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Tidal control on gas flux from the Precambrian continental bedrock revealed by gas monitoring at the Outokumpu Deep Drill Hole, Finland

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Deep groundwaters within Precambrian shields are characteristically enriched in non-atmospheric gases. High concentrations of methane are frequently observed especially in graphite bearing metasedimentary rocks and accumulation of hydrogen and noble gases due to water-rock interaction and radioactive decay within the U, Th and K containing bedrock takes place. These gases can migrate not only through fractures and faults, but also through tunnels and boreholes, thereby potentially mobilizing hazardous compounds for example from underground nuclear waste repositories. Better understanding on fluid migration may also provide tools to monitor changes in bedrock properties such as fracture density or deterioration and failure of engineered barriers.

In order to study gas migration mechanisms and variations with time, we conducted a gas monitoring campaign in eastern Finland within the Precambrian Fennoscandian Shield. At the study site, the Outokumpu Deep Drill Hole (2516 m), spontaneous bubbling of gases at the well head has been on-going since the drilling was completed in 2005, i.e. over a decade. The drill hole is open below 39 m. In the experiment an inflatable packer was placed 15 cm above the water table inside the collar (Ø 32.4 cm), gas from below the packer was collected and the gas flow in the pipe line carefully assisted by pumping (130 ml/min). Composition of gas was monitored on-line for one month using a quadrupole mass spectrometer (QMS) with measurement interval of one minute. Changes in the hydraulic head and in situ temperature were simultaneously recorded with two pressure sensors which were placed 1 m apart from each other below the packer such that they remained above and below the water table. In addition, data was compared with atmospheric pressure data and theoretical effect of Earth tides at the study site.

Methane was the dominant gas emanating from the bedrock, however, relative gas composition fluctuated with time. Subsurface derived gases i.e. methane, hydrogen and helium peaked at the same time and temperature within the drill hole remained constant indicating that solubility fractionation could be ruled out. The longest frequency phenomenon of ca. 14 days and daily variation in gas composition which occurred in periods of approximately 12 and 24 hours were clearly correlated with the Earth tides, i.e. dilatation and contraction of the Earth due to gravitational fields of the Moon and Sun such that the non-atmospheric gases peaked during tidal gravitation minima. Earth tides were also reflected in the hydraulic head which, unlike gas composition, closely followed changes in the atmospheric pressure. Thus, dilatation of bedrock porosity and fractures can be more clearly seen in the gas data than changes in the hydraulic head or water table.