MINERALOGY AND IN SITU PB–PB DATING OF SILICATE INCLUSIONS IN MILES (IIE)

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Introduction: IIE irons contain silicate inclusions that are chemically and isotopically related to H chondrites [1, 2]. These inclusions display an array of compositional and textural diversity, from "ultra-metamorphosed chondritic" to basaltic or more evolved andesitic to rhyolitic lithic fragments [1]. The Miles IIE iron contains a few U-bearing phases (armalcolite and phosphates) with different occurrences, providing opportunities to date the timing of igneous fractionation of silicates and dynamic mixing with metal. We conducted a thorough analysis of the mineralogy and in-situ Pb–Pb dating of silicate inclusions in Miles with the aim of better understanding of the complex thermal history experienced by the IIE parent body.

Results and Discussions: Silicate inclusions in Miles are mostly <1 cm and have irregular margins. Most of them contain pyroxene and plagioclase but their proportions vary considerably. Subhedral clinopyroxene commonly has a lamellar exsolution texture and usually shows intergrowths with orthopyroxene. The matrix consists of intergrowths of alkali feldspar (mainly antiperthite) and tridymite. Petrographic and mineralogical evidence indicates that Miles experienced a slow–rapid–slow cooling history. The first stage is indicated by the coarse-grained phenocrysts and lamellar textures in clinopyroxene. It was followed by a rapid cooling at temperature around silicate solidus, as indicated by the formation of thin-sliced antiperthite and the existence of glass in the gabbroic inclusions. The rapid cooling is also required for preventing the gravitational separation of metal and silicate [1, 2]. The last stage of slow cooling is implied by the coarse Widmanstätten pattern of host metal [2].

Euhedral or acicular apatite (< 150 μm) occurs in the silicate matrix whereas large irregular grains (up to 1.5 mm) are present at the boundary of host metal and inclusions (Fe–SI boundary). The euhedral apatite in the matrix is likely to have crystalized from a fractionated melt, which may be related to the impact that mixed the metal and silicates in Miles [3, 4]. The large irregular apatite grains, on the other hand, may have formed by subsolidus reduction processes during the mixing. Cr–Zr–Ca armalcolite also have two occurrences. One is commonly (partly) included in Pl and Py phenocrysts (< 150 μm), indicating crystallization as a liquidus phase. The other occurs at the Fe–SI boundary (> 200 μm), and these armalcolite may also be formed by subsolidus processes.

Armalcolite has a relatively high closure temperature (similar to baddeleyite) for the U–Pb system, which is estimated from its ionic porosity [5]. Therefore, the Pb–Pb age of armalcolite enclosed by Opx phenocryst could record the primary crystallization timing in the silicate protolith. In this study, only two sets of data were obtained, defining a range of 4564–4592 Ma. The euhedral apatites could have recorded the timing of the impact mixing that generated the IIEs, but their U–Pb system could have been reset during the subsequent subsolidus slow cooling due to their low closure temperature. The euhedral apatites yield a Pb–Pb "age" (4578 ± 24 Ma) indistinguishable from that of large irregular apatites (4561 ± 19 Ma) at the Fe–SI boundary. This indicates that the igneous fractionation of silicates and their dynamic mixing with metal were invoked very early, concurring with the solar system formation. These processes occurred contemporarily that could not be resolved by the current SIMS technique.

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