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CHONDRULE-LIKE PARTICLES PROVIDE EVIDENCE OF EARLY ARCHEAN METEORITE IMPACTS, SOUTH AFRICA AND WESTERN AUSTRALIA; Donald R. Lowe and Gary R. Byerly, Department of Geology, Louisiana State University, Baton Rouge, Louisiana 70803

The scarred and cratered surfaces of the Moon, Mars, and Mercury bear witness to the major role meteorite impacts played in the early evolution of the planets. Current theories on the origin of the Solar System depict an early phase when dust, gas, and rock material forming the Solar Nebula were accreted through a complex, and still poorly understood series of events to form the primitive planets. The final stage of this accretionary history involved the intense bombardment of the planetary surfaces by meteorites representing much of the remaining interplanetary rock debris. Lunar rocks collected on the Apollo manned missions have shown that, on the Moon, this period of meteorite bombardment ended between 4,000 million and 3,900 million years ago. By 3,500 million years ago, impact rates on the lunar surface were only slightly higher than the low level of today. On Earth, a much more dynamic planet than most of its neighbors, the record of this terminal bombardment has been obliterated by weathering, erosion, and the recycling of crustal rocks due to tectonism. Until recently, it seemed probable that this portion of the Earth's history could be studied only by examination of materials collected on the Moon or in other parts of the Solar System.

In an attempt to develop a clearer picture of the early evolution of the Earth and its crust, geologists from the Department of Geology, Louisiana State University, have, for the past several years, been studying 3,500 to 3,300 million year old rocks in parts of Western Australia and South Africa. These form the oldest, relatively unaltered volcanic and sedimentary sequences preserved on the Earth, and are only slightly older than the oldest known terrestrial rocks, 3,800 million years old, from western Greenland. The LSU research team has included to date 5 undergraduate students in geology, 7 graduate students working toward Masters and Ph.D. degrees, and 4 LSU geology faculty members. This research has been supported by grants from the National Science Foundation. The work has been directed at a wide variety of projects dealing with the evolution of the Earth's early crust, oceans, atmosphere, and biosphere. Some of the more important results have demonstrated the importance, abundance, and diversity of life on Earth 3,500 million years ago.

In the course of this research, we have identified two rather inconspicuous layers, one in Western Australia and a second in South Africa, that contain abundant unusual spherical particles closely resembling chondrules. True chondrules are particles generally 0.1 to 2.0 millimeters in diameter, commonly roughly spherical, that are abundant constituents of many meteorites. They apparently formed over 4,500 million years ago by processes, as yet poorly understood, active during the accretion of matter within the primitive Solar Nebula. Chondrules also occur in small quantities in lunar soils. Their origins on the Moon have been attributed to both meteorite impacts and volcanic processes.

Chondrules and chondrule-like bodies are, however, rare in terrestrial settings. They have been reported as trace components of ejecta blankets around one or two relatively young meteorite impact craters. Similar particles, apparently produced by the melting of meteors during passage through the Earth's atmosphere, occur sparsely within deep-sea sediments. Chondrule-like particles have also been reported from 65 million year old detritus formed by the catastrophic meteorite impact that may have led to the extinction of the dinosaurs and many other groups of animals.

ARCHEAN IMPACTS

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In Western Australia and South Africa, chondrule-like particles have been found in two layers, each less than 1 m thick, interbedded within thick sequences of volcanic and sedimentary rocks. The chondrule-like grains appear to have accumulated almost instantaneously by the fall of material from the atmosphere into a wide variety of surficial sedimentary environments. Many of these environments were affected by wave and current activity, and the chondrule-like grains were transported and mixed with a variety of other detritus.

Most of these 3,500 million year old chondrule-like grains are spheroids that show internal structures and textures indicating that they formed by the rapid cooling and quenching of liquid silicate droplets. Their temperatures were probably in excess of 1000° Centigrade. The compositions of the particles suggest that the droplets represented melted portions of the immediately underlying rock sequences. The complex compositions, wide distributions, and absence of closely associated volcanic materials argue that the chondrule-like particles in these ancient terrestrial rocks also formed by melting of heterogeneous target rocks during meteorite impacts.

If formed by impact melting, these deposits document the oldest recorded terrestrial impact events. They lend strong support to the idea that some chondrules in meteorites could have formed on the surfaces of planet-sized bodies during impact events. Similar chondrule-like objects are extremely rare in the much more voluminous younger geologic record and abundances like those in these ancient deposits are unknown except in meteorites. These features suggest that a part of the Earth's terminal bombardment history is preserved in the geologic record and available for study, and also that conditions favoring chondrule formation, not present today, existed on the early Earth.