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Meteor Crater's Impact
When a Star Fell in Canyon Country

by David Kring

Meteor Crater

Quiet places sometimes belie violent origins. An Arizona landmark steeped in violence, or at least catastrophe, is Barringer Meteorite Crater, which was produced when an unearthly iron asteroid came hurtling through the sky.

This impact site, popularly known as Meteor Crater, exposes the same layers of rock that are visible along the rim of the Grand Canyon. Unlike the rocks in the Grand Canyon, however, the rocks at Meteor Crater were tortured by explosive forces that dwarf all but the largest nuclear explosions. And unlike the Grand Canyon, which was carved over millions of years, Meteor Crater was excavated in a few seconds.

The culprit responsible for the crater was over 4.5 billion years old. One theory is that the iron-rich core of a small planet between the orbits of Mars and Jupiter was exposed in a collision that occurred at least 540 million years ago, producing the asteroid that eventually hit northern Arizona 49,000 years ago.

Traveling around 28,000 miles per hour, thousands of tons of metal blazed a glowing trail of ionized gas through the atmosphere, splitting the sky in half as with fire. With a fiery rush, measured only in seconds, the asteroid pierced the rocky surface of Earth, releasing an explosion of energy. Shock pressure obliterated most of the asteroid, although surviving fragments and molten droplets rained down on the surrounding landscape for miles. The meteoritic fragments are called Canyon Diablo and contain minerals not of this earth. Iron crystals of kamacite and taenite dominate the meteorites, and shock pressures converted pockets of graphite to microscopic clusters of diamond and a new mineral called lonsdaleite.

Simultaneously, a shock wave radiated through the Earth's crust, producing pressures that obliterated target rocks in a fine spray of melt and vapor. The vast majority of rock affected by the shock wave, however, was pulverized and in some cases converted to new minerals. Quartz crystals in some samples of sandstone, for example, were transformed to high-pressure crystals of coesite and stishovite. High pressures also converted some quartz to a bubbly, flowing glass that when quenched formed pumice-like fragments of material. Surviving quartz in these samples are cross-cut by microcrystalline faults called shock lamellae. These features are unique to impact crater events, except where synthesized in laboratories and around nuclear weapons blasts.

Crushed rock beneath the point of impact began flowing in curving arcs that moved downward, outward, and then upward from the center of the blast, carving the bowl-shaped cavity we see today. Layers of rock in the walls of the crater, initially flat like those in the Grand Canyon, were pushed upward to produce an uplifted rim. Some of the layers of rock in the crater also folded back on themselves, forming an overturned sequence of layers in the rim of the crater, as if the rock was made of taffy. A total of 175 million tons of rubble was excavated and deposited around the crater over a distance three times its diameter, often littering the rim with house-sized boulders. A residual layer of rocky debris that lined the walls of the crater then collapsed downward, producing a thick lens of debris on top of a highly fractured crater floor.

An event with enough energy to vaporize rock was a calamity for the ice age mammals that browsed and grazed in northern Arizona at the time of impact: mammoths, mastodons, giant ground sloths, bison, camels, tapirs, and horses. The damage inflicted was similar to a nuclear bomb blast, but without ionizing radiation damage. Plants and animals at ground zero were vaporized. The explosive shock wave produced an air blast with winds in excess of 1,000 miles per hour near the impact, stripping away any grass and flattening any juniper and piñon trees out to radial distances of several miles. The air blast propelled animals for short distances, unceremoniously dumping them back onto the ground, sometimes with crippling injuries. The shock wave also caused internal bleeding and swelling in animals even if they managed to keep on their feet. The blast also flung branches, rocks and other debris, causing shrapnel-type wounds over distances of several miles. Heat from the blast burned both plants and animals.

Although these effects are severe, they were confined to the immediate region and did not cause the type of extinctions that are associated with the Chicxulub impact event and the demise of dinosaurs. In an interesting turn of events, the impact generated a new habitat. The ice-age climate was wetter and, thus, the water table was much higher than today. Immediately after the impact, artesian-fed waterfalls cascaded down the walls of the crater, filling it with a lake that was home to cattails, snails and other organisms, some of which are preserved in 100 feet of sediment that covers the crater floor. Complete recolonization of the area probably occurred within a hundred years.

Meteor Crater is the most pristine impact crater in the world and, for that reason, has been a valuable resource in planetary exploration. It was used during the Apollo era to train astronauts who walked on the Moon, so that they were better prepared to explore lunar impact craters and their ejected debris. Meteor Crater is still being used by scientists in their study of impact cratering processes throughout the solar system, including the hazards for humans on Earth. A Meteor Crater-size event occurs at an average rate of about once per 1,600 years somewhere on Earth (although this is still a poorly constrained estimate). Most of those impacts occur at sea, however, meaning impacts on populated land occur much less frequently. But this type of impact has sufficient energy to destroy a modern city. As the population of the Earth grows and the portion of the planet settled by people grows, the hazard of impact meteors will also increase. It is something to think about when staring into the hole produced by a multi-megaton blast at Meteor Crater.

David Kring studied geology and astrophysics as an undergraduate student at Indiana University and then geological sciences for his Ph.D. at Harvard University, while also working for the Harvard-Smithsonian Center for Astrophysics. He has been with the University of Arizona for the past 17 years. He has studied impact cratering processes around the world, including those at Meteor Crater. Kring is also one of the co-discoverers of the Chicxulub impact crater, which has been linked to the extinction of dinosaurs and most other plant and animal species on earth 65 million years ago. He has also written a book about the geology in the Tucson area, Desert Heat - Volcanic Fire*, which is published by the Arizona Geological Society and available from the Arizona Geological Survey.*

Additional Information:
Meteor Crater is part of the Colorado Plateau, a mile high geologic wonderland that is also riven by the Little Colorado River Gorge and the Grand Canyon to the north, home to the Hopi Buttes and Painted Desert to the northeast, the Petrified Forest to the east, the Mogollon Rim to the south, the red rocks of Sedona, which spill out of the plateau to the west, and the foundation for the towering volcanics of the San Francisco Peaks to the northwest. Along Interstate 40, including Flagstaff and Winslow, are pleasant lodging options, including the historical Winslow's La Posada Hotel and Gardens, which is one of Mary Colter's architectural landmarks. A newly renovated museum sits on the crater rim and viewing platforms are staggered from an even higher point on the rim (Moon Mountain) to a lower point on the interior wall of the crater that stretches out into space above the crater floor. An hour-long guided tour of the rim is available to those wearing suitable hiking shoes (no open toed foot ware) and a short movie about the impact event is available in a modern auditorium for the less intrepid.