IMPACT, AND ITS IMPLICATIONS FOR GEOLOGY; Ursula B. Marvin, Harvard-Smithsonian Center for Astrophysics, Cambridge MA 02138

The publication of seminal texts on geology and on meteoritics in the 1790s, laid the groundwork for the emergence of each discipline as a modern branch of science. From the first, the two subjects engaged the interest of different communities of scientists. With few exceptions those pursuing geology focused their entire attention on the Earth itself. Astronomers were more numerous among those investigating meteorites, the Moon, and planets . The constituencies and research programs of both communities have changed markedly during the past two centuries, but, to this day, a yawning chasm separates meteoritics from geology. To bridge the chasm is in the interests of both sciences, but to do so it will be essential to fully recognize its magnitude.

The implications of impact processes for geology are tremendous. Within the past three decades, impact cratering has become universally accepted as a process that sculptures the surfaces of planets and satellites throughout the solar system. An impacting projectile instantaneously excavates a crater, melts and shock-metamorphoses concentric zones of target rock, forms a plume of condensing vapors, and blankets the surroundings with ejecta. Since 1980, lively debate has taken place on the possibility of impact-generated extinctions--periodic or not periodic. It seems reasonable to assume that, over geologic time, exceptionally large and energetic projectiles may have plunged through planetary crusts and set up major, long-lasting disturbances in mantles and cores.

Nevertheless, one finds in-depth discussions of impact processes mainly in books on the Moon or in surveys of the Solar System. Textbooks in geology tend to treat impact craters and the impact theory of extinctions in a far more cursory fashion. A rapid survey of university catalogs shows that a graduate or undergraduate student can routinely receive a degree in geology (or earth sciences, including geophysics and geochemistry) from most major American universities with no exposure at all to the ramifications of impact. Those earth science departments that offer courses in planetary sciences do cover impact and related topics, but they often do so by adding cosmochemists to their faculties and addressing a separate subgroup of students. Full integration of planetary subjects into classical geology curricula is rare.

The historical source of the separation between meteoritics and geology is easy to identify. Geology was founded on concepts enunciated by James Hutton (1726-1797) who argued that the Earth is both the proper subject for geological investigations and the ultimate repository of all the answers. He formulated the idea that, during an unlimited expanse of time, the Earth has undergone slow, ceaseless change by processes we may observe in operation. Hutton asserted that we cannot, legitimately, call upon any powers not natural to the globe, admit of any action of which we do not know the principle, nor allege extraordinary events to explain a common appearance.

Meteorite impact is an extraordinary event acting instantaneously from outside the Earth. It violates Hutton's principles, which were enlarged upon and firmly established as fundamental to the geological sciences by Charles Lyell (1797-1875). It is probably not accidental that in four decades of prolific publication on geology, Lyell wrote only a few paragraphs on meteorites. As all of the meteorites that fell during his lifetime were small bodies that scarcely pock-marked the soil, Lyell was able to dismiss them as natural curiosities of no consequence to global geology. Two years before Lyell died, the British astronomer Richard A. Proctor (1837-1888) hypothesized that some of the basins and craters of the Moon might have originated from meteorite impact. That idea had been suggested and rejected several times since the early 17th century; it was rejected again when Proctor's book appeared. One of the arguments used against Proctor's thesis was that impact craters on the Moon should have counterparts on the Earth, where, obviously, there are none.

Impact and Geology
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The split between meteoritics and geology surely would have healed as early as 1892 if the investigations conducted by Grove Karl Gilbert (1843-1918) at the crater in Northern Arizona had yielded convincing evidence of meteorite impact. Gilbert had grasped the full implications the moment he heard of a rimmed crater in limestone on the Colorado plateau, at a site strewn with iron meteorites. With an imaginative leap, he confidently postulated crater-formation by meteorite impact and predicted the presence of a "buried star" beneath the crater floor. Gilbert was the first scientist ever to investigate the possibility of impact origin for a terrestrial crater. Had he found positive evidence for his buried star, Gilbert could have introduced the radically new and exciting concept of meteorite impact as a geological process, and, by the turn of the century, geologists around the world might well have been searching out and studying impact craters. But Gilbert discovered no satisfactory evidence for an impact origin. Although his report on the crater does not entirely rule out the possibility of impact, his arguments for a volcanic explosion at depth were widely accepted as final. For the next half-century only a few, scattered individuals pursued research on meteorite impact, while the larger geological community rejected the very idea of impact as a crater-forming process.

The 1950s and 1960s saw a burgeoning of interest in impact processes. The same period witnessed the so-called "Revolution in the Earth Sciences," when geologists yielded up the idea of fixed continents and began to view the Earth's lithosphere as a dynamic array of horizontally moving plates. Plate tectonics, however, is fully consistent with the geological concepts inherited from Hutton: the plates slowly split, slide, and suture, driven by forces intrinsic to the globe. How much more revolutionary is the very idea of geological change by sudden, violent collisions with bodies from space! New research programs may prove even more subversive to classical geology if causal links can be found between impacts and plate tectonics. We already know that collisions scar the Earth and may interrupt the course of biological evolution, but could they not also provide a key to the rifting of plates; to activation of plate motion; to heterogeniety in the mantle; the siting of continental nuclei; the location of mantle plumes? The idea of impact currently holds the attention of a strong constituency, but, for the most part, it has failed to engage the interest of geologists whose expertise will be essential to working out the problems in earth science it presents. How can we generate a meaningful dialog across the disciplines?