Fluid composition in veins of the Outokumpu drilling site, Finland

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The Outokumpu drilling site is situated in SW Finland, approximately 2 km from the centre of the town Outokumpu in the vicinity of the Outokumpu ore deposit.
The drill hole, which was finished in January 2005 at a depth of 2516 metres, transects the Paleoproterozoic Outokumpu formation and was intended to encounter the Archaean basement. The Outokumpu formation represents a 1-5 km thick remnant of folded and imbricated overthrust terrain, consisting of mica schist with black schist interlayers, serpentinite, skarn rocks, and pegmatitic gneisses, which are underlain by Archaean basement. The formation was strongly deformed during the Svecofennian orogeny (1.9 Ga) (Gaál et al., 1975).
Fluid inclusions occur in quartz and carbonate veins, which can be found in all rock types except the black schists. Three different types of vein types can be distinguished macroscopically: (i) quartz-filled with a biotite-rich alteration halo, (ii) quartz-filled without alteration zone, and (iii) carbonate-filled with an Mg-Hbl alteration zone. The quartz veins show variable sizes in length and thickness ranging from a few mm to several cm. The carbonate type (iii) veins have a smaller thickness of a few mm and occur mainly in skarn rocks.
Primary, pseudosecondary and secondary fluid inclusions can be found within the quartz veins showing up to three different phases containing vapour and/or liquid and partly a solid phase. The fluid inclusions occur together on intragranular trails, in clusters, or as single inclusions in the veins.
Different types of fluid inclusions can be distinguished within the quartz veins. The water rich fluid inclusions show eutectic temperatures (T_{e}) of around -22°C with a final melting temperatures (T_{m}) between -4° and -10°C, which indicates a salinity of about 6-14 mass% NaCl equivalent in the aqueous solution. CO_2bearing inclusions show a T_{m}(ice)between -57° and -60°C, which suggests the presence of another gas phase, most likely CH_4.
The homogenisation temperatures (T_{h}) of the water rich secondary fluid inclusions plot between 180°C and 220°C. The rare primary aqueous inclusions show T_{h}(LV→L) over 300°C. The T_{h} of these inclusions could not be exactly determined because of decrepitation. The CO_2 rich inclusions show different T_{h}(CO_2 LV→L) at -11°C and +6°C. CO_2 bearing aqueous fluid inclusions show T_{h}(CO_2 LV→L) of +20°C and T_{h}(total) over 330°C.
The determined minimum temperature from the fluid inclusions higher than 300°C and the alteration mineralogy (Hbl, Bt) suggest a formation of the hydrothermal quartz veins at conditions of the lower amphibolite facies. The saline and carbonic fluid composition is typical for magmatic and metamorphic rocks.
References:
Gaál, G., Koistinen, T., Mattila, E. (1975): Tectonics and stratigraphy of the vicinity of Outokumpu, North Karelia, Finland. Geological Survey of Finland, Bulletin 271, 67 p.

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