Linking laboratory seismic velocity measurements with the mineralogical content and (micro)structures of the COSC-2 drill core, central Scandinavian Caledonides

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COSC-2: Collisional Orogeny in the Scandinavian Caledonides

The COSC-2 borecore was drilled to study the Lower Allochthon and the underlying basement based on pre-drilling seismic studies (Fig. 1). However, the borecore showed a discrepancy between expected and actually occurring lithologies (Fig. 2).

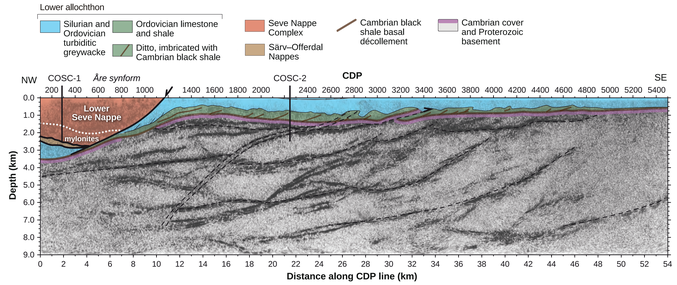


Fig. 1: Reflection seismic image including pre-drilling geological interpretation and locations of the COSC-1 and COSC-2 drill holes. COSC-1 transects middle allochthonous units. (CDP = common depth point, adapted from Rast, 2022; Gee et al., 2010 and Juhlin et al., 2016).

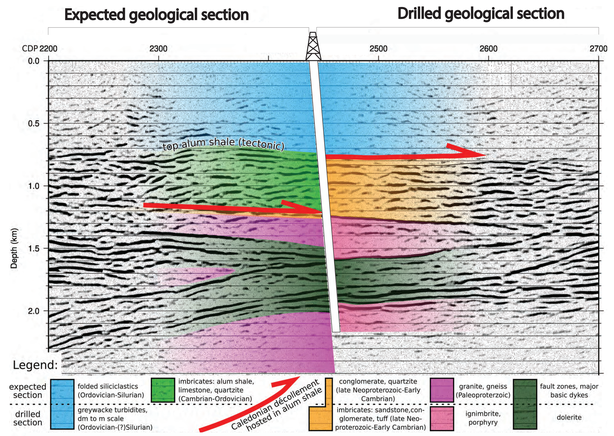


Fig. 2: (left) The expected geological section outlined in Fig. 1. (right) Based on the on-site geological interpretation, the drilled section cuts through the Lower Allochthon, the Alum shale between ~775 m and ~820 m depth and a sedimentary succession with no abrupt transition from Allochthon to Autochthon, which overlays porphyry interrupted by doleritic sequences (adapted from Lorenz et al., 2022).

What is the origin of velocity changes leading to strong reflectors in the seismic images?

Approach: Measurement of laboratory seismic velocities (Vp, Vs), mineralogical composition and (micro)structural analysis

Main questions:

1) Do the lab-generated seismic velocities match the p-wave sonic log data?
2) What are the dominant parameters leading to velocity changes and seismic anisotropy?
3) Which lithology contacts generate prominent reflections?

Sampling Strategy

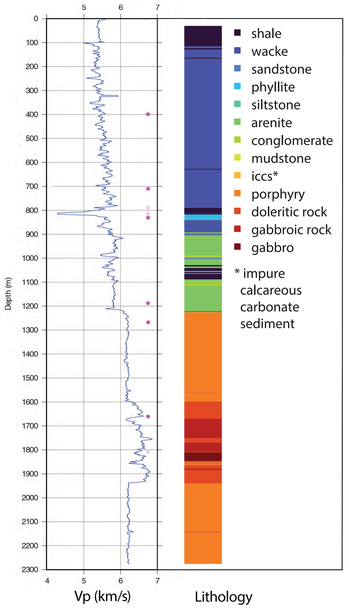


Fig. 3: (left) P-wave sonic log velocities adapted from Lorenz et al. (2022).
(right) The lithologies of the COSC-2 core plotted after the detailed core description outlined in Lehnert et al. (2022). The selected samples are marked by pink stars. Filled stars are first priority samples and non-filled stars are second priority samples, which are analysed if time allows.
The samples are chosen to represent the main lithologies and prominent changes in Vp.

Density Analysis and further Calculations

1. Determination of porosity and density (Fig. 4)
2. Calculation of the seismic wave anisotropy
3. Calculation of the acoustic impedance
4. Calculation of dynamic elastic properties (Poisson's Ratio and Bulk modulus)

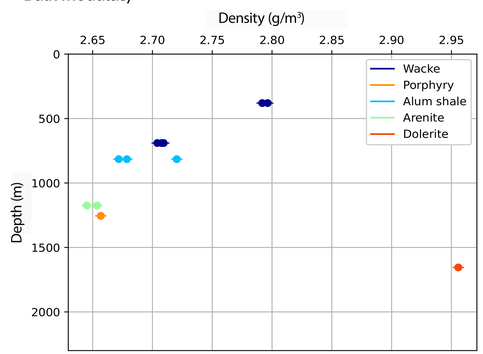


Fig. 4: Plotted density versus depth of the first priority samples labeled with filled pink stars in Fig. 3.

Velocity Measurement

① Sample preparation

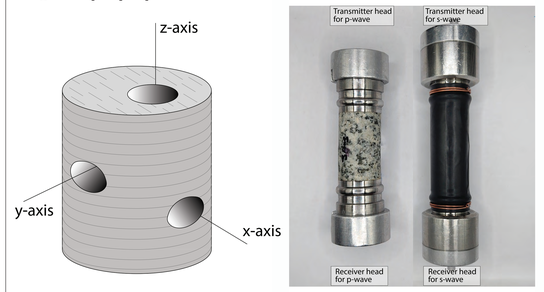


Fig. 5: (left) Three plugs along three mutually perpendicular axes are cut and drilled for each core section. The x-axis is parallel to foliation and lineation, y-axis parallel to foliation and perpendicular to lineation and z-axis perpendicular to foliation and lineation.
(right) The plugs are positioned between transmitter and receiver head and are fastened to each other with a shrink tube and a wire.

② Velocity measurement: Seismic Geneva Rig

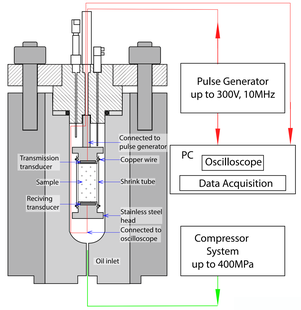
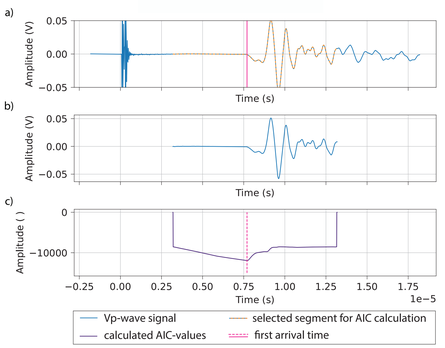


Fig. 6: The prepared sample is placed into the oil-filled pressure chamber and connected to transmitter and receiver. The travel time of the seismic wave is measured during a stepwise pressurization and depressurization cycle up to 240 MPa with a step size of 30 MPa (adapted from Kästner et al., 2020).

③ First arrival picking: AIC-picker

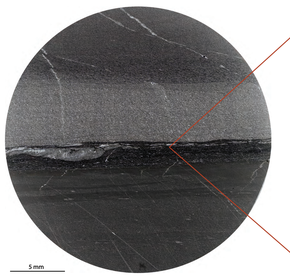
Fig. 7: To pick the first arrival time the Akaike Information Criterion (AIC, in detail described by St-Onge, 2011) is used. As a mathematic formula it defines the transition point between two adjacent signals.
(a) shows the complete Vp-signal recorded by the oscilloscope.
(b) shows the selected time slot used for the AIC-calculation. It consists of random noise with a very low amplitude and the Vp-wave with a varying amplitude.
(c) shows the calculated AIC-values. The minimum demarks a phase change and therefor the first arrival time of the Vp-wave labeled by the pink vertical line.



Mineralogical Analysis

① Optical microscope

Fig. 8: Thin section (magnified 5x, plane-polarized light) of a wacke (first sample of the core in Fig. 3), on drill site determined as turbidite. An upper sand-rich section is clearly separated from a clay-richer lower part.



② SEM: EDS, BSE

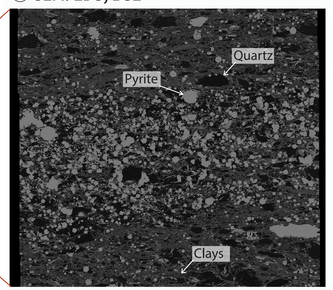


Fig. 9: BSE-image of the clay-rich zone with dark quartz minerals and fromboidal pyrite accumulation parallel to the compositional zoning and various types of clay minerals.

③ Quantitative mineral analysis with XMap tools and AZtec

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Header (Map): Map showing South Scandinavia. Google Earth, earth.google.com/web/.

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