Palaeoclimatic Controls on Hydrological Systems: Evidence from U-Th Dated Calcite Veins in the Fennoscandian and Canadian Shields

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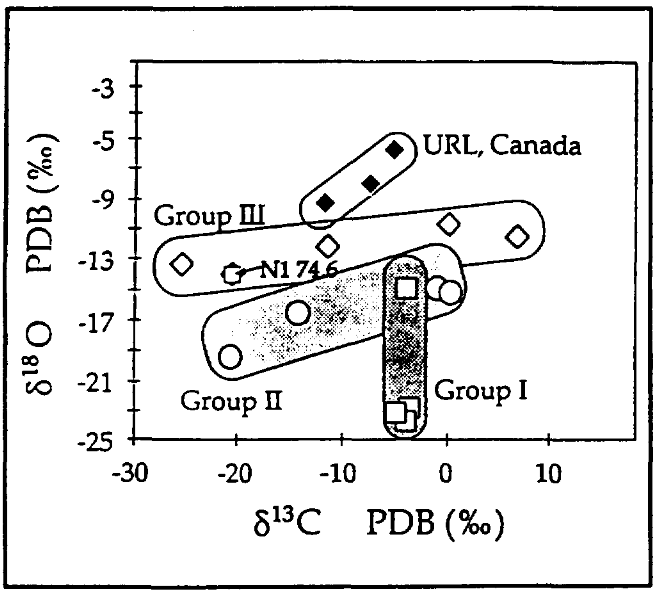
High salinity groundwaters occur widely in granitic basements (e.g. in Canada, Sweden, Finland, the UK, Australia, Central and Eastern Europe, the Baltic and the Kola Peninsula), and a better understanding of the timescales over which their flow regimes remain stable is critical for models of heat and mass-transport in the continental crust, the development of mineralisation, and the potential use of granitic rocks as hosts for long-term radioactive waste disposal. Fractures in crystalline rocks can provide major and relatively rapid pathways for the migration of radionuclides in the far field of such repositories, but the presence of surficial mineral coatings can have a dramatic effect on their hydraulic properties and sorption characteristics. Such coatings and veins yield useful information on the chemistry and origin of the groundwater, the nature of water-rock interactions (e.g. Clauer et al., 1989) and the timing of active flow (e.g. Milton (1987) and Ivanovich (1995)). In particular, an improved understanding of the behaviour of natural actinides (U, Th and Ra isotopes) in the fracture filling minerals (e.g. Gascoyne (1982) and Schwarcz et al. (1982)) may provide further insights into the behaviour of waste radionuclides in this environment.



The new U-Th age data for Stripa indicate that the previously defined threefold mineralogical classification (Fritz et al. 1989) which in the case of the samples analysed here is reflected in their stable isotope geochemistry (see Figure 2) is robust. Thus, each group defines a characteristic age range.

Figure 1. Plot of $\delta^{13}C$ against $\delta^{18}O$ showing the stable isotope systematics for the shield calcite studied. Note that sample N1 74.6 has a low $\delta^{13}C$ value compared with the Group I samples (data from Fritz et al. 1989 and Blyth 1993).

The mass-spectrometric U-Th age data reported here for nine weak-acid leachates of calcite-bearing fracture fillings from three sites on the Fennoscandian and Canadian shields (Stripa, Sweden; URL, Canada and Olkiluto, Finland) define a bimodal distribution with ranges of 84-90 kyr and 173-203 kyr (see Figure 2). In detail, four leachates from the Group 1 fractures at Stripa yield an age of 87.2 ± 3.2 kyr and three

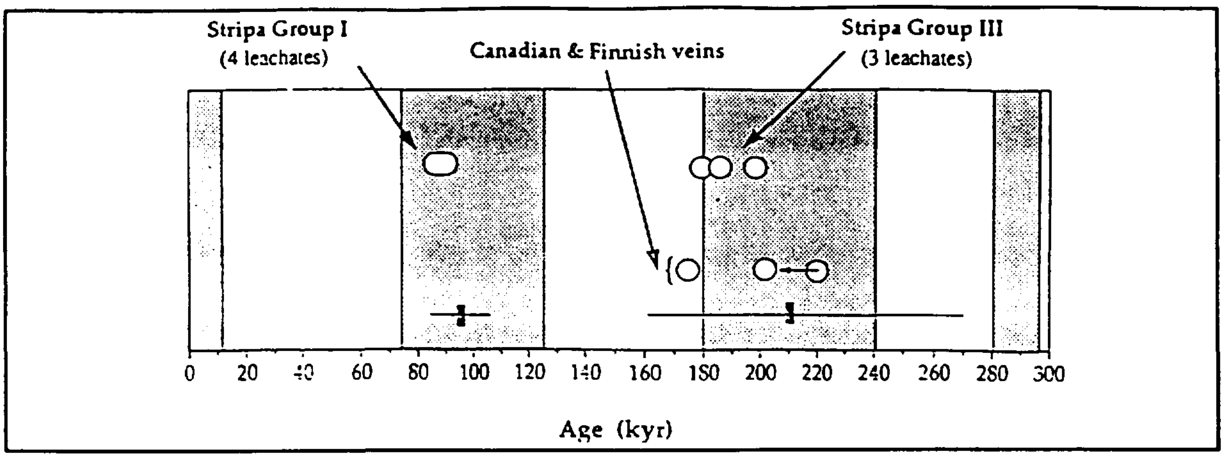


Figure 2. Summary of the U-Th age data for the Stripa, Canadian and Finnish calcite veins. Also shown are Milton's [2] ages for two Stripa Group III calcites (solid squares). The horizontal arrow indicates the effect of applying a detrital correction ($^{230}Th/^{232}Th$) = 1.5). Note that the calcite ages appear to be confided to, (or post-date by <8 kyr) the interglacial conditions of isotope stages V and VII (stippled areas) .

from open-fractures (Group III) yield ages in the range 178 ± 8 to 201 ± 6 kyr. The latter age range is identical to that defined by two calcites from the Canadian site ($202.8 \pm ^{6.4}_{6.0}$ kyr) and the Finnish site (172 ± 2.3 kyr). Taken together, these ages coincide with the end of the interglacials of isotope stage V and VII and are interpreted as reflecting the shutoff of meteoric recharge due to the onset of permafrost at these high latitudes. Four leachates from another group of closed, fluorite-bearing fractures at Stripa (Group II) are close to secular equilibrium but show evidence for U uptake during the last 1 Ma. Three of these exhibit evidence for a complex open-system history while the remaining sample can be modelled by a single-stage U-loss event.

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