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Libyan Desert Glass: New evidence for an extremely high-pressure-temperature impact event from nanostructural study

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Abstract

The origin of Libyan Desert Glass (LDG) found in the western parts of Egypt close to the Libyan border is debated in planetary science. Two major theories of its formation are currently competing: (1) melting by airburst and (2) formation by impact-related melting. While mineralogical and textural evidence for a high-temperature event responsible for the LDG formation is abundant and convincing, minerals and textures indicating high shock pressure have been scarce. This paper provides a nanostructural study of the LDG, showing new evidence of its high-pressure and high-temperature origin. We mainly focused on the investigation of Zr-bearing and phosphate aggregates enclosed within LDG. Micro- and nanostructural evidence obtained with transmission electron microscopy (TEM) are spherical inclusions of cubic, tetragonal, and orthorhombic (*Pnma* or OII) zirconia after zircon, which indicate high-pressure, high-temperature decomposition of zircon and possibly, melting of ZrO_2. Inclusions of amorphous silica and amorphous Al-phosphate with berlinite composition ($AlPO_4$) within mosaic whitlockite and monazite aggregates point at decomposition and melting of phosphates, which formed an emulsion with SiO_2 melt. The estimated temperature of the LDG melts was above 2750 °C, approaching the point of SiO_2 boiling. The variety of textures with different degrees of quenching immediately next to each other suggests an extreme thermal gradient that existed in LDG through radiation cooling. Additionally, the presence of quenched orthorhombic OII ZrO_2 provides direct evidence of high-pressure (>13.5 GPa) conditions, confirming theory 2, the hypervelocity impact origin of the LDG.

Keywords: Granular textures, transmission electron microscopy, zircon, phosphates, zirconium oxide, orthorhombic zirconia OII, cubic zirconia, immiscibility