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A TOMOGRAPHY APPROACH TO INVESTIGATE IMPACTITE STRUCTURE

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Summary: We investigate the structure of impactites from the Wabar iron meteorite impact site in Saudi Arabia. In order to understand the physical and chemical processes involved in the formation of the impactite, we applied a non-destructive investigation approach, which combines X-ray and neutron tomography. This bi-modal imaging method allowed for a better understanding of the impactite's chemical composition.

1. INTRODUCTION

Meteorite impacts have recently been recognised among the most important processes able to modify planetary surfaces. It also happens to be one of the least understood in details. In particular it is a challenge to understand both the extent of impacts and the physical and chemical changes that occur during and following the impact, where materials (e.g., rocks, sand, meteorite fragments, etc.) are subjected to temperatures of several thousands degrees and pressures of several GPa. In addition, most accessible Earth impact areas are highly affected by weathering, which causes extensive secondary chemical alterations.
Iron meteorites impact on planetary surfaces cause shock-induced rock deformations that happens both at macroscopic and at microscopic level, e.g. shatter cones (macroscopic) and planar deformation features in quartz (microscopic). Another indicator often correlated to meteoritic impacts is the presence of iridium concentration anomalies [1, 2]. Despite the strong correlation, these factors are not truly unique to meteoritic events. In order to univocally identify impacts of iron meteorites, two elements would co-occur [3]: the presence of vesiculated partly melted sandstone, the impactite rock, and metallic projectile droplets, FeNi micro-spheres of meteoric origin, scattered in the impactite.
To understand the complex build-up of impactites we have investigated field samples of impactites from the Wabar meteorite impact site by applying both X-ray and neutron tomography. The Wabar site consists of three small craters (the largest of which measured 116 and 64 metres diameter) in the uninhabited Empty Quarter of Saudi Arabia. Wabar craters represent the ideal research site, as the region has no iron deposit and the impact was confined to the sand surface. For these reasons, it is possible to assume the pre-impact material as fairly uniform quartz dominated sand [4], while all the chemical and physical changes observed are due to the impact.

2. EXPERIMENTAL METHOD

Computed tomography is used as a non-destructive method of studying composition and morphology of the impactites, and distribution and size variability of the vesicles and metallic spheres. The combined use of neutron and X-rays provides additional chemical information as the two methods are characterised by different attenuation coefficients with a non-linear relation. Neutrons, in particular, provide high contrast for e.g. platinum-group and noble metals, as Cu, Re, Ir, Pt, Au, which represents trace elements in the meteorite. The contrast of X-rays is highly dependent on atom density. X-ray CTs were carried out at the 3D Imaging Centre, DTU Lyngby (DK), while white beam neutron tomographies were carried out at the IMAGINE beamline [5], the cold neutron imaging facility at the Laboratoire Léon Brillouin CEA/CNRS (FR).

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The two data sets have been transformed into a common coordinate system using the Statistical Parametric Mapping SPM8 software package [6]. The images were rotated and translated using Normalized Mutual Information as the similarity metric [7]. This process allows for pixel-wise comparison between images from the two different data sets.

3. RESULTS

X-ray CT allowed us to obtain details on the morphology of the impactite, and on the distribution and size variability of the metallic spheres. Neutron imaging provided complementary attenuation information which was used for material segmentation of the samples; an example is shown in Figure 1.

References

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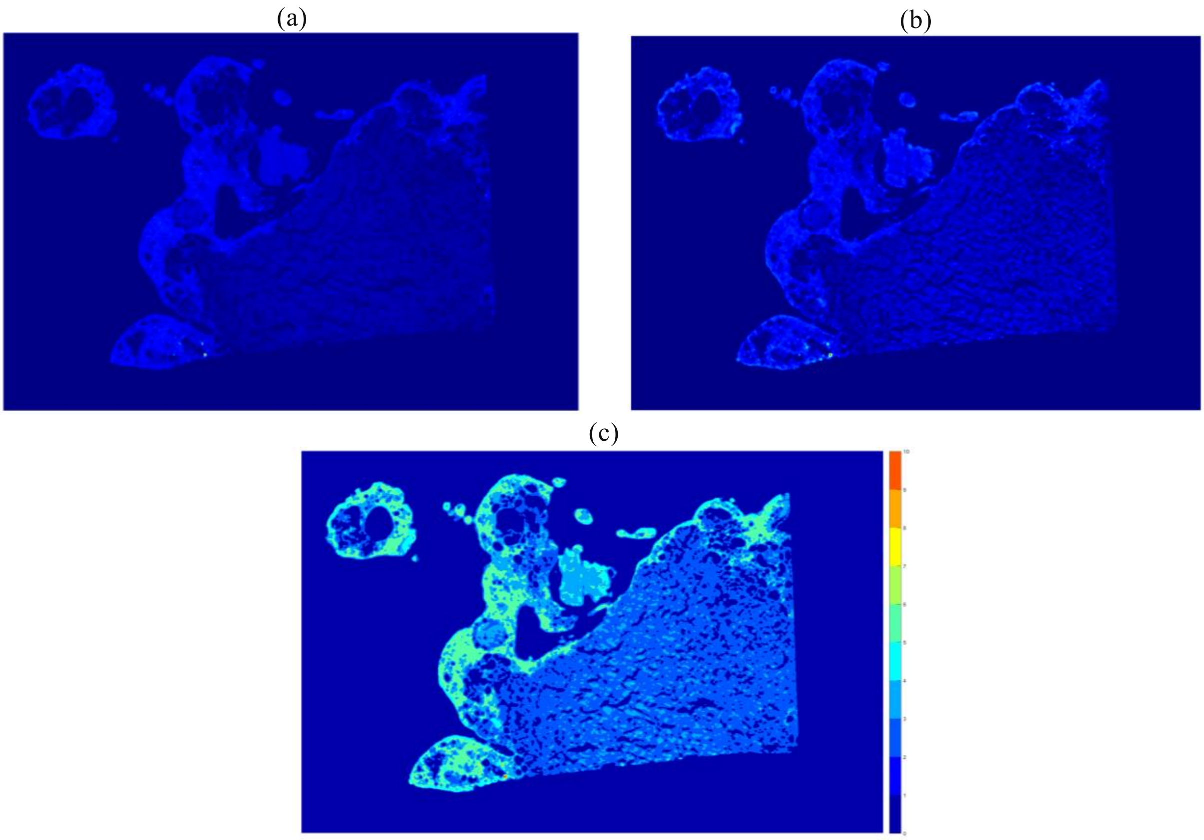

Figure 1: Corresponding slices of an impactite from (a) X-ray and (b) Neutron tomography. (c) Computed segmentation showing the different classes of materials.