SEARCH (AND DISCOVERY) OF NEW IMPACT CRATERS ON EARTH

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When looking at other terrestrial planetary bodies of the Solar System, such as our Moon, Mars, Mercury or the asteroids, it is obvious that impact craters are the dominant geological features to be seen on their surfaces. On Earth, however, impact craters are not so obvious and, in most cases, they are hard to spot. Our planet is geologically active. Its surface is constantly altered by plate tectonics and erosion and is largely covered by oceans and (densely) vegetated areas, making the identification of impact craters difficult. In addition, on Earth, an impact crater cannot be recognized, like on other planetary bodies, based only on its morphological characteristics because circular features can be formed by a variety of completely different geological processes (e.g. volcanism, salt diapirism, etc.). A requirement for the confirmation of an impact structure on Earth is the finding and characterization of diagnostic indicators for shock metamorphism, such as shatter cones (Fig. 1), planar deformation features in minerals (Fig. 2), high-pressure mineral glasses, high-pressure mineral phases, and/or anomalies in platinum-group elements (e.g. iridium) or isotopic anomalies (e.g. osmium) in specific geological settings [for further information see French and Koeberl (2010) and Ferrière and Osinski (2012)]. Rarely do projectile fragments survive an impact event. Thus, finding meteorite fragments spatially associated with a crater is restricted to small and relatively young impacts.

The search (and discovery) of new impact craters on Earth is a mix between a Sherlock Holmes detective investigation and an Indiana Jones adventure (Fig. 3). The first step is to identify an anomalous feature using morphological or geophysical surveys. In recent years, an increasing number of people are using Google Earth to spot possible candidates. However, definitive evidence (i.e. diagnostic indicators for shock metamorphism) can only be achieved by sampling. Thus, fieldwork and/or drilling is mandatory and should be the second investigative step. The final step is to carefully analyze the samples using a microscope to see if they contain shocked minerals.

When in the field, the only distinctive shock-deformation features that can be seen with the naked eye (meso- to macroscale features) are shatter cones. These are distinctive curved to curvilinear fractures decorated with divergent striations radiating from the apex of a conical feature or from a narrow apical area (Figs. 1 and 3). Partial to complete shatter cones can occasionally be observed in coarse-grained rocks, such as granites or conglomerates, but they are best developed in fine-grained rocks. Care should be taken to properly characterize field samples. People often report they have found shatter cones when what they have actually found are ventifacts, slickensides, or other features that may look like shatter cones. Nice examples of shatter cones and further information on how to identify them can be found in Ferrière and Osinski (2012) and Baratoux and Reimold (2016). Other odd looking rocks, in particular brecciated rocks (which are not diagnostic), should be collected and then investigated under the microscope.

Finding shocked minerals – the equivalent of DNA or blood at a crime scene – would indicate that the samples were affected by an impact (note that the absence of shocked minerals doesn’t allow a conclusion to the contrary!). The microscopic part of the work can be long and tedious due to, in some cases, a ratio of one shocked grain to hundreds or thousands of unshocked grains. Shocked grains will show planar microstructures that formed upon shock compression, if the involved pressure was strong enough (i.e. several GPa). Planar microstructures are mainly of two types: (1) planar fractures, which are planar, parallel, thin open fissures; (2) planar deformation features, which are narrow, individual planes of amorphous material comprising straight, parallel sets spaced 2–10 µm apart that generally occur as multiple sets per grain (Figs. 2 and 3). Both types of microstructures are crystallographically controlled. The finding and proper characterization of these microstructures can be used to confirm an impact origin knowing that they are, in nature, uniquely formed by shock metamorphism [i.e. in the case of planar fractures in quartz, they are diagnostic indicators only when occurring in multiple sets; see French and Koeberl (2010) for further information]. Shocked quartz grains are typically used to identify impact craters [see French and Koeberl (2010) and Ferrière and Osinski (2012) and references therein], but other shocked minerals, such as zircon and other accessory minerals have been increasingly used in the last few years [see Cavosie et al. (2010) and Timms et al. (2017) and references therein] and appear to be very promising, in particular for old erodedshatter cones. These are distinctive curved to curvilinear fractures decorated with divergent striations radiating from the apex of a conical feature or from a narrow apical area (Figs. 1 and 3). Partial to complete shatter cones can occasionally be observed in coarse-grained rocks, such as granites or conglomerates, but they are best developed in fine-grained rocks. Care should be taken to properly characterize field samples. People often report they have found shatter cones when what they have actually found are ventifacts, slickensides, or other features that may look like shatter cones. Nice examples of shatter cones and further information on how to identify them can be found in Ferrière and Osinski (2012) and Baratoux and Reimold (2016). Other odd looking rocks, in particular brecciated rocks (which are not diagnostic), should be collected and then investigated under the microscope.

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As for shatter cones, special care should be taken in the identification and characterization of planar fractures and planar deformation features because some features commonly found in quartz (and also in other minerals) – tectonic deformation lamellae, irregular fractures, or trails of fluid inclusions (or cleavages for a number of minerals) – may superficially look like shock microstructures. In addition to planar fractures and planar deformation features, some high-pressure glasses (e.g. diaplectic quartz glass, maskelynite, etc.) and high-pressure phases (e.g. coesite, stishovite, reidite, etc.) are also diagnostic. However, their use should be done with extreme care as some of those are also products of endogenic processes (i.e. not exclusively formed by impact metamorphism). It is vital to know the geological context of the specimens.

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New impact structures are discovered/confirmed (almost) each year. As of today, about 190 impact structures have been unambiguously identified on Earth, based on the finding of diagnostic indicators for shock metamorphism. Finding a new impact structure is something very exciting, but what is even more interesting is the number of new questions that arise: When did it form (i.e. how old it is), How big was the impact (in the case of eroded structures this “basic question” is not so trivial), and, What local or regional effects did it have?

Impact structures (and their associated phenomena) offer unique opportunities to help answer fundamental questions on the impact cratering processes. Many impact structures have not yet been discovered/confirmed and a number of the confirmed ones have not been studied in detail. In some cases, the only publication available is a conference abstract that reports the discovery. There are many impact structures just waiting to be discovered/confirmed and investigated. Let’s start the hunt!

REFERENCES


