U-Pb dating of meteoritic perovskite

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Perovskite ($CaTiO_3$) is a minor but important oxide in Ca-Al-rich inclusions (CAIs) and is a particularly useful mineral for precise geochronology as it can contain significant concentrations of U and Th. Ireland et al. (1990) investigated U-Pb systematics of perovskite from Allende and Murchison CAIs using SHRIMP and obtained a $^{207}Pb/^{206}Pb$ age of 4565 ± 34 Ma for Allende. Here we report new TIMS and ion-probe data with significantly improved precision on perovskite grains from an Allende CAI.

The CAI, referred to as 134-1, is a large elongate (1.8 cm x 0.9 cm) Compact Type-A inclusion composed of melilite with minor amounts of spinel and perovskite. It also has a very thick (>1 mm) multi-layered rim sequence surrounding the coarse grained interior. Perovskite occurs as small (<50 μm) rounded grains scattered throughout, but is more abundant towards the core. It occurs as both interstitial grains and as inclusions in melilite.

Nine (~1μg) fractions of perovskite were separated and analysed via TIMS. Fractions were washed in acid to reduce surface contamination. The residues yielded low $^{206}Pb/^{204}Pb$ ratios between 43.5 to 167.5. Seven points define a Pb-Pb isochron indicating a $^{207}Pb/^{206}Pb$ age of 4568.3 ± 2.4 Ma (MSWD = 1.3). This age is consistent with other studies on Allende CAIs. Two analysis are lower than the line determined by the points defining the isochron. One of these two points has the highest proportion of common Pb.

U-Pb SHRIMP analysis of in-situ perovskite was investigated using a polished thick section of the same inclusion. U concentration in perovskite was between 3 and 23 ppm. Perovskite analyses yielded raw $^{206}Pb/^{204}Pb$ ratios between 437 and 6340. The data define a 16-point isochron indicating a $^{207}Pb/^{206}Pb$ age of 4562.2 ± 5.5 Ma (MSWD = 1.09) and within error of the more precise TIMS results.

There is a significant difference in the $^{206}Pb/^{204}Pb$ ratios between SHRIMP and TIMS analysis indicating that most of the common Pb in the TIMS data is from surface contamination and that there may be no initial Pb present. The data also suggests that there is some scatter in the $^{207}Pb/^{206}Pb$ ratios although no apparent age differences are resolvable at this level.

Reference

Ireland T.R., Compston W., Williams I.S., and Wendt I. (1990), *Earth and Planet. Sci. Lett*. 101. 379-387.

Pb-Pb geochronology of the early solar system

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We report high-precision Pb isotope data by MC-ICP-MS on whole-rocks and chondrule separates from ordinary chondrites (OC). Compared with literature CAI and mineral separate data [1-3], the ages obtained for OC throw new light on the timescale for the formation and cooling of planetary bodies in the early Solar System.

All age calculations were done in $^{207}Pb/^{206}Pb$-$^{204}Pb/^{206}Pb$ space, which minimizes noise-induced correlations between variables. We then assumed that the sample is a mixture of radiogenic (*) and common lead and used the intercept of the residue-leachate array in the $^{207}Pb/^{206}Pb$-$^{204}Pb/^{206}Pb$ plot to estimate the $^{207}Pb^*/^{206}Pb^*$ ratios. Full error propagation inclusive of blank contribution (0.01-0.9% of the total Pb contents) required the development of a specific correction scheme. We find that whole-rocks yield ages clearly less reliable than those of chondrules. Chondrules from Ste Marguerite (H4) give an age of 4563.4 ± 0.6 Ma indistinguishable from the phosphate age of 4562.7± 0.7 Ma [2]. These values are also indistinguishable from the age of the chondrules from Nadiabondi (H5) (4562.5 ± 0.9 Ma), whereas the phosphates give a younger age of 4555.6 ± 3.4 Ma [2]. The oldest age is obtained for Forest City (H5, 4567.8± 0.7 Ma). The chondrules from Tuxtuac (LL5) are 4559.9 ± 0.5 Ma old, again older than the phosphates (4543.6 ± 2.1 Ma) [2]. Overall, the ages of L OC are younger than those of H and LL OC. Cooling rates may be estimated using the data of [4] on Pb diffusion in rock-forming minerals: a fast cooling rate (~300°C/My) is inferred for Ste Marguerite, whereas Nadiabondi (~40°C/My) and Ausson (L5; 10°C/My) appear to have cooled much more slowly. The age of Ste Marguerite is therefore the closest to the temperature peak. Assuming that the dominant heat source was ^{60}Fe ($T_{1/2}$ = 1.5 My), this places the age of the protoplanet at 4567 ± 1 Ma, which is similar to the age of the CAI of [1].

References

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[4] Cherniak et al. (1991) GCA 55, 1663-1673.