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Comparison of computer image analysis with mercury porosimetry in sandstone porosity measurement

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Computer image analysis was used to determine porosity volume in sandstones from Upper Silesia and Jura Krakowsko-Częstochowska. Calibration of the data was made by comparison with the results of mercury injection capillary pressure methods. Image analysis can yield many useful parameters. This study obtained chosen size parameters and diameters of equivalent area circles, calculated for all samples after 100 partial observations. Results obtained by image analysis are close to those measured by mercury injection capillary pressure. They could complement standard mercury porosity measurements, and in some cases, replace them.

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INTRODUCTION

Quantitative image analysis of rock samples in thin-section is mainly used to establish mineral composition, or in some cases chemical composition (Muszer, 1998; Ratajczak *et al*., 1998). Computer processing enables easy and rapid automatic measurements.

This study tests computer image analysis in determining the porosity volume of sedimentary rocks, calibrated against mercury injection capillary pressure measurements (Labus, 1996).

Similar studies were undertaken by Leśniak (1999) and Leśniak and Such (1999).

SAMPLING MATERIAL

This study used sandstone samples from Upper Silesia and Jura Krakowsko-Częstochowska.

Samples 1 to 4 are from the Late Carboniferous sandstones (the Orzesze beds) in the Mikołów region. These are medium-grained quartz sandstones, with an iron-clay-siliceous cement, reddish and light grey with yellow stripes. They show random and fairly compact (samples 1 and 4) or compact (samples 2 and 3) textures. The grains are moderately sorted, and variably rounded. They comprise grains of quartz, feldspars, and muscovite, with biotite in sample 1. Two quartz varieties are present, one of which is cataclased with strongly wavy extinction. The grains of quartz are poorly sorted, cracked, sharp-edged, rarely slightly polished, 0.2– 0.3 mm in diameter. There are also a few alkali feldspar grains, about 0.5 mm in diameter, strongly degraded, cloudy and often kaolinised. Products of feldspar disintegration are components of the rock cement. Some igneous or metamorphic rock fragments are also visible; in sample 3 they are up to 0.6 mm in diameter. Lithic fragments of quartzite and gneiss were distinguished; the latter of quartz with rare biotite.

Samples 5–8 are of fine-grained and medium-grained sandstones, with a siliceous-clay cement. The rocks are of Early Carboniferous Culm facies, from near Toszek. They are greenish-grey or dark grey, with obvious muscovite flakes. Grains are poorly rounded and sorted, the quartz grains being strongly cracked, 0.1–0.2 mm in diameter, reaching up to 0.5 mm in sample 5. Lithic fragments with biotite and muscovite occur. Plagioclase grains are commonly kaolinised. In sample 8 there

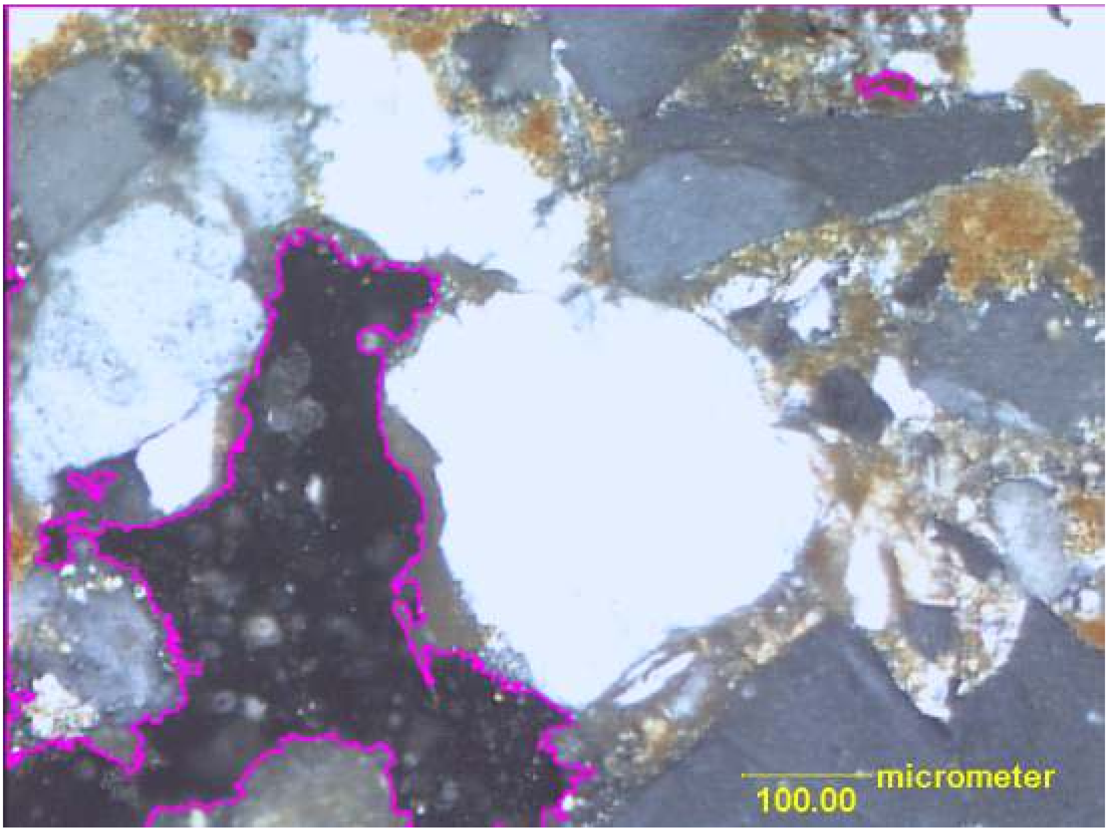

Fig. 1. Contoured pore area in sample 2 (magnification x 100)

are also cloudy orthoclase grains, as well as small coal fragments and occasional zircons.

Sample 9 is a Cretaceous sandstone, from an eroded klippe of the Albian/Cenomanian age, found as loose rock blocks near Mirów (Jura Krakowsko-Częstochowska). The sandstone is coarse-grained, red-brown, massive, with a ferrous-clay-siliceous cement. The quartz grains are poorly rounded and well sorted, about 0.2–0.5 mm in diameter. There are occasional lithic fragments.

COMPUTER IMAGE ANALYSIS

Porosity parameters were measured using a *KS300 Imaging System* by Carl Zeiss *Vision GmbH*. Each of the microscope slides was analysed at 100 places, each 0.5 mm apart. The observed area visible on the computer monitor was 860 x 750 μm, when x 100 magnification was used, and 430 x 375 μm with the use of x 200 magnification. The images were transformed into grey colours and segmented (using a threshold function). The result of the segmentation was a histogram of the brightness of the image pixels. Populations of different brightness were chosen in an interactive operation, leading to a binary map of two pixel populations — black and white. Dark pixels correlate with pores in the rock, and were contoured (in Figure 1 the contours are overlaid on to a colour image for clarity). Following the contouring, some areas were eliminated manually, where not all the dark areas were pores; such verification was possible because of simultaneous observation of the microscope image and the coloured image on the computer monitor.

The total porosity was calculated as a percentage of contoured (chosen) regions to total image area. Table 1 shows the results obtained using different magnifications (x 100 and x 200).

Table 1

Results of porosity measurements obtained by computer image analysis

Sample	Pore area [%] image magnification	
	x 100	x 200
1	13.37	13.40
2	15.28	16.10
3	16.82	20.27
4	5.15	6.39
5	3.10	3.52
6	10.43	12.51
7	9.50	9.36
8	5.22	6.30
9	15.98	17.60

Table 2

Results of pycnometric and porosimetric analysis

Sample	Pycnometer *AccuPyc 1330*		Porosimeter *AutoPore 9220*		
	density [g/cm^3]	total porosity [%]	porosity obtained with mercury porosimeter [%]	median pore diameter [mm]	total pore area [m^2/g]
1	2.30	12.32	10.92	0.81	0.24
2	2.26	15.67	13.60	0.33	0.73
3	2.22	15.81	13.62	0.42	0.58
4	2.51	5.25	4.88	0.26	0.30
5	2.56	3.68	3.48	0.10	0.55
6	2.43	9.26	8.40	0.28	0.49
7	2.43	9.62	8.78	0.21	0.70
8	2.55	4.43	4.16	0.02	2.14
9	2.46	14.46	12.29	0.04	1.28

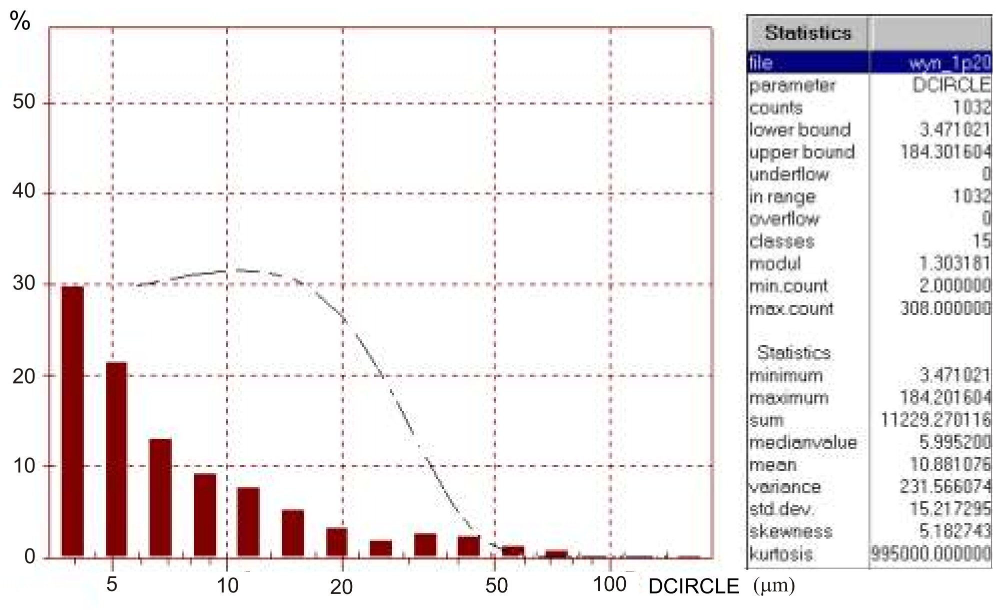

Fig. 2. Histogram of diameters of equivalent area circles for the sample 1

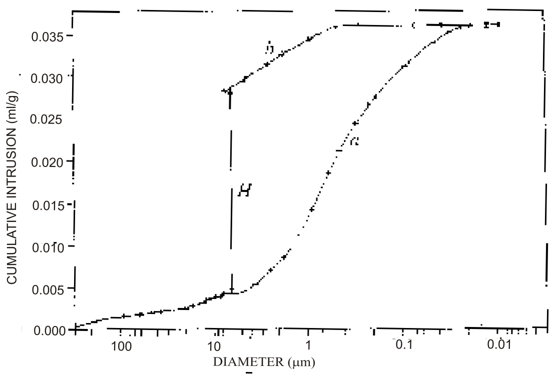

Fig. 3. Cumulative intrusion curve — obtained using the mercury capillary pressure method for the sample 7

a — increasing pressure, *b* — decreasing pressure, *H* — hysteresis; for other explanations see text

Image analysis gave many useful parameters. These included the maximum and minimum sizes of dark areas (pores) in vertical and horizontal directions, as well as the diameter of equivalent area circles. This last parameter is useful for comparing mercury porosimetric measurements, where pore diameters are calculated.

Diameters of equivalent area circles was calculated for all samples, after completing 100 partial observations. Results can be given in tables or graphically. Figure 2 shows a histogram of equivalent area circles ("dcircle"), for sample 1 at x 200 magnification.

RESULTS OF POROSIMETRIC AND PYCNOMETRIC MEASUREMENTS

Porosimetric measurements were carried out using analytical equipment at the Oil and Gas Institute in Kraków. The pycnometer *AccuPyc 1330* yielded rock density values. These differed slightly from density values measured using mercury injection capillary pressure apparatus: in the *AccuPyc 1330* the pore-filling medium is helium, and this gives higher values of mass density (by about 0.1–0.2 g/cm^3), than those obtained using the mercury porosimeter *AutoPore 9220.* Using these values it is possible to calculate a "total porosity"; in the Table 2, this lies near the porosity value obtained using the porosimeter. The two values differ because small pores have not been penetrated by the mercury.

The *AutoPore 9220* results include:
— total mercury intrusion volume;
— total pore area;
— median pore diameter;
— average pore diameter;
— apparent (skeletal) density;
— bulk density.

Porosity values can be calculated using skeletal and bulk densities.

The chart obtained (Fig. 3) is a cumulative intrusion curve of pore volume versus diameter, in increasing and decreasing pressure regimes. Figure 3 shows the diagram for the sample 7. The logarithmic *x*-axis is for pore diameter (μm). The *y*-axis is scaled in millilitres of the mercury injected into the pore space per 1 g of rock (ml/g). The total volume of the mercury injected is proportional to the total effective porosity of the sample. Point (0.0) marks the beginning of the cumulative curve for increasing pressure *a*, while *b* — represents the curve obtained as pressure decreases. The latter reflects the difference between the shape of the real pore space and a presumed cylindrical shape. The nearer the both curves are (the hysteresis *H* is smaller), the closer is the pore space analysed to a cylindrical shape, implying that the pores are connected to enable liquid transport. If curve *b* is located significantly higher than curve *a* (as in Fig. 3) then significant amounts of capillary pores are indicated in the sample tested. Where curve *b* lies significantly beneath curve *a* it may be assumed that there are a lot of bulk pores with reduced liquid flow in one direction only.

CONCLUSIONS

The results obtained by image analysis (Tab. 1) are close to those obtained using mercury injection (Tab. 2). In case of coarse- and medium-grained samples (1–4 and 9) the porosity calculated using microscope observations is usually a little higher than that measured with the pycnometer *AccuPyc 1330*. In case of fine-grained sandstones (samples 5–8) such a relationship was not observed.

The porosity values calculated at x 100 magnification are mostly lower than the ones calculated at x 200 magnification (Tab. 1), the latter diverging more from the pycnometer results shown in Table 2. This is probably caused by the greater magnification revealing smaller pores (dark areas), which do not influence the real rock porosity (effective porosity). Thus the results obtained using x 100 magnification are more clear-cut and useful.

Porosimetric analysis obtains additional parameters, such as permeability. Nevertheless, computer image analysis can usefully complement porosimetric measurements, and in some cases replace them.

The computer image analysis provides rapid, reproducible measurements, and gives a range of parameters in the form of tables or/and graphs. Problems image area selection can be resolved, as shown above. The results of this study confirm the value of this technique.

REFERENCES

LABUS M. (1996) — Relation between porosity and preservation state of stone material in selected monumental buildings in Upper Silesia (in Polish with English summary). Prz. Geol., **44** (1): 55–58.

LEŚNIAK G. (1999) — Application of computer analysis of microscopic images in petrophysical investigations (in Polish with English summary). Prz. Geol., **47** (7): 644–651.

LEŚNIAK G. and SUCH P. (1999) — Analiza przestrzeni porowej skał zbiornikowych czerwonego spągowca z południowej części niecki poznańskiej przy zastosowaniu komputerowej analizy obrazu i modeli perkolacyjnych. Prz. Geol., **47** (5): 478.

MUSZER A. (1998) — Analiza planimetryczna obrazu mikroskopowego — zastosowanie programu “Lucia-M”. In: Programy Komputerowe w Geologii. Mat. Konf. II Warsztaty Nauk., Państw. Inst. Geol., Sosnowiec.

RATAJCZAK T., MAGIERA J., SKOWROŃSKI A. and TUMIDAJSKI T. (1998) — Ilościowa analiza mikroskopowa skał. Wyd. AGH. Kraków.