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ACOUSTOPOLARISCOPY RESULTS FOR SOME ROCK-FORMING MINERALS

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As is known, mineralogists have a splendid reference book by V.E. Treger [1] in terms of completeness of the data presented on the optic properties of minerals. As to minerals' elastic properties, such a reference book has not been issued yet. To our mind, the reason for that was poor development of experimental equipment. When analysing the results of experimental observations one faces great difficulties since the elastic properties of the lowermost-symmetry minerals are described by the tensor of the forth order. It is also known that that the minerals' optical properties are described y the tensor of not higher than the second order. At the same time elastic properties of rock-forming minerals greatly influence some natural processes. Since a new investigation method - acoustopolariscopy has become available [2], an actual possibility to compile a reference book, similar to that by V.E. Treger, appeared. The reference book might contain information on peculiarities of elastic properties of rock-forming minerals. At present we lack information on direction of elasticity axes and spatial location of the greatest (least) values of elasticity modulus for a large number of rock-forming minerals. Therefore we have performed acoustopolariscopy for some widely-spread rock-forming minerals. Below some primary results of this work are presented. Certainly, this investigation does not claim to solve the problem to the extent it has been done in relation to minerals' optical properties in V.E. Treger's book. Our investigation is an initial stage on this way [3].

Investigation of elastic and anisotropic properties of minerals and mineral formations, as well as non-elastic effects peculiar to them, is a fundamental scientific problem related to the problem of thermodynamic balance of a mineral grain in the paragenetic ensemble of the crystalline rock's other grains under metamorphic transformations. For instance, the available method of dynamic analysis for the palaeostress field components orientation under metamorphic processes is based on the study of oriented arrangement of crystallographic, or more often, optical axes in minerals. This is the essence of the microstructural method. Recently on the basis of this and other methods it has been established that elastic-anisotropic properties of mineral grains make the greatest influence on the orientation of the crystallographic axes of these grains [4, 5 and 6]. Their orientation also follows the principle of the minimum of free energy that is a consequence of the theorem on the variation of thermodynamic potential of an anisotropic body in the field of mechanical stresses. As applied to mineral grains of polymineral nature it is formulated in the following way: in greatly deformed rocks the direction, in which the mineral compliance constant is maximum, appears to be in the direction of the greatest component of the palaeostress field [7]. Thus, by the distinctions in the spatial parameters of the rock elasticity, palaeogeodynamic setting of a massif may be reconstructed [5].

There are some minerals (biotite, phlogopite, muskovite et al.) in which the axes orientation of crystallographic and elastic symmetries is very close or coincides. In other minerals (quartz, calcite, diopside, amphibole, plagioclase et al.) the orientation of crystallographic axes may greatly differ from that of elastic symmetry axes and accordingly from the spatial location of the greatest (least) value of the elasticity modulus [4, 6 and 8]. Moreover, the angles between the directions, in which the values of elastic constants S_{ij} (C_{ij}) are extreme, and crystallographic axes depend on the mineral modification and its composition. For instance, for quartz of different modifications (α, β) these angles vary within ~30^0 to ~70^0 [4, 9]. For amphiboles and plagioclases these angles as well as the characteristics S_{ij}, C_{ij} depend on their composition [6].

As to cubic symmetry media we conducted acoustopolariscopy of minerals analcime, granite halite and pyrite. The same determinations have been done for a number of minerals of medium syngony: apatite (hex.), nepheline (hex.), tourmaline (trig.) and quartz (trig.) [3].

First we took mineral samples of the proper size (no less than 10x10x10 mm^3) and quality (lack of cracks, high homogeneity). The samples were produced in the form of a cube so that the principle crystallographic axis of the mineral coincided with the normal to one of the cube's sides. At the first stage the acoustopolariscopy of the samples was performed with parallel polarization vectors of the source and receiver (VP position). At the second stage the transducers' polarization vectors were set at a right angle (VC position). For some mineral samples the acoustopolariscopy was performed at various frequencies. Accordingly, we used acoustopolariscopes with transducers that have natural frequencies of 0.78, 1.26 and 2.67 MHz. The measurements were made on all the three pairs of the cubic sample's faces. For each of the three pairs the mutual angles between the symmetry elements projections were measured. Then the indexes of linear acoustic anisotropic absorption (LAAA) were determined. Comparatively full results of the investigation are presented in [3].

The acoustopolarigrams analysis of the mineral samples of cubic syngony showed that the shape of the VP diagrams is greatly influenced by the crystal inner defects.

The pyrite VC diagrams allow one to identify the directions of the symmetry elements projections for all the three pairs of faces. Due to a small size of the VC diagrams it is difficult to identify these directions for the samples of other cubic minerals. But this work can be done if we use the so called reverse acoustopolarigrams. They can be obtained if all amplitudes under acoustopolarization measurements are normalized to the minimum amplitude derived with the crossed polarization vectors of the source and receiver of shear waves.

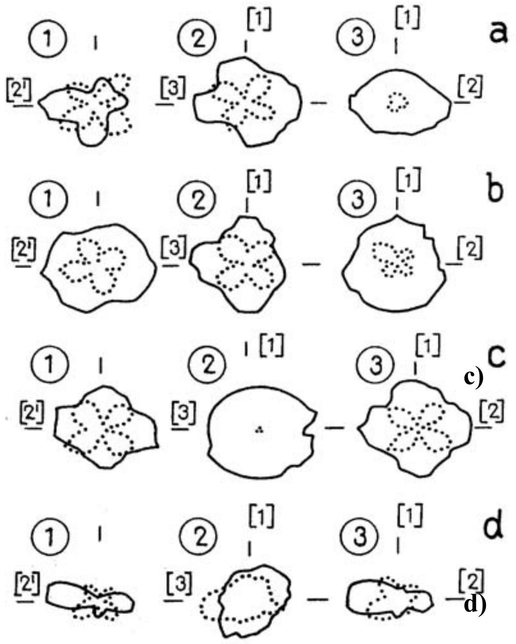

Fig.1. Examples of acoustopolarigrams of mineral samples: apatite at the frequency of 1.26 MHz (a) apatite at the frequency of 2.67 MHz (b), nepheline (c) and tourmaline (d).

By the reverse acoustopolarigrams we have measured the angles between the symmetry elements projections. The results of the measurements of direct and reverse acoustopolarigrams for the minerals of medium syngony: crystals of apatite, nepheline, quartz and tourmaline are given in Fig.1, 2.

The apatite crystal was selected from skarns of the Dashkesan iron ore deposit. It was a well cut crystal formed by the combination of two hexagonal prisms, hexagonal pyramids and a pinacoid. In the directions parallel to the sides (0001) and (1010) weak hair-like microcracks of imperfect cleavage were detected in the crystal. The sample prepared for the acoustopolariscopy was cut from the crystal centre as a rectangular prysm with the base 12x12 mm and a 15 mm edge oriented parallel to the crystallographic axis L_6 in the apatite.

Acoustopolariscopy of the apatite samples was performed several times and at various frequencies. The diagram of the sample A-1 first side was obtained in the axis direction [0001], Fig. 1a. As follows from the reverse acoustopolarigrams, Fig.2, the projections of the elastic symmetry elements form a right angle to each other and are perpendicular to the sample sides. In the direction 3-3', Fig. 1a, on the diagram obtained at the frequency of 1.26 MHz the projections of the elastic symmetry elements are virtually unseen. But for the sample A-1-3 whose diagrams were obtained at the frequency of 2.67 MHz, Fig.1.b, it is not difficult to reveal the projections direction of the elastic symmetry elements. The comparison of Fig.1 a and Fig. 1 b enables to note that it is easier to identify the symmetry elements directions on the VC diagrams, especially by side 3 at a higher frequency. At 2.67 MHz frequency the apatite sample shows an orthorhombic symmetry type.

No considerable manifestation of the LAAA effect has been detected in the apatite sample. The maximum values of the LAAA effect *D* do not exceed 0.14. In the sample A-1 at the frequency f_0 = 1.26 MHz as well as in the sample A-1-3 (L1) a linear type of LAAA (L2) is registered.

The nepheline sample (He-005, f_0 = 2.67 MHz), whose acoustopolarigrams are given in Fig.1c , is virtually a transverse-isotropic medium. Its symmetry axis passes along the normal to side 2. The reverse acoustopolarigram enables to clearly recognise the elastic symmetry elements projections on sides 1 and 3, Fig.2b. The mutual angles between the elastic symmetry elements are within 85-95^0.

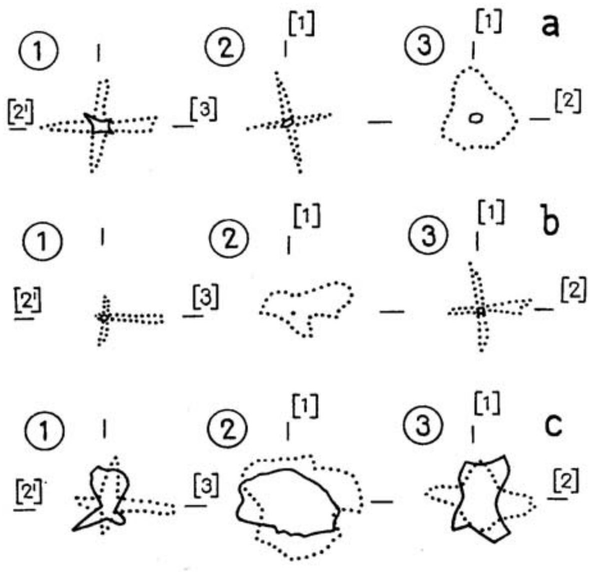

Fig 2. Examples of reverse acoustopolarigrams for the samples of apatite (a), nepheline (b) and tourmaline (c).

In the nepheline samples at low frequencies (f_0 = 0.78-1.26 MHz) the LAAA effect index may reach medium and great values. For instance, the maximum values *D* are 0.25-0.62. At the frequency f_0 = 0.78 MHz a linear type of LAAA has been registered (samples He-005, He-008), and at the frequency f_0 = 1.26 MHz - a plane one (sample He-008). Moreover, the plane passes through sides 1 and 3.

On the acoustopolarigrams of the tourmaline samples (P-011), Fig.1d, 2c, a simultaneous display of two effects - LAAA and depolarization of shear waves (DSW) is observed [10]. The LAAA effect is mainly detected on sides 1 and 3. At the frequency f_0 = 1.26 MHz the linear type (L2) of LAAA display is registered in the sample. At the frequency f_0 = 2.67 MHz a combination of linear and plane types is displayed, where the elongated elements are oriented in the direction of side 2 and the plane passes through sides 1 and 3. The DSW effect is greatly manifested on side 2. It means that in the planes parallel to side 2 a fan arrangement of the medium structural elements in this is observed. It should be noted that in optics tourmaline displays a great effect of pleochroism, too. The symmetry elements in the tourmaline samples are conspicuous only on sides 1 and 3. Their mutual angles are within 82-98^0.

The main results of the conducted investigation regarding mineral samples of highest and medium syngonies can be stated as follows.

As a rule, the mutual angles between the elastic symmetry elements in the measured mineral samples are close to a right one. Among the samples that underwent a set of measurements quartz and diopside are an exception. In one of the sections of these minerals three elastic symmetry elements, forming mutual angles differing from right ones, have been observed.

Classes of mineral elastic symmetry can differ from those determined by their optical properties. This is suggested, for instance, by determinations of elasticity parameters in the quartz sample which corroborate a distinction in the direction of crystallographic and elastic symmetry elements.

In minerals of medium and lower syngonies the LAAA effect, discovered before in rocks, is conspicuous. This effect is slightly displayed in minerals of higher syngony and is most likely related to the crystal lattice defects. In silicate minerals of lower syngonies this phenomenon is observed virtually in all samples. Moreover, LAAA can be observed simultaneously with pleochroism (tourmaline), or without it (orthoclase and microcline). In minerals, such as amphibole, orthoclase and microcline, its manifestation is related to cleavage in natural samples.

In some minerals we have observed distinct dependence of LAAA and its type on the wave frequency. For instance, in microcline, as well as in orthoclase, at one frequency the greatest absorption occurs with the structural elements of one cleavage, at another frequency - with the elements of another cleavage. Comparatively the same absorption with both elements occurs at f_0 = 1.26 frequency. Accordingly, when the action frequency changes, the LAAA type changes, too. For instance, when the absorption with one system of structural elements prevails, the plane type will be observed. With mutual and equal influence of two orthogonal systems of cleavage the LAAA linear type will be detected. In a section of the tourmaline sample an acoustopolarigram with a clear display of depolarization of shear waves (DSW) effect has been registered.

Part of this work was supported financially by INTAS Project 01-0314.

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