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Evidence for Extinct ^{92}Nb Radioactivity in Chondrites and SNC Meteorites

Chrystèle Sanloup (csanloup@ens-lyon.fr), **Janne Blichert-Toft** (jblicher@ens-lyon.fr), **Philippe Télouk** (ptelouk@ens-lyon.fr), **Philippe Gillet** (pgillet@ens-lyon.fr) & **Francis Albarède** (albarede@ens-lyon.fr)

Laboratoire de Sc. de la Terre, ENS Lyon, 46, allee d'Italie, 69364 LYON Cedex 07, France

Introduction

The ^{92}Nb nuclide forms in supernovae by p-processes (Harper, 1996) and decays by electron capture to ^{92}Zr with a half-life of 34.7 Ma. The first attempt to search for the extinct radioactivity of ^{92}Nb was unsuccessful (Minster and Allègre, 1982), leading to the conclusion that the solar nebula formed without significant ^{92}Nb. Because the size of potential Zr isotope anomalies in chondrites is on the order of only 10-500 ppm, the required precision cannot be routinely achieved by TIMS on small amounts of Zr. Meanwhile, large ^{92}Zr anomalies were found in Nb-rich rutile from two iron meteorites, Toluca, with ε^{92}Zr=9.1±1.7 (Harper, 1996), and Zagora, with ε^{92}Zr=20-26±6-10 using laser ablation ICP-MS (Yin et al., 1999). In the present work, we take advantage of the high precision and high sensitivity of magnetic sector ICP-MS (a VG model P54) to reinvestigate the Zr/Nb isotopic systematics among chondrites and some differentiated meteorites.

Analytical technique and results

The isotopic compositions of Zr were analyzed for carbonaceous, enstatite, and ordinary chondrites, as well as one eucrite and four SNC meteorites. All the Zr isotopes (^{90}Zr, ^{91}Zr, ^{92}Zr, ^{94}Zr and ^{96}Zr) were measured, as well as ^{95}Mo and ^{98}Mo in order to monitor for molybdenum interferences on masses 92, 94 and 96. Six of the analyzed chondrites show distinct negative ^{92}Zr/^{90}Zr anomalies, reaching down to -2.7±0.8 ε-units for Forest Vale (H4) (cf. Figure 1). A separate rich in CAIs from Allende also show a negative ε^{92}Zr of -2.4±0.5. CAIs are among the oldest known igneous objects of the solar system and have the highest Zr/Nb ratios. The SNC meteorites and Stannern do not show significant ^{92}Zr anomalies except Chassigny (dunite) with an anomaly of -0.47±0.30. The Zr/Nb ratio of all the chondrites, as measured by quadrupole ICP-MS, cluster tightly around the mean value of 15.1±2.8.

Discussion

When our data on Allende CAIs are combined with literature data on Toluca (Harper, 1996), the apparent age differences (225±15 Ma) imply that the initial ^{92}Nb/^{93}Nb ratio of the solar system was different for the Toluca and the Allende CAI reservoirs. It has been proposed that the CAI precursors were stripped from their volatile elements upon severe re-heating in the vicinity of the Sun (Shu et al., 1996), a process which would have preferentially removed the more volatile Nb relative to Zr and produced the measured ^{92}Zr anomaly. This hypothesis, however, can be ruled out as no clear correlation between ε^{92}Zr anomalies and Zr/Nb ratios is observed in chondrites. Meanwhile, a mixture of 95% "regular" chondrite + 5% ultra-refractory material (with a -50 ε.u. anomaly and a Zr/Nb ratio of 30 (Kornacki and Fegley, 1986) would generate a "whole rock" anomaly of -2.5 ε.u. and a Zr/Nb ratio of 16.4. We therefore propose that our results imply either a heterogeneous distribution of ^{92}Nb in the early solar system, as has also been demonstrated for ^{53}Mn (Lugmair and Shukolyukov, 1998), or Zr depletion of CAIs as they flew by close to the Sun (Shu et al., 1996). The anomalies would then result from mixing between a highly fractionated CAI component and some anomaly-free chondritic material. The anomaly measured for Chassigny argues against a protracted accretion history for Mars. In addition, the presence of Ca-pyroxene or garnet is required in the deep Martian mantle in order to fractionate Zr *vs* Nb, unless Nb is preferentially dissolved into the metallic Martian core.

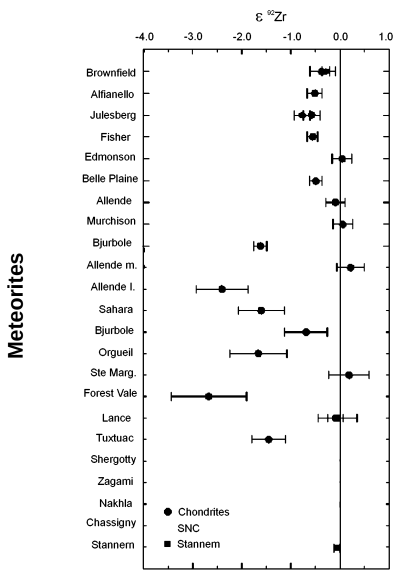

Figure 1: ε^{92}Zr in meteorites.

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