Application of ultrasound scanning method and geochemical analysis in granite samples

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SUMMARY: The poster deals with a quick method of granite matrix porosity laboratory evaluation. Ultrasound scanning method was preliminary tested on three Bohemian Massif's granite samples. Optical microscopy, scanning electron microscopy and mercury porosimetry were applied to match the data. Strategy of the consequent methodology setting up and validation was proposed. Furthermore, four types of the pore space in the granite matrix were documented in the samples. In accordance with previous researches various fissures were the most common. A range of size was determined for the observed fissures and pore size distribution was discussed.

Introduction

Matrix permeability has been studied intensively in the granites of Bohemian Massif (e.g. Sosna et al. 2007, Vaněček et al. 2008). The studied samples were collected in three different granite massifs (Fig. 1). The first sample (Pribram) was collected in the Central Bohemian Plutonic Complex, where light, medium-grained granites and granodiorites are present. The second sample (Krasno) is from the deposit of albite-aplite granite, which is used as a feldspar raw material. The third sample (Panske Dubenky) belongs to the Mrakotin granite massif.

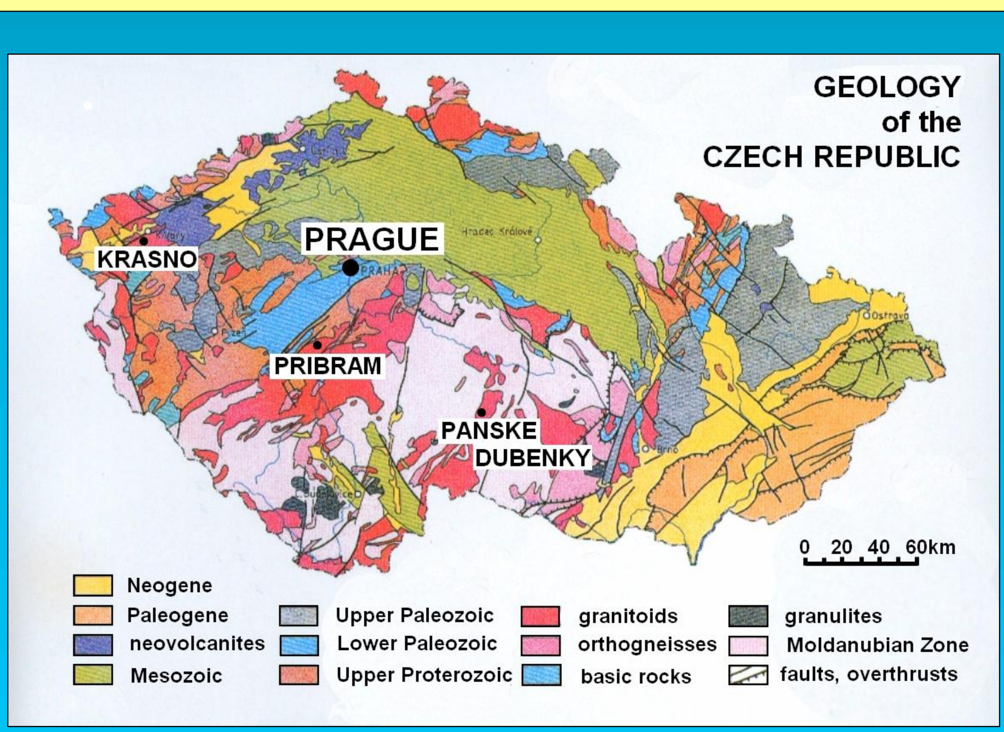

Fig. 1. Simplified geological map of the Czech Republic and marked samples localities (Krasno, Pribram, Panske Dubenky) (modified after Czech Geological Survey).

Ultrasound scanning

Ultrasound scanning system (Fig. 2a, b) consisted of 4 piezoelectric sensors, 4 ultrasonic pulser receivers and a digital oscilloscope recorder. The wave frequency was 1MHz. Primary (Fig. 2c) and secondary wave velocities were measured in the samples. Elasticity modulus and Poisson's (ratio) number were calculated using formulas (Brož et al. 2009):

$$E_d = \frac{\rho\left(3v_P^{\,2} - 4v_S^{\,2}\right)}{\left(\frac{v_P}{v_S}\right)^2 - 1}$$

$$\nu = \frac{V_P^{\,2} - 2V_S^{\,2}}{2\left(V_P^{\,2} - V_S^{\,2}\right)}$$

v_p = velocity of primary wave
v_s = velocity of secondary wave
ρ = density of granite
Ed = elasticity modulus
v = Poisson's number (ratio)

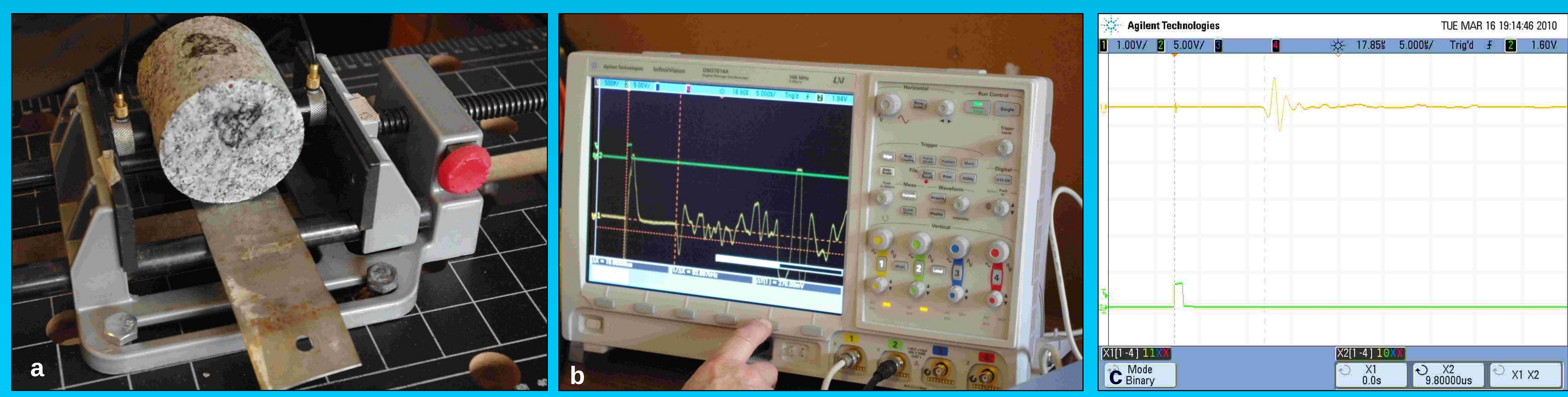

Fig. 2. a) Piezoelectric sensors on the granite core sample, b) osciloscope during the measurement, c) record of P-wave

Optical microscopy

Fracturing of the fragments was studied in detail using an OPTON-ZEISS (Opton-Zeiss) microscope and magnification 40 and 100 times (Fig. 3a, b, c). A small fragment (5x5x2 mm) was cut off each sample as carefully as possible to keep an additional fracturing as low as possible. Therefore fissures were localized on the natural surface of fragments produced by pressuring. Natural surfaces of the samples were observed to avoid artificially created fracturing during thin sectioning.

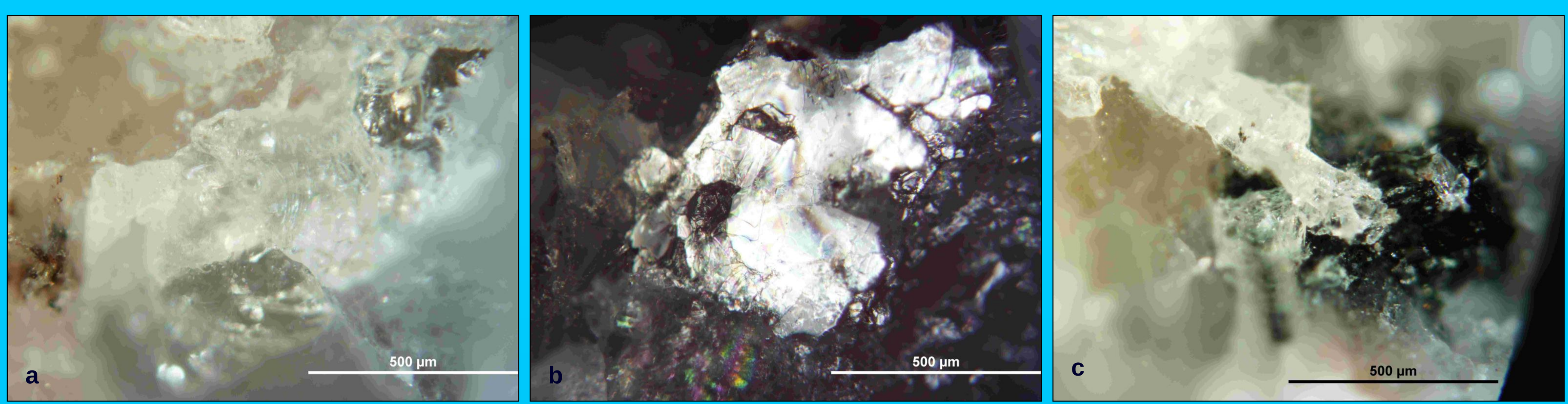

Fig. 3. The granite samples fragments under the miscoscope. a) Krasno, b) Panske Dubenky , c) Pribram

Scanning electron microscopy

The same fragments were studied using a scanning electron microscopy The microscope Quanta 450 was employed. Following the fissure distribution plans, the fragments were studied in their natural state and coated in gold. Fissure types were searched (Fig. 4a) and proportions of selected fissures were measured (Fig. 4b).

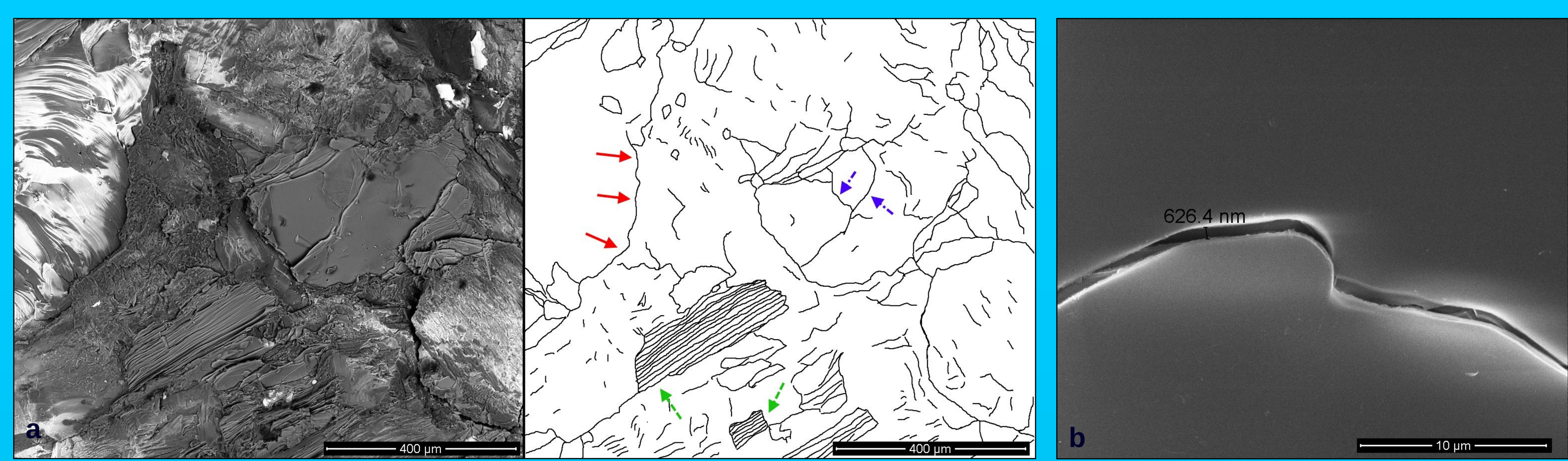

Fig. 4. a) On the left is a microphotograph of pores using scanning electron microscope, detector Backscattered Electrons, sample Pribram. On the right is a schematic draft of the pores, examples of grain boundaries: red full arrows-grain boundary pore between quartz and feldspar, blue dashed arrows-intragranular pores in biotite, green dotted arrows-sheet silicate pores in biotite grains. b) Measuring of the microfractures.

Tab. 1 Summary of the results

Method	Parameter		Locality		
			Krasno	Pribram	Panske Dubenky
Sampling	depth level [m]		80	200	10
Volume of samples	original [cm3]		98	53	477
	shape		core (cylinder) D50mm, L50mm	core (cylinder) D50mm, L27mm	part of core (cylinder sector) 265x62x38mm
	fragment 1 [cm3]		1	1	1
	fragment 2 [cm3]		1	1	1
Petrological description & stereo magnifying	color		light grey to light purple	dark grey to pink	black and white
	grains		medium grained	fine grained	fine to medium grained
	minerals		quartz(30%) Na-feldspar(40%) K-feldspar(20%) muscovite(2%) kaolinite (1%) fluorite(0.5%)	quartz(60%) K-feldspar(20%) Ca-felspar(10%) biotite(7%) muscovite(1%)	quartz(65%) Ca-feldspar(20%) biotite(10%) muscovite(2%)
Ultrasound scanning	vp [m/s]		4335	5768	4811
	vs [m/s]		2908	3355	2994
	vs/vp		0,67	0,58	0,62
	Ed [GPa]		191,32	196,25	175,66
	Poisson's number		0,09	0,24	0,18
Scanning electron microscopy	type of porosity		microfractures, grain boundary pores, sheet silicate pores, solution pores		
	size of fissures	min [μm]	L:13.04 W:0.10	L:5.14 W:1.07	L:2.45 W:0.63
		max [mm]	L: 2.69 W:0.03	L:1.73 W:0.05	L:0.82 W:0.06
Mercury porosimetry	total porosity [%]		1,86	0,71	0,77
	bulk density [g/cm3]		2,59	2,65	2,64
	pore size distribution		two lognormaly distributed sets		

Mercury porosimetry

Mercury-porosimetry was used to determine connected matrix porosity in the granite samples (Fig. 5). Therefore other fragments were cut off the samples carefully. The injection system Pascal 140+240, Thermo Electron-Porotec was used to determine the connected porosity of the samples. The apparatus uses pressure intervals from 0.1 kPa to 200 MPa allowing the identification of pores in the range of width from 3.7 nm to 58 μm (micro, meso and macro pores) (Brož et al. 2009).

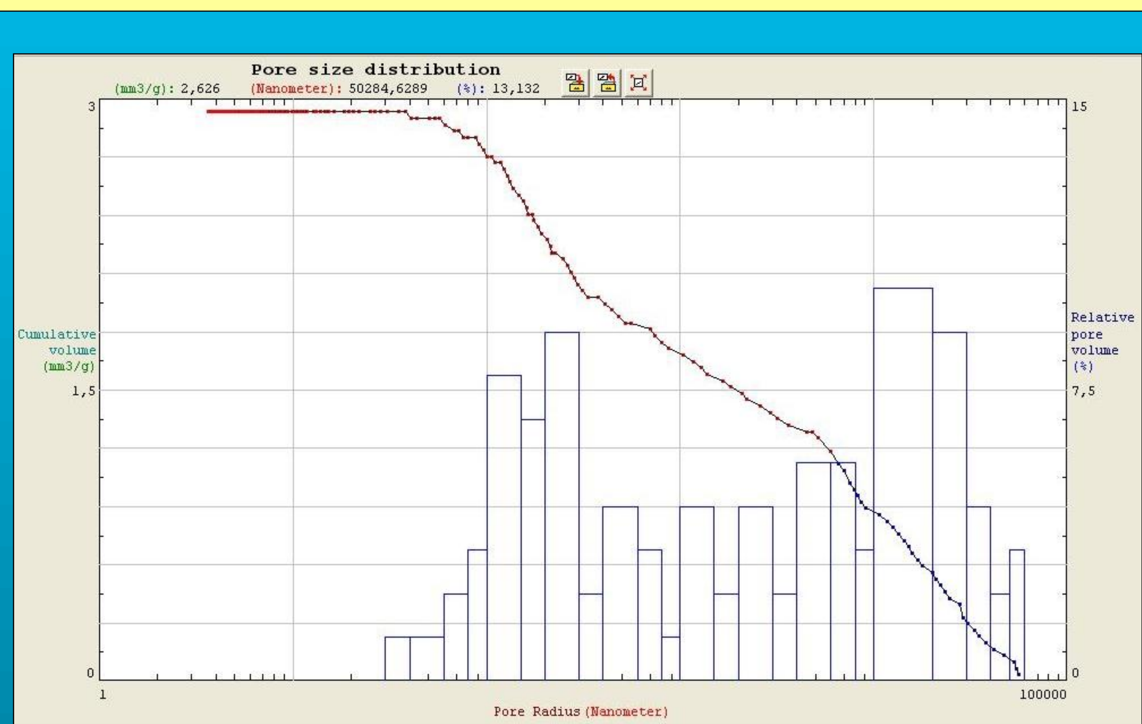

Fig. 5. Histogram of pore size distribution determined by mercury porosimetry in the Panske Dubenky sample. The picture demonstrates dual distribution of matrix porosity in the sample.

Conclusions

The ultrasound scanning method, scanning electron microscopy and mercury porosimetry provided consistent information about the granite matrix porosity (Tab.1). In spite of this the conclusions are generalised because of the small number of samples studied. Important lessons were learned. The ultrasound method is quick and easy enough to study a considerable number of samples in laboratory and in-situ conditions.

A statistical approach must be applied to analyse the method in full. Ultrasound scanning, pore size distribution and thin section pore visualization methods (e.g. 14C-PMMA method) are the optimal combination.

Pore size distribution in the studied granites displays two different sets. The small size set probably represents intragranular and grain boundary pores/fissure, while the other one intergranular fissure (microfractures).

Acknowledgements

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