A 3-D crustal model of the eastern Arabian plate margin below the Oman Ophiolite

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Summary

• Temporary seismic experiment across Oman Mountains
• Ambient noise tomography provides 3D crustal-scale model for northern Oman
• NE trending lateral changes in middle to lower crust from plate assembly
• Distinctly different crustal architecture along east coast
• Crustal deformation below topography

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Motivation

What is the state of the northern Arabian continental margin?
- Late Paleozoic opening of Neo-Tethys → continental stretching
- Early Cretaceous closure of Neo-Tethys
- Late Cretaceous formation of Semail Ophiolite offshore Arabia
- ... and obduction of ophiolite on continent → continental subduction, mountain building

Geodynamic models of obduction are typically schematic on the state of the continental lithosphere

A singular crustal-scale profile across Jebel Akhdar (JA):
- Crustal thickening below JA
- No significant Moho shallowing in coastal zone
- Thick pre-rifting sediments below and south of JA
- Ophiolite thickness ~5km north of JA, extending offshore
Motivation – COOL Project

What is the state of the northern Arabian continental margin?
• Lateral changes in crustal architecture?
• Moho topography?
• Crustal root below Oman Mountains?
• Variability in properties of subducted (Saih Hatat) vs. non-/less subducted continental crust (Jebel Akhdar)?
• Lateral variations of ophiolite thickness, anisotropy, … ?
• Properties of the eastern Arabian Plate?

COOL Project
(Crust of the Oman Ophiolite and ist Lithosphere)

• 40 temporary broadband seismometers*
• 15 stations from permanent networks
• Continuous waveforms
  Nov 2013 – Feb 2016

Methods
→ Ambient noise tomography
→ Receiver Functions

*) provided by the German Geophysical Instrument Pool Potsdam (GIPP)
Rayleigh wave phase velocity dispersion curves across COOL network derived from ambient seismic noise cross correlations
→ different geologic regions show distinctly different velocities
→ high velocities at low periods beneath the Oman Mountains
→ increase in velocity towards the east at highest periods

Azimuthally anisotropic Rayleigh and Love phase velocity maps
→ Arc-parallel azimuthal anisotropy in upper crust of mountains → deformation
→ Mostly W-E directed anisotropy in the east

Subsequent local 1-D inversion for radially anisotropic shear wave velocity profiles and compilation to 3D model

[all figures from Wiesenberg, PhD Thesis, CAU Kiel, 2020]
3-D Crustal Model – Horizontal Maps

Shallow crust:
- dominated by contrast mountains/ophiolite ↔ sediments
- shallow high velocities eastwards of Saih Hatat → northward extension of Huqf high below Wahiba Sands?
  → relates to reactivation of pre-Permian structures during Gondwana breakup

Middle to lower crust:
- general transition to east-west contrast
- linear, NE trending boundaries in middle, lower crust and Moho
  → Arabian plate assembly
- distinct velocity anomalies below topography
- slight crustal thickening below topography
  → obduction related

[all figures from Wiesenberger, PhD Thesis, CAU Kiel, 2020]
Ambient noise vs. Receiver Functions:
- Largely consistent west of Semail Gap
- 10 – 15km discrepancy west of Saih Hatat
- Origin uncertain, „double Moho“?

(Post-) obduction processes (Mountain belt/ophiolite):
- Thickest (<10km) ophiolite south of Saih Hatat [Profile EE’], elsewhere ~5km
- Distinct differences in upper crustal velocities beneath tectonic windows (slower below JA than SH)
- Slight crustal thickening and lower velocities throughout the crust below topography are indicative of deformation during orogeny/obduction (also from anisotropy)

Pre-obduction processes (Arabian plate):
- 40 – 45km crustal thickness in northwest [EE’ and FF’]
- Inherited from plate assembly (with later reactivation):
  - NW to SE thinning of the crust (stepwise?) [FF’]
  - Fast lower crust east of Saih Hatat [FF’ and GG’]
  - Shallow (20 – 30km) Moho in east [GG’]

for profile locations see previous slide

[all figures from Wiesenber, PhD Thesis, CAU Kiel, 2020]