Determination of crystal orientation fabric from seismic wide-angle data

Anja Diez1, Olaf Eisen2, Coen Hofstede1, Thomas Bohlen2, Ilka Weikusat3, Sepp Kipfstuhl1

1 Alfred Wegener Institute Bremerhaven, Germany
2 Institute of Polar Research, Warsaw, Poland
3 Alfred Wegener Institute Bremerhaven, Germany

Contact: Anja.Diez@awi.de

Introduction:
It is known from ice core analyses that the crystal orientation fabric (COF) of the ice in a deposition layer is determined by the local wind direction. This orientation is recorded in the ice for a long time and can be used to determine the COF fabric. It is further known that the ice core EDML, Dronning Maud Land, Antarctica is set in a relationship with the seismic fabric from the ice from which the anisotropic elastic fabric and seismic velocities are calculated. Additional factors for the seismic velocities v\textsubscript{P} and v\textsubscript{SV} are the density of the ice and temperature. The approximation of reflection horizons as isotropic (VTI)-media and is an important tool for the NMO-correction of wide-angle data.

From the results for the interval η-values the anisotropy for single layers could be derived. From the Thomsen parameters the anisotropy of vertical transverse isotropy (VTI) is obtained. The connection of seismic, radar and ice core data for a better understanding of these anisotropies as well as their remote detection is important to optimize flow models for ice.

Conclusion:
The elastic tensors were derived from eigenvalues of the COF.
The Halvfarryggen, Dronning Maud Land, Antarctica are set in a relationship with the seismic fabric from the ice core EDML, Dronning Maud Land, Antarctica. From this data, we defined the anisotropy of the ice and a total offset of 2294 m.

Eigenvectors A + n = k

To be able to compare measurements of COF from ice core data with seismic data, we need a connection between the description of the COF in eigenvalues (Fig. 1) and the elasticity tensor from the elasticity tensor ε\textsubscript{ij} = C_{ijkl} u\textsubscript{jk}. The seismic velocities, reflection coefficients, and δ-values are needed for the NMO-correction of wide-angle data. Thus, the elasticity tensor for different fabrics is obtained.

Eigenvectors V1, W1

Conclusion of interval values for velocity and η:
- v\textsubscript{P} - velocity
- n-MVO: n-values
- η-MVO: velocity

Comparison of derived values gives hint about anisotropy of layers:
- Large above internal reflector A: 0.77 ± 0.01 (angle φ = 20°)
- Small above internal reflector B: 0.72 ± 0.03 (angle φ = 0°)

4th order NMO-correction:
- Correcting for the anisotropy of the ice using the elasticity tensor ε\textsubscript{ij} = C_{ijkl} u\textsubscript{jk}
- Adding 30% anisotropy in calculation of travel times
- Re-scaling the elastic coefficients ε\textsubscript{ij}

5th order NMO-correction:
- Adding 40% anisotropy, thus the ε\textsubscript{ij} are further scaled
- Derived corresponding interval values

Ice core (COF)

Kohnen

Seismic

Halvfarryggen

Seismic

Ice core (COF)

Kohnen

Seismic

Halvfarryggen

Seismic

Figure 2: Measured COF into a relationship with the elasticity tensor. From the eigenvalues, we distinguish between gridle and cone fabric (Fig. 2). Averaged C\textsubscript{i,j} of a single crystal from ice core data is used to calculate the elasticity tensor of the fabric in integration over a density function (Nanthikesan, 1994). Thus, the elasticity tensor for different fabrics is obtained.

η-values:
- Calculating of interval values for velocity and η
- v\textsubscript{P} - velocity
- n-MVO: n-values
- η-MVO: velocity

Thomsen parameter for weak anisotropy:
- ε\textsubscript{ij} = C_{ijkl} u\textsubscript{jk} (NMO)

- Calculation from the elasticity tensor C\textsubscript{i,j}
- Approximate seismic velocities, reflection coefficients
- δ: phase velocity for horizontal component
- c\textsubscript{P} and c\textsubscript{SV} are the phase velocities for horizontal and vertical component

- c\textsubscript{P} is a measure for anisotropy

Wide-angle Survey 2010
- Snowstreamer 60 channels (each channel: 8 geophone)
- Channel distance: 12 m
- Borehole distance: 375 m
- 2 shots per hole
- Simultaneous 2 channel

Figure 6: Value calculated from elasticity tensor (each channel: 8 geophone)

Figure 5: Computing of NMO-correction of 4th order or anisotropic material

Figure 4: Consequence of large above internal reflector A and B.

As a result of the anisotropy of the ice the wavefront is no longer a sphere. The approximation of the reflections by hyperboloids is no longer valid.

Figure 3: Orientation of the ice, the wavefront being a hyperboloid.

Figure 1: Results of the analyses of seismic and ice core data at Kohnen, Halvfarryggen, and Thomsen parameter for weak anisotropy.

Figure 7: Remote detection is important to optimize flow models for ice.

Acknowledgement to Rick, Sven, Arne as well as the DFG.