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Review of Criteria for the Identification of Impact Structures on Earth

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All bodies in the solar system that have solid surfaces are covered by craters. In contrast to many other planets and moons in the solar system, the recognition of impact craters on the Earth is difficult, because active geological and atmospheric processes on our planet tend to obscure or erase the impact record in geologically short time periods. Impact craters must be verified from the study of their rocks – remote sensing and geophysical investigations can only provide initial hints at the possible presence of an impact crater or supporting information. Over the past decades, the study of impact craters and their formation has reached a degree of maturity that has led to a reasonably good understanding of the processes involved in their formation, and their importance for the evolution of planetary bodies in the solar system and, especially, on Earth. Over 30 years ago, the general geological community greeted evidence for a major asteroid impact on Earth at the end of the Cretaceous with disbelief. On the other hand, planetary scientists and cosmochemists, who were familiar with lunar samples and meteorites that show abundant evidence of impact and collisional processes, readily accepted the interpretation of an end-Cretaceous impact event. Research initiated by this controversy led to a better definition and understanding of impact evidence, particularly in terms of shock metamorphism and the identification of meteoritic components. One key result from these studies was also the acknowledgment that impacts may have influenced biological evolution on Earth. The recognition of geological structures and ejecta layers on Earth as being of impact origin is not easy. Morphological and geophysical surveys are important for the recognition of anomalous subsurface structural features, which may be deeply eroded craters or impact structures entirely covered by post-impact sediments. However, definitive confirmation of an impact origin requires to obtain the information required for understanding the ultra-high strain rate, high-pressure, and high-temperature impact process. This involves either shock metamorphic effects in minerals and rocks, and/or the presence of a meteoritic component in these rocks. Geochemical methods are used to determine the presence of the traces of such an extraterrestrial component. Shock deformation can be expressed in macroscopic form (shatter cones) or in microscopic form. In nature, shock metamorphic effects are uniquely characteristic of shock levels associated with hypervelocity impact. A wide variety of microscopic shock metamorphic effects have been identified (see Table 1). The most common ones include planar microdeformation features; optical mosaicism; changes in refractive index, birefringence, and optical axis angle; isotropization (e.g., formation of diaplectic glasses); and phase changes (high-pressure phases; melting). Kink bands (mainly in micas) have also been described as a result of shock metamorphism, but can also be the result of normal tectonic deformation. For the proper determination of the impact origin of a geological feature, the proper identification of either shock metamorphic evidence or the presence of extraterrestrial component is necessary - but this is not easy or straightforward to do and requires relevant experience, instrumentation, and expertise. For further details, see references [1] and [2].

References:

[1] French B.M. and Koeberl C. (2010) Earth-Science Reviews 98: 123-170

[2] Koeberl C. et al. (2012) Elements 8:37-43