REFINING THE NATURE OF THE PROJECTILE COMPONENTS PRESERVED WITHIN TERRESTRIAL IMPACT STRUCTURES AND EJECTA, AND THEIR LINK TO ASTRONOMICAL EVENTS

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Introduction: Through a combination of state-of-the-art geochemical and mineralogical proxies, a more complete picture of the variations in intensity and sources of the extraterrestrial flux to the Earth over geological time is emerging [1]. Here, we explore some of the geochemical data that exist for the ~190 terrestrial impact structures and ~30 (distal) ejecta layers currently recognized in the terrestrial record [2,3]. Only for a small fraction of the known impact structures and ejecta layers, it has been possible to determine the impactor type with confidence. Next to the rare finds of meteorite fragments in or near impact structures or ejecta layers [4,5], a handful of geochemical methods can be applied to confirm the impact origin of a structure and, in ideal cases, to precisely constrain the nature of the impacted projectile [6,7]. During crater formation on a solid planetary surface, a small amount of projectile material, generally (<1 wt%), is incorporated into the produced impactites. This contribution of extraterrestrial matter often leads to a measurable geochemical signal that differs from typical crustal signatures. Due to their geochemical behavior, the concentrations of the moderately and highly siderophile metals, including nickel (Ni), cobalt (Co), chromium (Cr), the platinum group elements [PGE: osmium (Os), iridium (Ir), ruthenium (Ru), platinum (Pt), rhodium (Rh), palladium (Pd)], as well as rhenium (Re) and gold (Au) are several orders of magnitude higher in chondrites and certain types of differentiated meteorites, compared to terrestrial crustal rocks. The admixture of a meteoritic component often leads to elevated concentrations of these elements, constituting a unique geochemical fingerprint in the impactites. In more recent years, a range of isotopic tracers – most commonly the Os and Cr isotope systems, but in specific cases also other isotopic systems such as ruthenium [Ru] and germanium [Ge] – have been used to unequivocally detect and identify this meteoritic contribution. By combining conclusive geochemical evidence with mineralogical proxies (e.g., spinel group mineral composition), some impact structures and ejecta layers have been linked to particular parent bodies, and potential asteroid breakup events [1].

Scope and outlook: Projectile determination within a fraction of the impact structures and ejecta layers recognized on Earth today, although in same cases ambiguous, suggests that (ordinary) chondrites likely represent a common type among the terrestrial impactor population, in agreement with their distribution among meteorites [6,7]. Important exceptions exist, as in the case of the 66 Myr old Cretaceous-Paleogene (K-Pg) boundary clay layer and some of the Early Archean spherule beds, for which carbonaceous chondritic signatures have been reported [8-10]. Precise age constraints coupled with a detailed identification of the impactor composition advocate for the existence of clusters in the geological impact record (e.g., during the late Eocene, middle Ordovician, Late and Early Archaean). The more precisely the projectile type is constrained, the more probable its provenance and parent asteroid can be determined, and consequently a mechanism for its delivery towards the Earth can be defined. Clearly, more work is required to confirm the pulsated nature of the terrestrial impact flux that may result from collisional disruptions in the Main Asteroid Belt. The K-Pg mass extinction remains the only impact event for which the consequences on the evolution of the bio- and geosphere of the planet Earth are clearly documented. Continued efforts on the entire Phanerozoic record and before may confirm (or not) the dominance of specific impactor types [1]. In this workshop, we discuss various currently available geochemical tools that may aid in the documentation and quantification of changes in the flux of crater-forming projectiles to the Earth over time.

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