Oxygen consumption by granite samples under sterile glacial melt water conditions

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Background

During future glacial periods in Fennoscandia it may not be excluded that, at least temporarily, increased groundwater recharge and flows may occur. The glacial melt water may have large amounts of dissolved O_2, and this might affect the stability of spent nuclear fuel canisters in the repositories planned in Sweden and Finland [1]. Several processes are able to remove dissolved oxygen: reactions with Fe(II) and sulphide minerals in the rock matrix and in fracture fillings and microbial processes consuming CH_4 or DOC [2].

As the availability of microbial substrates might be substantially reduced during glacial periods, there is a need to confirm the consumption of O_2 by abiotic reactions with Fe(II) minerals. The relative importance of inorganic and microbial processes is difficult to obtain unless special precautions are taken [3,4]

Experimental details

Batch experiments were performed at ~22°C under sterile conditions in serum bottles filled with minerals, MQ sterilized water and a gas phase containing N_2 at ~1.3 bar to which a known amount of air was added. The O_2 in the head-space gas was analyzed for up to 727 days by GC, using the Ar in the injected air as reference.

Two different rock types were used: a quartz monzodiorite and a fine-grained granite with several size fractions ranging between 0.25 and 10 mm. A chlorite sample was used as a Fe(II)-rich reference mineral, and quartz and pure water as un-reactive controls. The materials were characterized by BET, pore size distribution, Mösbauer, and chemical analysis.

Results and Conclusions

The quartz and water samples showed stable O_2 concentration within ±500 ppm while oxygen decreased to different degrees in the rock samples and it was completely exhausted in the chlorite experiments demonstrating oxygen consumption by Fe(II) under sterile conditions. The importance of the surface area is evidenced from the reaction rates expressed as "moles O_2 day^{-1} m^{-2}" which overall vary between -2.7×10^{-8} and -1.3×10^{-8} independent on mineral type, iron content or size fraction used.

The rates obtained are comparable to previous laboratory studies and support the long-term safety evaluation [1] of spent nuclear fuel repositories during glacial periods.

[1] Sidborn *et al* (2010) *Report SKB-TR-10-57*. [2] MacQuarrie et al (2010) *J. Contaminant Hydrol.* **112**, 64-76. [3] Puigdomenech *et al* (2000) *Scient. Basis Nucl. Waste Manag. XXIII*. (Smith & Shoesmith eds) 179-184. [4]Trotignon *et al* (2002) *Geochim. Cosmochim. Acta* **66**, 2583-2601.

A thermal and erosional history of cratonic lithosphere over billion-year time scales

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The continental lithosphere contains the oldest and most stable structures on Earth, where fragments of ancient material have withstood destruction by tectonic and surface processes operating over billions of years. Though present-day erosion of in these remnants is slow, a record of how they have uplifted, eroded and cooled over Earth's history can provide insight into the composition and density of the continents and forces operating to exhume them over geologic time. Because the exhumation or burial of the Earth's surface has a direct effect on the rate of heat loss within the lithosphere, a continuous record of lithosphere exhumation can be reconstructed through the use of a temperature-sensitive radiometric dating technique known as thermochronology. The combination of thermochronologic data with thermal models for heat transfer in the lithosphere can be used to measure the processes operating to cool or heat the lithosphere in the geologic past. Thermochronologic systems sensitive to cooling at high temperatures is insensitive to the "noise" associated with near-surface cooling and therefore provides a measure of the background rate of erosion or burial associated with the vertical motions of a craton. The U-Pb thermochronologic system is sensitive to cooling at temperatures of ~400-650 °C, corresponding to lower crustal depths in cratonic regions of ~20-50 km. Here we utilize this technique to reconstruct an ancient and long-lived thermal history of volcanically exhumed lower crustal fragments, samples that resided at depth for billions of years before recent volcanism transported them to the surface as xenoliths. A high fidelity reconstruction of time-temperature paths for these samples is produced using the U-Pb system's dual decay scheme, where parent isotopes 238U and 235U decay at different rates to daughter isotopes 206Pb and 207Pb, respectively. Coupling this dual isotopic system with diffusion's length scale dependency, which causes different crystal sizes to retain Pb over different absolute time scales, results in a set of daughter isotopic compositions for a range of crystal sizes that is unique to the time-temperature history of the sample. Combining these measurements with thermal and Pb-diffusion models constrains the range of possible erosion histories. Measured U-Pb data are consistent with near zero erosion rates persisting over time scales approaching the age of the continents themselves. This indicates that the isostatic balance observed in the present-day continents has been largely maintained over geologic time, extending back at least to the onset of cooling within each terrane. Since this stability was first meet, the craton has experienced a balance between erosion and burial, with a corollary balance between the lithosphere's internal buoyancy forces and near zero isostatic uplift, further indicating a minimal change in the relative densities of the lithosphere and mantle over intervals lasting billions of years.