RECOGNITION OF IMPACT STRUCTURES: PART I. THE ROCK AND SHOCK RECORD.

W. U. Reimold, Museum für Naturkunde Berlin, Invalidenstrasse 43, 10115 Berlin, Germany; Humboldt Universität zu Berlin; Geochronology Laboratory, Universidade na Brasília, Brasilia, Brazil (uwe.reimold@mfn-berlin.de).

Introduction: This contribution introduces the issues to be debated at the "*Recognizing the Criteria for Ancient Impact Structures*" Workshop. The terrestrial impact record is seriously limited, in comparison to the records of other planetary bodies (e.g., Moon, Mercury); it is badly skewed towards relatively young structures. In addition, impact in the stratigraphic record is limited to a few Archean and Proterozoic spherule layers and a small number of Phanerozoic distal impact ejecta horizons; only 1 shocked quartz grain has been discovered to date from these layers. Generally, it seems that the easy-to-find impact structures or remnants thereof have already been identified, and that it will be much more difficult in future to add further to the record. The purpose of this workshop is to evaluate accepted (shatter cones, shock metamorphism, and physical or chemical traces of extraterrestrial projectiles) and possible further recognition criteria. The latter have been repeatedly invoked when the accepted impact evidence did not "work" (e.g., for Manitsoq, Greenland, or alleged craters in the Bajada del Diablo, Argentina – [1]). In all such cases, the alleged evidence failed to meet the standard – and the proposers failed to deliver proof that these alleged new criteria are the true outcome of shock (impact) deformation.

The rock record and geophysical anomalies: The literature is full of erroneous statements that geophysical anomalies or the presence of 'pseudotachylite' represent evidence of impact. No morphological, geophysical, or breccia evidence represents bona fide evidence of impact! Ground- and/or laboratory proofing of any notion of impact remains required, and only then may shock metamorphic or chemical evidence be detected that can be regarded as essential and diagnostic. However, morphological and geophysical observations, perhaps coupled with regionally unique occurrences of lithic or melt (bearing) breccia, may provide first-order hints at impact – that then require detailed follow-up. If such observations are coupled with evidence of stratigraphic uplift and – in the case of very large structures/anomalies under consideration - elevated metamorphic gradient and/or occurrence of significant amounts of melt breccia, thorough exploration is warranted. This becomes problematic when only limited regional/local geological context is available, or an exotic terrain is studied. In those cases, detailed search for shock metamorphic indicators is then required.

Shatter cones (SC) are the only recognized meso- to macroscopic impact recognition criterion. In fact, they range in scale from mm size (recently recognized in MEMIN experiments) to 12 m (in the Slate Islands impact structure). They have been regarded as being typically formed in the low-shock regime (< 10 GPa) but in the literature there are reports that extend occurrence to 30-45 GPa. They were recognized in crater rim and central uplift settings. Long thought to occur mostly in fine-grained materials, recent work atVredefort and Keurusselkä resulted in the description of well-developed SC in medium- to coarse-grained granitoids as well. A recent special issue of MAPS was dedicated to SC, also promoting some new ideas about their genesis [2]. While there is general agreement that SC formation is the result of interaction between a shock front and target-rock heterogeneities, especially pre-impact fractures, the process is still not resolved completely.

Recent advances in shock metamorphism: Quartz and zircon are the minerals of choice, in terms of being advantageous for the recognition of impact structures and tracing remnants of impact in the geological record. Recent work – also including EBSD SEM, cathodo-luminescence, and Raman studies - have contributed largely to a better understanding of shock processes at the grain scale. Shocked zircon has been traced in fluvial sediments for 1500 km from its source. The MEMIN research group studies not only confirmed that stishovite crystallizes from shock melt, but it also showed that porosity strongly enhances shock and associated thermal deformation, so that diaplectic glass and lechatelierite could be produced at < 10 GPa shock pressures [3]. Further work with weathering-resistant trace minerals may enlarge the arsenal for shock barometry and impact detection.

Finally, a general remark. Much about the impact process and the interaction of shock waves and natural materials has been learnt – especially in the last decades – from dedicated numerical modelling. However, I perceive a serious shift from hands-on field work and mineralogical-geochemical lab studies to the modelling sphere. There is still a lot to be learnt and resolved from geological and laboratory investigations, and new generations of geo-students should not be deterred to tackle the many open problems in these fields.

References: [1] Crósta, A. P. & Reimold, W. U., 2016. Meteorit. Planet. Sci., 51, 996-999. [2] Baratoux, D. and Reimold, W. U., 2016. Meteorit. Planet. Sci., 51, 1389-1434, and other papers of this special issue.