Image analysis in sedimentology as application for high-resolution grain size analysis: a case study of lake sediments from Tangra Yumco (Tibetan Plateau)

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Granulometric data like distribution, sorting and also the shape of minerogenic grains are basic parameters for the characterization of various kinds of deposits. They are important to describe depositional milieus, flow velocities or transport distances of sediments in rivers or conditions of sedimentation in marine or lacustrine environments. During investigations of geo-archives these data can help to interpret paleoenvironmental /-climatic conditions and evolutions. Conventionally, grain size data are gathered by standard methods, e.g., laser-diffraction (laser diffraction particle size analyzers) or the separation of certain grain size classes based on certain sedimentation behaviour in the laboratory (e.g., "Köhn"-method). Pre-treatments for these analyses are usually the subsampling of the sediments (e.g., sediment cores) within defined intervals, dissolution of carbonates and removal of organic matter. After adding certain chemicals to avoid coagulation of single particles the sediments are analysed. Both conventional methods result in grain size distributions for each sample based on the initial sample weight or volume. Various statistical parameters can be calculates afterwards to obtain more detailed information of the distribution data (sorting, skewness, percentiles etc.). However, for example the shape of the grains is not analysed at all. Further, the subsampling technique is limited, as for the methods mentioned above, a certain minimum amount of sediment is needed to perform the analysis. Especially in case of very fine laminated lake sediments (e.g., varves) where it is important to get detailed granulometric data of each single layer, the standard subsampling can hardly be applied.

A unique method to get destruction free, high-resolution grain size data is based on the analysis of thin sections using image analysis [1] which was applied in a number of paleoclimate-investigations in the high arctic [2; 3]. Here we present a case study where for the first time lake sediments from the Tibetan Plateau are analysed using this technique. Lake sediment cores from Tangra Yumco (southern-central TP) were recovered during 2010 and 2011 using a modified ETH-gravity corer [4]. The cores were taken rather close to each other in the deepest part of the ~835 km² large lake at ~230 m water depth. Grain size information of the uppermost ~10 cm of core TAN 10-4 was analysed with a laser diffraction particle size analyzer (Beckman Coulter LS 13320) whereas at core TAN 11-2 image analysis technique was applied. From this core a 7.5 cm long sediment block was flash frozen using liquid nitrogen and freeze dried ensuring the preservation of all depositional structures. Following the embedding of the sediment into epoxy resin the final uncovered thin section was processed (http://www.MKfactory.de). For deriving granulometric information, the thin section was scanned with a standard flatbed scanner using plain light as well as cross-polarized light (2 polarizing films turned by 90° to each other, sandwiching the thin section in the scanner). The scanned images were imported into the software "Analyse Image" [5] where 53 regions of interest (ROIs) were defined. Backscattered electron images (BSEI) were taken from these ROIs using an SEM (Zeiss EVO® 50). The magnification was 390.5 at a working distance of 8.5 mm producing 8-bit grey-scale Tiff-images with a pixel size of 1 µm. Based on the interaction of the initial electron beam with the chemical compounds in the sediment the minerogenic grains are displayed in light grey colours and the surrounding matrix, i.e., organic contents and the resin itself, is much darker (depending on the atomic number). Using a large set of image processing methods implemented in the software, e.g., filter kernels, threshold values, particle segmentation, hole filling as well as manually editing steps etc., binary (black & white) images of the ROIs were generated where only the minerogenic grains are visible as black pixels. Aside of lamination thickness, granulometric base parameters, i.e., grain size distribution, median diameter, maximum diameter, various percentiles and a roundness index were distinguished.

Results show a very high-resolution grain size record (~2 mm spatial resolution) which can hardly be achieved with conventional subsampling and analysis. The fine lamination in the upper and lower part of the record is obviously not based on grain size variations. However, there are variations in the grain size distribution throughout the record. Especially, the 99th percentile shows fine silty sediments at the base and the top. In between there is a rather huge (~4 cm) layer which is characterized by a 1.5 cm thick sandy base with a very slight fining upward trend, interpreted as a result of a potentially erosive turbidite event. The shape parameter, i.e., roundness, also reveals that the sandy base of the turbidite layer consists of less rounded grains compared to the other areas of the record indicating a shorter transport distance and therefore an anomalous sedimentation event. Compared to the record of TAN 10/4, which was analysed with the laser diffraction method in a 1 cm interval, the image analysis technique reveals much more details and can be seen as an excellent addition or alternative for generating basic sedimentologic parameters which are needed for any paleoclimatic reconstruction.

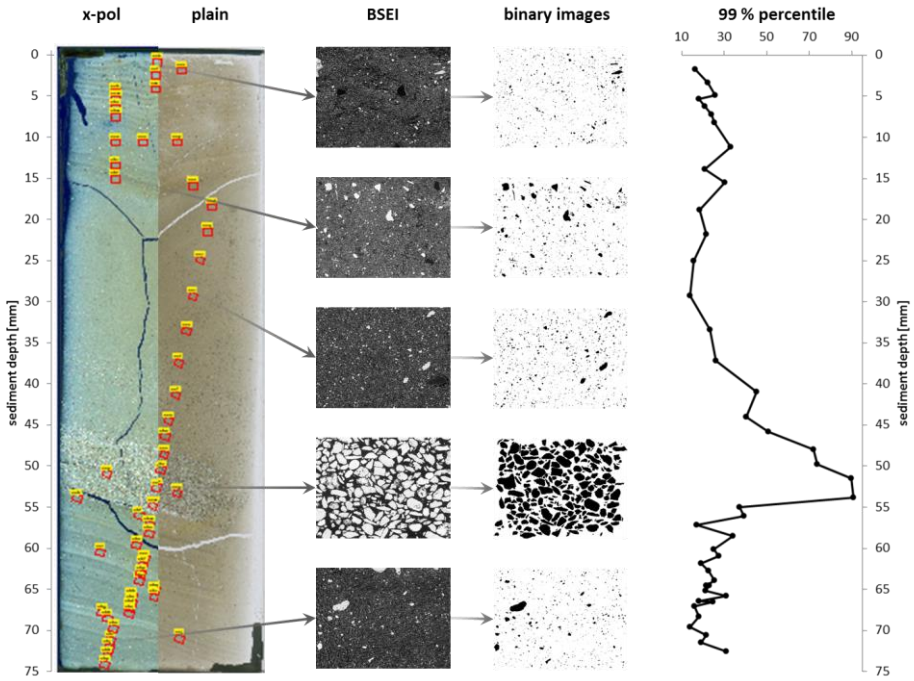

Fig. 1. The scanned thin section in cross-polarized and plain light with the ROIs (red rectangles). Generic BSE-images were processed with the software "Analyse Image" to binary images and analysed regarding ganulometric base parameters (here plotted is the 99th percentile).

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