EVALUATION OF MULTI-PHASE CRACK EVOLUTION IN THE GRANITE INTRUSION OF THE VELENCE MTS. (W-HUNGARY) ON THE BASIS OF STUDIES ON FLUID INCLUSION PLANES

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Introduction

The Velence Mts. consist of a Variscan post-orogenic, S-type monzogranite intrusion (280-300 Ma) hosted by Palaeozoic shale and an Alpean post-syncollisional intermediate intrusive-volcanic complex of Palaeogene age (29-42 Ma). Both igneous units are characterised by intense hydrothermal alteration. In the granite intrusion, hydrothermal mineralization is strongly controlled by fracture systems and some of the alteration zones can be related to the Palaeogene hydrothermal activity. Therefore studies on macro- and micro-fractures in granite together with fluid inclusion analyses offer a unique approach for modelling the evolution of fracture systems at different magmatic, hydrothermal and tectonic stages. Methods of studies include field surveying of fracture systems (orientation, thickness, extension and density of joints, faults and veins along baselines in various sections), analyses on orientation, extension and density of fluid inclusion planes (FIP) in rock forming quartz of granite and conventional fluid inclusion petrography and microthermometry in various hydrothermal paragenesis and FIP from the Variscan granite and the Palaeogene intrusive-volcanic complex. Geometrical peculiarities of FIP were determined in oriented sections of granite by combination of observations carried out on a universal stage and a digital image analyser system.

FIP develop in mode I, simple extension fractures, therefore their orientations are perpendicular to the σ_3 vector of the actual stress field. Thus determination of orientation of FIP containing different inclusion assemblages may help to characterise the temporal evolution of stress field in succeeding fluid mobilisation stages and results may support to establish a model regarding stress-field orientation during development of joints, faults and veins in the host granite. Statistical analyses on density, thickness, extension and distance data for FIP and macro-fractures support estimation of total porosity and permeability of host rock and variation of these parameters in different zones and tectonic structures.

Hydrothermal and fracture systems of the Velence Mts.

The emplacement of the Variscan monzogranite intrusion was associated with formations of quartz-feldspar pegmatite pockets. The granite body was subsequently intruded by NE-SW oriented granite-porphyry and aplite dikes. This stage was followed by formation of quartz-molybdenite stockwork and deposition of NE-SW and N-S trending Zn-Pb-Cu-sulphide-fluorite-quartz veins. Fluid inclusions related to pegmatite formation have relatively high homogenisation temperatures and low salinities (Fig. 1). Fluid inclusion assemblages in the quartz-molybdenite mineralization are characterized by variable carbonic/aqueous phase ratios due to aqueous-carbonic immiscibility. Late stage Variscan aqueous fluid inclusions associated with base-metal-fluorite-quartz vein formation have low homogenization temperatures and elevated salinities.During the Palaeogene igneous activity, andesitic dikes with NE-SW strike direction also intruded the old granite body. The stratovolcanic structure that joins to the granite intrusion along the NW-SW oriented syn-volcanic Nadap-Lovasberény fault (Fig. 2) is characterised by high-sulphidation type epithermal minerali-zation. At the subvolcanic levels, a ty-pical Cu-porphyry type mineralization occurs. Palaeogene hydrothermal fluids also penetrated the Variscan granite mostly along E-W and NE-SW oriented fracture systems: this is pro-ved by occurrence of epithermal mine-rals (enargite) and argillic alteration zones with Palaeogene K-Ar ages (32.7 Ma) in the granite body.

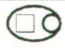
Type of inclusion	Phase compo-sition	Pegmatite in granite P1, P2, P3, P4, P5, P6, P7	Quartz-molybdenite stockwork in granite and shale M1, M2, M3, M4	Quartz-tourmaline veinlets in shale T1	Base metal and fluorite veins in granite V1, V2, V3, V6	Cu-porphyry in subvolcanic diorite PC-1, PC-2, PC-3	Chalcopyrite bearing breccia vein in granite CBX	Enargite bearing breccia granite/shale contact EBX	High-sulphidation type altera-tion zones in andesite EPI-1, EPI-2
	L+V V<10%	**S 90-180°C** *6 - 23 $CaCl_2$*	-	-	**S-P 80-140°C** *10 - 25 $CaCl_2$* **S-P 170-210°C** *7 - 21 NaCl* F - **P 110-160** *1 - 10 NaCl*	-	-	-	-
	L+V V=10-30%	**S-P 90-250°C** *2 - 20 NaCl* **S 320-350°C** *0-2 NaCl* **P 320-370°C** *3 - 4 NaCl*	**S 220-280°C** **S 280-320°C** *1 - 6 NaCl* *8 - 14 NaCl*	**S 240-300°C** **S 330-390°C** *0 - 1 NaCl*	-	**S 270-370°C** *13 NaCl - 24 NaCl+$CaCl_2$*	**S 260-360°C** *1 - 21 NaCl*	**S 210-400°C** *1-21 NaCl*	**S-P 310-380°C** **S 220-290°C** *1 - 13 NaCl*
	L+V V=40-60%	S present (sample P1)	-	-	-	-	**S-P 400-410°C** *3-5 NaCl*	**S-P 370-450°C** *1-8 NaCl*	-
	L+V V>80%	S present (sample P1)	-	**S 340-380°C**	-	**S-P 360-500**	**S-P 400-460°C**	**S-P 310-440°C**	**S-P 280-290°C**
	L+V+H (+Sy+X) V=10-30%	-	-	-	-	**S-P 270-520°C** *31 NaCl - 79 NaCl+KCl*	**S-P 410-450°C** *26 - 40 NaCl*	**S-P 260-450°C** *26 - 40 NaCl*	-
	Laq+LCO_2 (+VCO_2) LCO_2= 40-90%	-	**S-P 280-300°C** *0-11 NaCl*	-	-	-	-	-	-

Figure 1: Types of fluid inclusions in various mineralization of the Velence Mts

Fluid inclusion assemblages of Palaeogene hydrothermal systems are characterised by common occurrences of vapour-rich and liquid-rich (with halite and other daughter-minerals at subvolcanic level aqueous fluid inclusions indicating boiling under relatively low pressure conditions. Thus petrography characteristics and microthermometry data of Palaeogene fluid inclusion assemblages are significantly different from fluid inclusions related to the Variscan hydrothermal system (Fig. 1) and this allow determination of relative age of FIP. Analyses on FIP were carried out in the eastern zones of the granite intrusion, close to the stratovol-canic structure of Palaeogene age. Orientations of FIP that were formed during the early stages of Variscan hydrothermal circulation (pegmatite formation) are NE-SW, NNE-SSW and NW-SE. Variscan aqueous-carbonic FIP are characterized by NW-SE and NE-SW strike-directions. Fluid inclusion assemblages that are typical to epithermal and subvolcanic level hydrothermal systems of Palaeogene age occur in FIP of granite: this is an additional proof of that the old intrusion was affected by the Alpean hydrothermal system at different stages of syn-volcanic tectonism. FIP with fluid inclusion assemblages characteristic to the epithermal system of Palaeogene age have E-W orientation. Fluids that can be connected to the sub-volcanic level hydrothermal circulation were trapped in FIP with NE-SW and E-W orientations (Fig. 2).

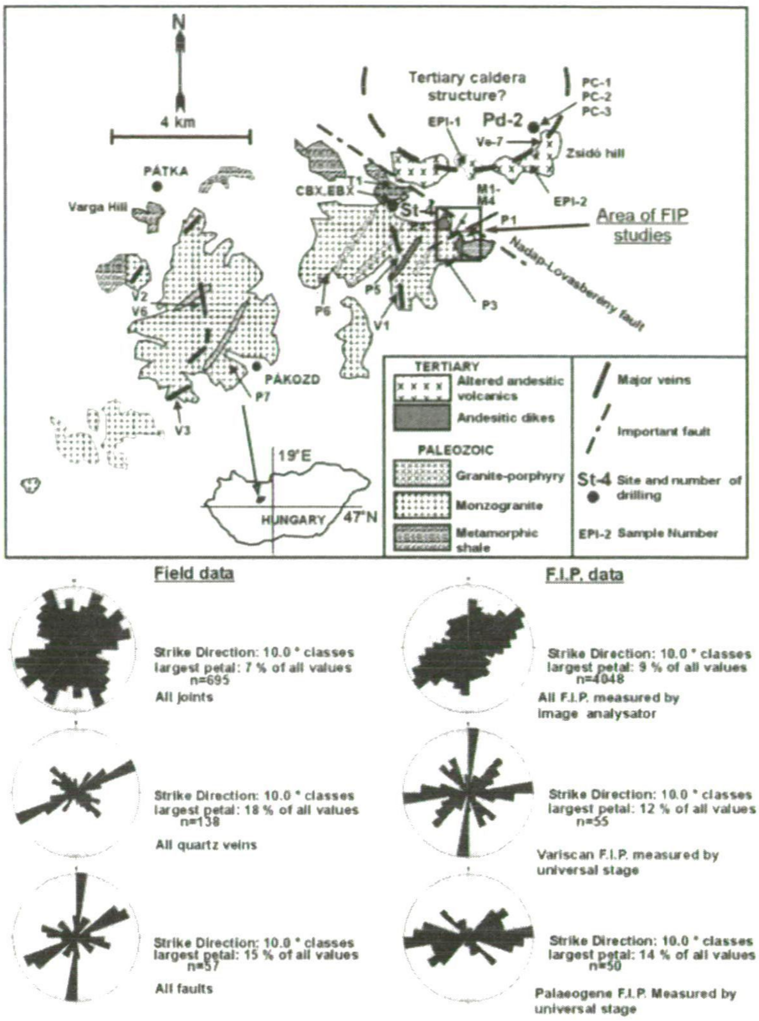


Figure 2: Orientations of macrofractures and FIP in the Velence Mts.

The major orientations of macrofractures in the granite intrusion are NE-SW and NW-SE. The N-S and E-W oriented fractures occur in a subordinate amount (Fig. 2). In the andesitic dikes and stocks in-truding granite, the most characteristic fracture ori-entation is N-S. Vertical-subvertical quartz veinlets have predominantly NE-SW and subordinately NW-SE orientations both in granite and its andesite stocks. An illite alteration zone of granite having Palaeogene K-Ar age has NE-SW strike-direction. Porosity and permeability (calculated from data of FIP) in the highly altered zones of granite are higher than those from less altered zones (Φ_f=4,02%, K_f=1,04 mD vs. Φ_f=3,32%, K_f=0,71mD, respectively). Permeability values calculated for FIP from the latter zones are higher than those for the still open microfractures in rock forming quartz (K_f=0,71 mD vs. K_f=0,11 mD, respectively).

Discussion and conclusions

At the time of intrusion of granite, the σ_3 vector of the stress field had NW-SE orientation according to the orientation of Variscan granite-porphyry and aplite dikes and early FIP. During the following stages of Variscan fluid circulation, orientation of σ_3 changed to ENE-WSW. This may correspond to that NNE-SSW compression regime which is displayed by the foliation and quartz veining in the host shale of the granite intrusion. The conjugated NE-SW and NW-SE macro-fracture system of granite may also be connected to the same compression regime. The Tertiary hydrothermal system penetrated the old granite partly by re-opening of the NE-SW oriented fractures. New fractures formed by activation of syn-volcanic normal faults and opening of E-W oriented fractures. Due to re-opening of old fractures and formation of new ones, the permeability of granite was enhanced in some zones: this allowed circulation of Palaeogene hydrothermal fluids in the old granite mass. Most of fractures were healed during the Palaeogene hydrothermal activity, thus the recent permeability of granite related to the still open micro-fractures is much smaller than it was at the time of hydrothermal fluid circulation.

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