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The use of X-ray Computed Tomography (CT) on varved lake sediments for the identification of different sedimentological facies

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Background

The use of non-destructive high-resolution analysis in sediment cores has been continuously increasing through out the years, due to the introduction of new techniques that can attribute to the visualization of different sediment structures, composition etc. Specifically, in paleoclimatic and paleoenvironmental studies, the use of Computed tomography (CT), can provide useful information concerning depositional changes, climatic driven events and short scale depositional changes that would not be recognized macroscopically. In order to distinguish density changes, complex sedimentary structures as well as grain size in lacustrine and marine sediment cores, the evaluation of the CT imaging has been widely used (Dewanckele et al., 2012; Gualda et al., 2010; Ketcham et al., 2010).

Apart from the 3D visualization of a sediment core, one of the most important parameters produced by the CT scanning is the Radiodensity. It is related to the bulk density and chemical composition of the core and has been widely used to describe bulk density (Kenter, 1989), periodic bedding patterns (Boespflug et al., 1995) as well as porosity and permeability (Mena et al., 2015).

Objectives

Sediment cores characterized by the presence of complex micro structures like varves, are most of the times difficult to be examined by conventional means, so the use of a more high-resolution techniques like CT scanning, seems necessary. The main aim of the present study is to distinguish different sedimentary structures (varve sequences, bioturbation, organic layers) and sedimentological phases, in a 6 m sediment core.

Methods

For the present study, a 6 m sediment core, retrieved from Vouliagmeni Lake in central Greece, was used. The acquiring of the CT images was conducted on General University Hospital of Patras in Greece, using a General Electric lightspeed 16x CT scanner. The acquisition parameters were set as follows: 0.8 gantry rotation time, 16*0.625 mm detector configuration, 8 Images per rotation, Axial thickness 1.25 mm, 120 kV and 175 mA. To enhance the density contrast of the CT acquisitions, the soft tissue and bone kernel were used. For every 1m sediment sequence that was scanned, around 1800 DICOM files were extracted. The raw DICOM files were then processed through the MATLAB based software SedCT v.1.01 (Reilly et al., 2017) and high-resolution Hounsfield Unit (HU) profiles were calculated. Hu values produced are determined by the attenuation of the X-rays, the density of the core and the atomic number.

In order to have a better understanding of the additional information provided from the CT scanner, the sediment core was also scanned with a jAi 3CCD RGB line scan camera, with resolution 4096*1px. Profile plots of the RGB colors were created, with the maximum possible resolution, using ImageJ software.

Results

From the analysis performed at the DICOM files that were extracted from the CT scanning, 4 different lithological facies and two different varve types were recognized (Fig. 1). The laminated sediments that were recognized (Phase A and D), present Hu values ~200 and~ 700 respectively, whereas the silty clay material (Phase C) presents Hu values above 1000 (Fig. 1). Organic rich layers (Phase B) in the core are attributed to HU values 200-400, indicating lower bulk density compared to the other units (Fig. 1).

The 3D intensity model that was compiled through the medical software Inobitec DICOM Viewer, provide robust information concerning bioturbation, organic matter and lamination boundaries. Darker areas which correspond to higher density values, attribute to silty clay barren material, whereas the green areas correspond to the $CaCO_3$ rich layers (white layers). Representative images as shown in Figure 1, shows 3 clear laminations with calcite rich material, whereas only one of them can be clearly visible through the line scan camera. Thus, formations that may be disturbed or overlapped in the surface of the core, can now be thoroughly examined.

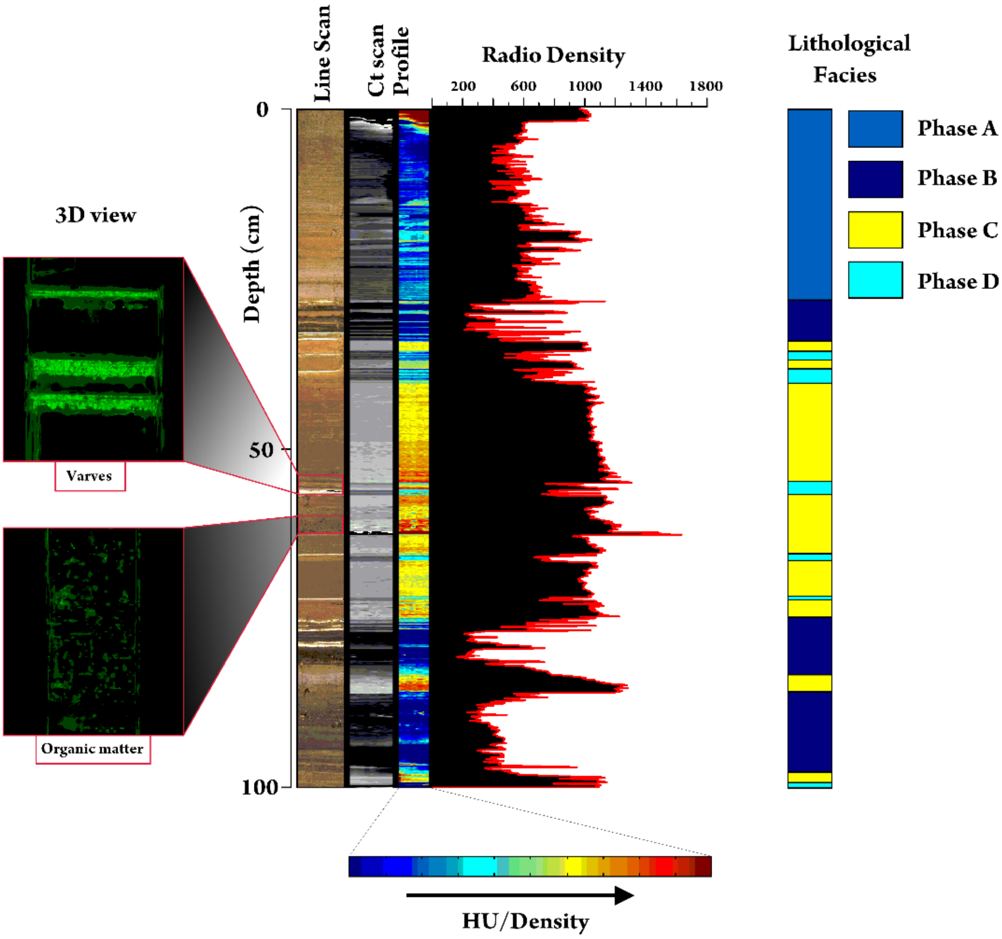

Figure 1. Representative Lithological Phases identified for the first 1 m of Vouliagmeni core.

Conclusion

Three-dimensional quantitative analysis using X-ray computed tomography combined with line scan digital core images was used for effective core characterization. Internal structure and different sedimentological facies such as (a) organic rich layers, (b) varves and (c) clay rich material were recognized. The applied methodology provide efficient information concerning high resolution sampling strategy avoiding core degradation. The development of new software for the processing of DICOM files and the development of new, more high-resolution CT scanners opens new possibilities in the reconstruction of past environmental changes from lacustrine or marine environments.

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