Recent Sediments and Grain-Size Analysis

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RESUMO

Prosseguindo a divulgação de dados relativos à utilização de parâmetros estatísticos de tamanho de grão, apresentada por MARTINS et al. (1997), são indicados resultados obtidos através da análise de 5.295 amostras, correspondentes aos ambientes fluvial, praial e eólico.

O material coletado segundo a metodologia de série de 10 amostras por ponto amostrado foi analisado por peneiragem a intervalos de $\frac{1}{4}$ φ, cujos parâmetros estatísticos (média, desvio padrão, assimetria e curtose) foram calculados pelos métodos gráficos e de momentos. Foi possível obter, após cuidadoso trabalho de sedimentologia, a distinção de forma efetiva dos três mecanismos deposicionais em 96% do material estudado, com base no tamanho médio, no índice de seleção e na assimetria. Os aspectos morfológicos (esfericidade, arredondamento e textura superficial) foram utilizados em muitas situações para reforço das propriedades de tamanho.

Uma lista de 191 trabalhos relativos às propriedades de tamanho é fornecida ao final do texto.

ABSTRACT

Following the publication of data related with the use of grain-size statistical parameters by MARTINS et al. (1997), new results from 5,295 samples of fluvial, beach and dune environments are presented.

Material collected according to the methodology of "sand suite" was analysed through sieving of $\frac{1}{4}$ φ interval and interpreted by using statistical parameters (mean, standard deviation, skewness and kurtosis) calculated by graphic and moment methods. After careful sedimentological work, it was possible to distinguish the sands based on central tendency measures and skewness. Morphoscopic properties (sphericity, roundness and surface texture), were used sometimes to reinforce grain-size properties.

A list of 191 papers published about grain-size properties and environmental interpretation is also furnished.

Keywords: grain-size, modern environments, statistical parameters.
INTRODUCTION

From the 60’s to the 80’s, a large number of papers on statistical parameters of grain-size distributions of recent sedimentary environments, and the distinction between beach, dune and river sands were published, using graphic calculation method (FOLK and WARD, 1957) or calculated moment measures (FRIEDMAN, 1961).


At the same time, there is a uniform agreement that texture of sands and sandstones represents one of the most important parameter used in the lithofacies interpretation, and that grain-size data is an indispensable measure to develop this purpose.

A discussion by SYVITSKI (1991a) indicates that a great number of scientists have tried to discern patterns in particle size information so as to understand the modern geological environments, and, according to TANNER (1991a, b), grain-size distribution of sand contains much more information about transport and deposition, two important steps in the sedimentary cycle.


A detailed analysis of the accuracy and precision of modern particle size instruments, an important phase to successfully obtain representative curves and parameters, can be found in SYVITSKY et al. (1991). Also, regarding their application in several other geologic studies as stratigraphy and sea-level (TANNER, 1991b), glacial and periglacial sediments (STRAVERS et al., 1991), marine geochemistry (KRANK and MILLIGAN, 1991) and marine geotechnical studies (HEIN, 1991), they demonstrate the need for precise and accurate grain-size data from sedimentary samples.

A large number of methods and instruments as Sedigraph (McCave and JARVIS, 1973; VITURI and RABBITT, 1980; STEIN, 1985; JONES et al., 1988); Microtrac (COOPER et al., 1984); Coulter Counter (SHELDON and PARSON, 1967; McCave...
and JARVIS, 1973); Settling Tubes (ZEIGLER et al., 1960; SCHELEE, 1966; GIBBS, 1972, 1974; ZANEVVELD et al., 1982); Malvern Laser Sizer (MCCAVE et al., 1986); Image Analysis, Photo extinction, Elzone Systems (MARTINS, 1962b; MARTINS and MARTINS, 1978; MARTINS et al., 1994; TREWEEK and MORGAN, 1977; WEINER, 1979, 1984; HENDRIX and ORR, 1972; SIMMONS, 1959; JORDAN et al., 1971; SLATT and PRESS, 1976; FORMOSO and FIGUEIREDO, 1964) were developed (some in use in our Laboratories at CECO/UFRGS) in order to implement accuracy in the grain-size analysis. Details regarding the textural proprieties and methods were also published by McCAVE and SYITSKI (1991); SINGER et al. (1988); KENNEDY and MAZULO (1991); MILLIGAN and KRANK (1991); CLOAKEY and SYVITSKI (1991b); TIANRUI (1991); BARTH (1984); LEWIS and CONCHIE (1994a, b); MIZUTANI (1963); MUERDTER et al. (1981); RIVIERE (1977).

Comparisons on the effectiveness of these methods and equipment were performed by several researchers (KOMAR and CUI, 1984; MARTINS and MARTINS, 1978; SHIDELER, 1976; MARTINS et al., 1994; COLEMAN and ENSTMINGER, 1977; BEHRENS, 1978; BENSON, 1981; ROSENFELD et al., 1953; STERNBERG and CREGER, 1961).

Finally, TANNER (1991a, 1991b) shows that a single sample of sand may not provide much information, since variability from one sample to another may be an important fact in the nature of the sand body. The author suggests the study of ten or more samples from the same sand, which is much more useful, and develops the concept of "sample suite": a set of closely related samples taken from a single transport and/or depositional system.

A comparison of the use of moment and graphic grain-size parameters developed by JACQUET and VERNET (1976) concluded that mean, sorting and skewness may be estimated either by moment calculation or graphic measures, without essential differences in interpretation.

SWAN et al. (1976, 1979) also discussed the effectiveness of graphical parameters as descriptors of grain-size distributions, comparing to moment measures calculated for ungrouped weight frequency data.

The importance of the particles size as a fundamental property of sedimentary materials, regarding their origin and history, was emphasized by McCAVE and SYVITSKI (1991). In fact, a large part of information related to sedimentary particles transport and deposition can be obtained from grain-size.

KRANK and MILLIGAN (1991) stated that size is thus the single most important property of the oceanic particles. HEIN (1991) indicates that the need for grain-size studies in marine geotechnical studies is paramount in understanding the engineering properties of the sediment on the seafloor grain-size in marine geology. Grain size distribution in combination with sedimentary fabric, packing, mineralogy and organic carbon content affects many of the main properties of seafloor sediments.


Contrasting with these findings, some authors disagree with the use of grain-size parameters as a helpful tool to distinguish some modern sedimentary environments, as SHEPARD and YOUNG (1961), SCHELEE et al. (1964), MOIOLA and WEISER (1968), SOLOHUB and KLOVAN (1970).

In our studies at the CECO/UFRGS laboratories (more than 15,000 samples from several transitional and marine environments) more than 93% of the samples were collected as "suite samples" to characterize and distinguish
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DISCUSSION

During the last decade new contributions were published on the question of the validity of grain-size parameters in environmental interpretation (TANNER, 1991a, b; CHRISTIANSEN and HARTMANN, 1991; SYVITSKI, 1991a, b; SENGUPTA et al., 1991; BITTENCOURT, 1992; BITTENCOURT et al., 1992; STRAVERS et al., 1991b; MEDINA et al., 1994; GAO and COLLINS, 1994; SAGGA, 1992; MARTINS et al., 1997). Working with this type of research during the last thirty years, and in order to give their contribution on the subject and introduce the problem for discussion, the author, using statistical parameters (mean, standard deviation, skewness and kurtosis) from 5,295 samples (beach, dune and river) from the McKEE, URIEN, MARTINS collection, decided to test their own findings along the Brazilian coast in a worldwide set of samples.

Table 1 gives the distribution of the samples from which grain-size parameters were used in this paper.

Samples were collected through a uniform methodology, always with more than 10 samples for each sedimentary body sampled, sieved using a ¼ φ interval, the results plotted in probability paper and the grain size parameters calculated by both FOLK and WARD (1957) graphic formulas and FRIEDMAN (1961) moment measures.

Analysed samples are from different composition, including quartz (the great part), calcium carbonate (oolites, shell fragments, foraminifers and algae), rock fragments, obsidian and gyspite.

MACK and LEISTIKOW (1996) discussed the occurrence of sand as the most common element on earth’s surface displaying various types of composition. Sand grains can be found as quartz (ex. Rio Grande do Sul ocean beaches and dune, Brazil); quartz feldspar and opaque igneous mineral (ex. northeast of the United States); obsidian (Punululu, Hawaii); hornblende (ex. North Light Lake, Canada); gyspite (ex. White Sands, New Mexico, USA); calcium carbonates as oolites (ex. Hawksbill, Exuma, Bahamas), coral fragments (ex. Silver Sands beach, Grand Bahamas), coral and shell debris (South Pacific); foraminifers (ex. Taketomii Shina, Ryukyu Island, Japan) or mixtures of sand and shell fragments (ex. Albardão beach, Brazil).

However, all these types of sand assume, when submitted to a beach, eolian or a river environment, typical grain-size parameter, reflecting the level of the transportation/depositional agent.

In this exercise, the most sensitive parameters where mean, standard deviation (sorting) and skewness, that were useful for beach, dune and river distinction, when data (from a large number of samples) were plotted in scatter diagrams.

About 95% of beach sands are negatively skewed, while 90% of dune and 87% of river sands showed positive skewness. Beach and dune sands are moderately to well sorted, while river sands are moderately to poorly sorted.

Positive skewness is due to the competence of the transportation agent unidirectional flow, and the negative is caused by removal of the fine-grained tail of distribution by winnowing action. SAHU (1964), MARTINS (1962a, 1965, 1967), AWASTHI (1970), CRONAN (1972), FRIEDMAN (1961) indicated that negative skewness has relationship with the intensity and duration of a high energy depositional agent through a removal of fines (swash and backwash) of a high energy ocean beach, for instance. MARTINS (1965) added that negative skewness can be caused by the addition of material to coarse fractions like shell fragments, what in fact represents a mixture of two textural populations (one terrigenous of quartz grains and a small one of bioclastic shell ash). Also HAILS and HOYT (1969), distinguishing ancient and modern sedimentary environments of lower Georgia (USA) coastal plain, conclude that the sign of skewness is related to energy variation and indicated that 90% of Holocene beach sands are negatively skewed and 70% of dune sands are positively skewed. DUANE (1964) elaborated similar reasoning and indicated that winnowing action induced by fluid media is the mechanism producing negative skewness, whereas sands deposited in sheltered environments are dominantly
positively skewed. According to the author, negatively skewed curves are indication of erosional or non depositional places, whereas positively skewed curves indicate deposition, and a mixture of positive and negative skewness indicates an area in a state of flux. VALIA and CAMERON (1977) also agree that positive skewness resulted from the addition of finer material.

CONCLUSION

The most important conclusion in the present exercise is to support that the grain-size parameters carefully obtain a potentially useful tool for recognizing sedimentary environments, as beach, dune and river and several sectors of the continental shelf through graphical or calculated methods used along with other textural properties. Scatter plots with mean, standard deviation and skewness can be used successfully for the distinction of these three environments, always using a large number of samples for each sedimentary body sampled. Other textural attributes like roundness, sphericity, surface texture and textural maturity, besides mineralogical composition, sedimentary structures and biogenic components, must be used when working in the characterization of an ancient equivalent, with a low degree of diagenesis.

MARTINS et al. (1997) listed the following aspects as responsible for several unsuccessful results usually found in the literature:

a) inadequate sampling, not representative of the environment sedimentary body in terms of each spot sample’s depth (crest, lower foreshore, backshore of a beach for instance).

b) inappropriate splitting of the representative original sample, turning the “field sample” in a non representative “laboratory sample”.

c) mechanical analysis without the sufficient number of points of reference (sieves with 1 or $\frac{1}{2} \phi$, instead of $\frac{1}{4} \phi$ as recommended in graphic or calculated methods) that can produce a false cumulative curve and a consequent failure in the graphic parameter calculation or inappropriate information data for moment calculation.

d) technicians not well trained to develop a sometimes “exhaustive” type of work.

e) erroneous drafting of the cumulative curve on probability paper (when using the graphic method to calculate the parameters).

f) reduced number of samples to give an overall picture of the studied sedimentary body.

If one of these steps is not well performed, all the work will be affected. The failure is not just in the method or equipment, but due to an inappropriate work with the sedimentary material from sampling to parameters calculation. Some differences are extremely sensible and can be perceptible if the routine field-laboratory-office work is developed attentively and carefully.

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Table 1 – Sample location of beach, dune and river environments tested in the present exercise.

<table>
<thead>
<tr>
<th>BEACH</th>
<th>DUNE</th>
<th>RIVER</th>
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<tbody>
<tr>
<td>Esmeraldas, (Ecuador) 30</td>
<td>Zobbas, Sahava (Tunísia) 27</td>
<td>Colorado, (Argentina) 42</td>
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<tr>
<td>Port Prince (Haiti) 15</td>
<td>Colorado River (USA) 26</td>
<td>Uruguai 66</td>
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<tr>
<td>Isla Margarita (Venezuela) 26</td>
<td>Rio Grande do Sul coast (Brazil) 324</td>
<td>Negro (Brazil) 39</td>
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<tr>
<td>Trinidad coast 28</td>
<td>Santa Catarina coast (Brazil) 208</td>
<td>Solimões (Brazil) 68</td>
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<tr>
<td>Guapi (Colômbia) 25</td>
<td>Paraná coast (Brazil) 108</td>
<td>Amazonas (Brazil) 97</td>
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<tr>
<td>Callao (Peru) 37</td>
<td>São Paulo coast (Brazil) 160</td>
<td>Camaquã (Brazil) 87</td>
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<tr>
<td>Brazilian coast from Maranhão to Rio Grande do Sul 670</td>
<td>Sonora (USA) 22</td>
<td>Santa Maria (Brazil) 73</td>
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<tr>
<td>Uruguay coast 168</td>
<td>Namibia coast 43</td>
<td>Taquari (Brazil) 108</td>
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<tr>
<td>Mar del Plata (Argentina) 65</td>
<td>Uruguay coast 104</td>
<td>Paraná 75</td>
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<tr>
<td>Barbados coast 84</td>
<td>Argentina coast 38</td>
<td>Ganges-Bramaputra (Bangladesh) 108</td>
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<tr>
<td>Antarctic Peninsula 59</td>
<td>Chile coast 63</td>
<td>Godvari (India) 48</td>
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<tr>
<td>Kapingamarangi atoll, Caroline Island 104</td>
<td>Peru coast 84</td>
<td>Mississipi (USA) 63</td>
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<td>Godvari (India) 89</td>
<td>Gobi desert (Mongolia) 68</td>
<td>Doce (Brazil) 69</td>
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<td>Chikai (Malaysia), 62</td>
<td>Gobi desert (China) 69</td>
<td>Jacú (Brazil) 118</td>
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<td>Trípoli (Líbia) 62</td>
<td>Pila (France) 28</td>
<td>Orinoco (Venezuela) 86</td>
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<td>Marshall Islands Kwajalein atoll 62</td>
<td>Long Island (USA) 38</td>
<td>Parnaíba (Brazil) 45</td>
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<td>Hawaii Islands (USA) 83</td>
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<td>White Sands (USA) 195</td>
<td>Madeira (Brazil) 67</td>
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<td>Negro (Brazil) 79</td>
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<td>Colorado (USA) 45</td>
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<td>Santa Bárbara (USA) 36</td>
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<td>Chola Bay (Mexico) 39</td>
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Figure 1 – Plot (1) comparison between standard deviation with skewness. Plot (2) mean with standard deviation.
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