Constraints added by the strontium and boron isotopes on the geochemical characterization of the Palmottu hydrosystem (Finland)

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The Palmottu U-ore deposit, located in a granitic host rock in southern Finland, provides an excellent location for analogue studies to assess the radionuclide transport from the U-ore deposit along well-defined pathways in the fractured crystalline rock [1]. In this context, strontium and boron isotope ratios are used to trace the degree of water-rock interaction and mixing processes in groundwaters. Sr and B analyses have been performed on groundwater from the Palmottu hydrosystem and, in particular, on the deep geochemical boreholes R385 and R386 [1]. This study should contribute to the understanding of recent hydrogeological and hydrogeochemical conditions of the site, including the design of a conceptual groundwater flow model.

Collection procedure and sampling site

Forty seven water samples have been analysed, including surface waters, springs, groundwaters in the overburden, waters from different former boreholes (packer and tube sampling) and the waters sampled during drilling of the R385 borehole. The chemical analysis of the water samples was performed by inductively coupled plasma mass spectrometry for B, Rb and Sr concentrations and by mass spectrometry for the $\delta^{11}B$ and $^{87}Sr/^{86}Sr$ ratios.

Chemical and isotopic data

The Rb and Sr contents exhibit large variations. Concentrations in surface waters are in the range 1.1–2.1 ppb for Rb and 16.4–58.1 ppb for Sr. In groundwaters, Rb contents are in the range 1.1–11.3 ppb and Sr contents ranged from 14.5 to 1080 ppb. There is no direct relationship between the Rb and Sr contents and samples are scattered between several fields. The $^{87}Sr/^{86}Sr$ ratios ranged between 0.716910 and 0.735606 in surface waters and between 0.719991 and 0.750787 in groundwaters. Most of the samples have $^{87}Sr/^{86}Sr$ ratios ranging between 0.720 and 0.735. The boron concentrations ranged from 251 to 657 ppb (5 samples). The $\delta^{11}B$ ranged from 33.6 to 43.5‰.

Discussion

One of the main results is the lack of correlation between the chemistry of waters viewed through the classification in different water types (Na-Cl, Na-SO_4, etc.) and the systematic strontium results (contents and isotopic ratios). From a water-rock interaction (WRI) point of view, this implies that the Sr behaviour is (i) independent of the water chemistry, (ii) site specific and (iii) mainly dependent on the lithology.

In spite of the complexity of the hydrochemical functioning of the Palmottu hydrosystem, the scattering of the Sr data ($^{87}Sr/^{86}Sr$ ratios *vs* 1/Sr; Fig. 1) can be understood through the existence of three end-members: a marine component, a deep granitic component and a snow component. These last two extreme end-members define a general WRI mixing line (probably on a Scandinavian scale) from which different local WRI end-members are identified. From the Palmottu hydrosystem alone, the Sr data define four local end-members: one very close to the marine signature, two local WRI end-members and a suggested local snow end-member. The Sr behaviour from borehole R385 is rather complex and partly summarizes the Palmottu hydrosystem as a whole.

As a working hypothesis, we can outline the local hydrological evolution as follows:

The oldest and deepest groundwater present in the Palmottu area was of Na-Cl type and originate from a former evaporitic sea (Permian?).

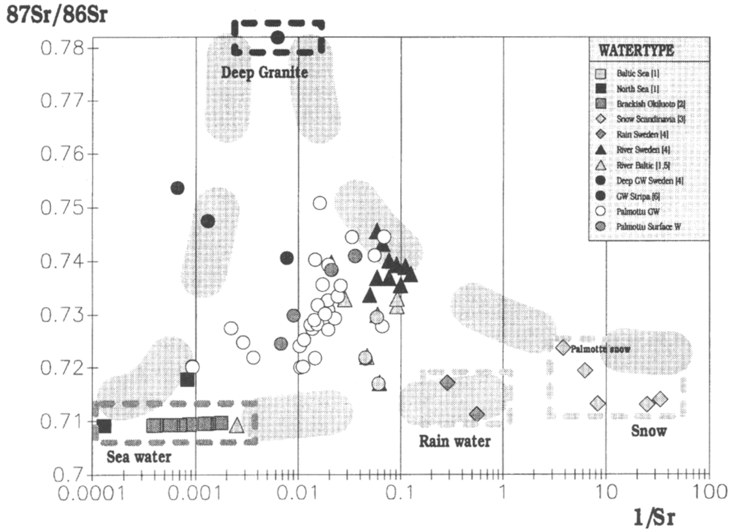

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FIG. 1. Conceptual mixing model of the Palmottu hydrosystem in a $^{87}Sr/^{86}Sr$ ratios vs. 1/Sr plot. Data reported from the literature [3] are also included.

After this deep recharge, the WRI processes between the granites and the atmospheric input generated as many groundwaters as the different types of crystalline rocks in the Scandinavian shield. These shallow granitic groundwaters defined a single mixing line between the snow and the more radiogenic granite.

The exact shallowness of the boundary between the 'marine' GW and the groundwaters already influenced by WRI processes is unknown. The depth of this limit was above 220 m during Late Glacial times. At the very beginning of the melting of the local Palmottu glacier, a certain amount of melt water was hydrologically forced into the deep "marine" GW by means of fractures crossing R385 at a depth of 220 m.

The younger and shallower groundwaters occurring today above 200 m result from different mixing lines between the 'marine' GW and the shallow granitic groundwaters, including the surface waters.

In Fig. 2, five samples from different water types are plotted on a $\delta^{11}B$ versus $^{87}Sr/^{86}Sr$ ratios diagram. Four samples show a $\delta^{11}B$ lower than actual mean seawater (MSW), whereas one sample has a $\delta^{11}B$ higher than MSW. No samples have a $^{87}Sr/^{86}Sr$ ratio close to the Baltic Sea [2], but one sample exhibits a $^{87}Sr/^{86}Sr$ ratio close to the brackish water from Olikuoto [3].

The scattering of the three points is in agreement with a mixing hyperbola, which characterizes a two-component mixing processes. The extreme end-member (R385/403-409; Na-Cl water type) shows a $\delta^{11}B$ enrichment with respect to MSW and might correspond to the dissolution of an old evaporite.

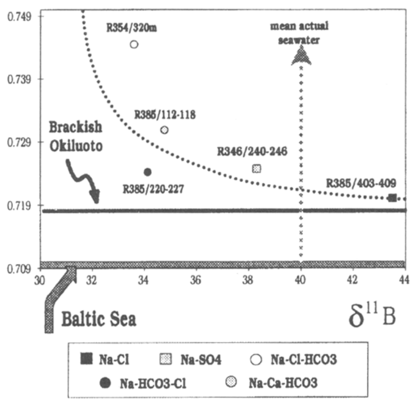

FIG. 2. Plot of $\delta^{11}B$ vs. $^{87}Sr/^{86}Sr$ ratios.

References

[1] Blomqvist *et al.* (1998) *European Commission, EUR18202, 96p.*

[2] Anderson *et al.* (1994) *EPSL*, **124**, 195–210.

[3] Négrel and Casanova (1997) *Technical report*, 26p.