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IDENTIFICATION OF TRANS - AND INTERCRYSTALLINE IMAGE OF THE FRACTURE SURFACES OF ROCK SPECIMENS

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ABSTRACT

One of the important aspects of the mechanism of brittle cracking is the geometry of fracture, i.e. its morphology and trans- or intercrystaline image. In the paper consideration has been given to fractures of dolomite and quartzite specimens obtained as a result of direct tensile test and brazilian test. Reconstruction of specimens was obtained by gluing. The linear stereological analysis was performed. Two groups of crystals have been identified: (1) crystals not adjacent to the fracture, (2) crystals adjacent to the fracture. It has been found in particular , that the mean intercept length of crystals in group 2 is significantly greater than the mean intercept length of crystals in group 1. Trans- or intercrystalline cracking depends not only on the type of the rock, but also on the mode of obtaining the fracture.

Keywords: Transcrystalline fracturing, intercrystalline fracturing, cracking of rocks,linear stereological analysis.

INTRODUCTION

One of the important aspects of the mechanism of brittle cracking of rocks is the geometry of the surface of a fracture, i.e. of the discontinuity causing the splitting of a piece of rock. Gentier and Riss (1985) worked out a method of the determination of surface area of fracture by means of systematic sections. In her doctoral dissertation Gentier (1987) presented an extensive study of a quantitative evaluation of the morphology of a fracture. Kraj (1985) developed a method for determination of distribution of a spatial orientation of the surfaces of discontinuities of materials on the example of granite.

A fracture may be also considered from the point of view of its location with respect to crystals which make up the rock. We can distinguish two extreme cases: (a) the fracture is identical with the contact surfaces of crystals, and then it is of the intercrystalline type, and (b) the fracture runs exclusively across the crystals, and then it is of the transcrystalline type. Obviously, fractures of a mixed type offer a whole spectrum of other possibilities. Intercrystalline fractures, in opposition to the transcrystalline ones, enable the liberation of minerals. This effect can be observed during the comminution of polymineral rocks (ores). The liberation effect is utilized to separate the useful mineral from the waste rock. Bodziony (1967) worked out a method of a quantitative evaluation of the partition of newly exposed (i.e. newly formed) surfaces during the comminution of rock, into the intercrystalline and transcrystalline types. This method has been practically applied by Górski (1972,1973) for the analysis of the comminution product of dolomite.

However, the comminution process, realized on industrial scale, gives no possibility to reconstruct the pieces of rock used to obtain the comminution product. Such a possibility exists only when individual samples of rocks are subjected to tensile test. In the present paper the authors describe the preliminary results obtained by means of reconstructing cylindrical samples of dolomite subjected to direct and indirect tests and quartzite samples subjected to an indirect tensile test.

DESCRIPTION OF THE METHOD

Two types of rock were selected for investigation: dolomite from Rędziny and quartzite from Wiśniówka. These are monomineral, isocrystalline rocks. Their crystals can be easily recognized in an optical microscope in polarized light passing through thin section. Cylindrical samples 42 mm in height and 21 mm in diameter were bored from larger blocks of rock. The tensile strength of dolomite was 7 MPa, and that of quartzite 21 MPa. The average length of the intercepts of the dolomite and quartzite crystals were 0.180 mm and 0.093 mm, respectively. The passing fracture in a direct tensile test was obtained by means of a standard testing machine (STM). In case of the brazilian test the Instron testing machine (ITM) and a servohydraulic testing machine (SHTM) were used.

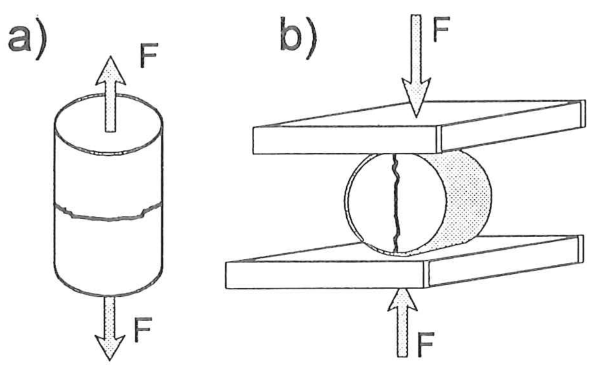

Fig. 1. A scheme of a tensile test of the samples: (a) direct tension, (b) indirect - brazilian test

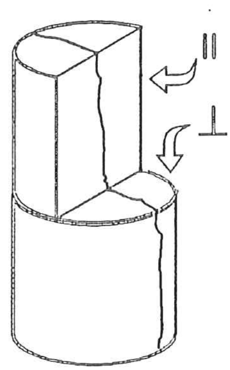

Fig. 2. Location of the cutting planes.

Fig.1 shows a schematic representation of the tensile tests. The displacement rate of the press piston was controlled. In the ITM the displacement rate was v=0.001 mm/s in case of dolomite samples, and v=0.0001 mm/s for quartzite samples. When SHTM was used two displacement rates were applied: v=0.001 mm/s and v=10 mm/s for samples of both rock types. A special equipment (the ITM was without it) of the SHTM enabled to prevent the occurrence of too great distance between the two separated parts of a sample after the fracture was obtained. After completion of the test each sample was fastened with an elastic band wrapped around it and placed in glass vessel. The next step in the procedure was to glue the samples together using the method developed in B.R.G.M., Orleans, France on a special stand set up for this purpose. After the glue had hardened plates were cut out from the samples in planes perpendicular to the fracture surface. In case of brazilian test the planes along which the plates were cut were of two orientations. In Fig.2 the cutting plane parallel to the sample axis is marked by the sign ∥, and the cutting plane perpendicular to the sample axis - by the sign ⊥. The plates were used to prepare thin sections which were next carefully examined in an optical microscope to check the correctness of the sample reconstruction. The sections revealing too much space within the fracture or shifting of a part of the sample along the slit were rejected. Fig.3 shows by way of example, the photographs of: (a) structure of an examined dolomite sample; the trace of a natural geotectonic fissure is visible, (b) structure of a dolomite sample not subjected to the tensile test, (c) structure of a dolomite sample subjected to the brazilian test, and (d) structure of a quartzite sample subjected to the brazilian test.

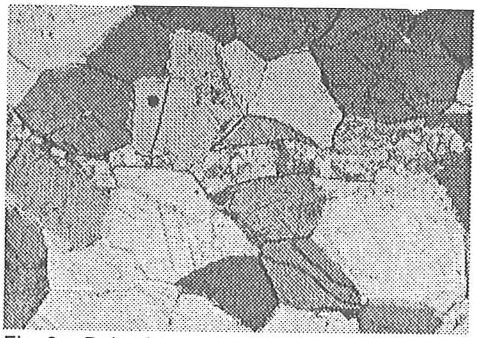

Fig. 3a. Dolomite - natural fracture. x 100.

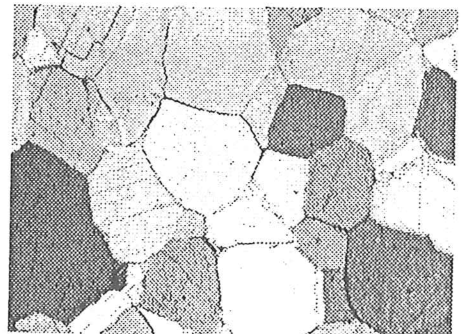

Fig. 3b. Dolomite before tensile test. x 100.

Fig. 3c. Dolomite after tensile test. x 100.

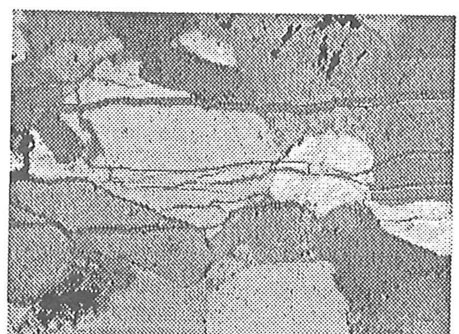

Fig. 3d. Quartzite after tensile test. x 200.

STEREOLOGICAL ANALYSIS

Let us consider a band of crystals adjacent to a fracture, and on the thin section adjacent to the trace of this fracture. Two groups of crystals can be distinguished (Fig.4): (1) crystals not directly adhering to the fracture, and (2) crystals adhering directly to the fracture. Each of the crystals in group 2 may occur in one of the three possible situations: (a) the crystal has not been split and the fracture coincides with the contact surface of the crystal with the neighbors; (b) the crystal has been split and outside the split area of the fracture runs along the contact surface with the neighboring crystals; (c) the crystal has been split only. Consequently, we will distinguish locally three types of fracture: (a) intercrystalline, (b) mixed, (c) transcrystalline. Having at our disposal only the information from a thin section, we may not unambiguously conclude about the spatial location of the crystal with respect to the fracture.

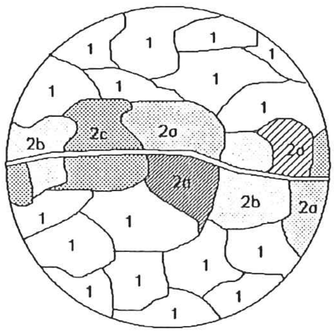

Fig. 4. Location of crystals adjacent to the fracture

the fracture.

19 thin sections of dolomite and 14 sections of quartzite were subjected to linear stereological analysis. The lengths of the intercepts of crystals in group 1 and groups 2a, 2b, 2c along a regular network of straight lines perpendicular to the mean direction of the fracture trace, were measured. The histograms of the intercept lengths were determined and the mean values calculated.

The measuring stand comprised an optical polarizing microscope Axioplan Pol (Opton) connected through a camera with a color monitor. The microscope stage with the thin section placed on it was controlled according to a IBM PC which was also used for storing and processing data.

RESULTS

The results of a stereological analysis of dolomite and quartzite samples are listed in Tables 1 and 2. Worthy of note are the analysis results of the intercepts lengths of crystals adjacent to a natural geotectonic fissure in dolomite (Table 1, line 1). Such a fissure has not been encountered in quartzite samples.

The analysis enabled to discover certain regularities in the location of the fracture in the geometrical structure of both dolomite and quartzite.

The mean intercept lengths of crystals in group 1, 2a, 2b, 2c, form an increasing sequence of values. The average length of the intercepts of crystals in group 2 (Tables 1,2, column 11) is significantly greater then the average length of intercepts of crystals in group 1, i.e. of crystals not directly adjacent to the fracture. This is especially clearly visible in the dolomite samples. The smallest differentiation is observed in case of a tectonic fracture: $\lambda=1.06$, and the greatest one - in case of fractures formed in a direct tension test: $\lambda=1.33$ (Tables 1,2, column 13). It is in this way that the geometrical structure of the rock reacts to the different states of stress resulting in a fracture. From the authors' investigations it follows that the cracking occurring in the field of tectonical forces has the most limited possibility of selecting its path. On the other hand, the field of stress in a direct tension test induces the occurrence of a fracture in the area of local agglomerations of large crystals. This effect has also been observed by Górski (1972,1973) on the occasion of an analysis of the comminution process of dolomite. Quartzite behaves in a similar way, however, the discussion of the results cannot be complete, as the stereological analysis was carried out on samples subjected only to the brazilian test. Unfortunately, the authors' attempts to master the procedure of reconstructing the quartzite samples subjected to a direct tensile test were not successful.

Stereological analysis enabled to discover another effect accompanying the formation of fracture in the dolomite samples subjected to the brazilian test, i.e. permanent deformation of crystals in group 1. As mentioned earlier, plates of two orientation denoted with signs $\|,\perp$ (Fig.2) were cut out from each sample subjected to the brazilian test. It has been observed that the mean intercept length of the dolomite crystals in group 1, measured on the thin sections $\|$ is greater by 20‰ than the mean intercept length of crystals in the same group measured on thin sections $\perp$. This result is consistent with the interpretation of the stress field in the brazilian test. The quartzite samples did not show this effect.

Table 1. **Dolomite. Mean intercept lengths of crystals adjacent to the fracture.**

No	Mode of obtaining the fracture	Mean length of the intercepts (l,µm) of crystals in groups 1, 2a, 2b, 2c and number of intercepts (n)										Quotient $\lambda = \frac{[11]}{[13]}$
		1		2a		2b		2c		2a,b,c		
		l	n	l	n	l	n	l	n	l	n	
1	2	3	4	5	6	7	8	9	10	11	12	13
1.	Geotectonic fracture	170	1755	170	221	192	36	219	47	180	304	1.06
2.	Indirect tension: ITM v=0.001mm/s	173	4049	183	353	199	58	256	143	204	554	1.18
3.	Indirect tension: SHTM v=0.001mm/s	185	2400	191	685	217	111	255	255	209	1051	1.13
4.	Indirect tension: SHTM v=10mm/s	198	3175	210	370	232	161	253	206	227	737	1.15
5.	Direct tension	172	1652	197	159	265	23	329	40	228	222	1.33

Table 2. **Quartzite. Mean intercept lengths of crystals adjacent to the fracture.**

No	Mode of obtaining the fracture	Mean length of the intercepts (l,µm) of crystals in groups 1, 2a, 2b, 2c and number of intercepts (n)										Quotient $\lambda = \frac{[11]}{[13]}$
		1		2a		2b		2c		2a,b,c		
		l	n	l	n	l	n	l	n	l	n	
1	2	3	4	5	6	7	8	9	10	11	12	13
1.	Indirect tension: ITM v=0.0001 mm/s	79	5070	101	381	96	122	109	211	103	714	1.30
2.	Indirect tension: SHTM v=0.001mm/s	104	4823	104	506	106	223	121	446	110	1155	1.06
3.	Indirect tension: SHTM v=10 mm/s	97	4321	109	375	110	196	126	513	117	1084	1.21

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