

GEOLOGICAL SURVEY OF NORWAY

GROUND AND BOREHOLE GEOPHYSICS AT ÅKNES

Jan Steinar Rønning Einar Dalsegg, Harald Elvebakk, Bjørn Heincke and Jan Fredrik Tønnesen

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Outline of talk:

- Geological and geophysical model at Åknes
- Geophysical methods and results
 - 2D Resistivity (ERT)
 - Refraction seismics
 - Ground penetrating radar (GPR)
 - 3D seismic tomography
- Borehole methods and results
 - Optical / Acoustic televiewer
 - Resistivity, sonic and gamma-log
 - Water quality probe and Impellar flowmeter





Further work?

Åknes, Geophysical and geological model

Tallus, scree material

- special high resistivity
- special low p-wave velocity
- special low dielectric constant

Fractured drained bedrock,

- high resistivity
- low p-wave velocity
- low dielectric constant

Fractured wet bedrock,

- moderate resistivity
- medium p-wave velocity
- high dielectric constant

Unfractured bedrock,

- high resistivity
- high p-wave velocity
- moderate dielectric constant



Suitable methods:

- 2D Resistivity (ERT)
- Refraction seismics
- Ground Pentrating Radar





Ground geophysics at Åknes (2004 – 2007)

2D resistivity (ERT) (Wenner, Dipol/Dipol. 10 m) 10 lines, 10 km Ground penetrating radar, (25, 50 MHz, 1m spacing) 10 lines, 5 km **Refraction seismics** (10 m geophone spacing) 3 lines, 1 km







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Validation test: Are vertical structures artificial effects?



Wenner Standard inversion Vert./Hor. Filter= 0.5







Undulating structures do not explain vertical structures

Validation test: Are undulating structures artificial effects?



Wenner Standard inversion Vert./Hor. Filter= 0.5

Calculated Apparent Resistivity Pseudosection



Dipol/Dipol Standard inversion Vert./Hor. Filter= 0.5



Synthetic model



Vertical structures do not explain undulating structures

Can undulating image be explained by a stepwise structure?

Wenner Standard inversion Vert./Hor. Filter= 1





Stepwise stucture is less likely!

Can undulating image be explained by a stepwise structure and vertical fractures?

Wenner Standard inversjon Vert./Hor. Filter= 1

CALCULATED APPARENT RESISTIVITY PSEUDOSECTION



Stepwise stucture and vertical fractures is less likely!



Geological model Åknes (Ganerød 2008) Based on geophysical and structural data.





GPR, Profile 1 ÅKNES



Joint interpretation, Profile 2 Resistivity, seismics and georadar



Seismic tomography – Profil S1 Close up view



Seismic tomography – Profil S1





Refraction seismics 2006



Upper borehole



Sonic logs from the middle borehole (Elvebakk, 2008)

Cross-section of 3-D seismic tomogram





Border of individual domains from Venvik Ganerød et al. (2008)

Extension fractures







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Borehole logging.

- Optical / Acoustic televiewer
- Fullwaveform sonic log
- Resistivity
- Total gamma radiation
- Fluid conductivity
- Water quality log
 - (Temperature, Fluid cond., pH, Eh, O₂, NO₃)
- Impellar flowmeter
- Spectral gamma (ETH)
- Heat pulse flowmeter (ETH)



Oriented optical images KH-8



Depth 17 - 20,8 m



Depth24,0 - 25,3 m

Groundwater level at 61 m





Depth 27,2 - 31 m

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Core drilling, Åknes KH-8 Foliation direction and dip. Fracture azimuth and dip.







2005 LOWER BOREHOLE, Full waveform sonic log



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Impellar flowmeter



Dynamic measurements:

Rotation number registrated with constant speed down and up in borehole. Difference in rotation number is caused by water flow.

Static measurements:

Rotation number measured at fixed positions in the borehole.

Measurements can be performed in boreholes with natural water flow or in combination with pumping.

For detailed measurements, a **heat pulse flowmeter** can be used.





170

170 ±



Bh drilled in 2006 Upper location

Water quality probe:

- Temperature
- Fluid conductivity
- pH
- Eh
- O₂
- NO₃







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Åknes KH-8 borehole images and water flow.



NGU









Borehole deviation KH-8. Included in televiewers.





Future work:

- More high resolution ground geophysics?
 - Resistivity, Ground Penetrating Radar, Hybrid Seismics
- Reprosessing of the existing geophysics?
- Drilling
 - Core drilling vs. percussion drilling?
- Borehole geophysical logging
- Borehole flow measurement
 - Impellar flowmeter
 - Heat pulse flowmeter
- Tracer experiments?
- 3D structural model and 3D hydrogeological model

