LARGE COSMOGENIC RHENIUM ISOTOPE ANOMALIES IN EVOLVED IIAB IRON METEORITES.

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Introduction: High-precision ^{182}Hf-^{182}W model ages for iron meteorites reveal rapid (1-2 Ma) formation of differentiated bodies in the early solar system [1]. Such ages need to be corrected for cosmogenic neutron capture on the W isotopes [2]. This is usually accomplished by seeking correlations with cosmogenic effects induced in other siderophile elements, particularly Pt isotopes [1-4]. Such corrections are approximate and leave significant residual uncertainties, so that the fundamental limit on the time resolution of the Hf-W model ages is determined by the cosmogenic neutron capture corrections and not by the precision of the W isotope mass spectrometry. We report a new way around this obstacle with the goal of achieving W model ages that are limited only by instrumental precision. Neutron capture on ^{184}W and ^{186}W produce ^{185}Re and ^{187}Re. The neutron capture cross-section of ^{184}W is small, and the cosmogenic effect is mainly burn-out of ^{186}W, so that normalization by ^{186}W/^{184}W propagates errors into the measured ε^{182}W and ε^{183}W. The cosmogenic burn-out of ^{186}W produces an excess of ^{187}Re/^{185}Re, which is most obvious in irons with a high W/Re ratio. The IIAB irons exhibit a large range in W/Re ratio, >200 in the most evolved irons, that, therefore, form an excellent testing ground for this method.

Analytical Methodology: The isotopic composition of Re was determined on a Thermo Neptune™ MC-ICP-MS, corrected for instrumental mass bias using sample-standard bracketing with an in-house Re standard. We have previously reported precise δ^{187}Re (±0.02 permil) for 40 ng aliquots of Re from iron meteorites [5]. To work with smaller samples, we measured the decrease in precision with decreasing aliquot size of Re down to 100 pg of Re, where counting statistics become the limiting factor. Precision for 100 pg aliquots of Re was about ±1 ‰, and about ±0.1 ‰ for ~1 ng of Re. The evolved IIAB irons Navajo, Mount Joy, Old Woman, Sandia Mountains, and Sikhote-Alin, were measured with sample sizes of 0.3-0.9 g resulting in aliquots of Re of 3-7 ng. Rhenium was extracted by using a combination of cation and anion separation chemistry [5]. Residual Os was corrected by Os isotopes measured at masses 188, 189 and 190.

Neutron capture effects were modeled following the approach of [2]. The thermal neutron capture rates on W and Re isotopes were used to calculate the effects on the Re isotopes. The spallation contributions from other siderophile elements were neglected.

Results: The irons Negrillos and Coahuila were measured at ±0.03-0.05 ‰ precision [5] with Coahuila exhibiting an anomaly of Δ^{187}Re of +0.34±0.05 ‰ relative to Negrillos, which has experienced undetectable cosmic irradiation. Large Re isotope anomalies were noted in evolved IIABs, from δ^{187}Re of +3.5±0.1 ‰ in Navajo to +50±2 ‰ in Sikhote-Alin, that correlated approximately with increasing W/Re ratio. Residual Os corrections were significant for some of the irons, but amounted to less than 10% for the Sikhote-Alin sample. Errors associated with the Os corrections were propagated to the reported precision.

Discussion: Based on an isotopic effect of +0.34±0.05 ‰ between Negrillos and Coahuila [5], we inferred an effect of ~+15 ‰ in Sandia Mountains, and we measured an effect of +13.0±0.2 ‰ for this meteorite. When the excess atoms of ^{187}Re are converted to atoms of ^{186}W, the inferred isotopic deficit in the ^{186}W/^{184}W ratio ranges from -0.7 to -2.7 epsilon units for the five IIABs. The observed Re isotope range extending to +50 ‰ is a surprisingly large effect when compared with results from modeled epithermal neutron energy spectra expected in irons ranging from 5-120 cm in radius [2]. The neutron capture model predicts a maximum value of δ^{187}Re of +2.5 ‰ in Sandia Mountains at a depth of about 80 cm, using an exposure age of 720 Ma and measured W/Re=147. The empirical data indicate effects that are nearly an order of magnitude larger for δ^{187}Re (+13 ‰) than predicted by the model results for reasons that are not fully understood at present. Because of the large amplification of the cosmogenic burn-out of ^{186}W on δ^{187}Re by the large W/Re ratios, errors in the neutron capture cross-sections of ^{186}W as a function of neutron energy will be magnified. Neglecting the spallation effects from Os, Ir and Pt is not likely to make a significant difference because Os and Ir abundances are in the ppb range, comparable to those of Re. The presence of large cosmogenic isotope anomalies in Re isotopes from neutron capture on W isotopes provides a new direct approach to correcting cosmogenic neutron capture on W isotopes that has the potential to improve W model ages to levels limited by analytical precision of the W isotopes, currently around ±5 ppm uncertainties.

References:

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