Geophysical Research Abstracts
Vol. 14, EGU2012-3404, 2012
EGU General Assembly 2012

Seismicity of the Pamir and Hindu Kush: new constraints on regional tectonics

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The Pamir and Hindu Kush regions in Central Asia host the most active zone of intracontinental seismic activity at intermediate depths (up to nearly 300km) in the world, which is still poorly understood in terms of its detailed structure and, most importantly, its origin. Being situated far from any typical subduction zone setting and displaying a change in its polarity along strike, this seismically active zone has been interpreted in numerous ways, e.g. as a single slab of Indian lithosphere originally subducted northwards which was subsequently overturned in its eastern part or as two adjacent subduction zones of opposing polarity. Several key questions concerning this region, among them the nature of subducted material (oceanic or continental?), the mechanism behind the generation of these intermediate-depth earthquakes and the region's tectonic framework have not been answered as of yet.

As the seismological subpart of the TIPAGE project, we deployed a network of 40 seismometer stations for a total duration of two years (2008-2010) in Tajikistan and southern Kyrgyzstan, covering the Pamir mountains and surroundings. Complemented with two more temporary deployments and additional data from several permanent networks in adjacent areas, this constitutes a seismic dataset of unprecedented station density for this part of Central Asia.
Showing the distribution of more than 9,500 earthquakes located with a highly precise double-difference method based on the cross-correlation of individual traces, fault plane solutions for shallow and deep earthquakes as well as preliminary results from traveltime tomography, we can resolve the exact geometry of the deep seismic zone and draw further constraints on the tectonic processes active in the region.

The S-shaped region of intermediate-depth seismicity is clearly subdivided into two separate parts, hence termed Hindu Kush and Pamir seismic zones.
The Hindu Kush seismic zone strikes due east-west at a latitude of about 36.4°N. Depth sections show that earthquakes extend from depths of 50 to around 250 km along a planar, steeply northward-dipping structure. Earthquakes are most frequent in the depth range from 180 to 220 km, whereas there is a seismic "gap" at about 150 km depth. Intriguingly, the Hindu Kush seismic zone features a small-scale reversal of dip polarity in its lower part (beneath the 150km gap) towards its eastern termination.
The Pamir seismic zone forms an arc, the strike of which varies by 90 degrees from north-south at its southwestern end (where it borders the Hindu Kush seismic zone) to east-west at its eastern termination. The dip direction of the structure changes from due east to due south from west to east. Seismic activity outlines a narrow (10-15 km) Wadati-Benioff zone displaying a constant dip of about 50 degrees all along its extent. Whereas seismic activity ceases at depths of 130-150 km in the east, the south-western part of the zone shows earthquakes reaching depths of up to 240 km that outline a vertical structure beneath 150 km depth. All along the arc, the upper termination of seismic activity is found at depths of 60-80 km, leaving a gap to shallow seismic activity which is confined to the uppermost 20-25 km.
Intermediate-depth earthquakes in the eastern Pamir and the low-velocity zone they are situated within can be linked with shallow seismic activity along the Main Pamir Thrust (MPT) further north, which implies ongoing intracontinental southward subduction, presumably of continental material, in the Alai Valley. Tracing the surface expression of the deep earthquakes along the Pamir arc, towards the southwest, proves complicated. It is possible that the western part of the Pamir seismic zone is linked to the ongoing east-west compression in the Tajik Depression seen by GPS, but evidence is scarce.

Shallow seismic activity concentrates along the Pamir's northern rim (MPT) and in its western part, wheras the eastern Pamir is seismically quiet. Fault-plane solutions obtained by moment tensor inversion show predominance of sinistral strike-slip events with presumably northeast-southwest striking rupture planes in the western Pamir, whereas the MPT mostly shows thrusting events along east-west trending rupture planes. Analysis of P and T axes shows a general trend of north-south compression and east-west extension throughout the Pamir, which is consistent with GPS observations.