ADDING IMPACT GEOLOGY TO A TEXTBOOK IN HISTORICAL GEOLOGY. D. T. King, Jr.[1]
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Introduction: Including impact cratering and its physical and biotic effects through geological time is as important in an introductory historical geology textbook as including plate tectonics. Impact cratering, which has been extant on Earth since the formation of the planet and thus pre-dates plate tectonics, is an Earth surface process that has continued to have far-reaching effects over time.

Overarching impact-related themes that can run through a modern historical geology textbook include: size and frequency of impact cratering through geological time; biotic effects and the connections between impacts and the physical and biotic geological record; cosmic breakup events and their timing (including possible periodicity); and the future threat from space as evidenced by impacts of the past.

Recommendations: After some early review chapters, most historical geology textbooks are organized as a progressive march through time [e.g, 1-5].

A typical chapter on Hadean, the first eon, usually contains content about the heavy bombardment interval and at least some discussion of comets and in relation to early water on Earth. But, the Hadean chapter could also include discussion and graphics related to the Moon-forming event [6] and the role of large body impacts on other planets [7]. The chapter on Archean could include discussion and graphics regarding the effects of early Earth impacts [8], for example, Archean spherules [9]. The chapter on Proterozoic could include the giant impacts at Sudbury [10] and Vredefort [11], and their coeval ejecta [12].

The chapter(s) covering Early Paleozoic may include discussion and graphics related to the noteworthy Ordovician L-chondrite breakup event and associated meteorites and chromite grains in Ordovician-limestones from Swedish quarries [13]. Early Paleozoic chapters could include mention of some of the 50+ Paleozoic impact craters on Earth listed in the Impact Crater Database [14]. Epicontinetal seas were quite vast during Early Paleozoic, thus Early Paleozoic marine impacts were likely quite common. Of these, the Early Ordovician crater doublet Lockne-Målingen (Sweden) [15] is an especially interesting example. These coeval structures are both of marine impact origin. Further, the doublet aspect of these craters (owing to a binary or rubble pile asteroid impact [15]) may be of interest to readers.

In the Late Paleozoic chapter(s), discussion and graphics could be included about one of the largest North American cosmic impacts, the Alamo impact event [16]. The associated Alamo Breccia contains ejecta as well as a spectacular record of marine carbonate shelf disruption and collapse [16].

Mesozoic chapter(s) could include discussion and graphics related to the impact effects at the Triassic-Jurassic boundary [17], the Jurassic-Cretaceous boundary (and thus Morokweng impact structure in South Africa [18]), and the end-Cretaceous boundary (and thus Chicxulub [19] and its global ejecta) [20]. Evidence of Mesozoic system-boundary (and various stage-boundary extinctions) presents an opportunity for discussion of the correlation of biotic effects of impacts (perturbations resulting in extirpations and extinctions [21]). The Earth Impact Database [14] lists 50+ impact structures with Mesozoic ages, including craters such as Manicouagan, Rochechouart, Upheaval Dome, Morokweng, Mjølnir, Sierra Madera, Manson, and Wetumpka. The end-Cretaceous event has a huge body of literature associated with it, and this deserves careful attention in any modern historical geology textbook. In this regard, important example topics include the global ejecta record, inferred global impact effects, ecosystem damage, and extinction mechanisms.

Cenozoic chapter(s) could include discussion and graphics related to prominent impact events such as Chesapeake Bay in Virginia and Popigai in Russia, and their close temporal occurrence during Late Eocene [22], plus the related cosmic He^3 flux/"comet shower" [23]. Impact(s) connected to the PETM (Paleocene-Eocene Thermal Maximum) event [24], the late Pliocene Eltanin impact in the southern ocean [25], and the 790-ka tektite forming event(s) in southeastern Asia and perhaps elsewhere [26] potentially may be included. There are 60+ impact craters and structures listed in the Earth Impact Database [14], and many of these can be utilized, including the well-preserved examples of simple craters Lonar, Barringer, and Tswaing and the larger, tektite-forming craters Bosumtwi [27], Chesapeake Bay [28], and Ries [29]. Discussion of the Younger Dryas impact event [30] of about 12,900 years ago may engage readers with its apparently connection to sudden climate change.

In a chapter that addresses future changes on Earth, the continuing threat from cosmic impact [31] could be addressed along with equally important issues of the future such as human population growth, climate change, and species loss.

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ble to his adding impact geology content similar to that noted above to the new (2016) edition of *The Earth Through Time* [1].

References [6-31] are presented as examples of papers, books, or monographs that could be a starting point for anyone seeking to update textbook or classroom lecture content in historical geology. In most instances, there are a large number of other scientific references on each of the impact examples mentioned in this abstract.

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