Lead Isotope Investigation of the Tagish Lake Carbonaceous Chondrite

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Summary

Since chondritic meteorites (chondrites) are the most ancient known rocks in our Solar system, they provide unique opportunities to constrain the ages of planetary materials and objects that formed in the accretion disk (Solar nebula) of our early sun, or on the parent bodies of the chondrites themselves. In particular, intense focus has been devoted to the Tagish Lake (CI UNGR) chondrite since its fall and recovery (Brown et al. 2000; Hildebrand et al. 2006).

Here we present the lead isotopic compositions of four 'pristine' bulk samples of the Tagish Lake carbonaceous chondrite measured by (1) laser-ablation inductively coupled plasma mass spectrometry (LA-ICP-MS), and (2) high-precision isotope-dilution thermal ionization mass spectrometry (ID-TIMS). The four samples acquired consisted of MM47/66, HG-11, MG-62 and MM-87 (Fig. 1). ID-TIMS regressions through the $^{206}Pb/^{204}Pb$ vs. $^{207}Pb/^{206}Pb$ data for these four samples (obtained on a VG-354 TIMS in Daly and dynamic-Faraday modes using a ^{205}Pb-^{235}U spike) yielded slightly radiogenic lead that is consistent with an initial isotopic composition similar to that of primordial Canyon Diablo troilite (Tatsumoto et al. 1973 and see Fig. 2). Subsequent analyses by LA-ICP-MS (on a single-collector VG PQ ExCell and UP213 laser ablation system) showed a similar pattern, consistent with a $^{207}Pb/^{206}Pb$ meteorite isochron age of 4.5 Gyr (Fig. 2 & 3). However a precise and well defined $^{207}Pb/^{206}Pb$ age-regression from the ID-TIMS data remains obscure due to the apparent lack of mineral phases in our samples with undisturbed radiogenic lead content. LA-ICP-MS surveying was unable to pinpoint any significant radiogenic lead-bearing phases across these four samples (Fig. 3) and, combining an SEM-BSE survey with micro-X-ray diffraction (on a large type-specimen 'P2 ROM') it appears that Pb has been substantially mobilized into the matrix of this meteorite due to pervasive aqueous alteration on the Tagish parent body.

Obtaining a precise $^{207}Pb/^{206}Pb$ age from datable phases in Tagish such as chondrules and/or calcium-aluminum-rich inclusions (CAIs) would be of significant interest. This would afford a better illumination of (1) any genetic connections of Tagish to both CI and CM chondrites including the development of the two known lithologies (Zolensky et al. 2002; Simon & Grossman 2003); (2) the relationship of the organic features detected in Tagish (references 3–5) with the formation of other planetary objects, and (3) the age of D-type outer Solar system asteroids which have never been previously sampled (Hiroi et al. 2001). Although bulk Tagish shows a very primitive and slightly radiogenic lead signature, a well-defined precise $^{207}Pb/^{206}Pb$ age is not possible to obtain unless phases containing radiogenic Pb are found (better preserved chondrules or CAIs). However our SEM, LA-ICPMS and micro-XRD surveying of Tagish suggests these phases, if present, are extremely rare.

Acknowledgements

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References

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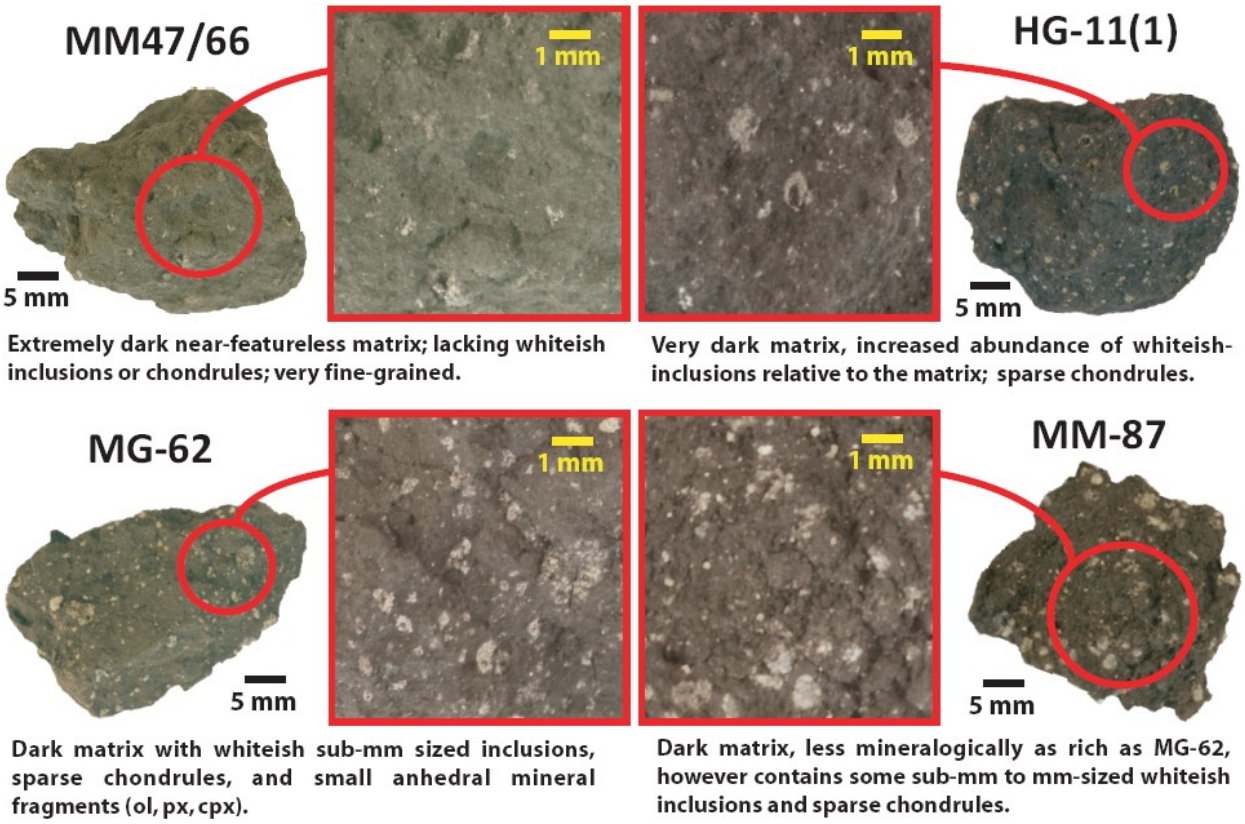


Figure 1: Representative photographs of the four Tagish samples obtained for lead isotope analysis by ID-TIMS and LA-ICP-MS.

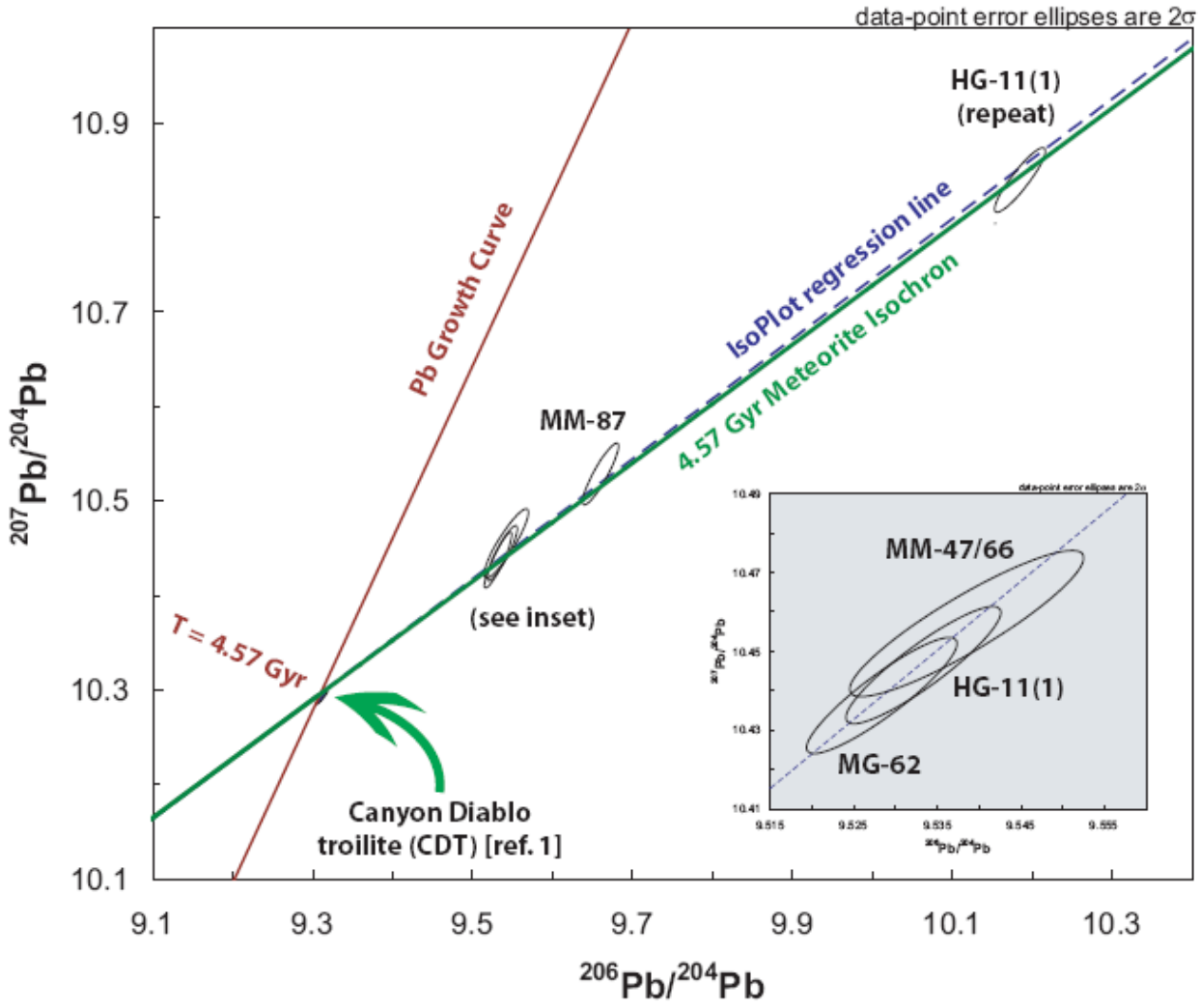
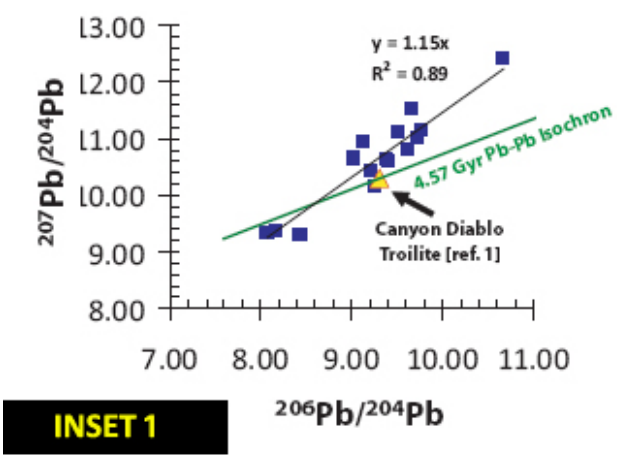
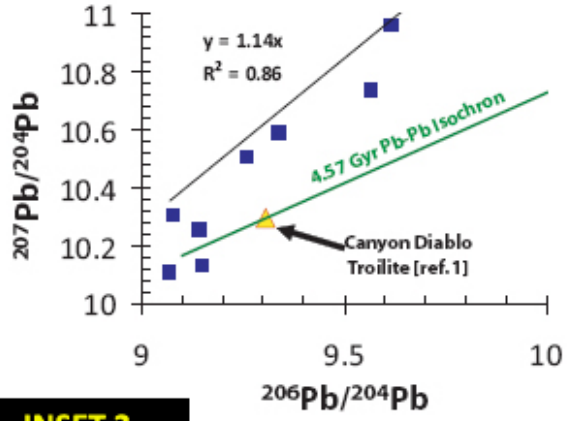


Figure 2: ID-TIMS bulk analyses from the four samples of Tagish in Figure 1 showing the $^{206}Pb/^{204}Pb$ vs. $^{207}Pb/^{204}Pb$ ratios. Data points (enclosed by their error-ellipses) are corrected for fractionation, blank and spike-addition. The data are regressed through Canyon Diablo troilite lead (Tatsumoto et al. 1973) and the lead growth curve of Stacey & Kramers (1975) is shown along with a 4.57 Gyr meteorite isochron through Canyon Diablo. Our analysis shows that the age of Tagish is consistent with the known ages of chondritic meteorites (ca. 4.5 Gyr) however a precise age was not possible to obtain from our Tagish samples due to the lack of radiogenic phases in our samples.



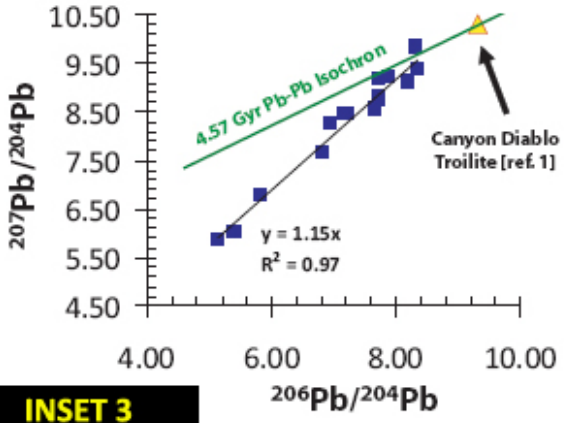
INSET 1

Baseline corrected analyses for HG-11. (50-200 um spots, 10 Hz, 60% output).



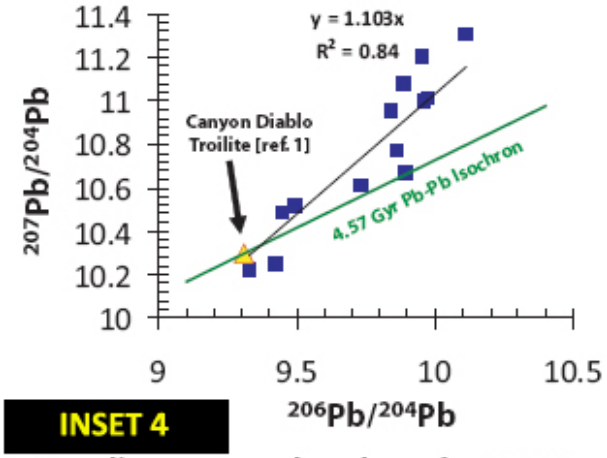
INSET 2

Baseline corrected analyses for MM-47/66. (50-200 um spots, 10 Hz, 60% output).



INSET 3

Baseline corrected analyses for MM-87. (50-200 um spots, 10 Hz, 60% output).



INSET 4

Baseline corrected analyses for MG-62. (50-200 um spots, 10 Hz, 60% output).

Figure 3: LA-ICP-MS results from the four bulk-rock Tagish samples of Figure 1. Each inset corresponds to a particular sample as stated.