Geophysical Research Abstracts
Vol. 19, EGU2017-13141, 2017
EGU General Assembly 2017

Three-dimensional imaging of sediment cores: a multi-scale approach

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Downscaling is a method used in building-material research, where several imaging methods are applied to obtain information on the petrological and petrophysical properties of materials from a centimetre to a sub-micrometre scale (De Boever et al., 2015). However, to reach better resolutions, the sample size is necessarily adjusted as well. If, for instance, X-ray micro computed tomography (μCT) is applied on the material, the resolution can increase as the sample size decreases. In sedimentological research, X-ray computed tomography (CT) is a commonly used technique (Cnudde & Boone, 2013). The ability to visualise materials with different X-ray attenuations reveals structures in sediment cores that cannot be seen with the bare eye. This results in discoveries of sedimentary structures that can lead to a reconstruction of parts of the depositional history in a sedimentary basin (Van Daele et al., 2014). Up to now, most of the CT data used for this kind of research are acquired with a medical CT scanner, of which the highest obtainable resolution is about 250 μm (Cnudde et al., 2006). As the size of most sediment grains is smaller than 250 μm, a lot of information, concerning sediment fabric, grain-size and shape, is not obtained when using medical CT. Therefore, downscaling could be a useful method in sedimentological research. After identifying a region of interest within the sediment core with medical CT, a subsample of several millimetres diameter can be taken and imaged with μCT, allowing images with a resolution of a few micrometres. The subsampling process, however, needs to be considered thoroughly. As the goal is to image the structure and fabric of the sediments, deformation of the sediments during subsampling should be avoided as much as possible. After acquiring the CT data, image processing and analysis are performed in order to retrieve shape and orientation parameters of single grains, mud clasts and organic material. This single-grain data can then be combined for a physical layer of sediments to collect data on the sediment fabric within the subsample. Additionally, it can be upscaled further to help reconstructing the depositional history of the sedimentary basin. As a proof of principle, a workflow was developed on an oriented sediment core retrieved from Lake Lucerne, Switzerland. After identifying a megaturbidite with medical CT, a part of that deposit was subsampled using a U-channel with a cross section of 2 by 2 cm, to perform a high-resolution μCT scan. The resulting 3D images with a spatial resolution of 15.2 μm enable us to attribute absolute flow directions to sand layers from different pulses within the turbidite. Yet, the limits of this method have not been explored fully, as applying different sampling methods can lead to higher resolutions and, therefore, more revelations on smaller-grained sediments.

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