculate (v_{mix}) by reading interface levels on the graduate.

(*f*) Calculate weight of sea water by the formula:

$$w_{sw} = \rho_{sw}(c) \cdot g v_{sw}(e)$$

(*g*) Calculate weight of sediment which is a mixture of mineral grains and interstitial water by the formula:

$$w_{mix} = w_t(d) - w_{sw}(f)$$

(*h*) Calculate density of flocculate by the formula:

$$\rho_{mix} = \frac{w_{mix}}{g v_{mix}}$$

The weight and density of the flocculate, however, is not that of the mineral grains as the volume of the flocculate contains interstitial seawater or:

$$w_{mix} = w_{solids} + w_{interstitial\ sea\ water}$$

$$\rho_{mix} v_{mix} = \rho_s v_s + \rho_{sw} v_{isw}$$

as:

$$v_{mix} = v_s + v_{isw}$$

then:

$$\frac{v_s}{v_{mix}} = \frac{\rho_{mix} - \rho_{sw}}{\rho_s - \rho_{sw}} \tag{1}$$

and:

$$\frac{w_s}{w_{mix}} = \frac{\rho_s}{\rho_s - \rho_{sw}} \left(1 - \frac{\rho_{sw}}{\rho_{mix}}\right) \tag{2}$$

Derivations of eq.1 and eq.2 are given in Appendix I.

From the above procedure $\rho_{sw}(c)$, $v_{mix}(e)$, $w_{mix}(g)$ and $\rho_{mix}(h)$ are known.

ρ_s can be determined pycnometrically (HURLBUT, 1959, p.160) by drying a portion of the sample, as density is an intensive variable, without sacrificing the rest of the sample. ρ_s is an average density so that its value should not vary greatly except with obvious changes in lithology and mineralogy, e.g., from red clay to foraminiferal ooze. For a particular mineralogical province use of a graphic solution of eq.2 as shown in Fig.1 is the simplest way to solve for w_s. Spot determinations of ρ_s by the drying method assure that the particular graph gives the appropriate solution for w_s as all the other parameters are fixed by the procedure.

Thus, the weight in air of a marine sediment sample is given by the sum of: (*1*) the weight of the sieved material; and (*2*) the weight of the passed material as determined by the above non-destructive technique.

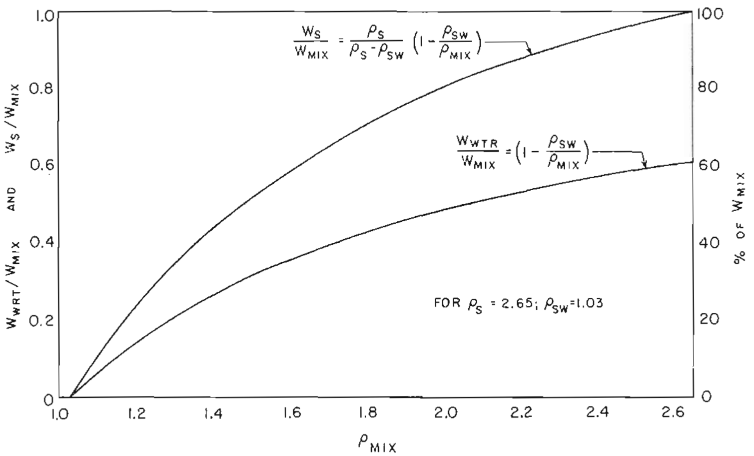

Fig.1. Graphic solutions for $\frac{\text{weight in air of mineral solids}}{\text{weight of mixture}} = \frac{w_s}{w_{mix}}$ and $\frac{\text{weight in sea water of mineral solids}}{\text{weight of mixture}} = \frac{w_{wtr}}{w_{mix}}$ for $\rho_s = 2.65$ and $\rho_{sw} = 1.03$, given, and ρ_{mix} determined by described procedure.

The weight in water of the mineral solid can be determined, if needed, in a similar way by:

(*1*) Calculating the ratio of the buoyant force (F) to the weight of the mixture:

$$\frac{F}{w_{mix}} = \frac{\rho_{sw}}{\rho_s - \rho_{sw}}\left(1 - \frac{\rho_{sw}}{\rho_{mix}}\right) \tag{3}$$

(*2*) Substracting eq.3 from eq.2 gives eq.4:

$$\frac{\text{weight in water}}{\text{weight mixture}} = \frac{\text{weight in air}}{\text{weight mixture}} - \frac{F}{w_{mix}}$$

$$\frac{w_{wtr}}{w_{mix}} = 1 - \frac{\rho_{sw}}{\rho_{mix}} \tag{4}$$

See Appendix I for derivation of eq.4.

Fig.1 gives an example of the graphic solution of eq.2 (weight in air) and eq.4 (weight in water) as a ratio or percentage of the calculated weight of the mixture (g) for $\rho_s = 2.65$ and $\rho_{sw} = 1.03$.

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APPENDIX I

Derivations of equations 1–4, mentioned in text

Given:

$$\rho_{mix} v_{mix} = \rho_s v_s + \rho_{sw} v_{isw}$$

$$v_{mix} = v_s + v_{isw}$$

then:

$$v_{isw} = v_{mix} - v_s$$

$$\rho_{mix} v_{mix} = \rho_s v_s + \rho_{sw} (v_{mix} - v_s)$$

$$\rho_{mix} v_{mix} = v_s (\rho_s - \rho_{sw}) + v_{mix} \rho_{sw}$$

$$\rho_{mix} = \frac{v_s}{v_{mix}} (\rho_s - \rho_{sw}) + \rho_{sw}$$

$$\frac{v_s}{v_{mix}} = \frac{\rho_{mix} - \rho_{sw}}{\rho_s - \rho_{sw}} \tag{1}$$

$$\frac{w_s}{w_{mix}} = \frac{\rho_s v_s}{\rho_{mix} v_{mix}}$$

$$= \frac{\rho_s}{\rho_{mix}} \left(\frac{\rho_{mix} - \rho_{sw}}{\rho_s - \rho_{sw}} \right)$$

$$= \frac{\rho_s}{\rho_s - \rho_{sw}} \left(1 - \frac{\rho_{sw}}{\rho_{mix}} \right) \tag{2}$$

$$F = \rho_{sw} v_s \, g$$

$$\frac{F}{w_{mix}} = \frac{\rho_{sw} v_s}{\rho_{mix} v_{mix}}$$

$$= \frac{\rho_{sw}}{\rho_{mix}} \left(\frac{\rho_{mix} - \rho_{sw}}{\rho_s - \rho_{sw}} \right)$$

$$= \frac{\rho_{sw}}{\rho_s - \rho_{sw}} \left(1 - \frac{\rho_{sw}}{\rho_{mix}} \right) \tag{3}$$

$$\frac{W_{wtr}}{W_{mix}} = \frac{W_s}{W_{mix}} - \frac{F}{W_{mix}}$$

$$= \frac{\rho_s}{\rho_s - \rho_{sw}}\left(1 - \frac{\rho_{sw}}{\rho_{mix}}\right) - \frac{\rho_{sw}}{\rho_s - \rho_{sw}}\left(1 - \frac{\rho_{sw}}{\rho_{mix}}\right)$$

$$= 1 - \frac{\rho_{sw}}{\rho_{mix}} \tag{4}$$