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Ridge flank processes at North Pond, Mid-Atlantic Ridge

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The uppermost part of the permeable ocean crust harbors the largest hydrologically active aquifer on Earth. It is well known that the geochemical changes associated with basalt alteration in the uppermost oceanic crust play an important role in setting ocean chemistry. It is unknown what role microorganisms play in mediating this seawater?ocean crust exchange. Worse still, the extent to which microbes colonize, alter, and evolve in subsurface rock is not known. Several lines of observation suggest that oxidative ocean crust alteration takes place primarily during the first 10 m.y. of ocean crust evolution. We hypothesize that hydrologically active, young ridge-flank crust releases energy associated with the oxidation of ferrous iron in the basalt, and a sizeable microbial biomass may be supported by these oxidative alteration reactions.

The North Pond study site,is a sediment pond on the western flank of the Mid-Atlantic Ridge, which is underlain by hydrologically active upper oceanic crust. Basement was drilled during DSDP Leg 45/46 (Hole 395A), and the uppermost 500m consist of depleted plagioclase-olivine phyric and aphyric basalt as well as a sedimentary breccia unit with gabbroic rocks and serpentinized peridotites. Previous heat flow and borehole logging work at North Pond showed that the basement is highly permeable and conducive to rapid lateral flow of cold seawater. Based on these results North Pond was selected as site for long-term observatory science, using state-of-the art CORK instrumentation. The principal aim of Integrated Ocean Drilling Program Expedition 336 was to install subseafloor observatories in the young ridge flank at North Pond to examine the extent and the consequences of microbial life within the basaltic ocean crust. The CORK observatories installed comprise packer seals and a string of osmotic pressure driven sampling and incubation devises, as well as temperature and oxygen sensors, all protected by perforated fiber glass casing. Additionally, pressure sensors and additional osmo samplers were installed in the CORK head, where they connect to the subseafloor through umbilical lines. Two observatories were sucessfully installed, a single-zone CORK in upper basement between 90 and 210 mbsf, and a multiple-zone CORK monitoring and sampling three zones to 331.5 mbsf (meters below sea floor). The North Pond microbial observatory is in place and collects unique data and samples for several years. A first follow-up ROV expedition to the area was conducted to install additional experiments and begin time series measurements. A third CORK was installed by ROV during this expedition. Seafloor mapping and sampling of basement outcrops surrounding North Pond yielded insights into the geological setting of the area. A prominent dome-shaped rift mountain south of North Pond turned out to be composed of serpentinized harzburgite and troctolite. In contrast, the two north-south trending ridges NE and NW of North Pond are volcanic.

Differences in trace element systematics of these basalts and the drill core samples indicate that the mantle source was heterogeneous on the scale of few kilometers. Alteration of the basalts is variably oxic to suboxic. Suboxic alteration results in the formation of celadonite and associated enrichment of alkalis in the altered basalt. Oxic alteration and palagonitization of basaltic glass leads to strong enrichment of phosphorous and uranium, which are tied to the formation of ferric oxyhydroxides. The distribution of the two alteration types varies on a meter scale within individual boreholes and on a kilometer scale within the North Pond area.

Keywords: Geochemistry-Petrology, Crustal accretion, Hydrology, Microbiology.