

TEXTURAL DETERMINATION VIA SEM ELECTRON CHANNELLING

Geoffrey E. Lloyd,
Department of Earth Sciences, The University,
Leeds LS2 9JT, England.

Niels-Henrik Schmidt,
Département Matériaux, Ecole des Mines de St.
Etienne, 42023 St. Etienne cedex-2, France.

David Mainprice,
Laboratoire de Tectonophysique, Place E.
Bataillon, 34060 Montpellier cedex, France.

Niels O. Olesen,
Geological Institute, C.F. Molles Alle, DK-
8000, Aarhus-C, Denmark.

Richard D. Law,
Department of Geological Sciences, VPISU,
Blacksburg, Virginia 24061, U.S.A.

Martin Casey,
Geological Institute, ETH-Zentrum, CH8092
Zurich, Switzerland

The SEM presents several advantages over classical methods^{1,2} of texture analysis: 1. orientation measurements are made on individual grains or subgrains; 2. large specimens of polyphase materials can be studied; 3. intergranular relationships are determined; and 4. true crystallographic orientations and distributions are measured. Two methods of crystal texture analysis³ are available: electron back-scattering^{3,4} (EB) and electron channelling^{5,6} (EC). We present examples of the potential of SEM/EC in texture analysis.

SEM ELECTRON CHANNELLING

SEM/EC^{5,6} provides two types of image: orientation contrast (OC), where variations in image contrast distinguish individual micro-

structural elements; and electron channelling patterns (ECP), which consist of configurations of contrast bands unique for a particular crystal orientation. Both result from the relationship between electron beam and crystal structure and it is a simple matter to switch between them.

ECP's are indexed by recognizing that there is a limited range of patterns possible for each crystal symmetry class. Individual ECP's are identified by comparison with an "ECP-map" for that symmetry; the location being fixed by spherical angles defined by the type of crystal texture diagram (i.e. Inverse Pole Figure, Pole Figure, or Orientation Distribution Function). Originally, these angles were measured manually^{7,8,9}, but a computer software system (CHANNEL) now exists¹⁰ which greatly facilitates SEM/EC textural analysis.

EXAMPLE SEM/EC TEXTURE ANALYSIS

We have performed a "complete" SEM/EC-CHANNEL textural analysis of Tongue quartzite⁷⁻⁹ (Fig. 1). The PF's are in excellent agreement with those determined by X-ray texture goniometry⁹. However, SEM/EC recognizes crystallographic axes which X-ray techniques ignore (e.g. $-a\{11\bar{2}0\}$ and $+a\{\bar{1}\bar{1}20\}$ forms, although the upper hemisphere $+a$ PF must be equivalent to the lower hemisphere $-a$ PF).

SEM/EC is able to derive directly the true ODF¹¹. Usually only the even coefficients can be determined via X-ray texture goniometry, with complex mathematics required to simulate the true distribution (resulting in negative areas and "ghost" orientations¹²). There is good agreement between the even and true ODF's (Fig. 2), although the former has less intense peaks and negative regions. The odd ODF contains significant negative regions and much reduced peaks.

We have used the true ODF to derive PF's (Fig. 3) for comparison with the ECP PF's (Fig. 1b). The agreement is excellent. We have also used the true and even ODF's to calculate IPF's (Fig. 4) for the lineation and shear directions. These

show that although the even ODF approximates the true ODF, the former has 60° (double maxima) hexagonal symmetry in the IPF's, whereas the latter has 120° (single maximum) trigonal symmetry (lineation off-set from an m -axis, shear direction coincident with $-a$ maximum).

PHYSICAL PROPERTIES OF TONGUE QUARTZITE

Elastic stiffness constants

These can be calculated (Table 1) via SEM/EC by using the ODF coefficients calculated by the harmonic method^{13,14}. We have verified that only constants of the even ODF up to the 4th order are required. This is important for X-ray goniometry, where only the even ODF can be directly determined. The order of the function required is proportional to the number of PF's measured. If only the fourth order of the even function is required, this reduces the measurements involved.

TABLE 1. Elastic constants (mbars).

0.9264	0.1071	0.0759	0.0119	-.0082	0.0467
0.1071	0.9013	0.0820	-.0323	0.0113	0.0208
0.0759	0.0820	1.0530	-.0081	-.0149	-.0457
0.0119	-.0323	-.0081	0.5155	-.0333	0.0047
-.0082	0.0113	-.0149	-.0333	0.5202	-.0041
0.0467	0.0208	-.0457	0.0047	-.0041	0.4835

Seismic P-wave velocity (V_p)

This can be calculated in three dimensions (Fig. 5a) from the elastic constants¹⁵ and shows an anisotropy of $\sim 11\%$. The maximum velocity correlates with the maximum intensity in the z -axis PF (Fig. 3), in agreement with quartz single crystal data.

Second order physical properties

Only a second order ODF is required to describe the orientation distribution of these properties. For uniaxial crystals (e.g. quartz)

the distributions can be obtained from the *c*-axis PF and are uniaxial ellipsoids with symmetry axis parallel to the *c*-axis (any coincidence in the basal plane with a specific crystal axis is fortuitous because these properties of uniaxial crystals have a unique value in this plane). The calculation method is the same as above. The results (Fig. 5b-d, compare with Fig. 3) show that the dielectric constant (anisotropy 1.3%) and thermal conductivity (anisotropy 30.1%) have maxima broadly coincident with the *c*-axis maximum, whereas thermal expansion (anisotropy 24.2%) has a minimum broadly coincident with this direction. The magnetic susceptibility (anisotropy <1%) is almost isotropic. These behaviours are consistent with the behaviour of a quartz single crystal.

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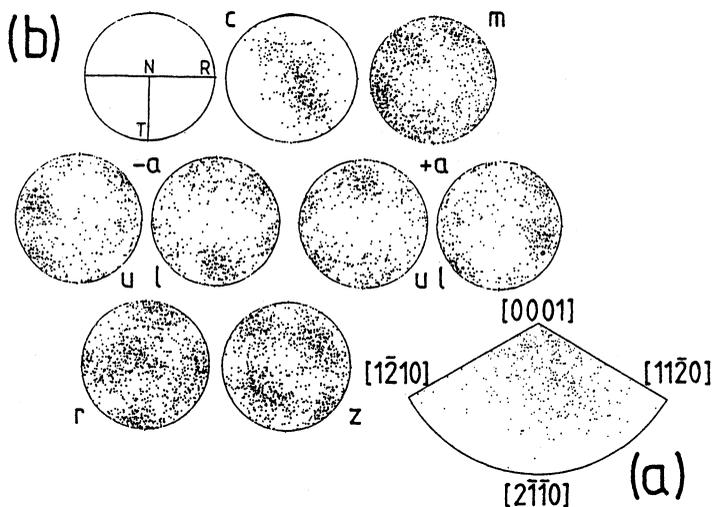


FIGURE 1. SEM/EC-CHANNEL texture analysis of Tongue quartzite. (a) IPF. (b) PF's.

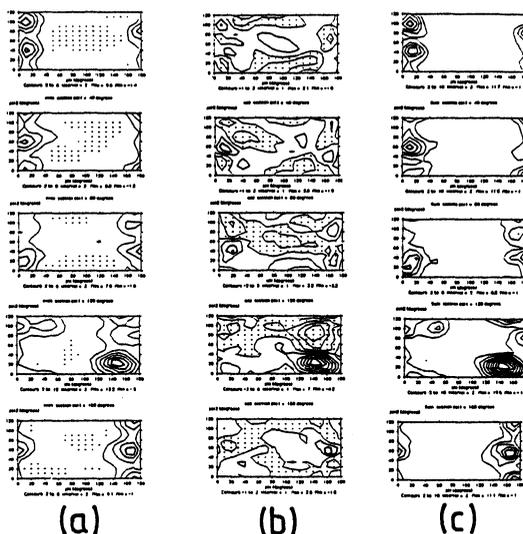


FIGURE 2. (a) Even, (b) odd and (c) true ODF's (contours multiples of uniform density).

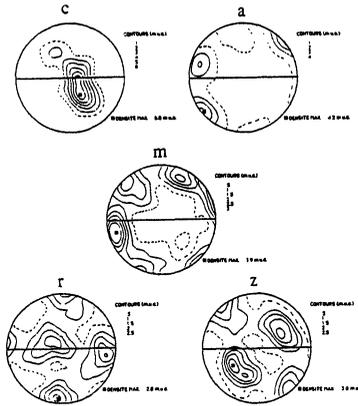


FIGURE 3. PF's derived from the true ODF (contours as Fig. 2). Compare with Figure 1b.

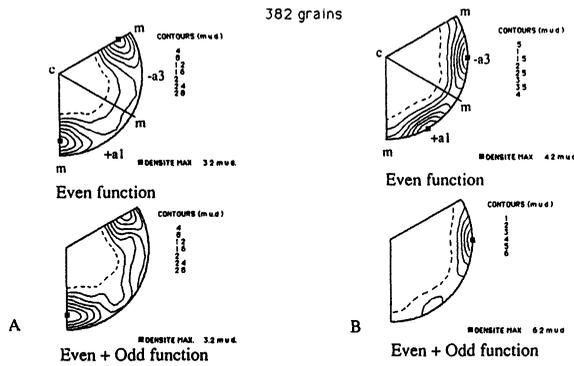


FIGURE 4. IPF's derived from even and true ODF's. (a) Specimen lineation. (b) Shear direction.

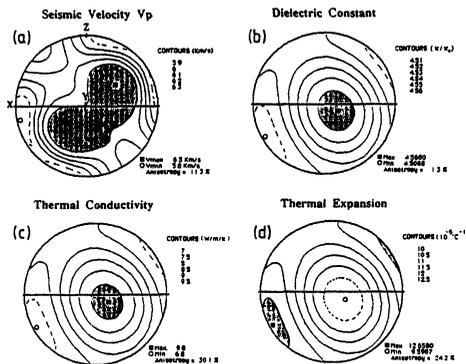


FIGURE 5. Tongue quartzite properties. (a) Seismic P-wave velocity. (b) Dielectric constant. (c) Thermal conductivity. (d) Thermal expansion.