

The source of Si in terrestrial plants: amorphous silica vs clay minerals

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Although Si is generally not considered as a nutrient for terrestrial plant, there are increasing evidences showing a beneficial effect of Si particularly under environmental stresses. Recent studies have suggested that land use and particularly agriculture can modify the Si cycle through a depletion of soil available Si. The extent of the perturbation, its impact on the plant cycle and food production is challenging and requires a better assessment of the biogeochemical acquisition of Si by plant. Si accumulated in plants originates from the dissolution of soil silicates. In soil solutions, Si is mostly present as the neutral molecule $\text{Si}(\text{OH})_4$ (silicic acid). $\text{Si}(\text{OH})_4$ is absorbed by the roots by a mechanism that is not fully understood. Both active and passive uptakes have been evidenced. In shoots, $\text{Si}(\text{OH})_4$ is polymerized through the elimination of water by evaporation and, eventually, phytoliths (amorphous opaline silica particles) form. Steady state models show that plants absorb a significant fraction of dissolved Si that originates from litterfall decomposition i.e phytolith dissolution. Laboratory experiments show that phytoliths are a source of silica amongst the most soluble of the soil minerals at slightly acid to neutral pH. However, because the concentration of phytoliths in soil is generally low (below 10 mg/g), the contribution of clay minerals as a source of bioavailable silica is poorly documented but could be crucial in nutrient-limited soils where highly soluble primary silicates have been exhausted. A pot experiment using Durum wheat was conducted to assess the capacity of different silicate sources to release bioavailable silicon. For this purpose we used three types of sources: quartz (Q), clay (C, vermiculite) and amorphous silica (D, diatomite, as an analogue for phytoliths). Mixtures (Q + C and Q + D) were prepared in different proportions. Wheat plants were grown for 60 days in these mixtures. We found that the plants grown in the Q + D mixtures accumulated in their shoots about twice more silica (16-22 g kg⁻¹) than those grown in the Q + C mixtures (7-13 g kg⁻¹). These results show that, although soil amorphous silica (phytoliths) constitutes the most bioavailable Si pool for plants, the contribution of clay minerals should be more fully evaluated.

Nucleosynthesis and Isotopic Anomalies in FUN CAIs

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Introduction

Millions of stars working over Galactic history generated the mix of isotopes present in the interstellar medium 4.6 billion years ago. Importantly, each of the roughly 280 different naturally-occurring isotopes in the Solar System had a different production route during this history, and present Solar System objects may contain a chemical memory of these varying histories [1]. Isotopes of Ca, Ti, Cr, Mo, and Ba in particular show anomalies in primitive Solar System samples, which thus give evidence of such chemical memory (e.g., [2]-[4]), and a key goal of isotope cosmochemistry in the coming years will be to understand what these anomalies are telling us about nucleosynthesis, Galactic chemical evolution, and Solar System formation.

Neutron-Rich Iron-Group Isotopes and FUN CAIs

The anomalies in the neutron-rich iron-group isotopes found in FUN (fractionation and unknown nuclear effects) CAIs (calcium-aluminum-rich inclusions) present a long-standing example of a likely cosmic-chemical memory effect [2]. FUN CAIs show correlated excesses and deficits in the isotopes ⁴⁸Ca, ⁵⁰Ti, and ⁵⁴Cr. All three of these isotopes have substantial production in a low-entropy environment [5], most likely the thermonuclear disruption of a dense white dwarf star [6]. At the same time, ⁵⁰Ti and ⁵⁴Cr, but not ⁴⁸Ca, have substantial production in massive stars (e.g., [7]). It is likely that the dust in the interstellar medium is highly anomalous. When this dust is incorporated into the Solar cloud, the Solar System will inherit these anomalies, and processing within the protoplanetary disk incorporates those anomalies in the FUN CAIs. In order to understand all of this history, we are making estimates of the siting of these isotopes in the interstellar dust along with their expected isotopic anomalies.

Tools for Understanding Nucleosynthesis and Galactic Chemical Evolution

Nucleosynthesis and chemical evolution are complex subjects that researchers best understand by running their own calculations. All of the computational tools we are developing to understand chemical memory in Solar System samples are open source and available for download (e.g., [8]), and we hope these tools will help others gain a better appreciation for nucleosynthesis and Solar System isotopic anomalies.

[1] Clayton (1978) *Moon and Planets* **19**, 109-137. [2] Lee, Papanastassiou, & Wasserburg (1978) *Astrophys. J. Lett.* **220**, L21-L25. [3] Niederer, Papanastassiou, & Wasserburg (1980) *Astrophys. J. Lett.* **240**, L73-L77. [4] Qin, Carlson, & Alexander (2011) *Geochim. Cosmochim. Acta* **75**, 7806-7828. [5] Meyer, Krishnan, & Clayton (1996) *Astrophys. J.* **462**, 825-838. [6] Woosley (1997) *Astrophys. J.* **476**, 801-810. [7] Meyer, The, & El Eid (1996) *Lunar and Planet. Sci.* **27**, 875. [8] <http://sourceforge.net/projects/nucnet-tools/>.