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SANDSTONES PETROGRAPHIC AND POROSITY PARAMETERS INTERPRETATION WITH USE OF COMPOSITIONAL DATA ANALYSIS

INTERPRETACE PETROGRAFICKÝCH A POROZITNÍCH CHARAKTERISTIK PÍSKOVCŮ S VYUŽITÍM METODY CDA (COMPOSITIONAL DATA ANALYSIS)

Abstract

V této práci je otestována možnost implementace statistické metody: metoda CDA při interpretaci naměřených dat porózity a petrografických dat hornin. Vzorky hornin byly polské stavební pískovcové kameny rozdělené do 4 skupin dle geologické oblasti nebo stratigrafického umístění.

Analýza porosity, provedená na 35 vzorcích pískovců, zahrnuje měření efektivní porózity, dynamické porózity, a také parametry v oblasti póru. Výsledky analýz byly interpretovány využitím metody CDA. Stejný postup byl použit při korelaci s minerálním složením kamenů pískovců.

Abstract

In this paper is tested a possibility of implementation of a statistical method: Compositional Data Analysis in the interpretation of porosity measurement data and petrographic data of rocks. The sampled rocks were Polish building sandstones divided into 4 groups related to a geological region or a stratigraphical position.

Porosity analysis performed for 35 sandstone samples include measurement of effective porosity, dynamic porosity as well as the pore area parameters. The results of the analyses were interpreted with the use of CDA. This same procedure was used when the porosity date were correlated to mineral composition of the sandstones.

Key words: sandstones, petrographical compound, porosity parameter, Compositional Data Analysis

1 INTRODUCTION

Compositional Data Analysis (CDA) is a relatively new statistical method implemented into the Earth sciences. Some attempt for using the method for rock porosity measurement data interpretation was carried out before (Labus, 2005). This work was performed on a new sample set (sandstone rocks) to verify the possibility of interpretation of the porosity data by mineral composition of the rock. Analysed rock

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samples represent different Polish sandstones and muddy sandstones used for building purposes, collected from Sudety Mts., Carpathian Mts. and Holy Cross Mts.

2 ROCK SAMPLES CHARACTERISTIC

35 rock samples representing different sandstones from Poland were collected. They were divided into 4 groups related to a geological region or a stratigraphical position (symbols refer to diagrams in the following figures):

- Group 1 – Cretaceous sandstones from Sudety Mountains (samples 1 – 16)
- Group 2 – Cretaceous or Older Tertiary System rocks of Beskydy region (Carpathian Mts.) (samples 17 – 24)
- Group 3 – lower Triassic sandstones - Holy Cross Mountains (samples 25 – 31 and 34, 35)
- Group 4 – lower Jurassic sandstones - Holy Cross Mountains (samples 32 and 33).

Mineral composition of the rocks was analysed with the use of polarizing microscope Axioscope by Carl Zeiss. Data for the sandstones were collected using point-counting methods; these are: grains and cement mineralogy and grain sizes.

Sandstones of the Group 1 (Sudetan rocks) consist mainly of quartz (79-98%); the other components are feldspars and muscovite. They are usually not well-cemented, that is caused by a great share of clay minerals within the matrix.

Carpathian sandstones (Group 2) are mainly fine-grained and firm (with the exception of rocks from Ciężkowice locality). The quartz content oscillates from 49 to 71%. The other components are mainly lithic fragments (mudstones) as well as muscovite and feldspars. The cement is generally clay-siliceous or siliceous-clay-carbonate.

The rocks of Holy Cross Mountains are: Triassic red sandstones (Group 3) and the Jurassic white ones (Group 4). The quartz share in the analysed rocks oscillates from 75,5 to 95,5%. The other components are: feldspars, lithic fragments and muscovite. Clay-ferruginous cement is the most frequent; in some cases the siliceous- ferruginous cement is present.

3 COMPOSITIONAL DATA ANALYSIS

CDA method was introduced by Aitchison in 1986 (Aitchison, 1986). The compositional data are “closed” data consisting of vectors x with positive parts $x_1,...,x_D$, representing proportions of some whole. Therefore they are subject to the constraint: $x_1+...+x_D=1$, which means x being a composition of D parts, summing to 1 (or 100 %). As a consequence the components of the above equation cannot be independent since they sum to a constant. Such “closed” data are popular in Earth sciences (e.g. geochemistry, mineralogy, sedimentology, palaentology, environmetrics, etc.), as well as in other fields, i.e. medicine, archeology, agriculture, economics, etc.

Characteristic features of a compositional data set are (Reyment, Savazzi, 1999):

- a compositional data set (samples of a population) may be represented in form of a matrix;

- each row of the data-matrix corresponds to a single specimen (i.e. rock sample); this is known as a *replicate* (= a single experimental or observational unit);
- each column of the data matrix represents a single chemical element, a mineral species, in short a part;
- each entry in the data-matrix is non-negative;
- each row of the data-matrix sums to 1 (proportions), respectively, 100 (percentages), (sometimes another row-constant can be found, e.g. owing to some manipulation on the part of an analyst);
- correlation coefficients change if one of the variables is removed from the data-matrix and the rows are made to sum to 1 or 100 again. The same effect is also produced if a new component is added to the study.

The last property means that deleting (or adding) one or more variables from (to) the data-set might have a significant numerical effect on correlations between the remaining variables.

More crucial than the constraining property of compositional data is the scale-invariant property of data of this kind (Barceló-Vidal et al., 2001).

The Compositiona Data are usually visualized with the use of ternary diagrams and biplots. A special feature of the ternary diagrams in CDA is a possibility of obtaining a visual representation of the variability of compositions with more than four parts. In is performed by constructing subcompositions or amalgamations of parts (Aitchison, 2003 a, b).

Apart from ternary diagrams the biplot is very popular in CDA (Aitchison, Greenacre, 2002), introduced by Gabriel (1971). Biplot enables a graphical display of observations and variables in the same chart in a way that approximates their correlation. In a biplot the observations are usually marked by points and variables by rays (vectors) emanating from the origin.

Statistical methods designed for unconstrained data may lead to inappropriate inferences when applied to compositional data. This is because the sample space (in statistical sense) for compositional vectors is radically different from the real Euclidean space associated with unconstrained data. The problems of compositional data are associated with the sample space of the unit simplex (Aitchison, 2003a).

4 POROSIMETRIC DATA INTERPRETATION

Porosimetric measurements were carried out using the mercury injection capillary pressure method at the Oil and Gas Institute in Kraków (Poland). Capillary pressure curves were obtained with the use of Micrometrics Injection Porosimeter AutoPore 9220. Density of the samples was measured with use of a helium picnometer AccuPyc 1330.

The obtained cumulative intrusion curves of pore volumes versus diameter enable the determination of percentages in different pore classes (Fig.1). The porosimeter penetrates pores from 0.01 to 100 μm. Therefore the pores have been classified into: transitive pores (10^{-8} – 10^{-7} m), submacropores (10^{-7} – 10^{-6} m), real macropores (10^{-6} –

10^{-4} m) and over capillary pores (>10^{-4} m) based on pore classification used in petrography and hydrogeology (Pazdro, 1983).

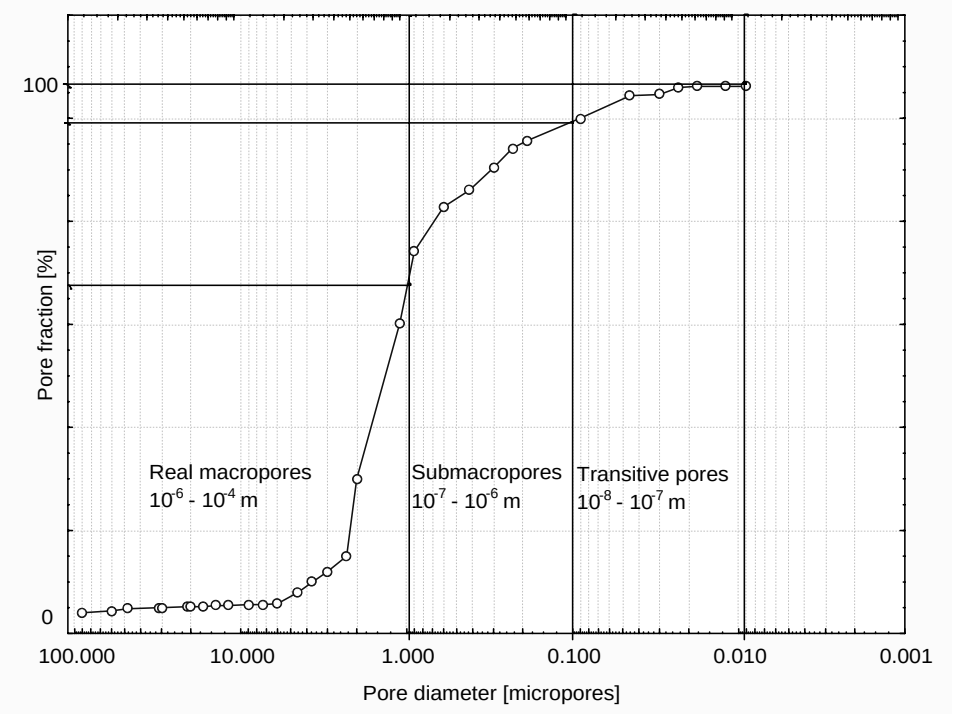

Fig. 1 Example of the capillary pressure saturation curveand determination of percentages in different pore classes

In a few samples the effective porosity was 0 and those samples were not taken into consideration. Some other rock parameters were also determined, these are: skeletal density; bulk density, median pore diameter, total pore area = specific surface, hysteresis and threshold pore diameter.

The 4 classes of pore dimensions are “closed” data in the sense of CDA because the sum makes 100%. But it was assumed that the full composition is the data set of classes of pore sizes and the share of skeletal grains. In order to combine these data the “unconstraining” operation was used. It means the factors of the groups of pore sizes were recalculated to form a unit sum together with the share of grains.

Fig. 2 represents the biplot of subpopulation of pore sizes distribution with the share of skeletal grains (rock). The link 4-2 is the longest which indicates the greatest relative variation in the ratios of components between over capillary pores and submacropores. They are negatively correlated and there is no constant proportion between over capillary pores and submacropores. Relatively insignificant is the variation in the ratios of macropores and the share of skeletal grains. The last mentioned two are independent to the over capillary pores and submacropores. The transitive pores variation determines the porosity variation within Group 2 of sandstone samples (flysch sandstones from Carpathian Mts.). The variation of macropores and skeletal grains

determine porosity variability of Cretaceous sandstones from Sudety Mountains (Group 1).

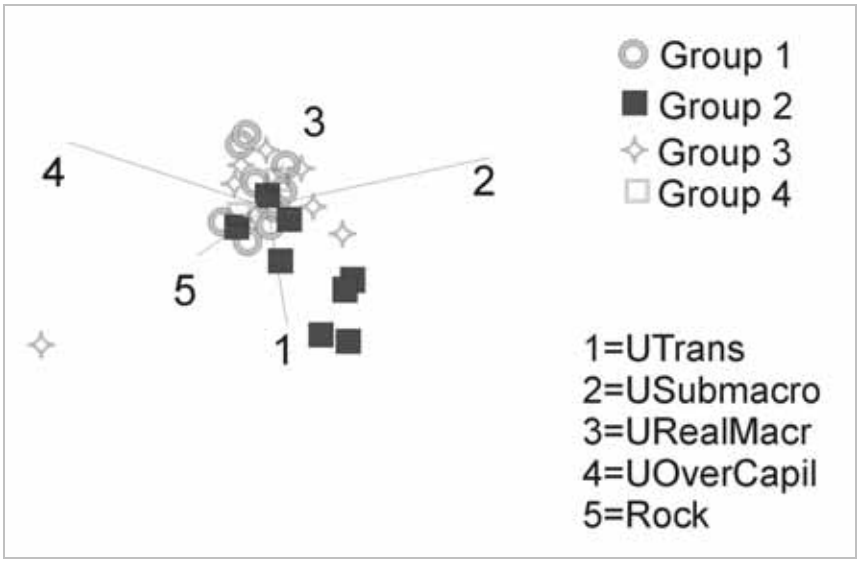

Fig. 2 Biplot of subpopulation of pore sizes distribution with the share of skeletal grains (rock).
Explanations: 1 – Transitive pores, 2 – Submacropores, 3 – Real macropores, 4 – Over capillary pores, 5 – skeletal grains, "U" means unconstraining operation.

5 PETROGRAPHIC DATA INTERPRETATION

5 components of grains (quartz, feldspars, micas, lithic grains and others) as well as the rock cement were separated with the use of point-counting method in each of the samples. The unconstraining procedure was used for recalculating of the above mentioned factors of components in a way that they make 100% together with porosity of the rock.

Porosity is a parameter obtained with the use of the method of mercury injection capillary pressure. Pore area in the thin-section of the sample was also measured with use of image analysis method. However the serious problem is the loose structure of some sandstones (especially from the Sudety region), which causes the detachment of grains during polishing of a thin-section sample. This leads to a frequent overestimation of the porosity value by means of microscopic techniques including the image analysis (Labus, 2001).

The method of mercury injection capillary pressure then gives more accurate results.

The obtained component factors are marked with the letter "U" meaning the "unconstraining" operation (Tab. 1).

Table 1 Percentage of sandstone components

Region	Sample No	Sandstone components obtained with point-counting method						Sandstone components after "Unconstraining" operation Regarding rock porosity						
		Quartz	Feldspars	Micas	Lithic fragments	Other components	Cement	Quartz U-Q	Feldspars U-Felds.	Micas U-Micas	Lithic fragments U-Lithic	Other components U-Other	Cement U-Cement	Porosity
Sudety	1	91.8	2.6	0	1.0	0	4,6	76.9	2.1	0	0.8	0.	3.8	16.2
	2	91.1	1.0	1.0	0	0	6,9	75.5	0.8	0.8	0	0	5.8	17.1
	3	89.6	1.0	0.3	0	0	9.1	77.5	0.9	0.3	0	0	7.8	13.5
	4	79.0	4.5	0	0	0	16.5	68.0	3.9	0	0	0	14.2	13.9
	5	84.0	1.5	3.0	0	0	11.5	73.0	1.3	2.6	0	0	10.0	13.1
	6	89.4	2.0	1.5	0	0	7.1	77.9	1.7	1.3	0	0	6.2	12.9
	7	98.0	0	0	0.9	0	1.1	84.2	0	0	0.8	0	0.9	14.1
	8	99.0	0	0	0	0	1.0	85.0	0	0	0	0	0.9	14.1
	9	89.0	2.0	0	3.0	0	6.0	74.8	1.7	0	2.5	0	5.0	16.0
	10	80.0	0	0.5	0	0	19.5	58.4	0	0.4	0	0	14.2	27.0
	11	81.5	0	0.5	0	0	18.0	63.5	0	0.4	0	0	14.0	22.1
	12	82.0	0	0	0	0	18.0	63.1	0	0	0	0	13.9	23.0
	13	83.5	0	0	0	0	16.5	65.7	0	0	0	0	13.0	21.3
	14	81.0	0	0	0	0	9.0	64.2	0	0	0	0	15.1	20.7
	15	92.0	0	0	0.5	0	7.5	78.8	0	0	0.4	0	6.4	14.4
	16	90.0	0	0.5	0	0	9.5	72.8	0	0.4	0	0	7.7	19.1
Carpathian Mts.	17	70.0	5.0	1.0	2.0	0	22.0	66.9	4.8	0.9	1.9	0	21.0	4.5
	18	70.0	7.0	2.0	3.0	0	18.0	67.2	6.7	1.9	2.9	0	17.3	4.0
	19	48.0	0	4.0	30.0	0	18.0	47.9	0	3.9	29.4	0	16.6	2.2
	20	51.0	0	2.0	23.5	0	23.5	50.6	0	1.9	22.4	0	22.4	2.7
	21	67.0	5.0	1.0	17.0	0	10.0	55.6	4.2	0.8	14.1	0	8.3	17.0
	22	53.0	2.0	0	23.0	6.0	16.0	47.9	1.8	0	20.8	5.4	14.5	9.6
	23	71.0	1.5	0	18.5	0	9.0	57.7	1.2	0	15.0	0	7.3	18.8
	24	60.0	0	1.0	7.0	0	32.0	54.5	0	0.9	6.4	0	29.1	9.1
Holy Cross Mts.	26	91.5	1.5	0	3.0	0	4.0	84.8	1.4	0	2.8	0	3.7	7.3
	27	93.0	1.0	0	4.0	0	2.0	86.6	0.9	0	3.8	0	1.8	6.9
	28	94.0	0	0	5.0	0	1.0	91.0	0	0	4.8	0	1.0	3.2
	29	75.5	0	0	22.0	0	2.5	63.2	0	0	18.4	0	2.1	16.3
	30	80.0	0	0	18.0	0	2.0	67.5	0	0	15.2	0	1.7	15.6
	31	83.5	0	0	14.5	0	2.0	73.9	0	0	12.8	0	1.8	11.5
	32	89.0	0	0	5.5	0	4.5	69.6	0	0	4.3	0	3.5	22.6
	33	89.0	0	0	4.0	0	7.0	74.3	0	0	3.3	0	5.8	16.6
	34	96.5	0	0	2.0	0	1.5	72.6	0	0	1.5	0	1.1	24.8
	35	89.0	0	0.5	4.0	0.5	6.0	85.1	0	0.3	3.2	0.3	5.7	5.4

Some of the data values in table 1 are non-positive (0) which makes the analysis with CDA procedures impossible (Aitchison, Kay, 2003; Bacon-Shone, 2003). The first approach to the problem was presented in the biplot diagram (Fig. 3) showing data of selected columns with non-zero values (quartz, cement and porosity). The biplot vectors position shows that the mentioned components are not correlated.

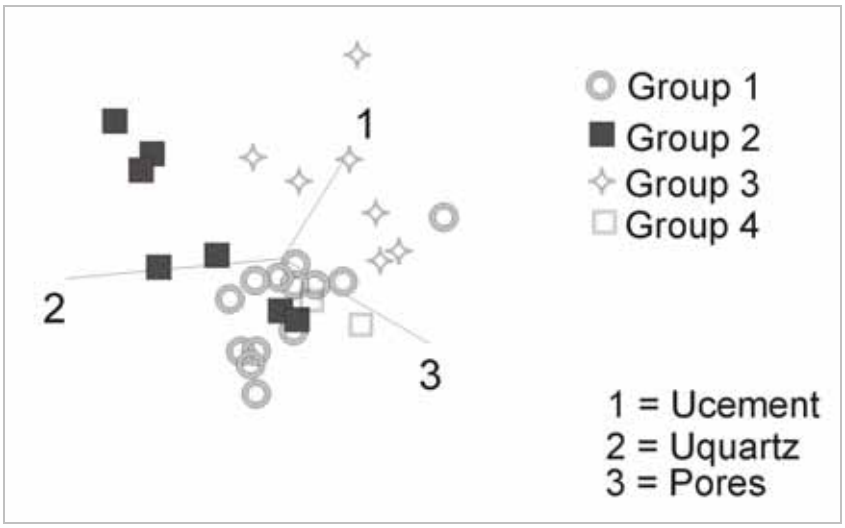

Fig. 3 Biplot of quartz (2), cement (1) and porosity (3) distribution

In the diagram in Fig. 3 the points representing sandstones of the distinguished groups are concentrated in their own areas around particular rays of biplot what is interpreted as follows:

- Group 1 – proportions of the rock components presented in Fig. 3 are related to correlation between porosity and quartz content,
- Group 2 – the most important is the share of quartz,
- Group 3 – the most important is the share of cement,
- Group 4 – is represented by two samples only. They are located near the porosity ray (3) therefore this parameter seems to be the most important in this rock group.

To make further interpretation possible the rest of the components (Tab.1) should be included. This could be performed while all of the values are not zero-values. The so-called zero problem in CDA is widely discussed in literature (e.g. Aitchison 2003b; Pawlowsky-Glahn, Olea, 2004). Strategies applied in most cases are: to replace the zeros by some small proportion or to amalgamate parts in such way that all zeros are eliminated. The last one solution may be sensible if the parts amalgamated are similar in character and where the zeros may have arisen because of the definition of an unnecessarily fine division of parts (Aitchison, Kay, 2003).

In the examined situation it could be assumed that the occurrence of zero-values in the table 1 is connected to the sensitivity of chemical analysis so the zeros are “rounded” or “trace” zeros. For such situations the “rounded zero replacement” strategy is used. This time the zero-values are replaced with the value: 0,005%. Consequently the

sum of the components in the table row is bigger than 100%. In order to return to a sum of 100% the closure operation is implemented, which is necessary in CDA procedures.

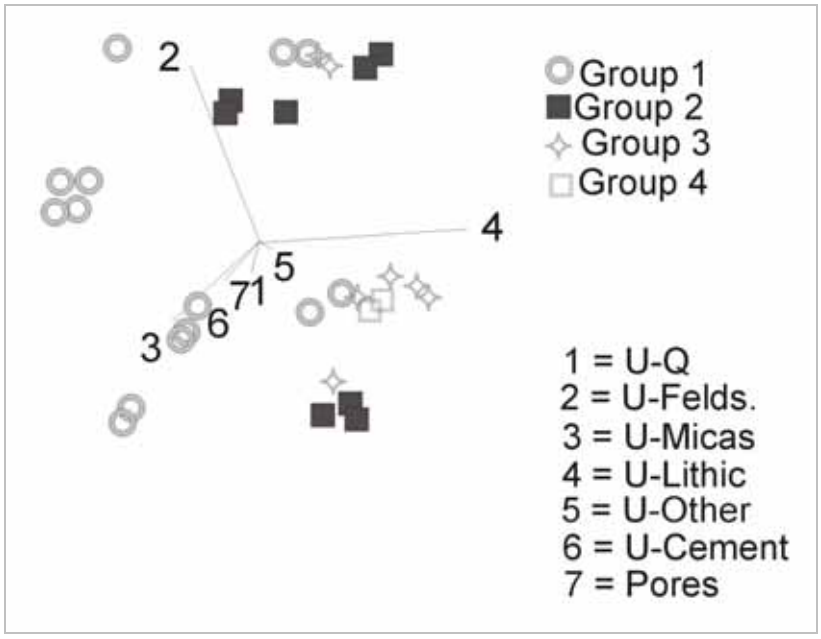

Fig. 4 Biplot distribution of all of the sandstone components
Explanation: 1 – quartz, 2 – feldspars, 3 – micas, 4 – lithic fragments, 5 – other rock components, 6 – cement, 7 – pores. The letter "U" means unconstraining operation.

In Fig. 4. is presented a biplot of all of the components of sandstones presented in tab.1 as well as the porosity share. Rays of the variables 1, 3, 6 and 7 are close together, i.e. the angles between them are quite small. One of the elements of compositional biplot interpretation is an assumption that cosine of an angle between rays approximates correlation between variables. In Fig.4 the correlation of variables 1, 3, 6 and 7 (i.e. quartz, micas, cement and pores in the rock) is then evident. Variation of the above mentioned determines the composition of upper cretaceous sandstones (Group 1). In the other groups of rocks the compound variation is connected in a wider extent to presence of feldspars and lithic fragments within the skeletal grains.

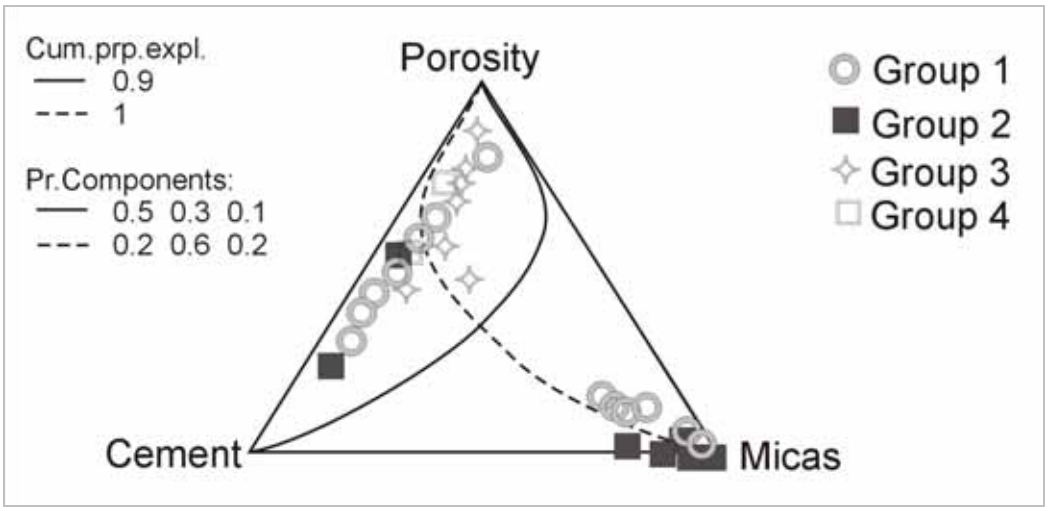

Fig. 5 Ternary diagram of pores, cement and micas distribution in sandstones
Explanations: Cum.prp.expl - cumulative variation explained by (n-1) principal components,
Pr.components – regression parameters of the principal components

In Group 1, which is the greatest one (16 samples) the most important components determining the sample compound were: quartz, micas and cement. Quartz as a dominant in all groups of samples was not taken into consideration in the following graph (Fig.5). Ternary diagram in Fig.5 presents centered subcomposition of data. The curves inside the graph represent axes of principal components – log-contrast principal axes in the sense of Aitchison (2003b) which may be understood as "regression lines" in a regression model for compositions (Billheimer et al., 1998). Numbers (summing to 1) near the explanations of each of the principal components are the values of the regression parameter vectors. "Cum.prop.expl." means cumulative variation explained by (n-1) principal components, where n is a number of analysed variables with the assumption that the components explain 100% of the variation. In the presented example (Fig.5) the first component explains 90% of variation and the second – 10%. Regression parameters indicate that the first principal component is highly correlated to porosity (regression parameter vector 0,5) and the second principal component is correlated to the cement content (regression parameter vector 0,6). The point representing samples are concentrated along the line Cement-Porosity and in the corner "Micas".

6 CONCLUSIONS

1. Porosimetric data analysis show the following relations:
   - the Group 2 of rock samples representing flysch sandstones from Carpathian Mts., the transitive pores (10^{-8} – 10^{-7}m) variation determines the total porosity variability.
   - The porosity variability of Cretaceous sandstones from Sudety Mountains (Group 1) is determined by the variation of macropores (10^{-6} – 10^{-4} m) and skeletal grains.

2. The analysis of petrographic data combined with porosimetric data show the following relations:
   - The angles between biplot rays of some variables (i.e. quartz, micas, cement and pores in the rock) indicate that the correlation among these variables is relatively strong.
   - In all of the sandstone groups the most important parameter determining their composition are porosity and cement fraction.
3. The performed analysis indicates that the procedures of Compositional Data Analysis (CDA) are useful in visualization and interpretation of prosimetrical and petrographic data.

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RESUMÉ

Metoda CDA (Compositional Data Analysis) je poměrně novou statistickou metodou, která se používá zejména ve vědách o Zemi. Aplikace této metody pro analýzu porózity hornin byla provedena již dříve (Labus, 2005); v této práci jsou interpretaci podrobeny porozimetrické údaje ve spojení s analýzami mineralogického složení horninového prostředí (v tomto případě vybraných polských pískovců).

Metoda CDA byla poprvé použita Aitchinsonem v roce 1986. Compositional Data se skládají z **x** nezáporných hodnot vektorů $x_1,....,x_D$, jejichž suma je jedna (resp. 100 %), tj.

$$x_1 + ... + x_D = 1$$

Přesto, že se v daném případě vektory sumují do hodnoty jedna (100%), nejsou to hodnoty závisle proměnné. Označují se zjednodušeně jako tzv. „uzavřená data“ (closed data). Je to způsob dat, nejčastěji se vyskytujících v geologii (např. geochemii, sedimentologii, petrografii, palynologii aj.), paleoekologii a jiných přírodních vědách. Charakteristické znaky těchto souborů jsou následující (Reyment, Savazzi, 1999):

- každý řádek datové matice se vztahuje k jednomu vzorku (např. horniny),
- každý sloupec datové matice prezentuje vybraný parametr („part”), např. chemický prvek, minerál apod.,
- každý z těch znaků je kladný,
- každý řádek matice se sumuje do 1 (např. rozměr), případně do 100 (pokud jsou hodnoty vyjádřeny v %). Může být použita i jiná stabilní hodnota sumy, a to s pomocí vhodného přepočtu dat (pomocí tzv. odchylek),
- součinitel korelace se mění, jestliže je např. jeden z parametrů vyřazen z matice a sumace řádku je prováděna opět na hodnotu 1 nebo 100 (je to vlastnost korelace, která záleží na proměnných). Tentýž efekt získáme v případě, že dodáme nový parametr (složku) do matice charakteristik.

Analýze bylo podrobeno 35 vzorků pískovců pocházejících z polských povrchových lomů v karpatském, svatokřižském a sudetském regionu. V článku jsou v diagramech použity různé symboly pro skupiny (Grupy) vzorků z jednotlivých lokalit:

- ⭘ skupina 1 – pískovce ze svrchní křídy – Sudety (vzorky 1-16),
- ■ skupina 2 – flyšové pískovce křídové nebo třetihorní – Beskydy (Karpaty) (vzorky 17-24)
- ¤ skupina 3 – pískovce spodního triasu – Svatokřížské hory (vzorky 25-31 a 34-35),
- □ skupina 4 – pískovce spodní jury - Svatokřížské hory (vzorky 32 a 33).

Při prováděných porozimetrických analýzách byla rozlišována efektivní a dynamická pórovitost a další charakteristické parametry jako: aktivní povrch pórů, rozměr střední kapiláry, hodnota efektivní hystereze apod. Pro kumulativní křivky (obr. 1), vyjadřující vztah pórového objemu ku průměru póru, byly vytvořeny 4 skupiny pórů, které jsou rozlišitelné rtuťovým porozimetrem (od 0.01 do 100 μm). Jedná se o skupinu pórů podkapilárních (10^{-8}÷10^{-7} m), o submakropórů (10^{-7}÷10^{-6} m), póry kapilární

($10^{-6} \div 10^{-4}$ m) a póry nadkapilární (>10^{-4} m). Rozložení pórů o různých velikostech je považováno za tzv. „uzavřená data“ ve smyslu výše popsané metody CDA.

Na obrázku č. 2 je uveden plošný diagram (biplot) subpopulací na základě rozložení velikosti pórů a podílu matrix. Největší rozptyly vytváří podíly pórů nadkapilárních (>10^{-4} m) a submakropórů ($10^{-7} \div 10^{-6}$ m) v hornině. Navíc je patrna i záporná lineární korelace. Poměrně nevelké jsou změny ve skupině kapilárních pórů ($10^{-6} \div 10^{-4}$ m) a podílu matrix. Změny nejsou závislé od dříve uvedených skupin pórů (nadkapilárních a mikropórů). Variace podkapilárních pórů determinují změny pórovitosti ve 2. skupině pískovců, tj. pískovců flyšových. Variace kapilárních pórů a podílu matrix determinují rozdělení pórovitosti v 1. grupě pískovců ze Sudet.

Na základě provedených planimetrických analýz bylo v každé grupě zkoumaných pískovců ještě vyčleněno 5 základních složek a to: křemen, živec, slída, úlomky hornin a jiné složky a tmel. Při použití operace tzv. „uvolnění“ byl přepočten podíl výše uvedených složek tak, aby současně s hodnotou pórovitosti v hornině tvořily 100 %. Takto přepočtené hodnoty byly označeny symbolem U- (unconstraining) – tab. 1.

Jako první je na plošném diagramu prezentována závislost mezi údaji, které byly vybrány z třech sloupců tab. 1, ve kterých byly vždy hodnoty větší než 0. Patří sem údaje o obsahu křemene, tmele a pórovitosti (obr. 3). Postavení paprsků v plošném diagramu ukazuje na to, že tyto tři složky jsou na sobě nezávislé.

Aby bylo možné provést další interpretace pro všechny parametry vzorků hornin, bylo pomocí procedury tzv. „rounded zero replacement” přistoupeno k zlikvidování nulových hodnot v tabulce. Na obr. 4 je plošný diagram, ve kterém byly zohledněny všechny složky pískovců současně a podíl pórů v horninových vzorcích.

Skupina 1 pískovců je nejreprezentativnější (16 vzorků). Proto byla v následujících úvahách kladena váha zvláště na parametry, determinující změny rozložení vzorků v této skupině hornin. Jak již bylo dříve uvedeno, mezi tyto složky patří: křemen, slída, tmel a pórovitost. Křemen, i přesto, že je složkou dominující, nebyl do trojúhelníkového grafu (obr. 5) zahrnut.

Shrneme-li získané poznatky můžeme uvést:

1. Analyza porozimetrickich údaju ukazují, že:
   - změny pórovitosti v dosahu skupiny 2 – tj. pískovců flyšových jsou determinovány variabilitu podkapilárních pórů ($10^{-8} – 10^{-7}$m),
   - pórovitost v rozsahu pískovců (skupina 1) podmiňuje variace pórů kapilárních ($10^{-6} – 10^{-4}$m) a podílu matrix.
2. Petrografické údaje ve vztahu s výsledky pórozimetrických analýz ukazují že:
   - úhly mezi paprsky biplotu některých složek (křemen, slída, tmel a pórovitost) ukazují na poměrně silnou vzájemnou korelaci,
   - na variabilitu petrografického složení ve všech zkoumaných vzorcích (bez rozlišení ke které skupině náleží) nejvýrazněji reagují pórovitost a obsah tmele.
3. Provedené analýzy zkoumaných objektů dokládají, že metoda CDA je použitelná a vhodná pro interpretaci pórozimetrických i petrografických dat.

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