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Variation of Quartz Textures within the Plattengneiss of the Koralm Complex (Eastern Alps)

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Mit 7 Abbildungen

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Zusammenfassung: Variation von Quarztexturen innerhalb des Plattengneises des Koralm-Komplexes (Ostalpen). – Im Plattengneis der Koralpe (Ostalpen) wurden Kristallographische Gittervorzugsregelungen an verschiedenen Probepunkten untersucht. Der Plattengneis stellt eine wichtige krustale Scherzone innerhalb des Ostalpinen Deckenstapels dar, welche während des unterkretazischen Kollisionsereignisses gebildet wurde. Die Quarz-c-Achsen bilden entweder zwei Maxima zwischen Y und Z, was als bevorzugtes Gleiten entlang der Rhomboederflächen gedeutet werden kann, oder ein stark betontes Maximum in Y mit der Tendenz zur Bildung von Einfachgürteln, und damit zusammenhängend drei a-Achsen Maxima am Rand der Polfigur. Solche gut ausgeprägten kristallographischen Gitterregelungen sind sowohl für hochgradige Metamorphosebedingungen charakteristisch, als auch für hohe finite Verformung. Allerdings zeigen Detailuntersuchungen von Gitterregelungen in distinkten Zonen, daß sich diese straffen Regelungen aus Typ I oder Typ II Kreuzgürtelverteilungen entwickelt haben. Das zeigt, daß die Deformation während der Bildung dieser Scherzone auf einzelne Zonen mit unterschiedlichem Deformationsfluß aufgeteilt wurde. Diese Entwicklung ist unabhängig von der modalen Zusammensetzung des Plattengneises. Deshalb können die beobachteten Gittervorzugsregelungen am Besten im Sinne von Deformationsaufteilung im Klein- und Großmaßstab, und von lokal variabler Verformungsgeometrie aus Kompatitbilitätsgründen interpretiert werden.

Summary: Lattice Preferred Orientations (LPOs) have been investigated from several sampling sites within the Plattengneiss of the Koralm Complex (Eastern Alps). The Plattengneiss forms an important shear zone within the Austroalpine nappe complex of the Eastern Alps, which has been developed during the Lower Cretaceous collisional event within the Austroalpine unit. The quartz c-axes form either two maxima between Y and Z, that can be interpreted in terms of preferred slip on the rhombs, or a strong maximum near the Y- axis with the tendency to be distributed along a single girdle, with three corresponding maxima of a-axes near the margin of the pole figure. Such strong LPO fabrics are both characteristic for high grade metamorphic conditions and high finite strain. However, LPOs from distinct domains show that these strong fabrics developed from either type I or type II cross girdle distributions. This shows, that the deformation during formation of this major shear zone was partitioned in distinct zones of different mean flow types. Furthermore, this evolution is independent from the modal Plattengneiss composition. Therefore, the different LPOs that have been observed in the area of investigation are best interpreted in terms of micro- and macroscale deformation partitioning, and locally contrasting strain geometries due to compatibility reasons during bulk deformation.

1. Introduction

The Plattengneiss forms an important shear zone within the Austroalpine nappe complex of the Eastern Alps (Fig. 1), which has been developed during the Lower Cretaceous collisional event within the Austroalpine unit. Therefore, this major shear zone was subject for many structural and microstructural investigations for several years (e.g., FRANK & al. 1983; FLÖTTMANN & al. 1986, KROHE 1987). Furthermore the Plattengneiss has been investigated in order to get information about the evolution of microfabrics and the development of Lattice Preferred Orientations (LPOs, Textures) within high-grade, amphibolite facies crustal shear zones (SIMPSON & SCHMID 1983; FRANK & al. 1983; DE ROO 1983; FLÖTTMANN & al. 1986; SCHMID & CASEY 1986;

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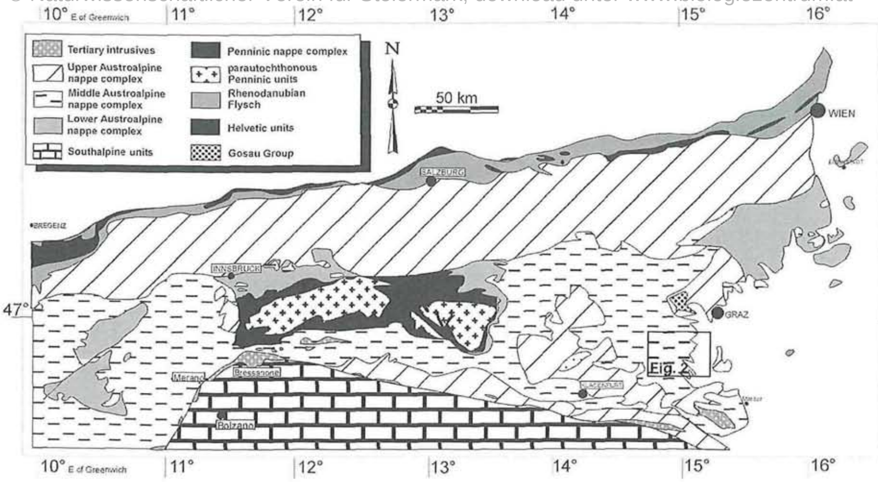


Fig. 1: Simplified tectonic map of the Eastern Alps; the area of detailed investigation is marked.
Vereinfachte tektonische Karte der Ostalpen; das Untersuchungsgebiet ist gekennzeichnet.

Krohe 1987). However, these investigations were limited both locally and from a methodological point of view. Therefore, we would like to compare LPOs from different sites within the Plattengneiss in order to get information on the homogeneity of deformation, and on the strain geometry.

2. Geological Setting of the Koralm Complex

The Koralm Complex within the Eastern Alps (Figs. 1, 2) forms part of the Middle-Austroalpine Nappe complex which has been in corporated into the Austroalpine nappe stack during the Lower Cretaceous (Krohe 1987, Frank & al 1983; Frank 1987; Neubauer & al. 1992). During this collisional event a number of regionally important shear zones (like the Plattengneiss investigated in this paper) have been formed. The Koralm Complex is part of the Koriden Unit within the Middle-Austroalpine Nappe complex, mainly exposed within the Koralpe and the Saualpe (Frank & al. 1992). The Koriden Complex is an eclogite-bearing basement complex ("Gneiss Group"), which is overlain by the "Micaschist Group", including the ophiolitic Plankogel Complex.

The Koralm Complex is characterized by a poly-metamorphic history with signatures of pre-Alpine events (Frank & al. 1983; Frank 1987), and reached amphibolite to eclogite facies conditions during the eo-Alpine metamorphic peak (Morauf 1980, 1982; Miller & Frank 1983; Miller 1990; Thöni & Jagoutz 1992, 1993; Ehlers & al. 1994, 1995; Stüwe & Powell 1995; Miller & Thöni 1997), which has been dated around 90 Ma (Thöni & Jagoutz 1992, 1993; Thöni & Miller 1996; Miller & Thöni 1997).

3. Methods

We discuss the evolution of microstructures and LPOs within the Plattengneiss of the Koralm Complex. We investigated several outcrops in order to get information on the lateral and vertical variations of LPOs. X-ray texture analyses of quartz were carried out

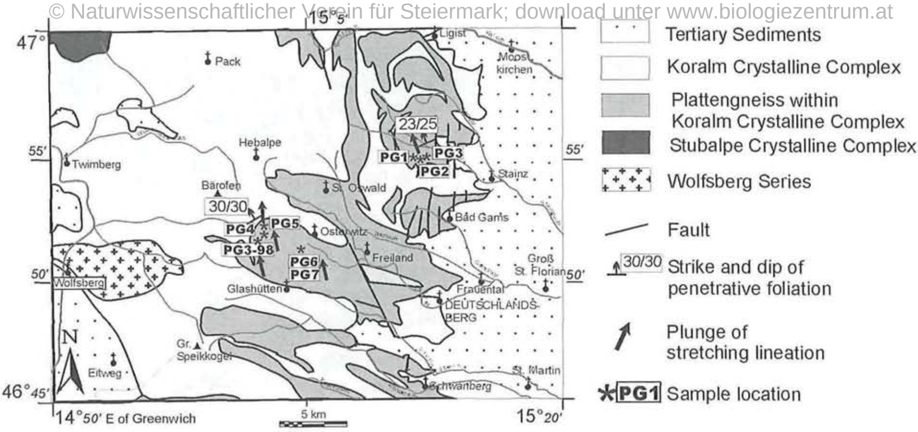


Fig. 2: Tectonic map of the Koralm area; the sampling sites and corresponding structural data are marked.
Tektonische Karte des Koralmgebietes mit Probenpunkten und dazugehörigen Strukturdaten.

with a Siemens D500 X-ray goniometer at the University of Graz (Austria) in reflexion mode. The apparative and methodical limitations provide samples with a size of 2.5 x 1.5 cm. The X-ray beam is reflected within an area of about 5x5 mm. The evaluation of pole figures was done with the program TexAT v. 2.2c/ODF AT v.1.1a provided by Siemens Co. (Harmonic Method (Bunge 1981, 1985; Bunge & Esling 1985)), and with the program MENTEX (Vector Method (Schaeben & al. 1985; Schaeben 1994)). Both program packages include corrections for background and beam defocussing. Furthermore, neutron texture analyses have been carried out with the goniometer SKAT at the pulsed neutron reactor IBR2 at the Joint Institute for Nuclear Research (JINR) in Dubna (Russia), which allows the measurement of samples of about 27 cm^3. These analyses are based on the Time of Flight (TOF) of neutrons within a neutron beam, which is directly related to their wavelength (Ullemeyer & al. 1998), and, therefore, d-spacing.

4. Quartz Microstructures

Within the Plattengneiss, quartz typically forms layers and lenses (Fig. 3). Within these lenses the quartz grains are characterized by uniform size between 0.1 and 0.2 mm. However, the occurrence of additional mineral phases, especially plagioclase, white mica and biotite resulted in a irregular grain size distribution between several domains. Generally, the quartz grains show an equidimensional shape. The grains are characterized by high temperature (HT) fabrics like serrate and lobate grain boundaries, and subgrain formation. In many cases the subgrains show undulatory extinction. Most of the subgrain boundaries are oriented parallel to the prism-planes. The main mechanism of dynamic recrystallization is assumed to be grain boundary migration. Accordingly, recrystallization by grain boundary migration assocated with grain growth lead to a wide spectrum of grain sizes (30-1000μm).

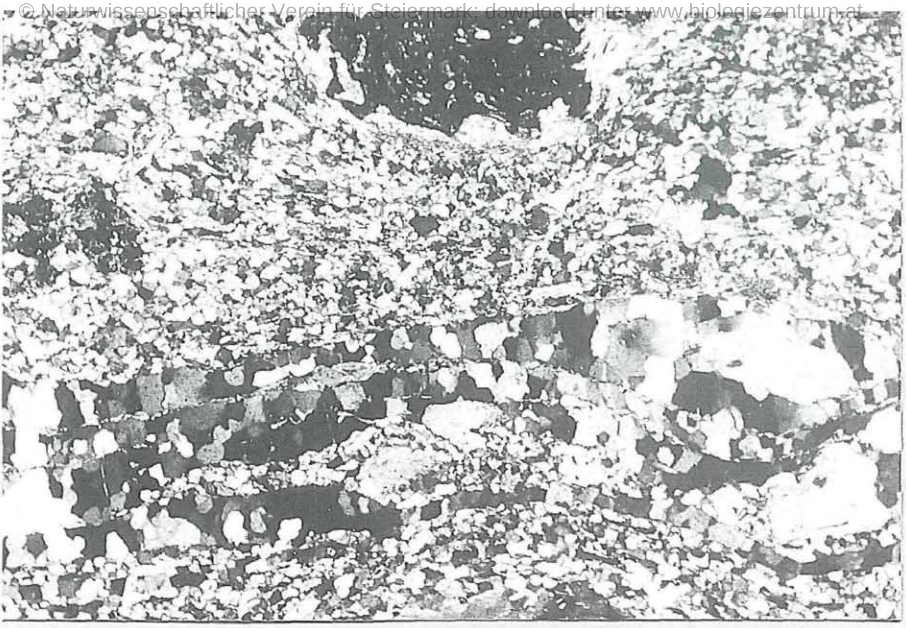


Fig. 3: Representative microfabric from the Plattengneis, with typical quartz layers showing HT microstructures (for explanation see text); crossed polarizes; long axis of photograph about 4mm.
Repräsentatives Quarzmikrogefüge eines Plattengneises; die typischen Quarzlagen zeigen HT-Mikrostrukturen (zur Erklärung siehe Text); gekreuzte Polarisatoren; lange Bildkante 4mm.

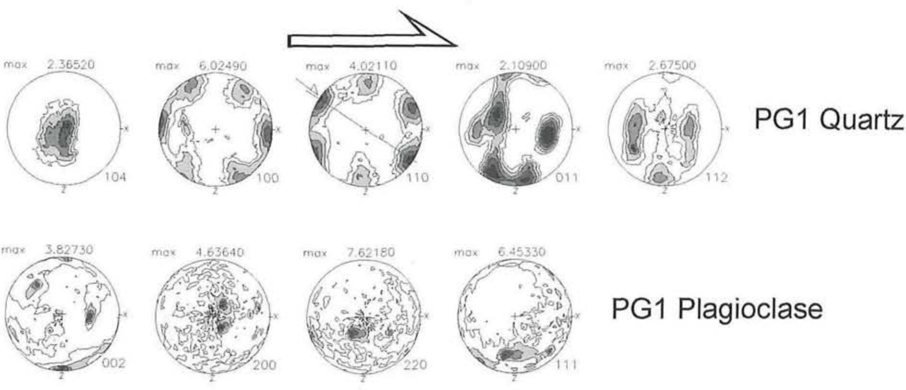


Fig. 4: Quartz LPOs from the Plattengneiss determined by neutron texture goniometry. The (104)-poles have directly been measured and are closely oriented to the c-axes [001]. Stereographic projections, lower hemisphere; logarithmic gradation of isolines; first isoline: uniform distribution; fifth isoline: 85% of maximum.
Quarz-Gittervorzugsregelungen von einem Plattengneis, bestimmt durch Neutronentexturgoniometrie. Die (104)-Pole wurden direkt gemessen und liegen nahe der c-Achsen [001]. Stereographische Projektionen, untere Halbkugel; logarithmische Abstufung der Isolinien; erste Isolinie: Gleichverteilung; fünfte Isolinie: 85% des Maximums.

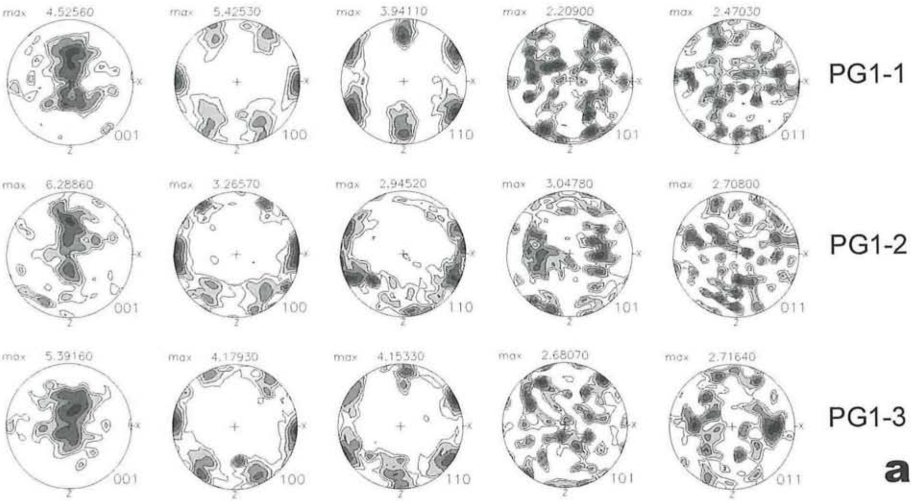
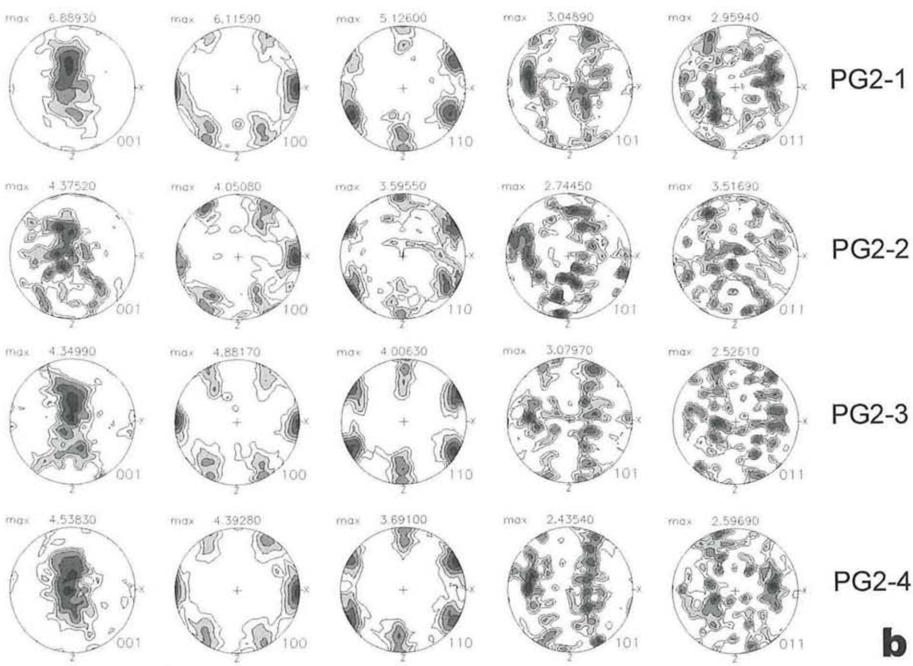


Fig. 5: Quartz LPOs from the Plattengneiss (sampling site west of Stainz) determined by X-ray texture goniometry. Stereographic projections, lower hemisphere; logarithmic gradation of isolines; first isoline: uniform distribution; fifth isoline: 85% of maximum.
Quarz-Gittervorzugsregelungen von einem Plattengneis (Probenlokalitäten westlich von Stainz), bestimmt durch Röntgentexturgoniometrie. Stereographische Projektionen, untere Halbkugel; logarithmische Abstufung der Isolinien; erste Isolinie: Gleichverteilung; fünfte Isolinie: 85% des Maximums.



5. Quartz Lattice Preferred Orientations (LPOs)

Samples for texture analyses have been taken from three distinct areas in order to get information on the lateral and vertical variations: (1) The area west of Stainz (samples PG1, PG2, PG3); (2) The area of the Weinebene and Handalpe (samples PG3-98; PG4; PG5); (3) and the area between Trahütten and Glashütten (samples PG6, PG7).

LPOs that have been evaluated by neutron texture goniometry (Fig. 4) are characterized by a strong maximum of c-axes [001] within the Y-axis of the finite strain ellipsoid, with a slight tendency to the formation of a single girdle. Accordingly, the poles to the primary prisms (a-axes) [110] form three maxima at the margin of the pole figure. They are slightly asymmetrically distributed about the macroscopic fabric axes. One maximum is centered about 5° from Z within the NE and SW sectors of the pole figure. However, the strongest maximum can be observed in the SE/NW sector of the pole figure, which indicated the macroscopic shearing direction with a top-to-the N sense of shear, and the orientation of preferred slip, respectively. Accordingly, the poles to the secondary prism planes [100] form three maxima at the margin of the pole figure, too. The poles to the negative rhoms z [011] form two maxima between X and Y, and two maxima near Z, with a tendency to form a N-S- trending double-girdle distribution.

Detailed X-ray texture analyses for this sampling site gave similar results (Fig. 5).

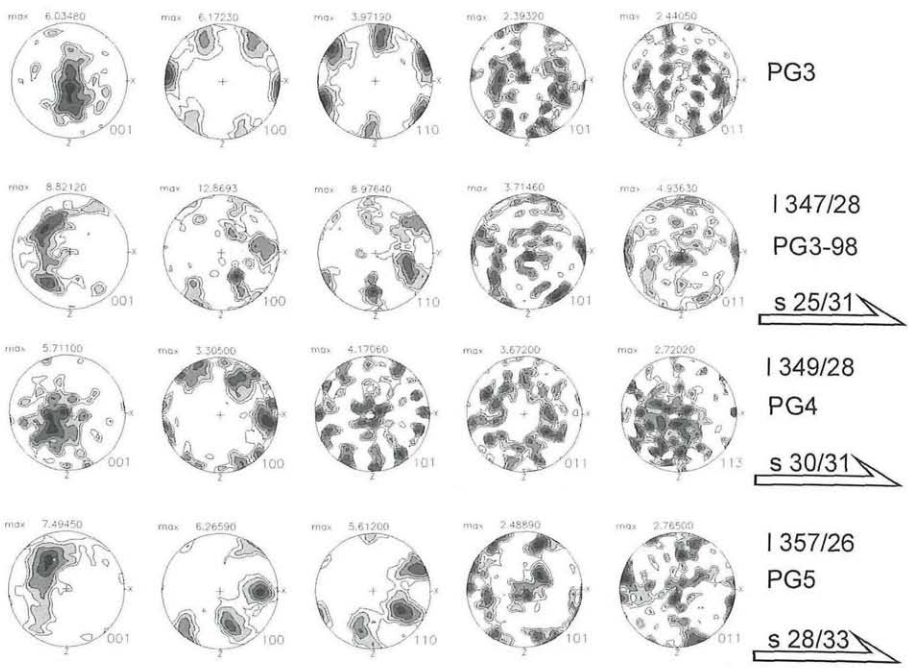


Fig. 6: Quartz LPOs from the Plattengneiss (sampling site Weinebene-Handalpe) determined by X-ray texture goniometry. Stereographic projections, lower hemisphere; logarithmic gradation of isolines; first isoline: uniform distribution; fifth isoline: 85% of maximum.
Quarz-Gittervorzugsregelungen von einem Plattengneis (Probenlokalitäten Weinebene-Handalpe), bestimmt durch Röntgentexturgoniometrie. Stereographische Projektionen, untere Halbkugel; logarithmische Abstufung der Isolinien; erste Isolinie: Gleichverteilung; fünfte Isolinie: 85% des Maximums.

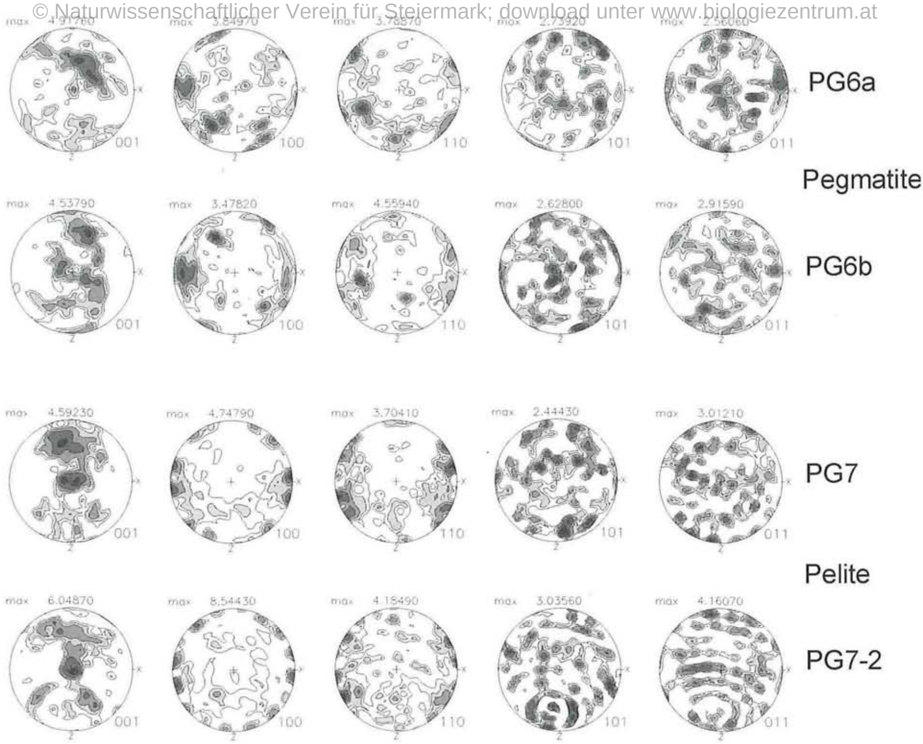


Fig. 7: Quartz LPOs from the Plattengneiss (sampling site Trahütten-Glashütten) determined by X-ray texture goniometry. Stereographic projections, lower hemisphere; logarithmic gradation of isolines; first isoline: uniform distribution; fifth isoline: 85% of maximum.
Quarz-Gittervorzugsregelungen von einem Plattengneis (Probenlokalitäten Trahütten-Glashütten), bestimmt durch Röntgentexturgoniometrie. Stereographische Projektionen, untere Halbkugel; logarithmische Abstufung der Isolinien; erste Isolinie: Gleichverteilung; fünfte Isolinie: 85% des Maximums.

However, the c-axes show a stronger tendency to be distributed along a single girdle within the Y-Z- plane. Especially textures from the sample PG2 show remnants of cross girdle c-axes distributions. For PG2-2 remnants of a type II cross girdle (Lister 1977) have been observed, PG2-3 shows remnants of a type I cross girdle (Lister 1977), although the corresponding a-axes and secondary prism poles show the formation of three strong maxima near the margin of the pole figure, similar to the bulk texture described in Fig. 4. The poles to the positive rhombs r [101] and the negative rhombs [011] show less pronounced maxima and are characterized by a distribution along two N-S- trending girdles between the X- and Y- axis of the finite strain ellipsoid.

The samples from the Weinebene and Handalpe are characterized by similar quartz textures (Fig. 6). PG3, PG4, and PG5 show strong clusters within the Y- axis of the finite strain ellipsoid, and accordingly three a-axes maxima and three maxima for the poles to the prisms. Only PG3-98 shows remnants of a type I cross girdle.

From the site near Trahütten-Glashütten two different types of Plattengneiss have been sampled (Fig. 2). PG6 can be derived from a pegmatitic protolith, while PG7 can be derived from a pelite. PG6 shows larger amounts of K-Feldspar and plagioclase, while

PG7 contains larger amounts of white mica, biotite, and garnet, and less plagioclase. However, the LPOs of both types are quite similar (Fig. 7). The c-axes [001] are distributed along a type II cross girdle subparallel to the Y-Z- plane. Several maxima and sub-maxima are irregularilly distributed along this girdle, one stronger maximum can be observed near Y. The a-axes [110] are distributed along a small circle (opening angle 60°), centered within the direction of the stretching lineation, about 10° from X within the SE sector of the pole figure, which indicates the macroscopic shear plane with a top-to-the N sense of shear. One sub-maximum plots near the Z- axis. The poles to the secondary prisms [100] form three maxima near the margin of the pole figure, with the strongest maximum located about 10° from X within the SE/NW sector. The poles to the rhombs [101][011] are distributed along two N-S- trending girdles between X and Y.

6. Discussion

Several types of LPOs that have been described from the Plattengneiss (e.g., SIMPSON & SCHMID 1983; SCHMID 1982; DE ROO 1983; SCHMID & CASEY 1986; FLÖTTMANN & al. 1986; KROHE 1987) show similar results. The c-axes form either two maxima between Y and Z, that can be interpreted in terms of preferred slip on the rhombs (e.g., SCHMID & CASEY 1986), or a strong maximum near the Y- axis with the tendency to be distributed along a single girdle, similar to the patterns of PG1, PG2, PG3, PG4, and PG5, and three corresponding maxima of a-axes near the margin of the pole figure. Such strong LPO fabrics are both characteristic for high grade metamorphic conditions and high finite strain. However, LPOs from distinct domains (PG2-2; PG2-3) show that these strong fabrics developed from either type I or type II cross girdle distributions. This shows, though the very high finite strain of the Plattengneiss, which can be observed from the mesoscale, that the deformation during formation of this major shear zone was partitioned in distinct zones with different flow. Similar assumptions can be drawn by comparing the neutron textures (Fig. 4), that have been evaluated from a sample volume of about 27 cm^3, with X-ray textures (Fig. 5), that only represent about 25 mm^2 of a distinct sample, with a penetration depth of about 0,08 mm. Therefore, X-ray texture goniometry gives more information on details, like deformation behaviour in distinct domains, while neutron textures bear information on bulk deformation. However, differences between certain LPO patterns can be observed by comparing different sampling sites, too. Whilst samples from the sites W of Stainz and the Weinebene-Handalpe preferrably show the development of strong c-axes maxima within Y (Figs. 2, 4, 5, 6), the site near Trahütten-Glashütten is characterized by the formation of type II cross girdles (Fig. 7), despite the modal Plattengneiss composition (pegmatitic or pelitic). This might be interpreted either in terms of different strain geometries and a localized constrictional strain geometry which is responsible for the development of type II cross girdle distributions (LISTER & HOBBS 1980), or locally decreased finite strain. However the independence of the LPOs from the modal composition argues for both high grade metamorphic conditions (which is a matter of fact) decreasing the ductility contrast, and high finite strain, too. Therefore, the different LPOs that have been observed in the area of investigation are best interpreted in terms of micro- and macroscale deformation partitioning, and locally contrasting strain geometries due to compatibility reasons.

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