Geophysical Research Abstracts
Vol. 21, EGU2019-17493, 2019
EGU General Assembly 2019

Joint application of non-destructive 3D imaging and analytical techniques on Miocene echinoid specimens

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A great number of fossils are collected systematically in the public collections, museums all around the world, by storing, systematizing and maintaining these invaluable objects of cultural heritage. Beside of their aesthetic and educational value most of these artefacts are suitable to scientific studies applying non-destructive scientific analytical methods. X-ray based imaging techniques are commonly used in such studies. However, X-rays are not sensitive for light elements, and often not capable to give contrast for neighboring elements. Neutron imaging techniques are used in the field of geology and palaeontology more often. Neutrons are highly penetrating particles, thus, the internal structure of bulky objects can be determined. Hydrogen has high neutron capture cross section for neutrons, therefore, materials with elevated hydrogen content give stronger contrast, revealing structures that are invisible for X-ray imaging methods.

In this pilot study we focused on Parascutella gibbercula specimens representing an important Miocene echinoid (sea urchin) species in the Paratethyan realm. The 3D shape of the specimens are essential to study in order to understand the growing of the individuals as well as to reveal the inter- and intraspecific morphological differences. On the other hand the shell composition of this species is expected to carry information about the contemporaneous geochemical environment during their lifetime as well as information on the sedimentary environment during the subsequent fossilization and burial of the animals.

We integrated the 3D shape, surface patterns and the volumetric elementary composition as a start of a future database of specimens. Structured light-optical scanning and stereophotogrammetric reconstruction were capable to reconstruct the 3D surfaces of artefacts. Neutron tomography provided further information on the internal support structure in the fossils. Using the virtual cross sections of the tomogram, the wall thickness of the fossil was determined as well as the volume of the air gaps and the sediment could be also visualized.

With the help of the non-destructive 3D reconstruction of the specimens, the results of the local PGAA (Prompt Gamma Activation Analysis) measurements were linked to an exact volume, and the joint interpretation of the results was possible. The measurements show that the 3D shape can be reconstructed with submillimeter accuracy. PGAA measurements revealed significant differences in $CaCO_3$ percentage in the various parts of the shells. Boron concentrations show an interesting variation; we speculate whether a locality-specific behaviour can be proven.

Our conclusion is that this integrated approach provides the in-depth analysis of the specimens. Our goal is to build an increasing data bank of these data and evaluate the similarities and differences found. For the evaluation we plan to use modern artificial intelligence methods to extract common features from the large data set.

B.P. was supported by Hungarian National Eötvös Scholarship 2018-19 and the Hantken Foundation. B.Sz. contributed as an Alexander von Humboldt Research Fellow. We thank the Budapest Neutron Centre for funding the neutron experiments, as well as the project no. K_17 124068 of the National Research, Development and Innovation Fund of Hungary. L.Sz. is grateful for the János Bolyai Research Fellowship of the Hungarian Academy of Sciences.