From depth to surface: how deep-earth processes and active tectonics shape the landscape in Pamir and Hindu Kush

Silvia Crosetto[1], Sabrina Metzger[1], Dirk Scherler[1,2], Onno Oncken[1,2]

Author contact: silvia.crosetto@gfz-potsdam.de

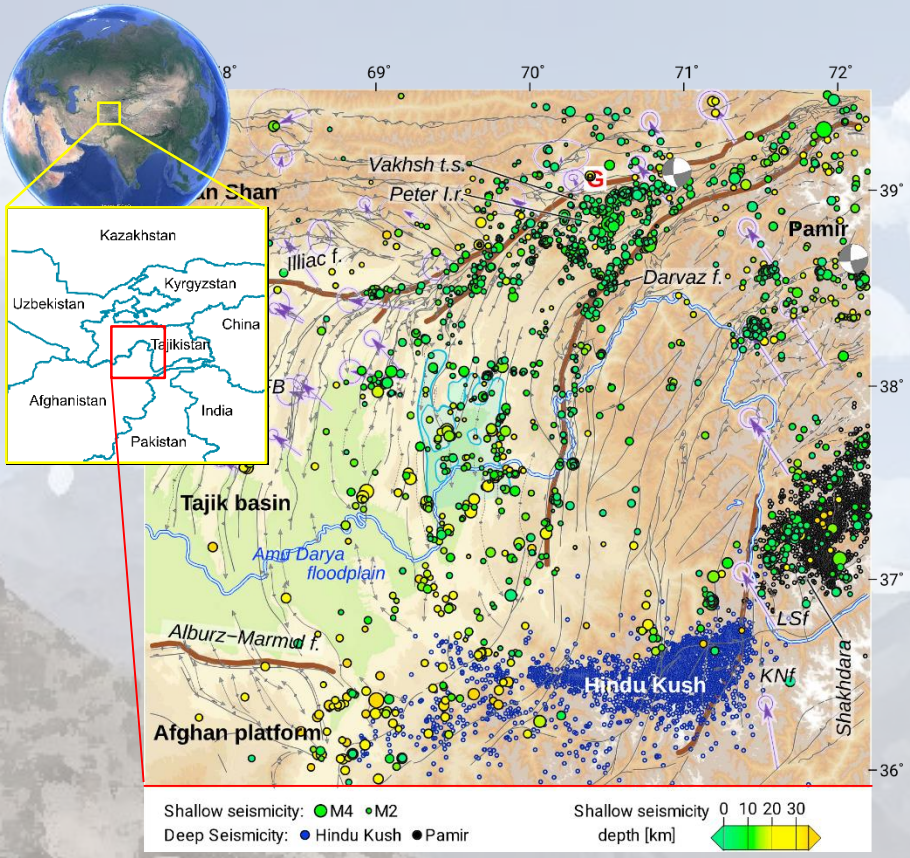
(1) GFZ German Research Centre for Geosciences, Telegrafenberg, 14473 Potsdam, Germany

(2) Institute of Geological Sciences, Freie Universität Berlin, Germany

About the display

- The display is organised in three sections:
  - Background (to get to know the area)
  - Darvaz fault (what we are planning to search)
  - Slab break-off (what we hope to find)
- This is a work-in-progress study; therefore, results are not presented
- Instead, background information and main working ideas are provided as a preliminary proposal
- **Your feedback is very welcome!**

Geological background



Modern seismicity and Cenozoic structures in the NW Pamir, Hindu Kush and Tajik basin. [Kufner et al., 2018]

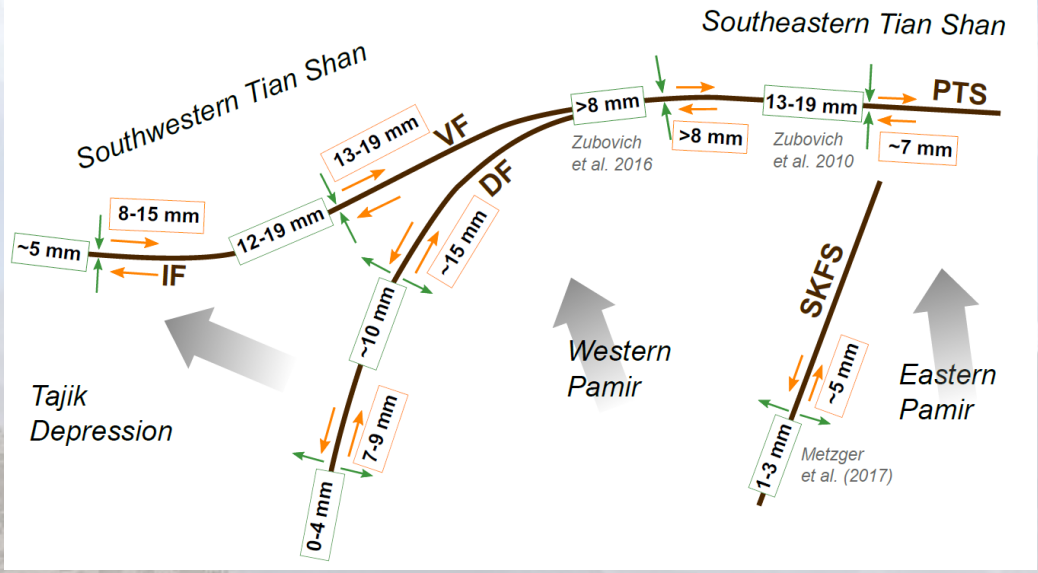
The Pamir and Hindu Kush are located at the western tip of the India-Asia collision zone.

On its way northwards the arcuate, convex Pamir mountain range acts as a rigid indenter penetrating the weaker Eurasian plate, while lateral extrusion occurs to the west in the Tajik Depression.

Intense present-day shallow seismicity indicates active deformation along the northern and north-western semi-arid margin of the Pamir, in the proximity of three main fault systems: the Pamir thrust system to the north, and the Darvaz fault and Vakhsh thrust system to the north-west.

Deep seismicity characterises the Hindu Kush, to the south.

Main active faults of NW Pamir



Main active faults of NW Pamir and their slip sense. Gray arrows indicate the main direction of motion with respect to stable Eurasia observed by GPS; orange arrows indicate shear, green arrows shortening or extension. VF: Vakhsh fault; DF: Darvaz fault; PTS: Pamir Thrust System; SKFS: Sarez-Karakul fault system. [Metzger et al., 2020]

The Darvaz fault and the Vakhsh fault splay from the main Pamir Thrust System.

The sinistral-transpressive Darvaz fault separates the Pamir from the Tajik Depression, while the dextral-transpressive Vakhsh fault zone marks the boundary of the southwestern Tian Shan.

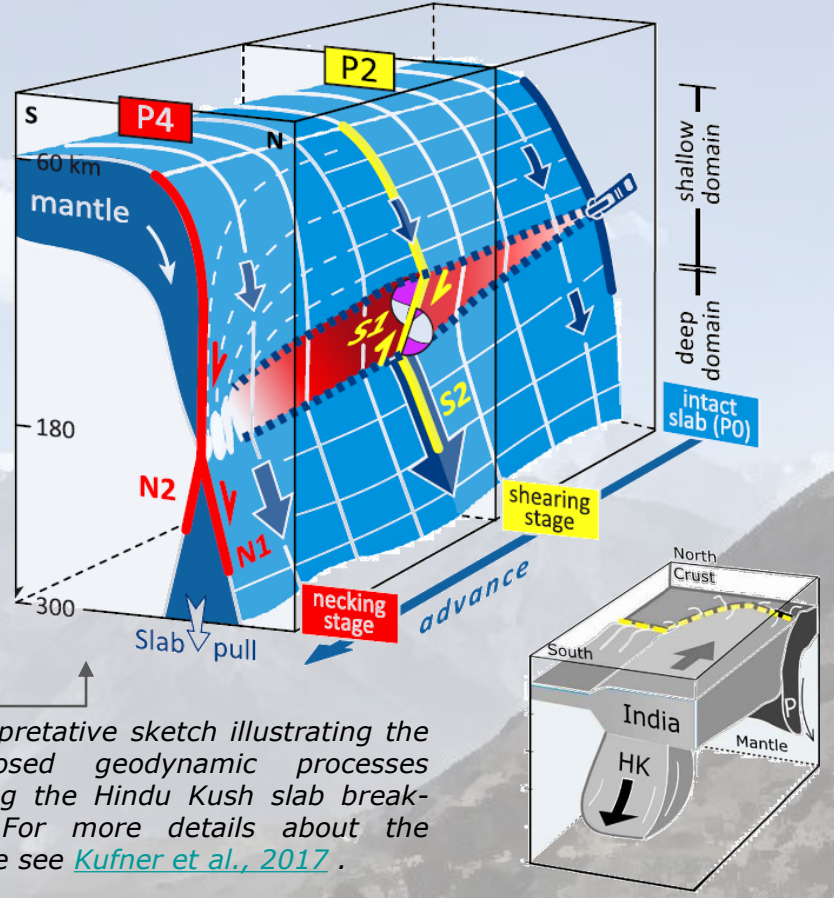
Together, these faults accommodate NW-SE shortening and southwestward flow of Western Pamir material into the Tajik Depression.

Imaging the slab break-off

Kufner et al. (2017) proposed that sub-crustal seismicity beneath the Hindu Kush, clustered in a near-vertically dipping narrow volume and displaying repeating large earthquakes at depth>200km, represents the expression of ongoing subducted slab break-off.

The loss of the gravitational slab pull force can translate to the overlying crust, which would start uplifting in a relatively uniform mode over a large region.

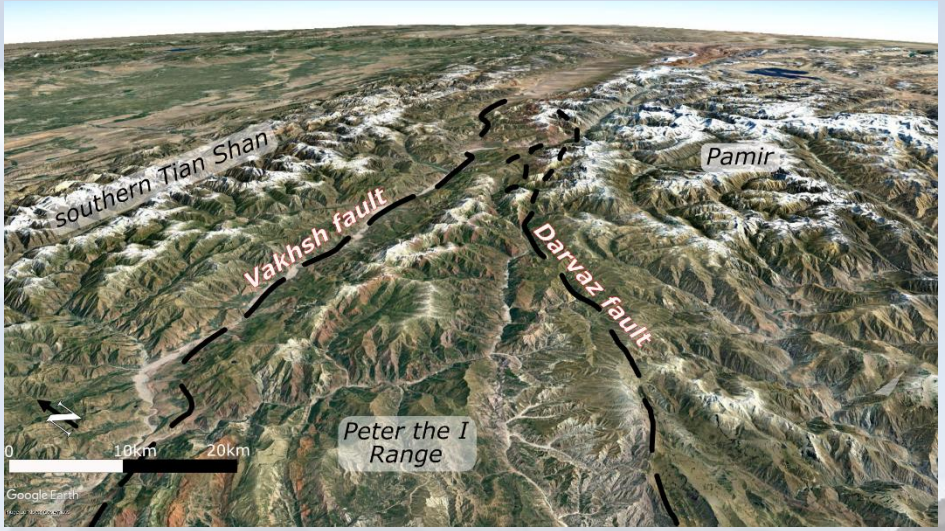
Consequently, deformation would focus along the margins of the uplifting area, as observed along the western edge of the Hindu Kush.



Interpretative sketch illustrating the proposed geodynamic processes during the Hindu Kush slab break-off. For more details about the figure see Kufner et al., 2017 .

Darvaz fault: slip rates

The Darvaz fault currently accommodates ~15 mm/yr sinistral shear and up to 10 mm/yr of dip-slip, with seismicity clustering at its northern and southern termination.



View of the Darvaz fault and Vakhsh fault parallel segments.
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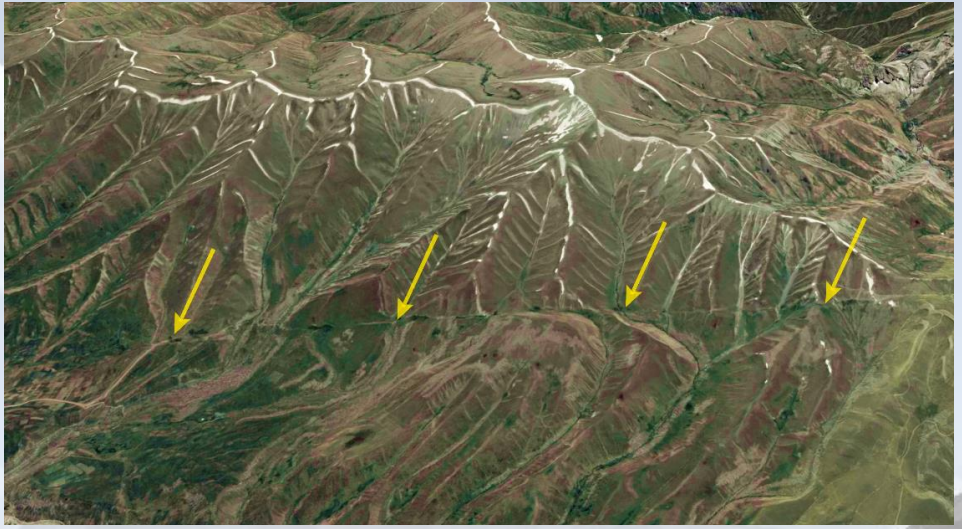
Holocene to Late Pleistocene slip rates

Southern segment:
- 10-15 mm/yr sinistral slip [Trifonov, 1978]

Northern segment:
- 10-40 mm/yr of sinistral slip, according to ~21 m displacement of a ~1500-2200 years old, man-made defense structure [Kuchai & Trifonov, 1977]
- 3-4 to ~8 mm/yr sinistral-transpressive slip rates since the last glacial maximum ~20 ka [Trifonov, 1983]. However, an association of the mapped fault segments with either the Vakhsh or the Darvaz fault is unclear.

Darvaz fault: palaeoseismology

Existing slip rates are based on relative and regional terrace chronology and are probably prone to high uncertainty, as indicated by rates that vary by 300% depending on the respective authors (Burtmann & Molnar, 1993).



Trace of the northern segment of the Darvaz fault, highlighted by the arrows. View to SE. © Google Earth

Future work

By analysing the abundant geomorphic markers, such as river terraces, moraines, alluvial fans, and streams, we aim at identifying:

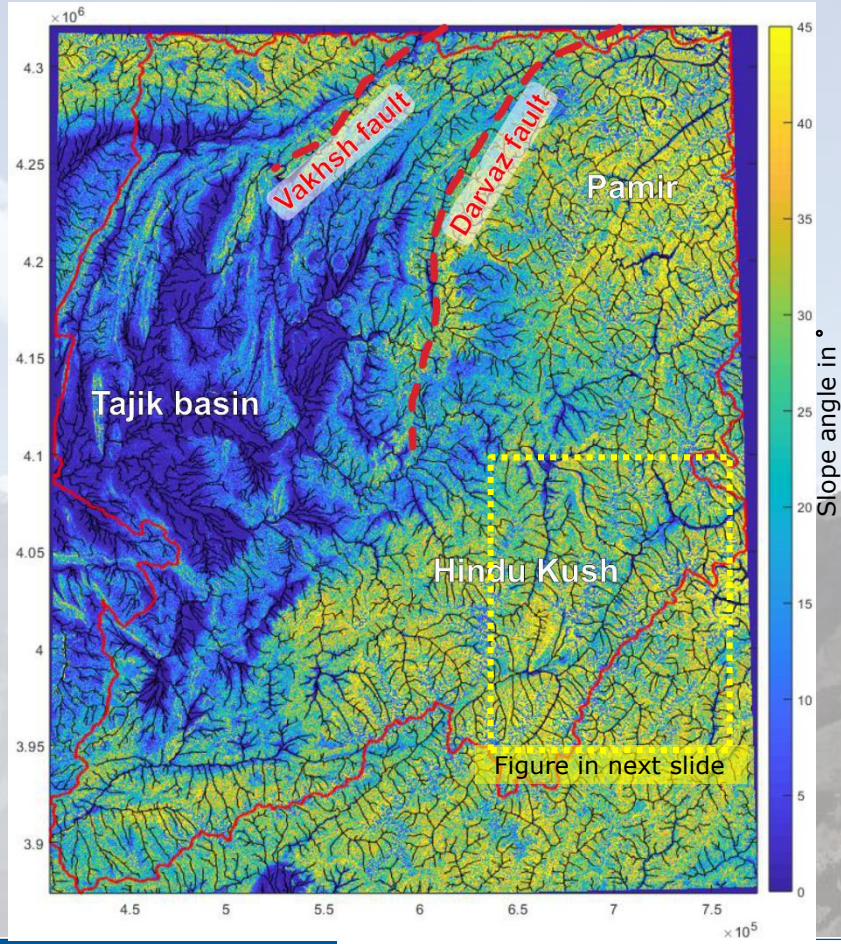
- datable offset surfaces, in order to determine a comprehensive absolute age for the slip events
- suitable palaeoseismological trenching sites, to define the number of rupture events occurred along the fault.

Landscape response to slab break-off

Regional uplift associated to past slab break-off is not new in literature (e.g. Molinaro, 2005; Schildgen, 2012, 2014). However, less in known about current observations on the development of this process. The Hindu Kush certainly offers a rare opportunity to seismologically observe break-off, but **can we already see its effects in the overlying topography**?

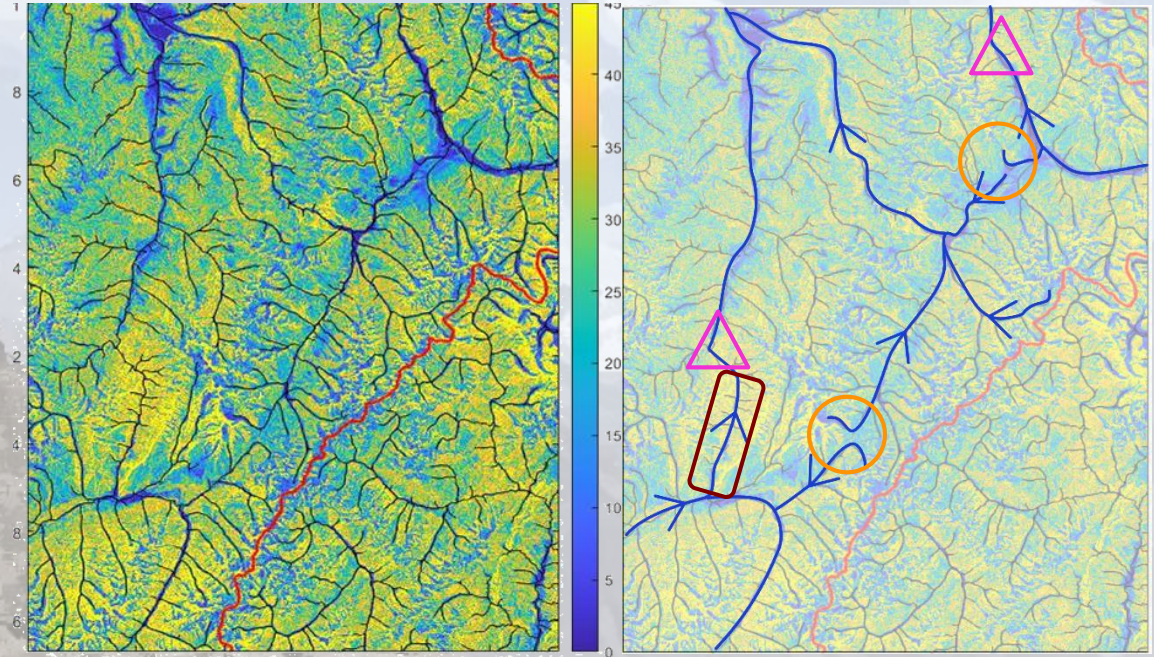
Observed evidence of uplifted landscape:

- Low divides
- Stream flow reversal
- River captures



Drainage basin of the Panj river, defining the border between Tajikistan and Afghanistan, over a topographic slope map (generated with TopoToolbox, Schwanghart&Scherler, 2014)

Landscape response to slab break-off



Zoomed-in view of a portion of Panj river drainage basin (left) with simplified scheme of the main flow directions (right).

Observed evidence of uplifted landscape:

- **Low divides**

Many examples of low divides indicate relatively recent uplift of a section of the old stream drainage

- **Stream flow reversal**

Is observed in correspondence of river captures due to headward erosion of an adjacent sub-basin

- **River captures**

Are frequent and often associated to fault offset

- **.. and more to come!**

THE END!

Thank you for reading

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