RECOGNITION OF TERRESTRIAL IMPACT STRUCTURES, PART 2: METEORITIC COMPONENTS, SHOCK EFFECTS, AND OTHER CHARACTERISTICS.

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Introduction: Impact craters on Earth are difficult to recognize because of the active geological processes that constantly reshape the Earth's surface. Depending on the age of the crust, the intensity of local geological processes, and other factors, such as accessibility or vegetation cover, known impact craters show a rather irregular distribution on the Earth's surface; in contrast to their formation, which is evenly distributed. There is a set of commonly accepted impact characteristics, including the finding of meteoritic components in impactites and/or the discovery of the effects of high (shock) pressure in crater rocks.

Identification of Terrestrial Impact Structures: 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. Craters of any type and morphology are not a common landform on Earth. About 190 impact structures are currently known on Earth. Considering that some impact events demonstrably affected the geological and biological evolution on Earth, and that even small impact events (or atmospheric explosions known as airbursts) can disrupt the biosphere and lead to local and regional devastation, the understanding of impact structures and the processes by which they form is of broad interest.

Impact craters (before post-impact modification by erosion and other processes) occur on Earth in two distinctly different morphological forms. They are known as simple craters with diameters up to about 2 to 4 km, and complex craters, which have larger diameters. Complex craters are characterized by a central uplift in the form of either a central peak or a central ring of hills. As noted above, the recognition of geological structures and ejecta layers on Earth as being of impact origin is not easy. Even though morphological and geophysical surveys are important for the recognition of anomalous surface or subsurface structural features, which may be deeply eroded craters or impact structures entirely covered by post-impact sediments, definitive confirmation of an impact origin requires the presence of specific evidence (see, e.g., [1-3] for details. Such definitive evidence was obtained in the case of the Santa Fe impact structure (even though the feature is so deeply eroded that its original extent has not yet been reconstructed).

This involves the need 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. 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. 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). For the 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. The presence of “spherules” of any sort, often cited in favor of an impact origin, is by itself NOT unambiguous or unique evidence for impact.

Although projectile fragments rarely survive an impact event, detectable amounts of melted and recondensed projectile are often incorporated into impact-produced breccias and melt rocks during crater formation. This dispersed projectile (meteoritic) material can be conclusively identified by distinct chemical and isotopic signatures in the host rocks, thus providing reliable evidence for a meteorite impact event. Geochemical lines of evidence can include the following: elevated platinum-group element (PGE) abundances and interelement ratios (with the caveat that in some cases terrestrial geological processes can lead to increased abundances) and (better) various isotopic compositions, such as characteristic Os, Cr, or W isotopic ratios. Similar to other aspects of impact studies, geochemistry is vulnerable to overinterpretation and wishful thinking. It is imperative that data be carefully obtained and verified, using independent methods and multiple laboratories, and that they be calibrated with the appropriate methods and standard reference materials. In summary, it is important that lines of evidence are seen in context and not in isolation. Any “new and unique” methods or observations have to first be verified at confirmed impact sites.

References: [1] French B.M. and Koeberl C. (2010) *Earth Science Reviews* 98: 123–170. [2] Koeberl C. et al., (2012) *Elements* 8: 37-42. [3] Koeberl C. (2014) in: Treatise on Geochemistry 2nd Edition, Elsevier, vol. 2, p. 73-118.