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Impactite from Henbury, Australia

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ABSTRACT

Impactite was formed in several small, closely spaced craters by the impact of iron meteorites on sandstone at Henbury, central Australia. Through application of energy dispersive X-ray spectroscopy, convergent-beam electron diffraction, and selected-area electron diffraction, chemical compositions and space groups were determined for multiple crystalline phases in the impactite. Based on this chemical and structural information, sub-micrometer fayalite (approximately 40% of the total volume of crystalline phases), magnetite (25%), α-quartz (20%), hercynite (10%), diamond (3%), and a Ni-sulfide phase (2%) were identified, in addition to abundant glass.

Compared with the pre-shock rock, the Henbury impactite was subjected to dramatic phase transformation and chemical redistribution and fractionation processes during the impact event. The newly formed dendritic crystalline phases such as fayalite, magnetite, and hercynite, as well as the surrounding glass, may represent metastable eutectic crystallization that occurred between approximately 1600 °C (liquidus temperature of hercynite) and 850 °C (75% of the liquidus temperature of fayalite) on a time scale of seconds. Generally, the composition of glass surrounding magnetite, fayalite, and hercynite is close to SiO_2, plus small amounts of Fe (about 10%), but the glass around magnetite can also be considerably more enriched in Fe. The distribution of magnetite and fayalite is probably related to the Fe^{3+}/Fe^{2+} ratio in the original melt as altered by the local oxygen fugacity, and the formation of hercynite is governed by both the Fe^{3+}/Fe^{2+} ratio and the distribution of Al in the sample. Alpha quartz probably formed from Fe-depleted silica in the autoannealing period, at low pressure and relatively low temperatures. Diamond crystals in the impactite are euhedral and may have formed through chemical vapor deposition (CVD) at very high temperatures. Nickel sulfide probably crystallized directly from sulfide vapor or quenched sulfide melts, under supercooled and reduced conditions. The impactite is chemically very heterogeneous, presumably due to the limited diffusion time available for mixing of Fe and silica during the rapid cooling history. Iron, Ni, and Mg tend to concentrate in fayalite, magnetite, and hercynite, whereas K and Si are enriched in glass. Hercynite contains more Al, and other crystalline phases less Al, than the glass. In general, the Henbury impactite reflects a chaotic mixture of equilibrium, metastable, and non-equilibrium domains produced at high temperatures in a very short time, and most crystallization appears to have occurred in the post-shock period.