Towards image based assessment and characterization of cyclic paleo-wind and flow fields

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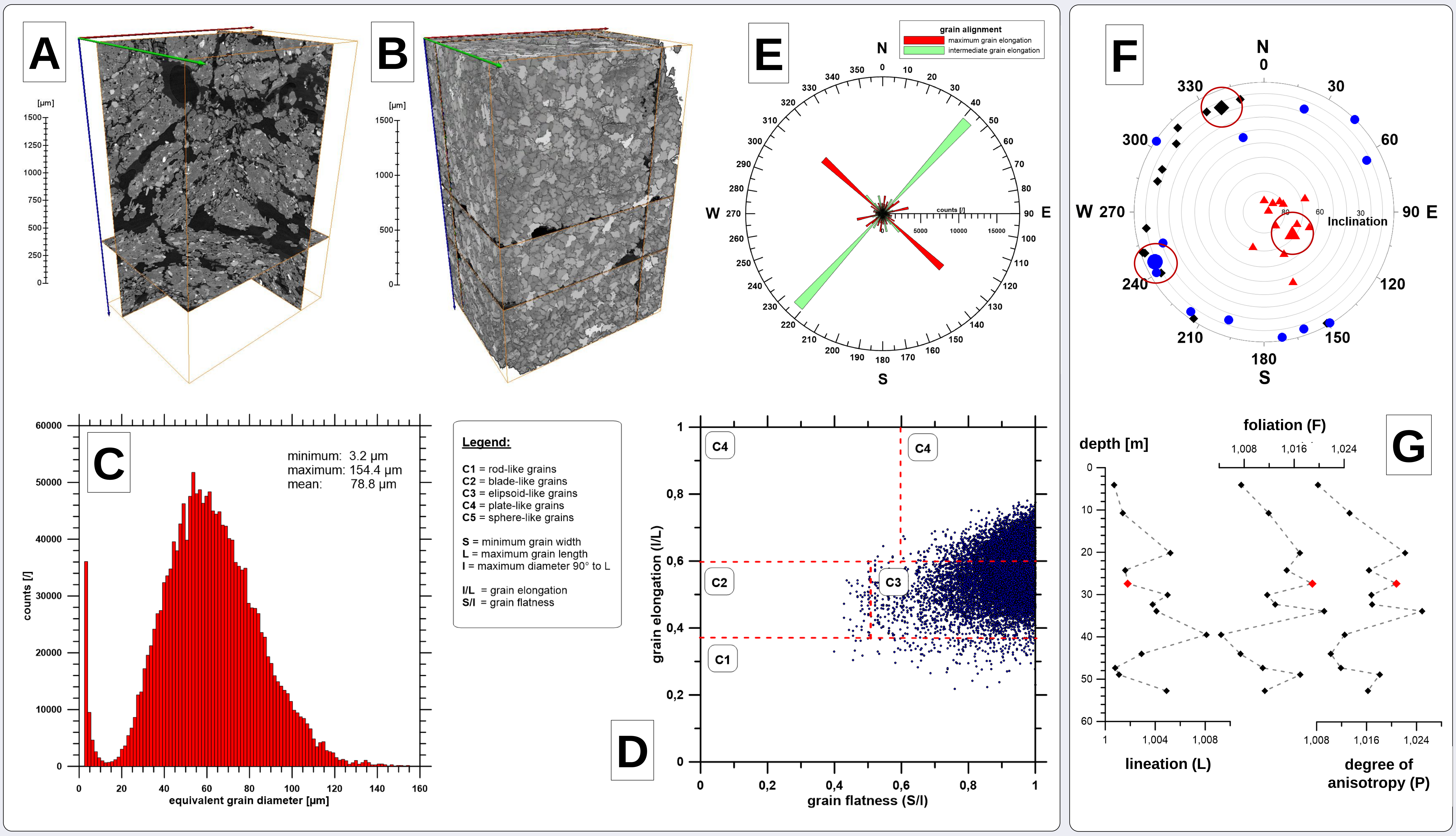
Motivation, Sample Material & methodical Approach

Cylcostratigraphy is used to investigate quasi-cyclic patterns in sediments. It often provides insight about time and climate. While most studies utilize proxies related to precipitation and temperature, reconstruction of wind and flow directions is more challenging. The grain size of aeolian sediments can give insight into the transport distance of material, wind directions and atmospheric dynamics, as well as to post-sedimentary alteration. One geophysical key method is the assessment of the anisotropy of the magnetic susceptibility (AMS). Nevertheless, the so derived AMS data are of volume-integrated nature, i.e. a result of the combined mineral composition and structure of the entire investigated sample material. Accordingly, it would be most favorable to link and assess this volume integrated data with spatially resolved sample features. X-ray micro computed tomography (µ-CT) enables non-destructive sample characterization in 3-D, with special regards to mineralogical, textural, geometrical and topological material features. By combining volume specific magnetic anisotropy data with state of the art µ-CT imaging data sets, we can derive spatially resolved information about grain sizes, grain shapes, sorting, layering patterns, preferential grain / pore/ layer orientations, secondary precipitates, pore sizes, pore shapes and many other parameters. For this study, we have determined exemplary AMS data from a terrestrial loess-paleo soil sequence. For one sample with a distinctively high degree of anisotropy, µ-CT imaging and digital image analysis has been performed. By this, different grain characteristics have been quantified and compared with the results from AMS determination. First results are presented and critically discussed. Alltogether, we conclude that these very first results are very promising, and will help to increase our understanding about ancient depositional environments significantly.

Digital Image Analysis & AMS Results



Figures A and B show a 2-D orthoslice and a 3-D µ-CT representation of the investigated material. Grey-values represent different types of material, in which black color represents pore space and light to dark greyish colors represent different grains / minerals. From the 3-D image analysis, individual grains have been segmented and labelled, in order to calculate a grain size distribution (C), represented by an equivalent grain diameter. By calculating different geometrical extensions of each labelled grain, equivalent grain shapes have been estimated (D), which are dominated by ellipsoid to spherical shapes. Furthermore, individual angles of grain alignment have been calculated (E), showing that the maximum elongation of the ellipsoid-shaped grains strikes in direction NW to SE (and vice versa). Figure F showcases measured AMS directions for 13 samples from a terrestrial loess-paleosol sequence. Black spades represent max, blue circles intermediate, and red triangles min directions. The sample investigated by µ-CT is highlighted by red circles. Figure G represents depth profiles of the AMS parameters lineation, foliation and degree of anisotropy, with the µ-CT sample highlighted by red diamonds.

Discussion, Outlook & References

The comparison of these first results from AMS and µ-CT measurements is very promising. The orientation of the maximum grain elongation, obtained from digital image analysis, is in excellent accordance with the measured direction of the maximum and intermediate susceptibility value. Grain orientation and AMS are clearly related to each other in this particular case. Nevertheless, the segmentation and quantification of individual grains of this particular loess-paleo soil sample has been very complex and challenging, and still gives room for improvements. Especially the grain size distribution is influenced by cementation and compaction effects within the material, leading to over-estimated, i.e. larger grain sizes in these areas of the sample. For the future, we are working on the improved and joint integration of these methods, as well as on the extension of the database by adding more samples from this and other locations. The combination of both, AMS and µ-CT presents itself as a powerful and valuable approach for the assessment and characterization of paleo-wind and flow fields.

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