The oldest isolated life-bearing macrosystem on the planet?

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Water bearing macrosystems that have been isolated from the surface, preserved on geological timescales (>10Ma) and capable of supporting life, are seemingly rare. The only study of its type is now established in the South African Precambrian Crystalline Shield [1, 2]. The Witwatersand Basin provides the case type study and a unique insight into the evolution of chemolithotrophic life, the ability of even the most nutrient poor environments to support life in extremis, and thus environments that may support life on other planets [2]. The stable isotopic composition of the water, showing a high degreee of water-rock interaction, allows the inference of isolation from surface waters and a long residence time. It is the in-situ buildup of radiogenic noble gases (e.g. ^{4}He, ^{21}Ne, ^{40}Ar, ^{136}Xe) that has provided the basis for quantifying how long this system may have been isolated from the surface [1]. An outstanding question is how rare are such systems?

We have determined the noble gas concentration and isotopic composition of 6 gas samples, co-produced with water, from deep exploratory boreholes in a producing mine in the Timmins region of the Canadian Precambrian Crystalline Shield. Neon isotopic compositions are similar to the Witwatersand study and used to validate the closed system assumption for the radiogenic noble gases [1]. Using a similar model to [1], modified for local conditions (2.8ppm U, 10.6ppm Th, 3.4% K and 1% porosity and 100% release efficiency), we calculate closed system noble gas ages of the free produced fluids to be between 650Ma to 1.5Ga. These are the oldest 'free water' yet found in a crustal system.

Multi-collector noble gas mass spectrometry provides an order of magnitude more precision in the isotope determination of some free fluids [3]. We also resolve in all samples a clear ^{129}Xe signal in excess of atmospheric values. We can discount mass fractionation mechanisms and need to identify the source of the ^{129}Xe enrichment, only ever observed before in mantle-derived terrestrial fluids. ^{3}He/^{4}He allows us to discount a significant magmatic fluid source. Similarly, U-fission Xe (e.g. $^{132-136}$Xe) are produced at a known rate with fission ^{129}I (^{129}I → ^{129}Xe, t½=15.7Ma). The excess U-fission ^{136}Xe precludes a simple U-fission source for the ^{129}I → ^{129}Xe.

The ^{129}Xe excess observed is nevertheless most likely due to a local source of ^{129}I. We are collecting data to resolve two possible sources: i) U-fission ^{129}I released at steady state into the porewater through an extreme CFF (Chemical Fractionation of Fission products) process. CFF is required to prevent the associated fission Xe products reaching the porefluid and in turn would impact our previous assumption of 100% release efficiency and require older ages yet; or ii) the possibility of organic rich sediments associated with the formation lithologies supplying either the ^{129}I or its decay product (^{129}Xe). The latter would require a fluid closure date related to the last major mineralising event at 2.670Ga.

While the age determinations undgergo refinement with the new Xe information, our results nevertheless suggest that ancient and isolated macrosystems that have the potential to support life [2] may yet be found in a substantial portion of the Earth's Precambrian Crystalline Shields.

[1] Lippmann-Pipke et al. (2011) *Chemical Geology* **283,** 287-296.
[2] Lin et al. (2006) *Science* **314,** 479-482.
[3] Holland et al. (2009) *Science* **326,** 1522-1525.

Biotite Weathering in Watersheds of the Slavkov Forest, Czech Republic

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Introduction and Methods

Biotite is one of the primary sources of potassium and magnesium in soils and is easily weathered by microbes and plants to access these nutrients. It is shown that ectomycorrhizal fungi play a significant role in mineral dissolution and nutrient translocation to their host plant. Numerous controlled laboratory experiments have demonstrated physical and chemical interactions of ectomycorrhizal fungi with biotite, ranging in scale from individual grains to artificial mineral soils. However, whether ectomycorrhizal fungi have a significant contribution to soil mineral weathering under natural forest conditions, remains controversial.

In our study, mesh bags containing 1 wt% small biotite flakes and one large freshly cleaved flake in quartz sand, were buried in spruce forest soils for two years at three sites where the bedrocks were serpentinite (K limited), leucogranite (Mg limited) and amphibolite (no limitations). The 60 µm mesh size allowed fungal hyphae to grow in the bags, but excluded direct plant root contact with the minerals, allowing us to test the direct contribution of ectomycorrhizal fungi on biotite weathering under naturally occuring K and Mg limitations. Mineral surfaces were examined with scanning electron microscopy (SEM) and atomic force microscopy (AFM). The total ectomycorrhizal biomass was determined by Ergosterol analyses.

Results and Discussion

Microscopy documented 5% or less direct fungal attachment to basal planes of biotite from all sites, with the lowest occurrence found at the low Mg site. The ergosterol results support these observations, with the lowest colonization of the bags at the low Mg site. Potassium limitation does not influence ectomycorrhizal colonizations. Shallow etched channels, similar to hyphae in size and branching pattern, are seen by AFM and SEM. These channels show short, segmented sections, i.e. a pulsive growth pattern and at each "pulse," the channel deepens in the direction of growth. We propose that this morphology reflects both chemical dissolution and physical force at the hyphal-mineral interface. However, abiotic processes, such as wear from sand grains rolling over biotite surfaces can produce similar patterns that are nearly indistinguishable from channels formed by hyphal activity.

Our observations from these field experiments support laboratory results, i.e., that fungal hyphae exercise both chemical dissolution and physical force at the hyphal-mineral interface, but abiotic processes cannot be excluded as an explanation for the formation of shallow channels on the soft biotite surfaces.