Goldschmidt 2024 Abstract
https://doi.org/10.46247/gold2024.24675

A New Approach to Probe Carrier Phases of Extraterrestrial ^{3}He in Pelagic Sediments

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Cosmic dust particles are implanted with solar wind noble gases, including helium with very high ^{3}He/^{4}He, during their residence in space. When accreted by Earth, cosmic dust grains smaller than ~35 μm do not experience intense atmospheric frictional heating, and can carry their volatiles to the Earth's surface [1]. Cosmic dust deposited in pelagic sediments retains extraterrestrial helium over hundreds of millions of years [2], and sediment extraterrestrial ^{3}He has been used to track changes in cosmic dust accretion flux and as a constant flux proxy over short time periods.

However, the <100-nm implantation depth of solar wind helium in cosmic dust makes its retentivity somewhat surprising. Acid leaching and magnetic separation experiments on deep sea sediments suggested magnetite to be the He-retentive phase [3], but such experiments were not conclusive. In addition, magnetite in cosmic dust is formed during atmospheric entry [4] and it is difficult to explain helium retention during chemical transformation. The identities and behaviors of the retentive carrier phases of solar wind helium in the cosmic dust remain unclear.

We provide new insights to this topic with helium, ^{230}Th, and magnetic data on a set of natural sediment samples and experiments. During periodic Mediterranean anoxia events, magnetite was reductively dissolved from the sediment, forming pairs of magnetite-depleted "dissolution intervals" and unaffected "normal sediment" [5]. Our work on two such pairs younger than 100 ka show that this natural experiment did not remove substantial extraterrestrial ^{3}He, indicating carrier phases that are insensitive to changes in redox states, thus unlikely being magnetite. We further extend this experiment into geologically ancient sediment by selectively removing magnetite through reductive dissolution [6], which is different from the traditional acid leaching approach. These results help us gain new insights into the carrier phases of extraterrestrial ^{3}He, the mechanism of its retention, and whether the retentive phases in pelagic sediments change with time.

[1] Farley, 1997
[2] Patterson, Farley and Schmitz, 1998
[3] Mukhopadhyay and Farley, 2006
[4] Brownlee, 1985
[5] Larrasoana et al, 2003
[6] Poulton and Canfield, 2005