Isotopic constraints on the genesis of world-class REE-P-U-Th mineralization, Nolans Bore, Central Australia

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The Nolans Bore deposit in central Australia is one of the world's largest known REE resources (current estimates 30.3 Mt containing 850 kt REE-oxides, 3.9 Mt P_2O_5, 6100 kt U_3O_8). Hosted in 1.9-1.8 Ga metasedimentary and meta-igneous rocks of the central Arunta region and postdating 1.60-1.57 Ga high-grade metamorphism, primary mineralization occurs in NE-trending swarms of F-apatite veins, associated with allanite, carbonate and calcsilicates. The bulk of the REE is hosted in cheralite, bastnaesite and other REE-rich mineral inclusions in apatite. Key geochemical features include remarkably uniform, strongly fractionated REE patterns (La/Lu_{cn}~281, Eu/Eu*0.89), elevated Ca, Sr, Th, U, Y, F, CO_2, but low HFSE. The mineralization is of high-temperature hydrothermal origin and, although lacking features such as alkalic minerals or fenitization, may be a distal hydrothermal expression of concealed carbonatitic/alkaline magmatism.

U-Pb dating of U-rich (260-700 ppm) F-apatite yields a well-defined upper intercept age of 1244±10 Ma. All other minerals analysed to date (allanite, pyroxene, epidote, garnet, calcite) contain variable amounts of unsupported radiogenic Pb ($^{206}Pb/^{204}Pb$ 35-58), indicating loss of U-Th (or gain of Pb). Initial $^{87}Sr/^{86}Sr$ ratios vary from 0.7047 to 0.7079, while ε_{Nd1224} ranges from -12 to -4; there is no correlation between Sr and Nd isotope ratios. All samples show some inter-mineral Sr-Nd isotopic disequilibrium.

The 1244±10 Ma apatite U-Pb age, the only currently available age constraint for mineralization, coincides with a global spike in kimberlite, lamproite and carbonatite emplacement (1300-1130 Ma), and several 1.3-0.7 Ga carbonatite, lamprophyre and alkalic intrusive complexes are known in Central Australia. Nolans Bore may be related to a currently unexposed intrusive of this type. The low $^{87}Sr/^{86}Sr$ of the ore fluid is consistent with such a source. Nd isotope data are less diagnostic as initial ε_{Nd} near -10 are characteristic of the local Arunta Block crust at that time; however, low ε_{Nd} values would be also be consistent with a source ultimately derived from lithospheric mantle.

Enigmatic archaea from the anoxic terrestrial subsurface

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Cave divers exploring a remote underwater passage in the sulfidic Frasassi cave system (Italy) discovered unusual, rope-like microbial biofilms in anoxic water. Geochemical data suggest that little redox energy is available for life, consistent with low signal from domain-specific FISH probes. The carbon isotope signatures of the biofilm (-33‰) and DIC (-9‰) indicate *in situ* production by lithoautotrophs using RuBisCO. 16S rDNA libraries constructed from the biofilm are dominated by archaea in the enigmatic Marine Benthic Group D (MBG-D/DHVE-1) along with diverse sulfate reducing bacteria. Most of the remaining clones affiliate with one of 11 major uncultivated or novel prokaryotic lineages. Diverse dsrAB gene sequences were retrieved from the biofilm, consistent with high sulfate concentrations and undetectable or extremely low oxygen, nitrate, and iron concentrations. Methane is detectable in the anoxic water although no 16S rDNA sequences associated with known methanogens or anaerobic methane oxidizers were retrieved. mcrA gene sequences retrieved from the biofilm are not related to cultivated methanogens or to known anaerobic methane oxidizers.

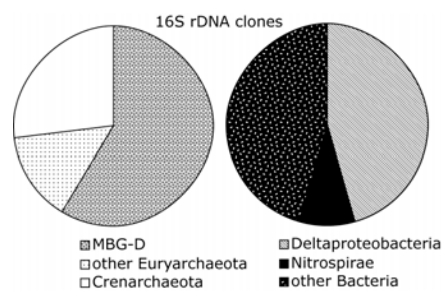

Figure 1: Summary of 16S rDNA libraries constructed using bacteria-specific, archaea-specific and universal PCR primers.

Our data suggest that novel archaea and bacteria, including MBG-D archaea, are important in the dark, energy-limited cave biofilm. These microorganisms and their potentially novel metabolic strategies are relevant for understanding biogeochemistry and biosignatures of non-photosynthetic, energy-limited environments on the modern and ancient Earth and elsewhere in the solar system.