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The evaluation of sand grain shapes using elliptic Fourier and principal component analyses: Discrimination of modern sedimentary environments and application to the geological records

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Investigations of the shape of clastic grains have long been pursued in sedimentology, because shape possesses important information regarding transportational and depositional histories that individual grains underwent. Recently, Suzuki et al. [1] introduced two new indices that quantitatively evaluate grain shapes by combining elliptic Fourier and principal component analyses (EF-PCA). The EF-PCA method based on variance and correlation matrices quantify the overall macroscopic form (REF1 index) and microscopic roughness (SEF index) features of the grains, respectively. However, the validity of this method in order to discriminate grains deposited in different sedimentary environments remains uncertain, and furthermore, its applicability to ancient geological records (sandstones) has not been attested.

In this regard, we aim to evaluate the variation of these macro- and microscopic indices for quartz sands collected from modern glacial (n=3 sites), foreshore (n=3), fluvial (n=3) and aeolian (n=3) environments. We further applied these indices to Cretaceous to Tertiary sandstones collected from shoreface (n=5), fluvial (n=1) and aeolian (n=1) environments.

The REF1 and SEF values of the modern sand samples show discrete clusters of individual sedimentary environments. Particularly, glacial sands can be clearly differentiated from other environments. Also, aeolian sands have the highest REF1 and SEF values, followed by foreshore and fluvial sands. Therefore, the case study of modern sands implies that this method enables a sensible discrimination of sedimentary environments.

Still, foreshore, fluvial and aeolian sands show overlaps in index values probably due to the differences in physical energies operated within each environmental site. For example, aeolian sands examined in this study include a series of collection from a small coastal dune complex (Tottori Sakyu, Japan) to mature desert (Gobi Desert, Mongolia and Junggar Desert, China), which the former grains returned more morphologically immature index values than the latter. Similarly, when sands from foreshore environments are compered, index values are smaller for grains in the inner bay foreshore and larger for grains in the foreshore facing the open ocean. Consequently, REF1 and SEF indices exhibit values that are concordant with the foreshore wave energies. In summary, these findings indicate that the REF1 and SEF values can serve as a proxy for a sedimentary environment distinction and measuring the physical energy operated in a given environment.

The application of this method to thin section samples of Cretaceous to Tertiary sandstones favourably distinguished grains derived from shoreface, fluvial and aeolian sedimentary systems. Also, comparison within shoreface sandstone samples demonstrate a weak correlation between grain shape index values with HCS wave lengths observed in outcrops. These initial results indicate that the REF1 and SEF indices can be applied to geological records in order to make distinctions of ancient sedimentary environments, as well as, to estimate an ancient physical energy during the transportation. However, further assessments with more cases are required to develop a firm basis for the actual applications to the geological records.

References:

[1] Suzuki K et al. (2015) Sedimentology 62(4): 1184-1197