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CRUSTAL STRUCTURE OF THE SOUTHERN PAMIR

Insights from the TIPTIMON magnetotelluric experiment

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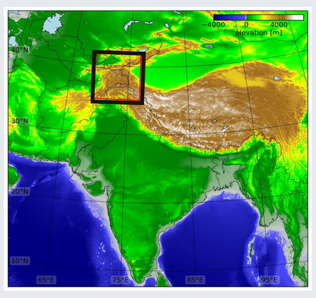
Introduction

Investigation area

The Pamir is a high plateau located at the N-W corner of India-Asia collision.



The Pamir has several unique features:

- 55-64% N-S internal shortening
- exposure of middle-lower crustal crystalline rocks with Cenozoic metamorphism in several domes
- occurence of intermediate depth seismicity caused by forced continental subduction.

Models of Pamir plateau formation and its present day kinematics propose crustal thickening and orogenic material flow whereby the ductile middle or lower crust is dragging the middle crust NNW-WNW.
(Burtman et al., 1993; DeCelles et al., 2002; Stübner et al., 2013)

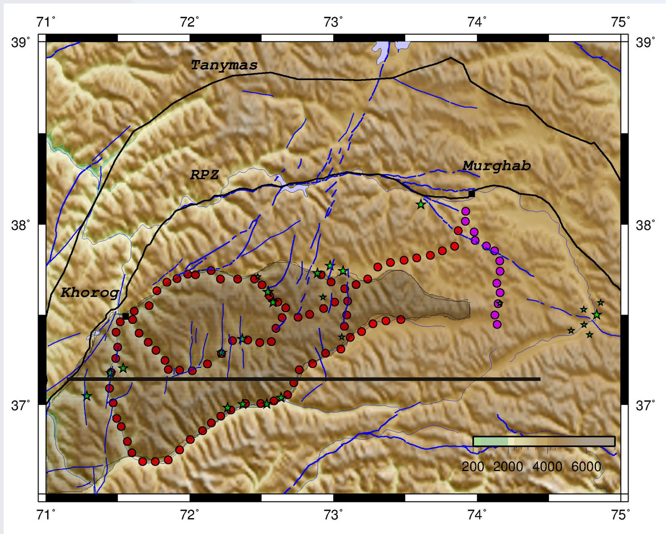
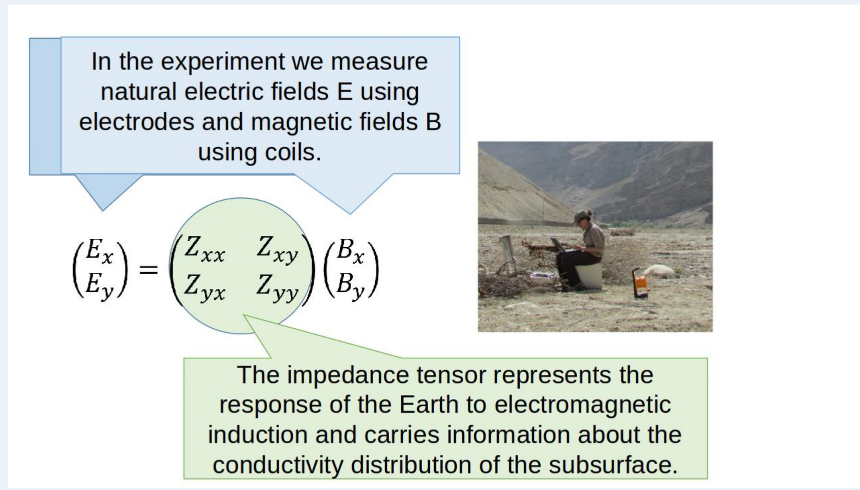


Fig. 1: Geological map with site locations (black lines: sutures, RPZ Rushan-Pshart Zone, blue lines: faults, green stars: hot springs, black shadow: Shakdara dome) Magnetotelluric sites are marked as red (TIPTIMON experiment, 2013) and purple (previous TIPAGE experiment, Saß et al., 2014) dots. The location of local earthquake tomography profile (see Fig. 2) is shown as black line.

Magnetotelluric experiment

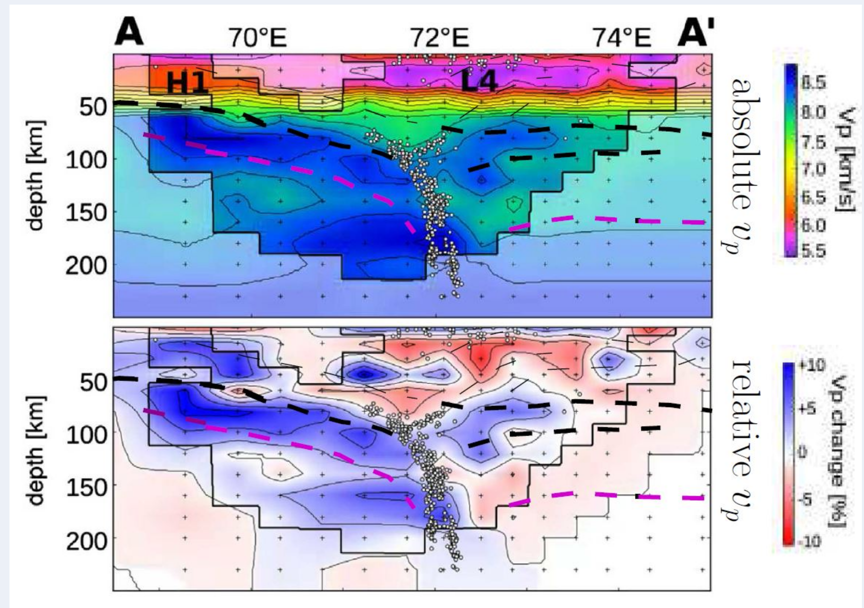
The magnetotelluric survey was conducted in the Southern Pamir as a part of the interdisciplinary TIPTIMON (Tien-Shan-Pamir Monitoring Program) project. We installed 85 wideband (10 000 Hz - 1000 s) magnetotelluric stations covering a 200 km x 100 km wide region between Murghab and Chorog in Tajikistan, with site spacing of ca. 8km. Recording duration was 3 days.



Geophysical information

Local earthquake tomography result, earthquake locations (from Sippl et al., 2013) with overlain seismic converter lines (from Schneider, 2014) are shown in Fig. 3. A zone of anomalously low P-wave velocities in the middle crust of the southern Pamir is observed. Along the profile, the observed earthquakes at intermediate depth indicate that Tajik Depression is subducting towards the east. Prominent seismic converters show upper and lower boundaries of the mantle lithosphere supporting this idea as well.

Fig. 2: Local earthquake tomography and seismic converter lines.



Electrical resistivity models

3D Inversion results

We run a series of 3D inversions using the "Modular Electromagnetic Inversion System" (ModEM, Meqbel, 2009; Egbert and Kelbert, 2012). All components of the impedance tensor were used. Additionally to TIPTIMON data, a part of the TIPAGE data (Saß et al., 2014) were included for the inversion.

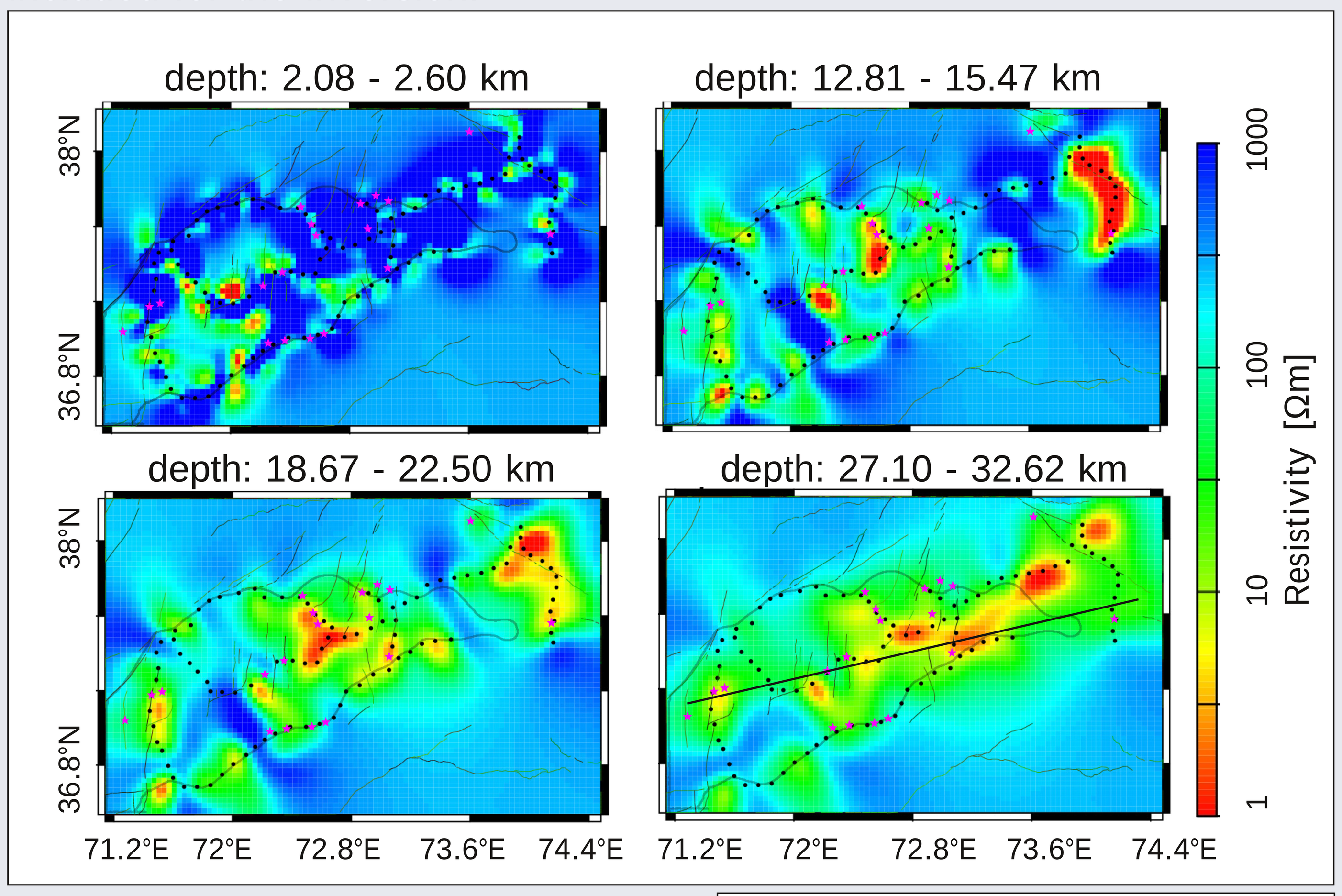


Fig. 3: Electrical resistivity distribution for horizontal slices at different depths. Starting at around 10 km depth, a prominent low-resistivity zone (below 10 Ohmm) appears in the south-eastern part and in the center. The conductive areas get connected in greater depths. In the south-western part of the survey area, a resistive core extends to larger depths (> 30 km) and a few conductive regions appear as isolated structures with limited extension.

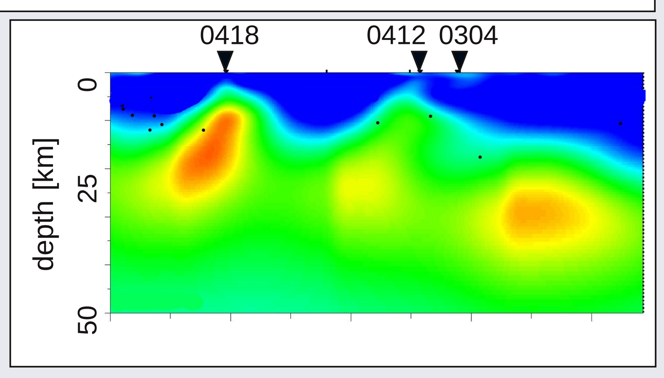


Fig. 4: Normal faults in the central part of the investigation area can be observed as conductive steps, since the resistive shallow crust is damaged in the fault zones and offers pathways for fluids.

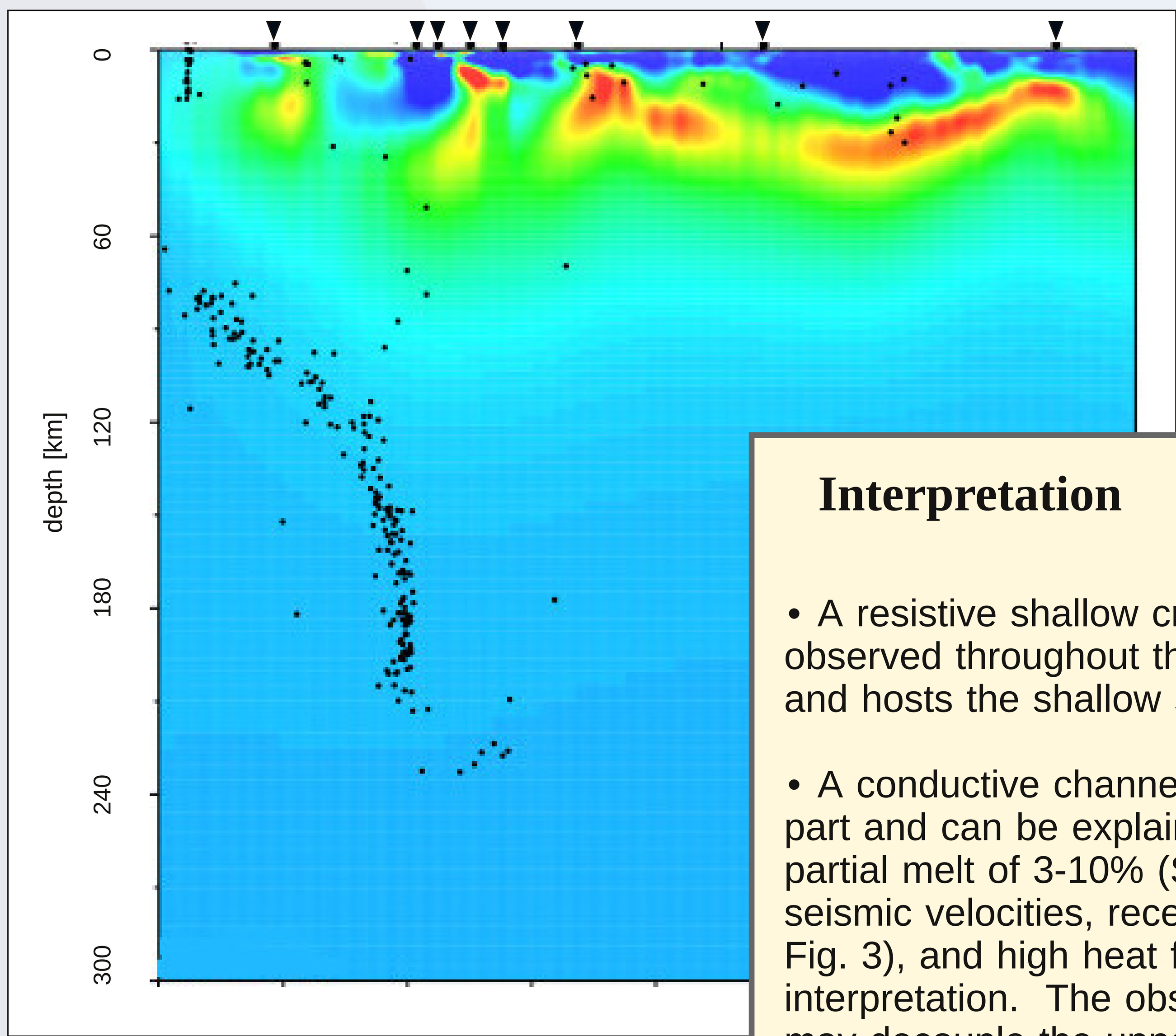


Fig. 5: Vertical cut through the 3D model (see Fig. 4). Black dots mark the earthquake locations (from Sippl et al., 2013, Sofia Kufner, personal communication).

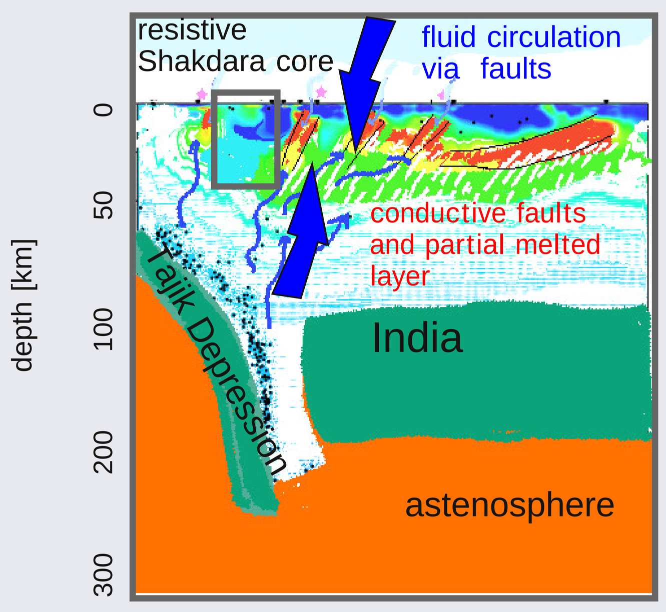


Fig. 6: Tectonic sketch summerizing magnetotelluric results for the upper crust and seismological results for the mantle.

Interpretation

• A resistive shallow crust (<10-15 km) is observed throughout the Southern Pamir plateau and hosts the shallow seismicity in this region.

• A conductive channel is resolved in the eastern part and can be explained with interconnected partial melt of 3-10% (Saß et al., 2014). Low seismic velocities, receiver function analysis (ref. Fig. 3), and high heat flow support this interpretation. The observed partial melted layer may decouple the upper crustal dynamic from lower crustal and mantle dynamics. However, the MT results do not support a crustal flow in the west direction. A crustal flow from the central part to the NNW remains possible.

• In the south-western part, the zones of high conductivity are interpreted as faults. Especially in the central part, the normal faults seem to reach very deep and may provide pathways for metamorphic as well as meteoric fluids and partly coincide with hot springs at surface.
• The Shakdara dome does not seem to influence the electrical resisitivity distribution.

• Burtman, V.S. and Molnar, P.H. (1993). Geological and Geophysical Evidence for Deep Subduction of Continental Crust Beneath the Pamir, Special Papaer Geological Society of America, 281
• DeCelles, P. G., Robinson, D. M., and Zandt, G. (2002). Implications of shortening in the Himalayan fold-thrust belt for uplift of the Tibetan Plateau. Tectonics, 21(6), 12-1.
• Egbert, G.D. and Kelbert, A. (2012). Computational recipes for electromagnetic inverse problems. Geophys. J. Int., 189(1), 251-267
• Meqbel, N. (2009). The electrical conductivity structure of the Dead Sea Basin derived from 2D and 3D inversion of magnetotelluric data. Dissertation. Freie Universität Berlin, Germany
•Sass, P., Ritter O., Ratschbacher L., Tympel J., Matiukov V. E. , Rybin A. K., and Batalev V. Yu. (2014). Resistivity structure underneath the Pamir and Southern Tian Shan. Geophys. J. Int.
•Schneider, F. M. (2014). Imaging an Intra-continental Subduction in Central Asia with Teleseismic Receiver Functions (Doctoral dissertation, Freie Universität Berlin, Germany).
• Sippl, C., Schurr, B., Yuan, X., Mechie, J., Schneider, F. M., Gadoev, M., & Radjabov, N. (2013). Geometry of the Pamir-Hindu Kush intermediate-depth earthquake zone from local seismic data. Journal of Geophysical Research: Solid Earth, 118(4), 1438-1457.
• Stübner, K., Ratschbacher, L., Rutte, D., Stanek, K., Minaev, V., Wiesinger, M., & Gloaguen, R. (2013). The giant Shakhdara migmatitic gneiss dome, Pamir, India-Asia collision zone: 1. Geometry and kinematics. Tectonics, 32(4), 948-979.

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