THE DIFFICULTIES OF STUDYING PLANETARY VERSUS TERRESTRIAL CRATERS.

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Introduction: Terrestrial and extraterrestrial impact structures each provide advantages and disadvantages with respect to furthering our understanding of the cratering process within our Solar System.

The Moon: Early studies of crater morphology and morphometry were principally founded on descriptions of lunar impact structures, e.g., [1]. The preservation of "form" in the absence of an atmosphere, plate tectonics and Earth-like weathering and erosional systems has meant that at least the younger craters have remained well preserved. Even those basins formed during the Late Heavy Bombardment (LHB) have retained their basic shape (e.g., Nectaris). The lunar surface is essentially saturated in craters, with successive bombardments building a stratigraphy of superimposed crater structures (including melt sheets) and associated ejecta. Aside from basaltic igneous activity (especially post-LHB mare eruptions), the only crater destroying/obscuring process is impact, wherein existing craters are hit directly and so disrupted, and/or are buried by ejecta. This has allowed researchers to build crater size-frequency distributions, understand bombardment rates and erect timescales for the Moon and other planetary bodies in our Solar System, e.g., [2]. Measuring lunar impact structures has been facilitated by remote observation; first by telescope from Earth, subsequently by orbiters whose resolution has increased over the decades (e.g., NASA's Lunar Reconnaissance Orbiter, launched 2009, has a high-resolution mapping capability of 50 cm/pixel). Thus, technology development has increased our ability to measure crater dimensions accurately.

A critical distinction between the Moon and Earth is the presence of a regolith forming the upper part of the lunar crust. This is, in turn, part of a megaregolith, which predominantly comprises displaced and fragmented materials. Given that very large impact events affected the Moon up until 3.8 Ga, it is probable that much of the lunar crust is fractured, with displacement decreasing with depth. However, the largest basins (e.g., South Pole Aitken Basin) would have penetrated the whole crust and accessed the mantle. The presence of regolith means that sampling of in situ rock was not possible by the Apollo and Luna missions. All returned materials were of displaced regolith components, including breccias, and basalts and other lithic fragments. There is no unambiguous context to the lunar sample inventory. So, while the Moon has provided an excellent foundation for understanding crater morphology and for classifying crater types (e.g., simple, complex, etc.), it has not provided us with the lithological context to understand, for example, shock effects and shock attenuation. A further consideration is scaling laws: the gravity field of the Moon is distinct from that of Earth, so the relationship between impactor energy, speed and size and final crater form and size is not the same as that for Earth.

Other Terrestrial Planets: Mercury represents a similar case study: its surface is largely crater saturated. However, its impactor velocities are significantly higher than those of the Moon, which, in turn affects crater form. Mars provides us with another inventory of craters, but, like the Moon (and Mercury) the presence of a regolith prevents direct access to in situ samples. Additionally, fluvial, eolian and glacial processes (some ongoing) add further complications in terms of accessing original crater lithologies (e.g., by rover). Venus, like Earth, remains an active planet and is currently resurfacing itself through igneous activity, e.g., [3]. Its crater inventory is therefore somewhat limited. Moreover, its thick atmosphere requires penetration by RADAR, rather than by more conventional optical means.

Earth: Earth presents a distinct record of impact. Because Earth is a dynamic planet, with ongoing plate tectonics, igneous processes, weathering and erosion, only a few craters survive. Unlike the Moon, its surface is relatively young (e.g., more than 60% of the lithosphere is renewed every 200 Ma), such that there are only ~190 impact structures currently known. The Earth retains little of the Hadean period (i.e., >4.0 Ga), whereas the Moons fundamental crustal structure is Hadean (or predominantly $\geq$3.8 Ga in age). Those craters that do survive are rarely pristine: they are typically eroded, tectonically deformed and overprinted. Performing morphometric studies on Earth is therefore problematic. This has led to numerous debates about the true sizes of certain craters, many of which may be academic in the worst sense. Only those craters that were buried very soon after formation retain their shapes, yet these can only be characterized by drilling and remote means (e.g., gravity, magnetics, seismics). The great advantage provided by Earth is the ability to access the target areas through outcrop exposure. Geologists can walk around them (and effectively "in" them) and sample material accordingly, much of it in situ. Unlike lunar materials retrieved as part of the Apollo and Luna missions, and lunar meteorites, the context of in situ sampled materials on Earth does allow for better exploration of shock effects and shock attenuation.

An important issue for field geologists is the scale of observation: is what one is seeing representative of all craters, or is it an aberration/anomaly (is the ant crawling on an elephant or a rhino)? Field work is time-consuming and requires considerable attention to observation and an understanding of mapping techniques (that are no longer necessarily taught as part of undergraduate degree programs).

This presentation will discuss the pros and cons of studying impact craters on Earth versus extraterrestrial examples, with the aim of furthering discussion and constructive "fusion" between the two perspectives.

References: [1] Pike R. J. (1980) U.S. Geol. Survey Prof. Paper 1046-C. [2] Hartmann W. K. et al. (2000) In: Origin of the Earth and Moon. Univ. Arizona Press, 493-512., 1151–1154. [3] Shalygin E. V. et al. (2015) Geophys. Res. Lett. *42*, doi.org/10.1002/2015GL 064088.