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EDITORIAL

Red Flags on the Beach, Part III

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ABSTRACT

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In former works TANNER (1998) discussed seven red flags, and BALSILLIE and TANNER (2000) listed an additional six red flags, where by "red flags" it was meant common uncertainties or errors in coastal applications. Though the list is still by no means complete, an additional seven items are discussed here. They are:

(14) Granulometric statistics—an evaluation problem.
(15) Graphic measures versus moment measures.
(16) The mean equals the median?
(17) Composite versus suite statistics.
(18) Sieving versus settling.
(19) Particle size classification scales.
(20) Carbonate granulometry.

INTRODUCTION

This is the third in a series of "red flag" articles dealing with problems inherent in coastal science and engineering applications. The items discussed here all concern sedimentology. Although they are tailored to coastal concerns, they also apply to sedimentology in general. These items are presented in order to punctuate the need to compile a set of littoral sedimentology standards.

GRANULOMETRIC STATISTICS—AN EVALUATION PROBLEM

During the past decade and-a-half, the Florida Geological Survey (FGS) has been involved in granulometric analyses of offshore sediments in cooperation with the U. S. Minerals Management Service. Following is a list of the steps involved in the typical analysis of sediment samples: (1) field sampling, (2) sample preparation for laboratory analysis, (3) laboratory analyses and reporting results, (4) statistical/numerical analyses, (5) interpretation of results, and (6) written report. Steps 3 and 4 comprise the areas of interest in this item.

During 2001 the FGS agreed to provide deliverables (HOENSTINE *et al.,* 2001a, 2001b) to a subcontractor of the U. S. Minerals Management Service using non-standardized analytical procedures. Specifically, statistically determined moment measures were required to be calculated using the retaining sieve size, rather than the sieve interval midpoint size. Ostensible justification to do so is that it is required by ASTM D422-63 (AMERICAN SOCIETY FOR TESTING AND MATERIALS, 2000a) which uses the retaining sieve. It is to be understood that ASTM D422-63 solely addresses data measurement and reporting of sieved data weights. One should, in fact, report sieved data weights for each retaining sieve (step three above). However, ASTM D422-63 does not address the next analytical step—the calculation of descriptive statistics. ASTM E1488-96 (AMERICAN SOCIETY FOR TESTING AND MATERIALS, 2000b) is the "standard guide" for statistical procedures, providing guidelines for specifying statistical procedures for those ASTM standards that do not address statistical application procedures. This has been accomplished and addressed here in abbreviated form.

Numerical information can be collected as either unclassified (or non-grouped) data, or as classified (or grouped) data. Sieved sediments result in classified data (*e.g.,* LINDHOLM, 1987, p. 17) because they are obtained by using sieves normally spaced at ¼-phi intervals, rather than measuring the exact size of each grain in the sample. Resulting data are statistically treated using standard statistical procedures (*e.g.,* REMINGTON and SCHORK, 1970, p. 44; FOGIEL, 1978, p. 54), geological procedures (*e.g.,* KOCH and LINK, 1971. p. 30), and granulometric procedures (*e.g.,* LINDHOLM, 1987, pp. 168–169; MCBRIDE, 1971, pp. 118–120; SENGUPTA, 1994, pp. 30–31; BOGGS, 1995, pp. 90–91; BALSILLIE, 1995, pp. 84–85; MCLANE, 1995, pp. 168–169). Basic to these procedures are the calculation of moment measures (*e.g.,* mean, standard deviation, skewness, kurtosis) which uses the midpoint size value of any two adjacent sieves, termed the **midpoint deviation** standard (MCLANE, 1995, p. 168).

Use of the retaining sieve rather than the sieve interval midpoint introduces significant error to resulting descriptive statistics. For 211 samples (HOENSTINE *et al.,* 2001a), it was found that using the retaining sieve rather than the sieve interval midpoint resulted in means that are finer by 13% (r = 0.9954; r is the correlation coefficient), standard deviations are 27% larger (r = 0.9814), skewness values are 26% larger (r = 0.9176), and kurtosis values are 29% larger. Suppose that these data are used in the design of a beach restoration project. It should be apparent that impact of these results could either not allow the project to proceed, or seriously affect project design, effectiveness, and economics.

One often finds in the literature, that ASTM standards are generically referenced in text. This is frustrating given the number of ASTM standards that have been published. These standards should be referenced as one would reference a journal article (*e.g.,* as has been done in this work).

GRAPHIC VERSUS MOMENT MEASURES

Understanding of graphic and moment measures requires some background information. Statistical measures such as the mean, standard deviation, skewness, and kurtosis are calculated precisely using the method of moments (*e.g.,* FOGIEL, 1978). However, this method requires significant computational resources that were not available during the majority of the preceding century. This resulted, therefore, in the invention of abbreviated, surrogate predicting equations that could be expediently evaluated to provide approximations (called graphic measures, *e.g.,* FOLK, 1974) since data are estimated from cumulative frequency plots of sand sample data. By the mid-1980's computers had become common in the work place, and by the mid-1990's to the public-at-large. Most researchers have taken advantage of the available computing power and have employed the method of moments. Some practitioners, however, persist in using graphic measures. For 211 sediment samples, BALSILLIE *et al.* (2002) found that the means generally have approximate agreement, although graphic means underestimate the moment means by 0.6ϕ. All higher measures, however, are not successful in replicating moment measures, the degree of disagreement progressively increasing with order of the moment measure. Standard deviation measures had a correlation of r = 0.8054, for the skewness r = 0.2841, and for the kurtosis r = 0.0990. Moreover, ratios of graphic to moment measures became increasingly degraded as the degree of moment measures increased. We concluded, therefore, that graphic measures are not good approximations to moment measures, and that their use should be discontinued.

THE MEAN EQUALS THE MEDIAN?

The mean, μ, is a straightforward calculation given by $\mu = (\Sigma x)/n$ where x represents the data values and n is the sample size. The median, on the other hand, is the data value corresponding to the 50^{th} percentile of the cumulative probability distribution, that is, the value of x where 50% of the values are larger and 50% are smaller.

Where the cumulative probability distribution is perfectly Gaussian, the mean and median will be precisely equivalent. However, very few natural sand samples are perfectly Gaussian. Nor would we wish them to be, since the deviation from the Gaussian can be interpreted to explain their transpodepositional history (BALSILLIE, 1995: BALSILLIE and TANNER (1999). Hence, except for very few sediment samples mean and median values are not equivalent.

COMPOSITE VERSUS SUITE STATISTICS

Multiple sediment samples are, without exception, preferable to single sample results. For multiple samples, ***suite*** and ***composite*** statistics constitute two valid approaches producing statistical descriptive measures (BALSILLIE and TANNER, 1999).

Suite statistics are realized by, first, assessing descriptive moment measures (*i.e.,* mean, standard deviation, skewness, kurtosis, *etc.*) for each sample, then determining the moment measures for each of the original measures. Hence, for the mean one has the mean of the means, standard deviation of the means, skewness of the means, kurtosis of the means, *etc.*; for the standard deviation one has the mean of the standard deviations, standard deviation of the standard deviations, skewness of the standard deviations, kurtosis of the standard deviations, *etc.*; continuing with the same statistics for higher moment measures.

Composite statistics could, conceivably, be determined by taking multiple samples and combining them by physical mixing in a container. This would not, however, produce a reasonable result. We would not wish the outcome to be a perfectly random mixture thereby producing a Gaussian distribution, since only very few natural sediment samples, themselves, are perfectly Gaussian. In fact, it is the departure from the Gaussian that provides us with valuable information about the samples. What we wish to have is a ***suitable*** mixture. Moreover, the physically mixed sample would be too large for sieving and would require splitting into smaller samples, each split introducing error. There is, however, a numerical solution for producing a precise composite sample. Numerically, multiple sample cumulative probabilities for each sieved screen interval, when averaged, provide the input data for composite moment measure computations.

Resulting statistics from the suite and composite methods, with one exception, result in different outcomes (BALSILLIE and TANNER, 1999). Suite and composite means (first moment measures) are always equivalent. Composite standard deviations (second moment measures) are ***always*** larger than suite standard deviations (KRUMBEIN, 1957). Very seldom are they equivalent for higher moment measures (*e.g.,* skewness, kurtosis), and normally yield significantly different outcomes.

It is, again, emphasized that both suite and composite statistics result in valid results. However, results from the two methods may be required in certain applications. For instance, composite statistics are required in the design of beach restoration and renourishment projects. However, it has been the experience of the author that a large percentage of practitioners who calculate input statistics for beach design work, will calculate suite and not composite statistics. The result is to either disallow the project or to adversely affect project economics.

SIEVING VERSUS SETTLING

Size analysis using settling tubes is a technique whereby sediment is introduced at the top of a still column of water. Using the time that it takes for the particles to reach the base of the water column (pressure difference or an accumulating balance at the base of the water column), particle size is determined using a calibrated theoretical numerical relationship. Settling tubes have gained popularity because of the rapidity with which analyses can be conducted; hence, they are often referred to as Rapid Sediment Analyzers (RSA's). There are, however, acknowledged problems with RSA's. Some of these (HOBSON, 1977) are: methods of sediment introduction, side-wall drag interference, varied particle shapes and densities, grain-to-grain interference, small sample size which, often requires multiple splits, *etc.* RSA's normally only use one gram or less of sediment; sieving uses from 40 to 60 grams. Hence, the latter should provide more confident results. Sieves are standardized, whereas RSA's are not calibrated from laboratory to laboratory. The most serious defect of RSA's, perhaps, involves the production of von Karman vortex trails as identified by W. F. Tanner (personal communications; BALSILLIE, 1995).

For an automobile or boat wake the von Karman effect is two-dimensional. In auto racing it is known as the tail-gating effect. For a sediment grain falling through a water column, it is a three-dimensional effect. Each vortex kicks off at different times, and are spaced at less than 120 degrees (from about 106 to 108 degrees apart) about the grain causing the entire grain-vortex system to spiral as it settles. Vortex affects extend two to three times the grain diameter. Results are: 1) larger grains entrain smaller grains thereby increasing the fall velocity of the smaller grains and the smaller grains appear larger than they actually are, 2) at the same time the entrained smaller grains slow the settling velocity of the larger grains, making the larger grains appear to be smaller than they actually are. The net result is that RSA techniques compress the real distribution.

Lack of agreement between sieved results and those from RSA's has been addressed by JONES and CAMERON (1976) using 26 littoral sand samples; COLEMAN and ENTSMINGER (1977) using 33 littoral sediment samples; BERGMANN (1982, 1983) using 30 littoral, 10 eolian, and 20 fluvial sand samples; and by DE LANGE *et al.* (1997) using 280 littoral and 245 eolian sediment samples. General works discussing the issue include BALSILLIE (1995) and TANNER (1997).

DE LANGE *et al.* (1997) analyzed the largest number of sand samples of any known study. Unfortunately, they used graphic measures rather than moment measures (see earlier section on graphic versus moment measures). Perhaps, then, the most compelling results are those of BERGMANN (1982), who performed a straightforward empirical analysis. He retained sieved ¼-phi fractions, then for each fraction determined from size measurements of 50 grains under a binocular microscope whether or not the grains belonged in that ¼-phi interval. Some uncertainties occurred at the tails of the samples and, including these, he found that at least 91% of the grains were in the correct ¼-phi interval. He concluded, therefore, that sieves correctly measure grain size.

Please note that the preceding discussion pertains only to sand-sized and larger sediment particles. For silts and clays, RSA's, among other methods, can be recommended for use.

PARTICLE SIZE CLASSIFICATION SCALES

As most of us are aware, it is not uncommon for coastal geologists and coastal engineers to disagree. The upside to this arrangement is that it more nearly assures a "system" of checks and balances. One such issue concerns descriptive size classifications for boulder, pebble, sand, silt, clay, *etc.* particle size, of which there are more than several. In the U. S., for instance, coastal geologists prefer the Wentworth scale for classifying sediment grain sizes, engineers more often prefer the Unified Soils Classification scale (see U. S. ARMY, 1984, p. 4–13). The two scales are different.

One should also understand that the sedimentology community now uses the phi size scale (KRUMBEIN, 1934, 1936, 1964) as adopted by the Society of Economic Paleontologists and Mineralogists (S.E.P.M.) *Intersociety Grain Size Study Committee* in 1963 for reasons specified by TANNER (1969). The intersociety approach included both geologists and engineers. In beach work, for instance, the phi scale is almost exclusively used (KRUMBEIN, 1957; KRUMBEIN and JAMES, 1965; JAMES, 1974, 1975; HOBSON, 1977; U. S. ARMY, 1984).

Finally, one should understand that the phi scale is based on the Wentworth scale (KRUMBEIN, 1936, p. 43; MCMANUS, 1963, p. 671). While differences between scales is not critical, it nevertheless needs to be recognized that when using the phi size scale, the Wentworth scale is, by definition, the proper classification to be used.

CARBONATE GRANULOMETRY

In general, except for beaches of the northwest panhandle Gulf Coast of Florida, Florida beaches are comprised of a mixture of siliciclastic and carbonate sediments. Generally, carbonate content increases from north to south along Florida's peninsular east and west coasts. Offshore sediments for Florida all, however, have varying carbonate content. Moreover, investigations of carbonate granulometry have generally not been conducted with frequency.

It is recommended here that, first, the total sample be sieved. Next, remove the carbonate material using hydrochloric acid and sieve the remaining sediment. Now, by subtracting from the total sample (siliclastic and carbonate) the siliclastic sample, the carbonate distribution is achieved. Hence, for two sieving applications per sample, three distributions are produced.

The procedure is fairly straightforward with several exceptions. The first is that the carbonate material is more friable than quartz; it can and does break-up during sieving producing finer carbonate material and carbonate "dust". The second is that treatment with HCl can release quartz inclusions contained in the carbonate material. These occurrences generally do not pose a problem because they can be considered to be randomly distributed across the sieves and percentages do not significantly affect ¼-phi intervals (see BALSILLIE *et al.,* 1999). However, it can significantly affect the sample if "dust" or released quartz inclusions result in a relatively large pan fraction (*i.e.,* grains smaller than four phi). The problem is solved using the following procedure.

First, for samples containing appreciable quantities of carbonate material (say greater than 10%) wet sieve the total sample using the four phi sieve. Material passing the four phi sieve then becomes the true pan fraction. Sieve as specified above the total sample and the siliclastic sample. However, for both do not include the sieved pan fraction that results as part of the distribution. It, in fact, is not part of the sample because it does not represent the original sample granulometry introduced to the sieves but, rather, carbonate "dust" due to grain attrition or from quartz or other inclusions. For each sample type, the total weight is all other sieve ¼-phi fractions plus the weight of the pan fraction obtained by the wet-sieving procedure.

CONCLUSION

The S.E.P.M. *Intersociety Grain Size Study Committee* of 1963 established certain needed sedimentologic standards. In the interim advances have been made, all of which appear in individual published works or in various treatments in general sedimentologic texts. Perhaps the most complete treatment of the subject remains with the work of CARVER (1971). With over 30 years of advances, there is a need to revisit the issue. The few items discussed above attest to some of the issues where improper procedures or applications have been used, testifying to the need for clear standards and/or protocols. Some of these are straightforward such as field sampling, sample size, sample preparation, splitting, sample components, *etc.* Others are more involved such as carbonate treatment, use of settling tubes, composite versus suite statistics, meaning of cumulative probability line segments, *etc.* In other cases, research is needed to reassess sieving times for siliclastic and carbonate fractions, sieving grain breakdown of carbonate shell, algal carbonate grains, *etc.*, determination of fine and coarse material percentages and how much is too much for beach restoration projects, thermal properties of bulk quantities of *insitu* sand, *etc.* While it is desirable to treat the entire sedimentologic field regarding standards, it is here suggested that at this time a comprehensive treatment of sedimentologic standards as they affect littoral sediments is to be viewed as a highly desirable goal.

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