Impact cratering: A planetary process as seen from Earth

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Planetary exploration highlighted impact as a ubiquitous solar system geologic process for surface and upper crustal modification, particularly in early solar system history. The Earth, however, is the most endogenically active of the ter-

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restrial planets and has the poorest preserved record of impact cratering, with the current known sample consisting of ~ 175 structures or crater fields and ~ 20 events in the stratigraphic record (some of which are related to known structures). The sample is biased towards (< 200 Ma), large (> 20 km diameter) impact structures on the geologically better-known cratonic areas, which has implications for cratering rate estimates and claims for periodic or clusters of impacts. This relatively small, biased sample, however, plays a critical role in understanding cratering process, as it is the only current source of ground truth data on the third dimensional structural and lithological character of natural, large-scale impact craters. Observations at terrestrial impact structures have led to such fundamental concepts as: shock metamorphism (including impact melting) and its attenuation, formation of a transient cavity by the cratering flow-field, and subsequent modification of this cavity, including structural uplift to form a positive topographic feature in large complex craters. Observations at the three largest structures: Vredefort, Sudbury and Chicxulub are consistent with models of peak ring formation but the models can not be independently confirmed, due to the small sample. While terrestrial structures were initially studied to understand impact as a planetary process, impact has also played a role in Earth evolution. Biological evolution was affected directly through the Chicxulub impact 65 Ma ago and the associated mass extinction. More important, however, was the formation of the Earth's moon as the result of a massive impact on the proto-Earth, which resulted in lunar tides and the creation of littoral zones to the world's oceans. On the time-scale of a million years or less, relatively small impacts are a continuing threat to the long-term survival of human civilisation. The creation of large, localized thermal anomalies and specific structural and morphological forms has resulted in historical and current economic quantities of natural resources in ~ 25% of terrestrial craters and related deposits. Some of these are world-class, e.g., Sudbury, Vredefort and the Campeche Bank oilfield, with the net result that impact structures produce ~ $20 B of natural resources per year. Although no rocks are preserved on Earth from the time of the heavy bombardment of the moon, a similar bombardment, scaled to terrestrial conditions, would have resulted in major remelting of the Earth's early crust. Thick impact melt sheets differentiate and such massive remelting would have led to secondary, felsic differentiates from basaltic materials of the early crust. Thus, these early massive impacts could have played a role in establishing the crustal dichotomy of felsic (continental) and mafic (oceanic) crust that distinguishes the Earth from the other terrestrial planets.