Deep groundwater evolution in Outokumpu, eastern Finland –from meteoric water to saline gas rich fluid

R. Kietäväinen[1]*, L. Ahonen[1], N. Hendriksson[1], I. T. Kukkonen[2], S. Niedermann[3] and T. Wiersberg[3]

[1]*Geological Survey of Finland (GTK), P.O. Box 96, 02151, Espoo, FINLAND*
(**correspondence: riikka.kietavainen@gmail.com)*
[2]*Department of Physics, P.O. Box 64, University of Helsinki, 00014, Helsinki, FINLAND*
[3]*Deutsches GeoForschungsZentrum (GFZ), Telegrafenberg, 14473, Potsdam, GERMANY*

The Outokumpu Deep Drill Hole spans 2.5 km of 2 billion year old bedrock within the Fennoscandian Shield in eastern Finland. Groundwater at the site is characterised by abundant dissolved salts dominated by Ca, Na, and Cl, (TDS up to 70 g/L) and gases (up to 1.1 L/1 L water) of which CH_4, N_2 and H_2 are the most abundant.

Based on the geochemical and isotopic studies, an evolution model for these groundwaters was derived. The O and H isotopic composition of water point out their origin as meteoric waters which were recharged during climatic conditions up to 10°C warmer than at present and subsequently modified at water-rock reactions. This combination produced the distinctive isotopic compositions above the meteoric water line, as well as increased the salinity and indicates residence times on the order of tens of millions of years. A further indication of very long residence times was gained from the noble gas isotopes (^{4}He, ^{21}Ne and ^{40}Ar) which show accumulation in the groundwater due to radioactive decay of U, Th and K of the bedrock within 30 million years on average. Based on the thermodynamic calculations, CH_4 can be produced from graphite and H_2. The process is likely on-going and potentially mediated by microorganisms.

As similar ancient groundwaters are found from the Olkiluoto nuclear waste repository site, our results have important implications for the long term safety of nuclear waste disposal. On one hand they manifest the isolation and immobility of the waters that has prevailed over millions of years. On the other hand, the results point out the complexity and vulnerability of these hydrosystems as they are being utilised. For example, the on-going process of CH_4 formation should be taken into account in the studies of mobilisation of potentially hazardous compounds and microbial activity within the bedrock groundwater.