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The fossil record of igneous rock

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The fossil record of igneous rock constitutes a new paleobiological archive that is largely underexplored with respect to abundance, taxonomy, and taphonomy. This record represents the fossilized remains of the deep biosphere: microorganisms that live in open pore spaces in the rock and subsequently become fossilized in situ. So far, most of the investigations have been carried out on subseafloor basalts, but ultramafic rocks as well as continental granites have been shown to contain similar fossils. Currently, the fossil archive ranges from present to 2.4 Ga, indicating that these deep environments have been inhabited by microorganisms from, at least, the Paleoproterozoic. The fossils have been interpreted as both eukaryotes and prokaryotes but, surprisingly, a majority of the fossils consist of fungal remains. Consortia of fungi and prokaryotes are common, which suggests frequent symbiotic relationships between both. A symbiotic lifestyle is most likely a prerequisite for colonization of, and survival in deep, extreme environments.

The microbial remains are associated with abundant bio-etching of secondary mineralizations like carbonates and zeolites. Precipitation of Fe-Mn-oxides and formation of clays and zeolites also indicates that both fungi and prokaryotes are important geobiological agents in these deep environments, being involved in cycling of elements and nutrients, which might influence global biogeochemical cycles.

Since the igneous portion of the oceanic and continental crust makes up the largest potential microbial habitat on Earth, it is somewhat of a paradox that our knowledge about life in the subsurface is extremely limited. Studying this biome in vivo is, with a few exceptions, beyond our reach, because sample sizes are typically very small and cell numbers low and because of the monumental challenges in culturing the organisms. As a consequence, interpretation of fossilized material is a necessary complement to molecular studies in the exploration of this deep, hidden biosphere. Fossilized material have several advantages over live material. Firstly, it gives us a spatial and temporal comprehension of the community structure and microbe-mineral interactions that live material lacks. Secondly, it is easier to prove indigenousness to the rock and exclude modern contamination from seawater and fluids than when dealing with live species. Exploring the deep life of our planet is one of the great challenges of our time, and using fossils as means of this exploration has proven to be a successful strategy.