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E14-87-678

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FABRIC ANALYSIS OF THE QUARTZ COMPONENTS IN ORTHOGNEISSES USING NEUTRON TIME-OF-FLIGHT DIFFRACTION

Submitted to VIII International Conference
on Textures of Materials ICOTOM 8,
Santa Fe, USA, 20-25 September, 1987.

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1987

Introduction

The orientation distribution of crystallites in tectonites contains valuable information on deformation processes which have taken place in the Earth's crust. Comparing the preferred orientations in naturally deformed rocks with the results from experimentally deformed material and computer simulations of deformation process, the data can be used to estimate the regime of temperature, pressure, stress and strain as well as the preferred operating mechanisms of deformation which were active in the investigated matter. Thus, important information for petrofabric analysis can be expected from the accurate and complete description of the relation between crystal and specimen orientations.

In this paper the partial texture of quartz in orthogneisses from the middle Erzgebirge (GDR) is studied. The samples have been taken from selected points of a recumbent fold structure. All pole figure measurements were carried out using neutron time-of-flight (TOF) diffraction at the pulsed reactor IBR-2 in Dubna (1). The orientation distribution function (ODF) reproduction from experimental pole figures and the determination of recalculated and inverse pole figures have been done by means of spherical harmonics analysis. (2).

Geological Background and Specimen Characterization

In the present paper the structural evolution is investigated within a folded complex being typical for the upper part of the Earth's crust (5 km depth). From the structural geological point of view this deformation consists in an intensely asymmetric folding of a ±parallel system of planes (crystalline schistosity, sk_1). As a result of this folding a younger crystalline schistosity (sk_2) is found nearly parallel to the orientation of the axial plane of the folds connected with intimate crenulation of the older schistosity (sk_1) near the crest of the folds having pencil structures (b-tectonites) in the very crest of the folds (see Fig. 1).

Together with increasing isoclinal structure of the folds the orientation of the younger schistosity (sk_2) approaches more and more an axial position. So it becomes obvious, that on the limbs of the fold the older and newly formed schistosities are approximately parallel. Near to the crest of the fold the intersection angle of both foliations is increasing and reaches 90^{o} in the very crest. The crest is, furthermore, characterized by the morphological dominance of the sk_2-plane as well as by stretching in b=x (pencil structure) combined with rotation around the b=x - axis.

Such deformation process is in wide range independent of different types of parent rocks, their chemical composition and regional geological position. According to critical minerals in the present case the deformed system of planes (sk_1) corresponds to a crystalline schistosity formed by regional metamorphism under the conditions of the amphibolite-facies ($p >$ 4,5 kbar, $T >$ 400-500°C).

Table 1. Mineral Composition of the Studied Gneisses (in%)

minerals	B190	B379	B380	B381
quartz	35	36	38	35
plagioclase	35	26	26	28
K-feldspar	15	10	9	13
muscovite	10	17	17	14
biotite	5	9	6	5
others		2	4	5

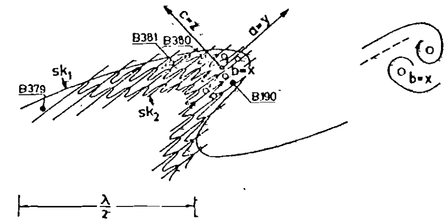

Figure 1. Structural geological position of the gneiss specimens. The relation between tectonic (abc) and sample coordinate system (xyz) is shown.

The studied specimen set represents four steps of structural evolution of an asymmetric recumbent fold with a half wavelength of about 1 km (Fig.1). The geological unit is an orthogneiss complex ("red gneiss") of the Erzgebirge-anticlinorium named "Reitzenhainer Rotgneisstrunktur" (3). The samples are cut as plates with about 1 cm thickness parallel to the c=z axis and an area of about 15 x 20 cm^2 in the ab=xy plane. By means of X-ray phase analysis proved by microscope modal analysis the main minerals are determined contributing to the composition of specimens under investigation (Table 1).

Experiments and Data Handling

The presented fabric analysis of quartz in pencil gneiss has been carried out at the pulsed reactor IBR-2 in Dubna using TOF diffraction. It is characterized by a simultaneous recording of all nonforbidden Bragg reflections in one diffraction pattern at constant scattering geometry. This means all pole figures under investigation are measured at the same time by only one scan of the texture goniometer. The experimental procedure is described in detail in (4).

The values of pole figures are proportional to the intensity of their Bragg reflection at the corresponding specimen position. These intensities were determined from TOF spectra by means of a computer fit. The quartz phase of the gneiss has been considered only. Because of several other components in the material having low lattice symmetries, the diffraction patterns contain a large amount of peaks.

In the present fabric analysis the quartz reflections have been picked up where the influence of other phases was lower than 40 %. For the understanding of weak textures of all components the arising errors are supposed to be small. The criterial and methods for pole figure selection and correction are outlined in (5).

The mathematical texture analysis up to the ODF calculation has been carried out using the well known series expansion method (2) up to l=14 for even l only. In the applied formalism real and imaginary terms were considered separately. In the trigonal system the lattice planes (hkil) and (khil) are not symmetrically equivalent although they have the same lattice spacing and are, therefore, overlapped in powder diffraction patterns. Consequently, pole figures of this type cannot be measured separately. They are taken into account with respect to the method outlined in (6).

Results and Interpretation

From TOF diffraction patterns of the different gneiss specimens 6 or 7 pole figures, respectively, have been determined and selected for texture analysis according to the checks described in (5). Three pole figures for each sample, with exception of B381, are shown in Fig. 2. The initial sets of pole figures have been reproduced via series expansion coefficients. In Table 2 the RP-values (7) are given. In all pole figures an approximately orthorhombic symmetry can be found. It may be improved after pole figure rotations around the y-axis, refering to an incomplete coincidence of tectonic and specimen coordinate systems caused by uncertainties in sample preparation.

For all samples the basal and prism I pole figures were determined from series expansion coefficients (Fig. 3). The character of the basal pole figures is not changed from one gneiss to the other. They show one intense maximum at y=a and a slightly various tendency to a weak girdle from y=a to z=c. For pencil gneiss {0001} pole figure has been compared with a fabric diagram of quartz axes determined by U-stage technique (200 axes in an a-c-section) (4). The prinicipal coincidence of both results is quite satisfactory.

The maxima of prism I and prism II pole figures rotate around the y-axis about 30° comparing pencil gneiss with all others. This change should be connected with the fabric rotation in the crest of the fold.

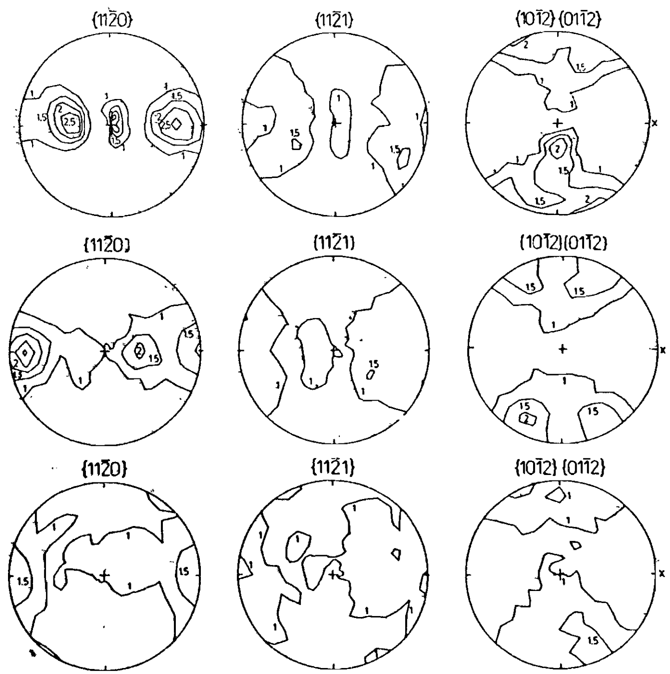

Figure 2. Experimental pole figures for the samples B190, B380 and B379 (downwards).

Table 2. RP-values for the pole figures (PF) of the specimens. Only one Miller index is given for coincident PF

PF	B190	B379	B380	B381
$11\bar{2}0$	11.8	6.6	7.2	7.2
$11\bar{2}1$	8.5	7.8	5.5	8.3
$10\bar{1}2$	12.4	6.6	11.4	10.5
$12\bar{3}1$	6.1	8.9	14.3	9.4
$20\bar{2}1$	10.4	7.4	7.7	7.3
$20\bar{2}2$		9.3	8.9	9.7
$12\bar{3}2$		7.1	6.5	7.3
$21\bar{3}0$	10.0			

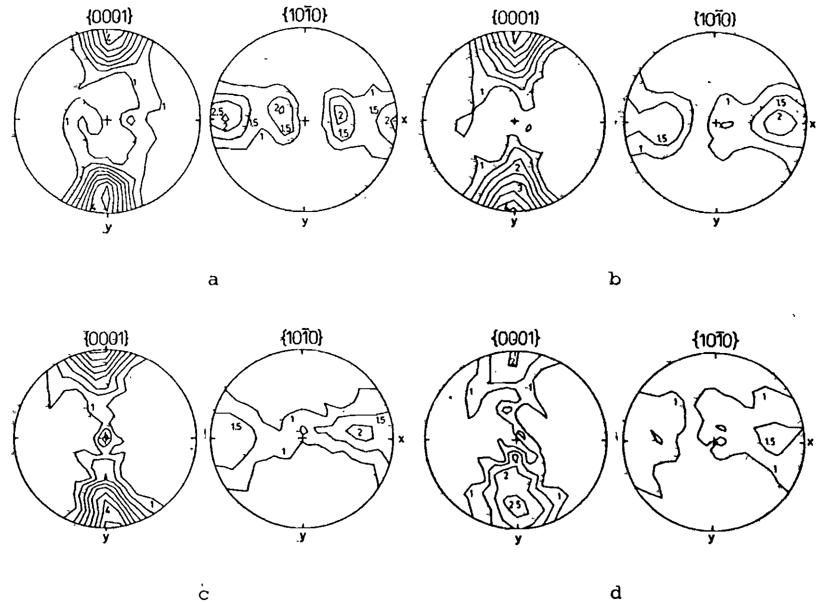

Figure 3. Basal and prism I pole figures for the samples a -- B190, b -- B380, c -- B381, d -- B379.

From sample B 190 via B380 and B381 to B379 a decreasing accentuation of texture is observed, beeing understood by the different deformation intensity at various positions of the fold. This may be emphasized by the appearing of coarse grain effects from nonquartz phases in the diffraction patterns of B379. Obviously, in all other specimens a more strong deformation has decreased the grain sizes.

The samples B380 and B381 are taken from nearly equivalent positions of the fold. The spots were separated by a distance of about 300 m. Therefore, no significant texture variations from B380 to B381 are found. The existence of only one pronounced texture components is confirmed by the ODF (4).

The fabric type of the quartz phase in the gneiss under investigation corresponds to the maximum I - preferred orientation of Sander (8) combined with the tendency to an ac-girdle formation.

The comparison of the determined fabric type with experimentally deformed quartzites refers to deformation conditions at relatively low temperatures (< 500° C), but higher strain states ($\dot{\varepsilon} \leq 10^{-4}$ sec^{-1}) (9).

According to Taylor Bishop-Hill computer simulations (10) the investigated texture corresponds to the "model quartzite A" in the range between axial extension and flattening, where the dominating slip system is (0001) [a].

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Дрекслер Л.П. и др. E14-87-678
Текстурный анализ кварцевых компонентов ортогнейсов с помощью нейтронной дифракции по времени пролета

Изучаются кристаллические преимущественные ориентации кварцевых зерен в четырех образцах гнейса с помощью нейтронной дифракции по времени пролета. Образцы были взяты от характеристических мест асимметрично лежащей складки в Рудных горах /юг ГДР/. Кратко описываются геологические основания. Все измерения проводились на импульсном реакторе ИБР-2 ОИЯИ в Дубне. Образцы состояли из нескольких фаз. Поэтому использовались специальные методы, чтобы получить внутреннюю и взаимную согласованности полюсных фигур. Математическая обработка полюсных фигур до определения ФРО проводилась с помощью разложения в ряд по сферическим функциям. Все полюсные фигуры базисной плоскости обладают интенсивным максимумом при тектонических направлениях ±a и имеют тенденцию к образованию пояса между ними. Резкость преимущественных ориентаций уменьшается от гребня до основания складки. Тип текстуры базисной плоскости существенно не меняется. В полюсных фигурах призменных плоскостей наблюдается вращение вокруг трехкратной оси.

Работа выполнена в Лаборатории нейтронной физики ОИЯИ.

Препринт Объединенного института ядерных исследований. Дубна 1987

Drechsler L.P. et al. E14-87-678
Fabric Analysis of the Quartz Components in Orthogneisses Using Neutron Time-of-Flight Diffraction

The crystalline preferred orientations of quartz grains in four orthogneisses are studied by means of neutron time-of-flight (TOF) diffraction. The specimens have been taken from characteristic spots of a recumbent fold structure in the Erzgebirge Mountains (southern GDR). The geological background is shortly outlined. All the measurements are carried out at the pulsed reactor IBR-2 of the JINR Dubna. Because of the complicated mineral composition of the samples some efforts have to be made to obtain internal and external compatibility of pole figures. Spherical harmonics analyses of experimental pole figures have been carried out up to ODF calculation. In all four samples single component textures have been found where the trigonal axes are parallel to the tectonic a-direction. In the quartz basal plane pole figures the relatively strong maxima at ± a are connected by a girdle of weaker intensity. Comparing the preferred orientations of different samples the sharpness of textures is found to decrease from the crest to the limb of the fold without significant changes of the type of basal plane pole figures. From the pole figures of the prismatic planes a rotation of the oriented crystal around threefold axis can be observed.

The investigation has been performed at the Laboratory of Neutron Physics, JINR.

Preprint of the Joint Institute for Nuclear Research. Dubna 1987