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Seismicity and lithospheric structure in the Pamir – Hindu Kush – Tien Shan region from TIPAGE seismological data

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One of the unsolved questions in geodynamics is the mode of deformation and ultimate fate of lithosphere in collisional mountain building. Complete continental lithosphere may subduct as whole in tow of the oceanic plate, buoyant forces, however, will then tend to halt convergence. The subducted slab may break off if gravitational forces overcome its strength. Alternatively the buoyant continental crust may in part or completely delaminate and remain at surface to shorten and thicken, as convergence continues. Remaining lithosphere may subduct as whole or deform and thicken too. Thickened lithosphere may become gravitationally unstable and founder in a Rayleigh-Taylor instability into the mantle substrate. All these scenarios have been suggested and observed in numeric or analogue simulations and ultra high pressure metamorphic rocks at various locations attest that crustal rocks, despite their buoyancy, maybe dragged into the mantle to depths greater than 100 km. If and how and under what circumstances these processes act in nature, however, is extremely difficult to deduce. The Pamir region in central Asia may be the best location on Earth to observe lithospheric deformation during orogeny in progress. This mountain range and high plateau formed at the tip of the western Indian promontory through Cenozoic shortening of a magnitude similar to the adjacent Himalaya-Tibet system. Shear between greater India and Eurasia is currently localized at Pamir's northern perimeter Main Thrust that is seismically active and accommodates a significant portion of India – Eurasia convergence. The Pamir - Hindu Kush region is one of the very few places on Earth, where vigorous intermediate depth (100 – 300 km) mantle seismicity occurs in an intra-continental setting. 15 earthquakes of $M > 7$ in the last 100 years testify of on-going intense strain in the mantle. The seismicity forms an S-shaped belt on map view and steeply dipping narrow slabs in cross section, reminiscent of Wadati-Benioff zones known from oceanic subduction, albeit of complex geometry. The zone beneath the Hindu Kush dips steeply north, the one beneath the Pamir to the south. Interpretation of the pattern as two slabs dipping in opposite directions or a single, highly contorted one depends not the least on the existence of a seismic gap between the two zones that is not unambiguous in global catalogues. The structure and material these earthquakes are occurring in is also debated and continental/oceanic crust/mantle are at choice.

The TIPAGE seismological experiment was designed to address these questions based on high resolution relocation of local seismicity and lithospheric scale imaging using tomography and receiver functions. We operated a network of 40 seismological stations for two years from 2008 – 2010 across the Tien Shan and Pamir mountain ranges in Kyrgyzstan (10 stations) and Tajikistan (30 stations). During the first year 24 of these stations formed a north-south profile along the road from Osh in Kyrgyzstan to Zorkul in southern Tajikistan with approximately 15 km station spacing. The other 16 stations are set up in a network configuration covering most of the Pamir Mountains and allowing location of earthquakes. In summer 2009 the profile was dismantled and stations were rearranged in order to increase the density of the 2-D seismic network. This new configuration covered the entire central Pamir with an average station spacing of approximately 40 km.

Receiver functions along the NS profile image a Mohorovičić discontinuity that is deepening from 60 km beneath the Tien Shan to up to 75 km beneath the central Pamir. A prominent southward dipping low velocity structure is visible in the mantle beneath the central Pamir coinciding with southward dipping mantle earthquakes. Based on crustal reverberations, Moho conversions and modelling of earthquake travel times we determined gross crustal poisson ratios indicative of an overall felsic crust. We find no obvious gaps in intermediate depth seismicity between the Hindu Kush and Pamir clusters not easily supporting the view of two separated subduction zones.