Evaluating past hydrogeological conditions at a site for nuclear waste disposal

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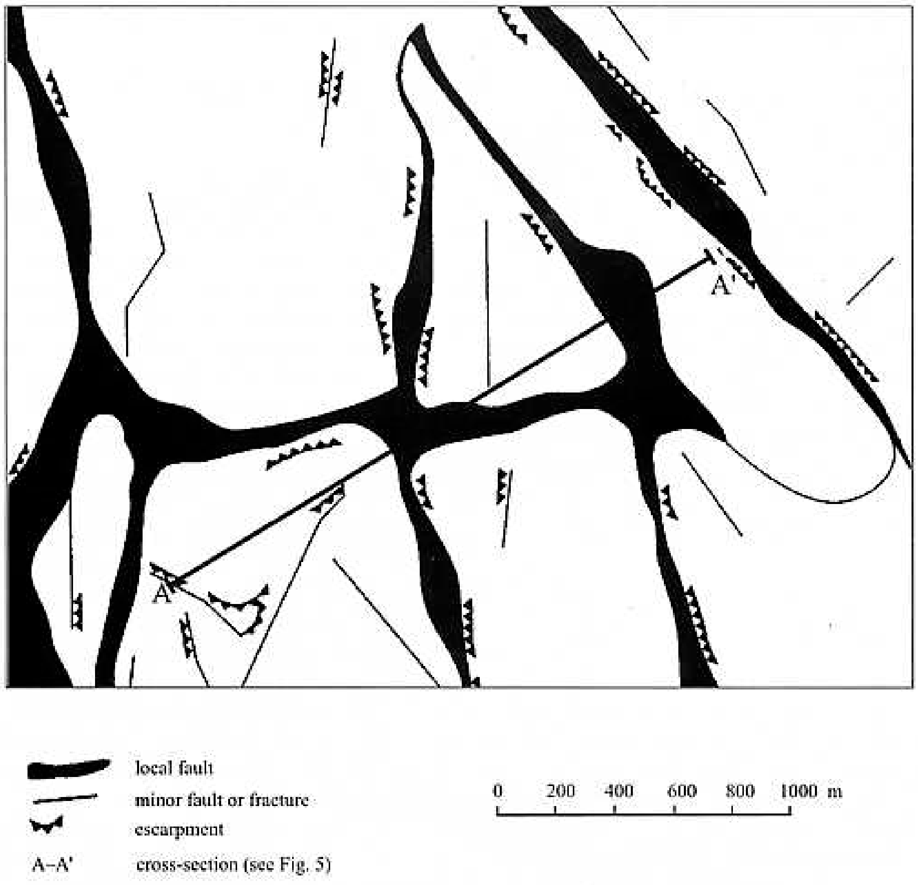
Geological environment of the disposal site at Olkiluoto

- The crystalline bedrock of the Fennoscandian shield formed 2000 – 3000 Myr ago
- Within-plate location, far from plate boundaries
- Some block movements related to the opening of the Atlantic ocean and glacioisostatic uplift after the last ice age
- Rare earthquakes of magnitude 2-3

Bedrock blocks

- A mosaic of solid bedrock blocks bounded by fracture zones

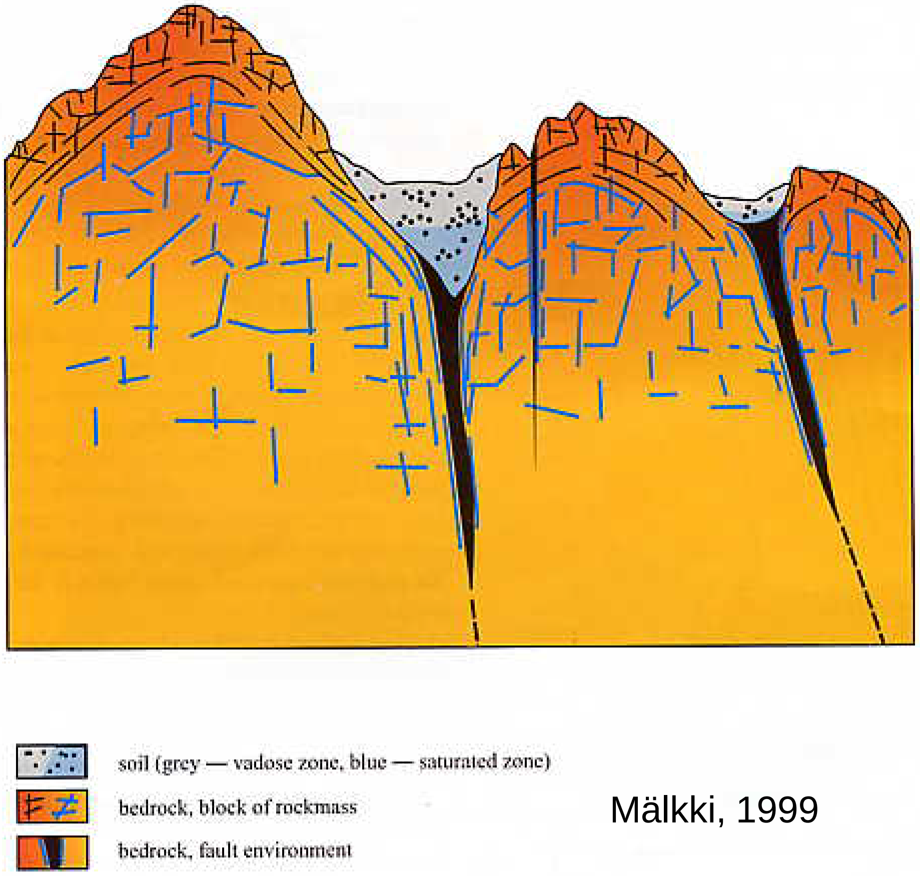
- Smaller fractures are present within the bedrock blocks



Mälkki, 1999

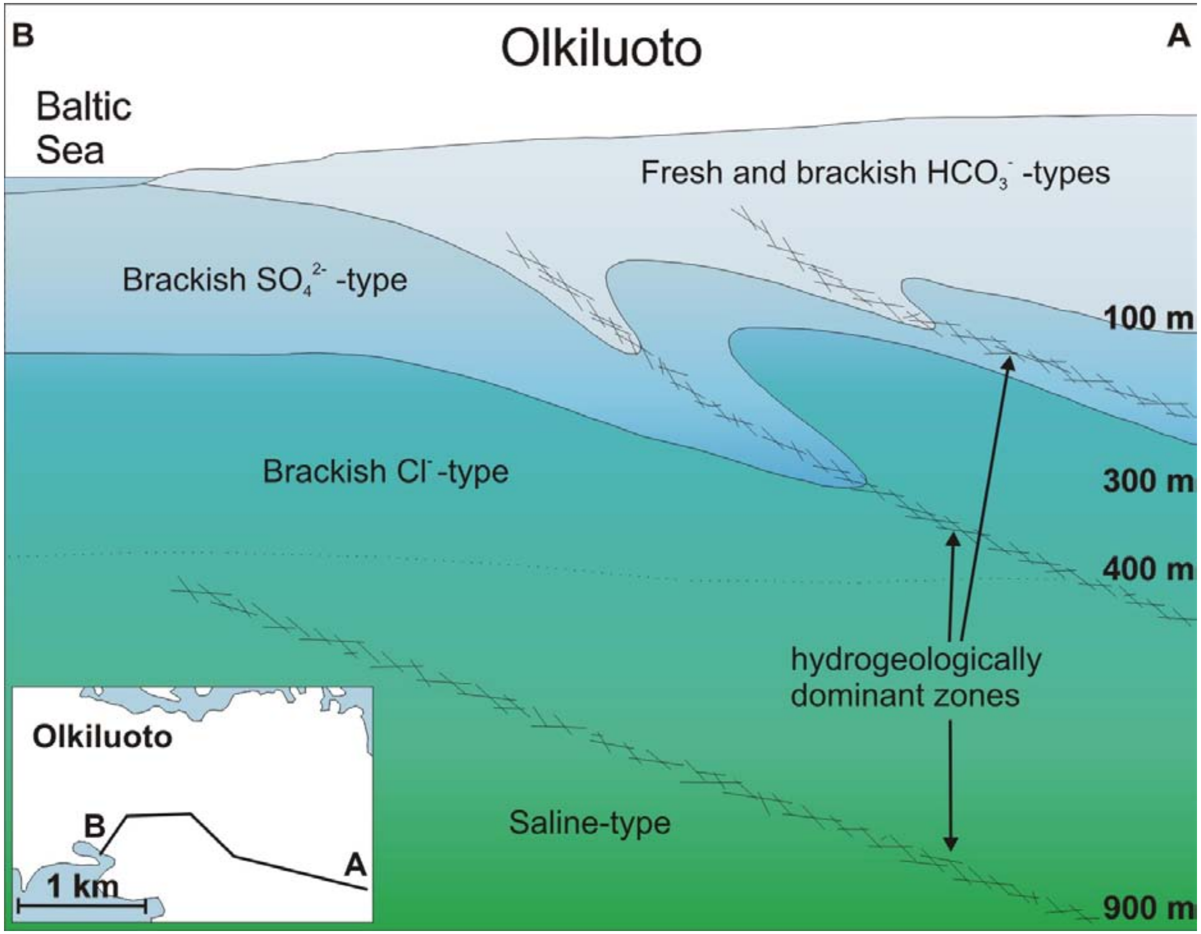
Deep groundwater

- Fracture networks are filled with groundwater
- Groundwater is a potential chemical agent affecting the repository
- We need to know the past evolution of the groundwater system in order to understand the potential future changes affecting the system



Mälkki, 1999

Salinity stratification of the deep groundwaters at Olkiluoto



Salinity (TDS)

0.01 – 2 g/L
7 g/L
16 g/L
80 g/L

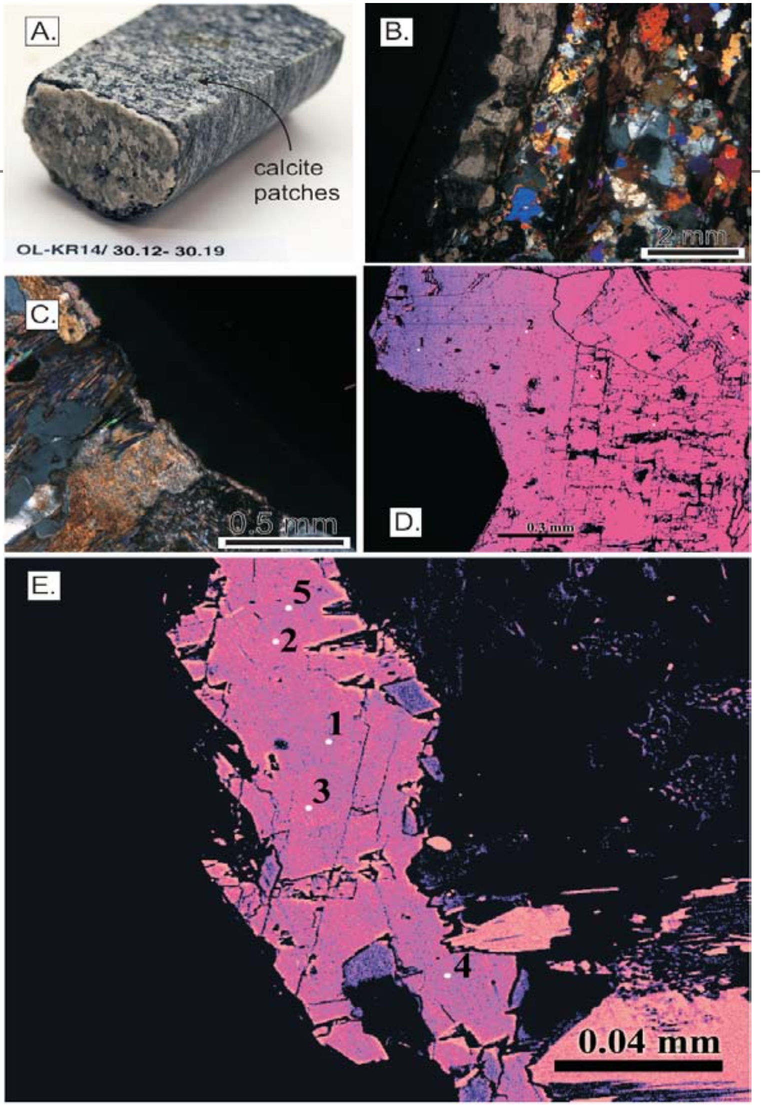
Long-term evolution of the groundwater system

Sources of information

- Old groundwater in low conductivity fractures
- Old groundwater in rock pore space
- Fracture minerals
  - chemical composition
  - stable isotope ratios of carbon, oxygen and sulphur
  - fluid inclusions
  - Radioactive isotopes of uranium and thorium - dating the mobility of uranium
  - radiocarbon dating of calcite

Calcite, drill core OL-KR14/30.15

- An open 2mm thick calcite filling
- Isotopic composition of carbon and oxygen: $\delta^{13}C = -10.6$ ‰, $\delta^{18}O = -8.2$ ‰ (VPDB)
- Two phase fluid inclusions, homogenization at 87 C
- U-Th disequilibrium evidencing uranium mobility within the last 1 Myr



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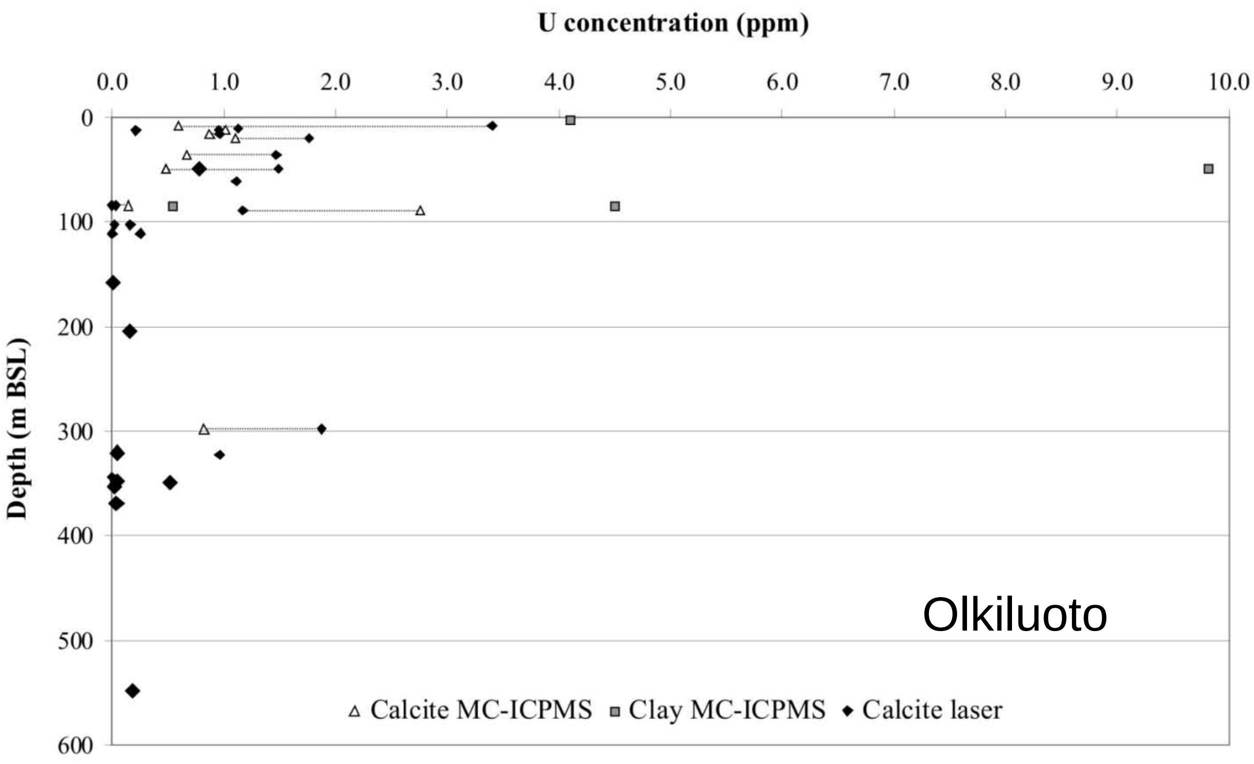
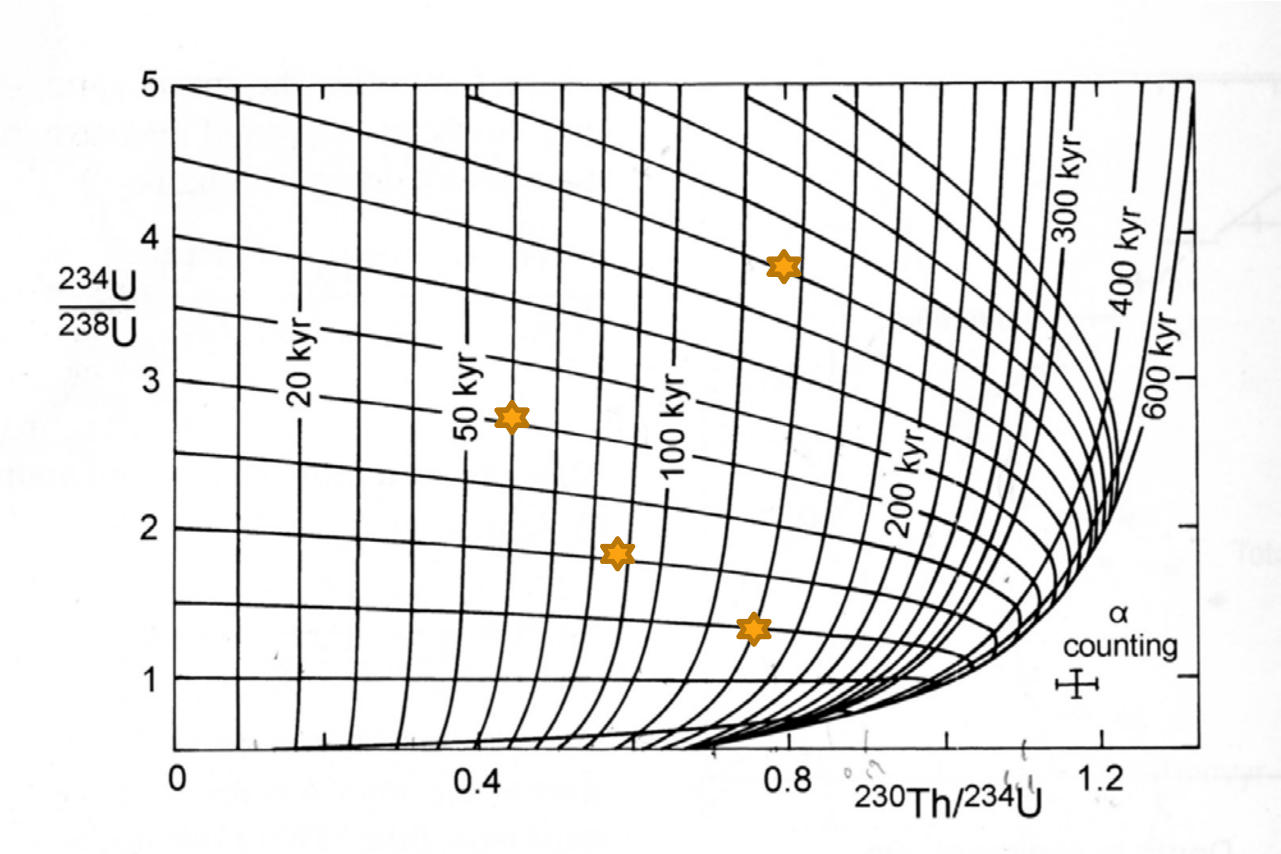
Uranium in fracture minerals



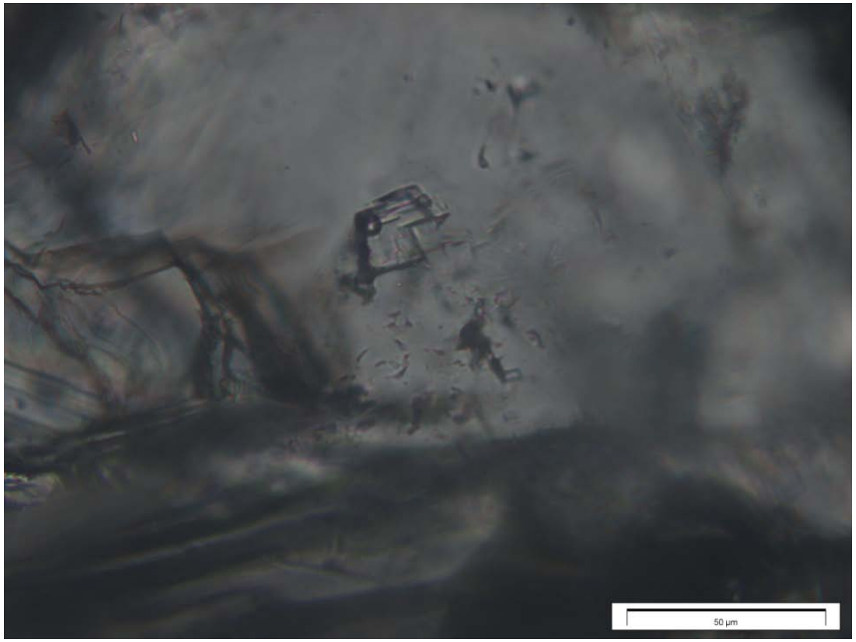
Dating uranium mobility: Th-U isochron diagram



Temperature of formation

- Fluid inclusion studies are used to determine the temperature of formation for fracture calcites

- The homogenization temperature of the inclusion is 132ºC, which gives the formation temperature of this calcite filling



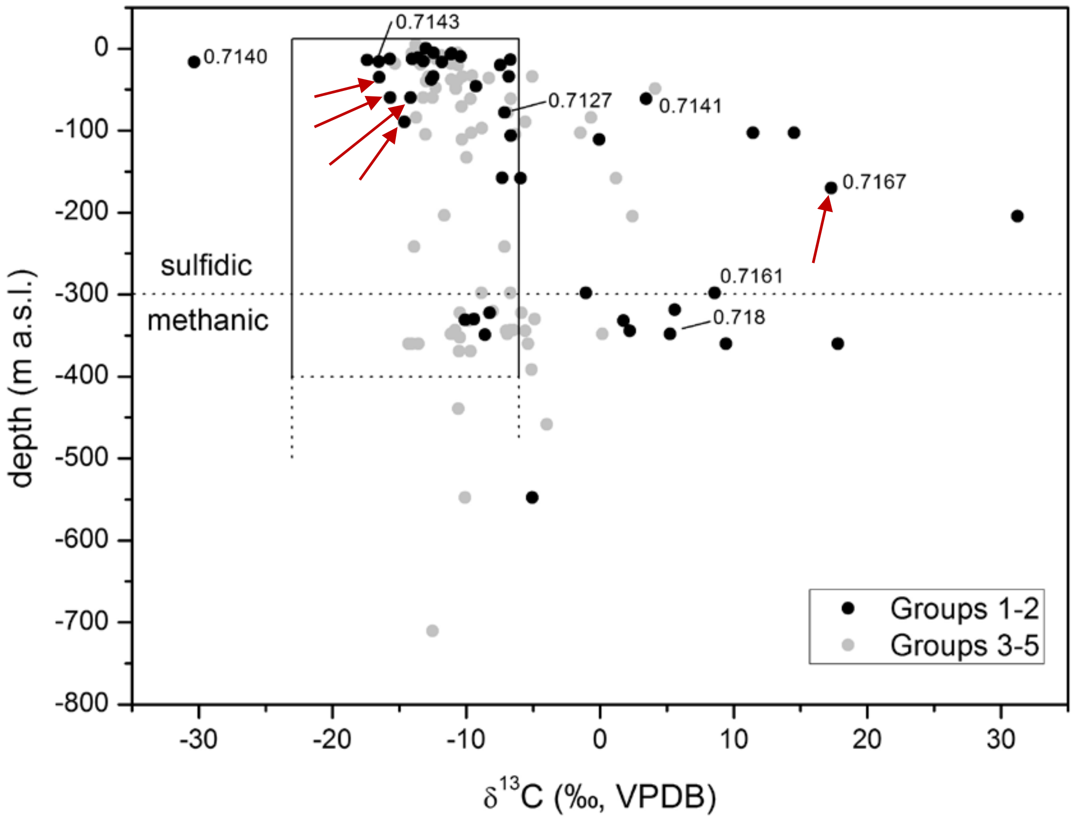
Microbial metabolic processes

Calcite precipitated from present-day groundwaters

Calcite formed in the presence of methanogenic bacteria

- Isotopic composition of carbon in calcite gives information on past metabolic processes

- red arrows point to calcite precipitates dated by radiocarbon method to >51000 years BP



Conclusions

- Fragmentary evidence for the long-term evolution of the groundwater system
- A change from high > 100 ºC temperatures at > 1000 Myr to ambient temperatures and methanogenic microbial processes in the latest fracture fillings
- We have not been able to demonstrate any fracture mineral growth during the last 50 000 years