Goldschmidt 2026 Abstract
https://doi.org/10.46427/gold2026.32919

Petrology and microstructure of ureilite meteorites to decipher early planetary body processes

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Ureilite meteorites are the second-most abundant group of achondrite meteorites. They are carbon-rich ultramafic rocks, dominated by olivine and pyroxene. They are considered to be primitive achondrites that formed in thermal conditions between undifferentiated chondrites and differentiated achondrites. It is currently accepted that ureilites represent partially-melted residual mantle rocks of a planetesimal of unknown size. The high variability in petrological textures suggests a complex history, including magmatic crystallisation, impact dispersion, heating, partial vaporisation, and high-temperature reduction.

To shed light on the primary magmatic and deformation processes, we investigated the microstructures of 14 ureilite meteorites. Most samples are olivine and clinopyroxene-rich, exhibiting varying textures from shape-preferred orientation of olivine grains to poikilitic pyroxene textures and/or layering. For example, NWA 7349 has a layer formed by poikilitic clinopyroxene enclosing rounded olivine grains without preferred orientations, while the rest of the sample is composed by layers of olivine grains with a marked preferred orientation. SaU 559 contains olivine and a large proportion of Opx, with a clear shape-preferred orientation and a strong internal deformation with the formation of subgrain boundaries in both. This internal deformation suggests a high-temperature plastic deformation which closely resembles the deformation observed in the upper mantle rocks formed by dislocation creep. The crystallographic preferred orientation (CPO) patterns of several samples show a strong concentration of olivine [001] axes along the supposed lineation, which is usually interpreted as crystal settling and magmatic flow. Olivine and Opx in SaU 559 show numerous subgrain boundaries, a strong concentration on the olivine [001] and [010] axes, and the Opx CPO is consistent with that of olivine ([001] axis parallel to olivine [001] axis), suggesting a common HT deformation, probably deep in the crust.

Our petrological and microstructural observations confirm that ureilite meteorites record a cumulate texture, and also indicate magmatic flow, compaction and early HT plastic deformation. These results provide additional constraints on the accretion and evolution of the parent body of ureilite meteorites.