

## FLUID INCLUSION STUDY IN FRACTURE FILLING MATERIALS IN GRANITOID ROCKS, MECSEK MOUNTAIN, SOUTH HUNGARY

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Disposal of low- and intermediate-level radioactive wastes raises several problems in Hungary. Therefore, study of evolution of fracture systems and fracture filling materials in the potential reservoir rock is one of the most significant issues today. Mórággy Granitoides, occurring in South Hungary might be identified as potential reservoir rocks on the basis of preliminary research. To prove the suitability of the Mórággy Granitoides, detailed petrographic, mineralogical and fluid inclusion studies were carried out on their fracture filling materials, especially carbonate, collected from drillings near villages of Üveghuta and Bátaapáti. The results of this comprehensive study, which were accomplished in the framework of a project of the Paks Nuclear Power Plant Ltd. and the Geological Institute of Hungary, are presented here.

The Mórággy Granitoides are Early Variscan in formation ages (340 Ma) and occur in an area of approximately 200 km<sup>2</sup> at the surface or close to the surface eastward from the Mecsek Mountains (South Hungary). Spatial distribution of the granitoides shows a continuation northeastward along a narrow belt beneath the Great Hungarian Plain at greater than 1000 m depths.

The granitoides have mostly syncollision S-type mixed with I-type characters, which are typical of *in situ* migmatite rocks in mostly monzonitic and less granitic compositions. The granitoid rocks formed by melting of sedimentary source rock and then the magma went through plutonic development. Dikes (pegmatite, aplite, microgranite and quartz) formed from the rest of the melt. Amphibole-rich restite can be also observed in the microcline megacryst bearing granitoides. The frequent occurrence of the microcline megacrysts suggests K-metasomatism. Schistosity of the granitoid rocks, related to dynamothermal metamorphism, occurred in the Variscan time (Csontos et al., 2002). Hydrothermal events, which caused fracturing, and fracture fillings within the granitoid rocks followed this episode. The fractures are filled by carbonates, quartz, clay minerals, chlorite, epidote, feldspar and Fe and Mn oxihydroxide.

The thickness of the fracture filling is up to 15 cm and the fissures are randomly oriented in the drilling cores. The majority of the fracture filling materials in the studied boreholes is observed in moderately or strongly altered mylonitic textured granitoid rocks. At the wall of the fractures small crushed rock fragments and clasts of the potash feldspar, plagioclase, chloritized biotite and amphibole, and quartz can be seen in different quantities. These rock and mineral fragments, incorporated into the hydrothermal precipitations, represent the host rocks. Four types of hydrothermal fracture filling materials can be distinguished: 1) quartz-calcite; 2) dolomite-calcite; 3) dolomite, and 4) calcite.

1) In the fracture filling material quartz-calcite and euhedral quartz crystals, as initial precipitations, occur on the wall of the fractures. Cores of the quartz crystals are full of fluid inclusions, whereas the outer zones are poor in fluid inclusions. Calcite formed following the quartz is coarse-grained and contains large amounts of fluid inclusions, and rock and mineral fragments from the host granitoides.

2) Fracture filling of dolomite-calcite is made up of complexly textured dolomite, which shows common oscillatory zoning. Precipitation of dolomite was followed by formation of fine-grained calcite connected to late-phase fracture.

3) Fracture filling of dolomite consists only of fine-grained pure dolomite, sometimes showing zoned texture.

4) The fracture-filling material is coarse-grained calcite, which contains plenty of fluid inclusions and clasts of host granitoid rock and minerals. The calcite grain sometimes shows oscillatory zoning.

Fluid inclusions (5-20 µm in diameters) occurring in calcite are primary inclusions (Fig. 1). They appear with negative crystal shape or irregular form. The fluid inclusions are two-phase (liquid and vapor) inclusions at room temperature. Bubbles represent 15-20 volume% of the whole the fluid inclusions. Both the homogenization temperature (vapor to liquid) and melting temperature of the fluid inclusions vary in wide range. Based on the homogenization temperature and ice melting temperatures two formation periods of fluid inclusions can be distinguished: 1) high homogenization temperature (180-280°C) with ice melting temperatures ranging between -0,5°C and -12,0°C. These

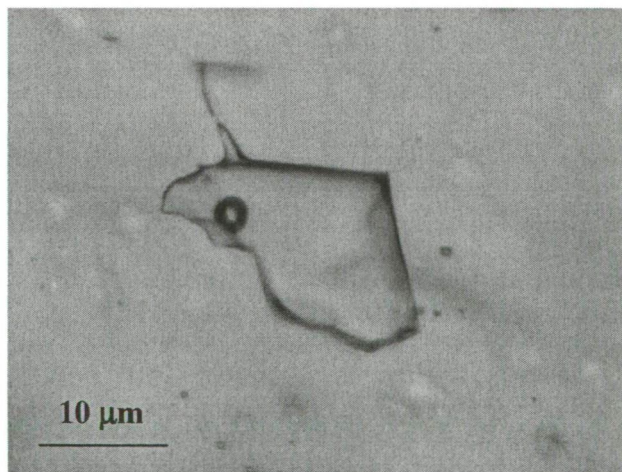
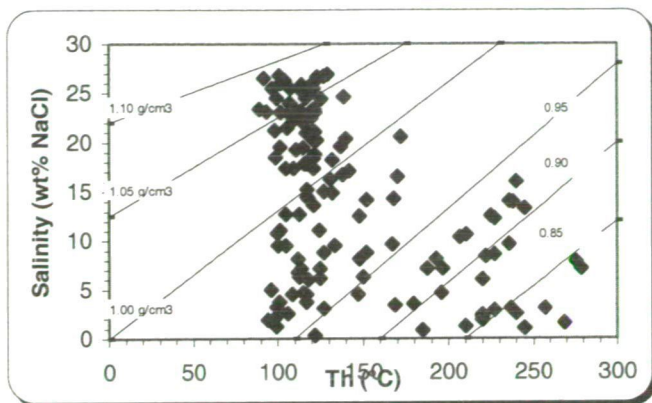


Figure 1. Two-phase (liquid-vapor) irregular shaped fluid inclusion in fracture filling calcite.



**Figure 2.** Homogenization temperatures as function of salinity in the fluid inclusions of calcite.

measurable sizes (5-15  $\mu\text{m}$  in diameters) have been found randomly in the outer zones of the quartz. These fluid inclusions consist of two phases (liquid and vapor) at room temperature. Bubbles represent 10-20 volume% of the whole of the fluid inclusions. Homogenization temperatures are nearly identical to those of the low temperature fluid inclusions measured in calcites (100-130 $^{\circ}\text{C}$ ). The calculated salinities changes within wide ranges (from 0,71 to 26,2 wt% NaCl eqv.) as in the case of calcite, but in the quartz a high salinity solution containing only NaCl and a low salinity solution containing NaCl and other dissolved salts can be identified distinctly.

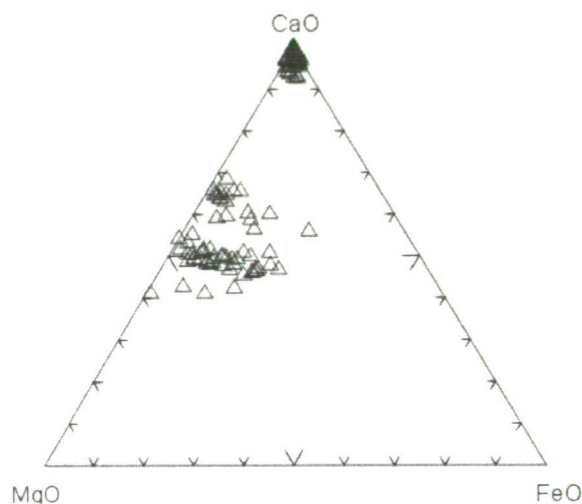
Based on the textural observations and the microprobe analysis of the fracture filling materials at least two separate major hydrothermal events can be distinguished. The first is represented by crystallization of Mg and Fe bearing carbonates, such as dolomite, Fe-dolomite and the second one is represented by nearly pure, coarse-grained calcite (fig. 3). Based on the microthermometric study of fluid inclusions this last event can be divided in two formation periods. One represented by inclusions with high homogenization temperatures (180-280 $^{\circ}$ ) and with low-middle salinity ranges. The other period is characterized by inclusions with low homogenization temperatures (100-150 $^{\circ}\text{C}$ ) and with changing salinity values, ranging between 0.2-26.2 wt% NaCl eqv. Some low melting temperatures suggest the presence of other dissolved salts ( $\text{CaCl}_2$ ). The fluid inclusions in the quartz-calcite fracture filling materials represent the last phase of the hydrothermal activity.

### References

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- CSONTOS, L., MÁRTON, E., WÓRUM, G. & BENKOVICS, L. (2002) Geodynamics of SW-Pannonian inselbergs (Mecsek and Villány Mts., SW Hungary). *EGU Stephen Mueller Spec. Publ. Series*, **3**, 1-19.

inclusions show calculated salinity ranges (Bodnar, 1993) from 0,88 to 15,96 wt% NaCl eqv.; 2) low homogenization temperature (100-150 $^{\circ}\text{C}$ ) with ice melting temperatures ranging between -0,2 $^{\circ}\text{C}$  and -21,2 $^{\circ}\text{C}$ . These inclusions have salinity ranges from 0,35 to 23,18 wt% NaCl eqv.. In the second formation period inclusion fluids characterized by lower than -21,2 $^{\circ}\text{C}$  ice melting temperatures (near of -25 $^{\circ}\text{C}$ ) contain varying NaCl and  $\text{CaCl}_2$ , typical of the final phase of hydrothermal processes (fig. 2).

Fluid inclusions occurring in euhedral quartz are also primary inclusions. Plenty of fluid inclusions are situated along growth zones in the core of quartz, however their sizes are too small (1-4  $\mu\text{m}$  in diameters) to study with microthermometric methods. Whereas, some fluid inclusions within



**Figure 3.** FeO-CaO-MgO ternary plot of the carbonate compositions.