The Hidden Past of the Alai Valley: Understanding the Seismic History and Behavior of the Central Pamir Frontal Thrust System through Paleoseismology.

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1 Introduction

The northernmost deformation front of the Pamir mountains, the Pamir frontal thrust system (PTS), is characterized by an array of deformed Quaternary landforms. Yet, the relationship between seismicity and surface rupture as well as the geometry of the thrust zone and differences between geodetic and geologic rates of contraction are not well understood.

To better characterize the seismogenic history of the PTS we investigated its youngest manifestation, the northward propagated Pamir Frontal Thrust (PFT). Based on tectonic geomorphology and paleoseismology, we want to understand its fault behavior in the context of present-day to millennial-scale deformation rates.

Here we present our observations from three trenches across the central segment of the PFT.

2 Research Questions

- How much of the PFT is activated during an earthquake rupture?
- Are there discrete seismotectonic segments that reflect limit ground rupturing earthquakes?
- Does the paleoseismic slip history agree with the geodetically-derived shortening?

3 Geological Background

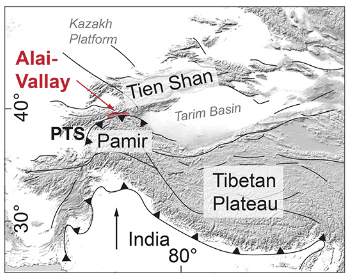

Figure 1. The Pamir in the Indian–Eurasian framework as a result of northward advancing India (arrow) and main active faults (black). Study area outlined in red.

The Pamir Thrust System (PTS)

- Part of a complex tectonic structure involving southward underthrusting of the Eurasian lithosphere and slab-break off; the PTS is located at the up-dip projection of the subducting Eurasian slab
- Separates the northward-advancing Pamir from the seismically active Tien Shan basement-uplift province in the north and accommodates most of the shortening in this collision zone
- Seismically active area is capable of producing large-magnitude earthquakes of >M7 or greater

The Pamir Frontal Thrust (PFT)

- Northern most fault of the PTS
- Northward propagation of the Main Pamir Trhust (MPT)
- Can be divided into the eastern, central and western segments, linked by northwest striking dextral transfer zones
- Late Quaternary slip rate: ~0.3-6 mm/yr
- 4 earthquakes with 6.5-7M in the past 40 years

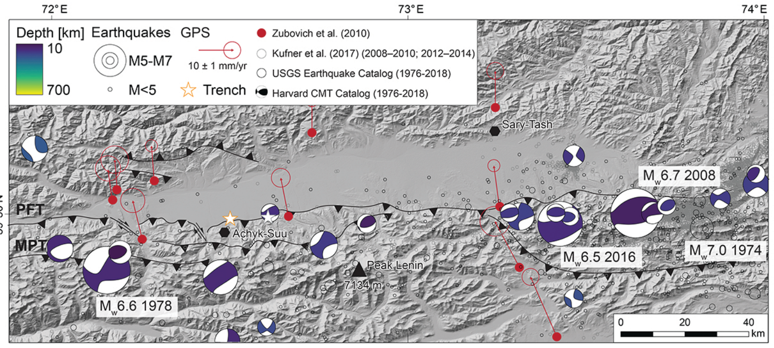

Figure 2. Earthquake distribution in the Alai Valley with simplified structures of the PFT and MPT. Significant earthquakes in the past 100 years are labeled with year and magnitude.

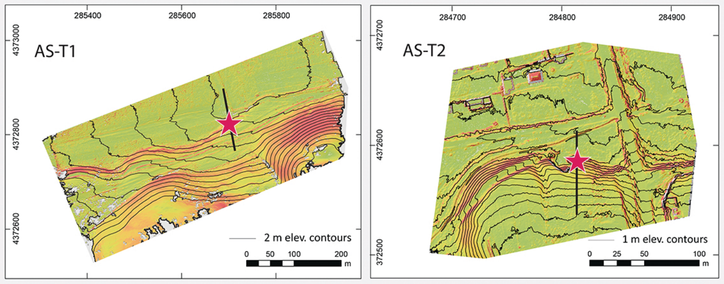

Figure 3. Hillshade model from photogrammetry of the two excavation sites at Achyk-Suu (orange star in Fig. 2), overlain by a slope solution of the raster surface. Red star indicates trench location. Black line perpendicular to the fault by the trench location indicates the scarp profile measured by dGPS (Fig. 4).

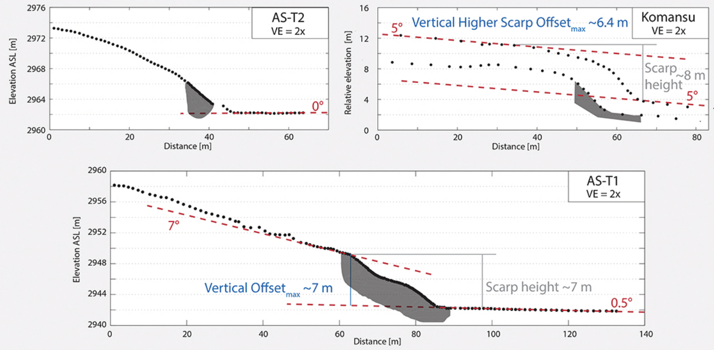

Figure 4. Topographic scarp profiles with fault related offsets and geometric parameteres surrounding the scarp. Grey polygons indicate the excavations (Fig. 5).

PALEOSEISMIC INTERPRETATION

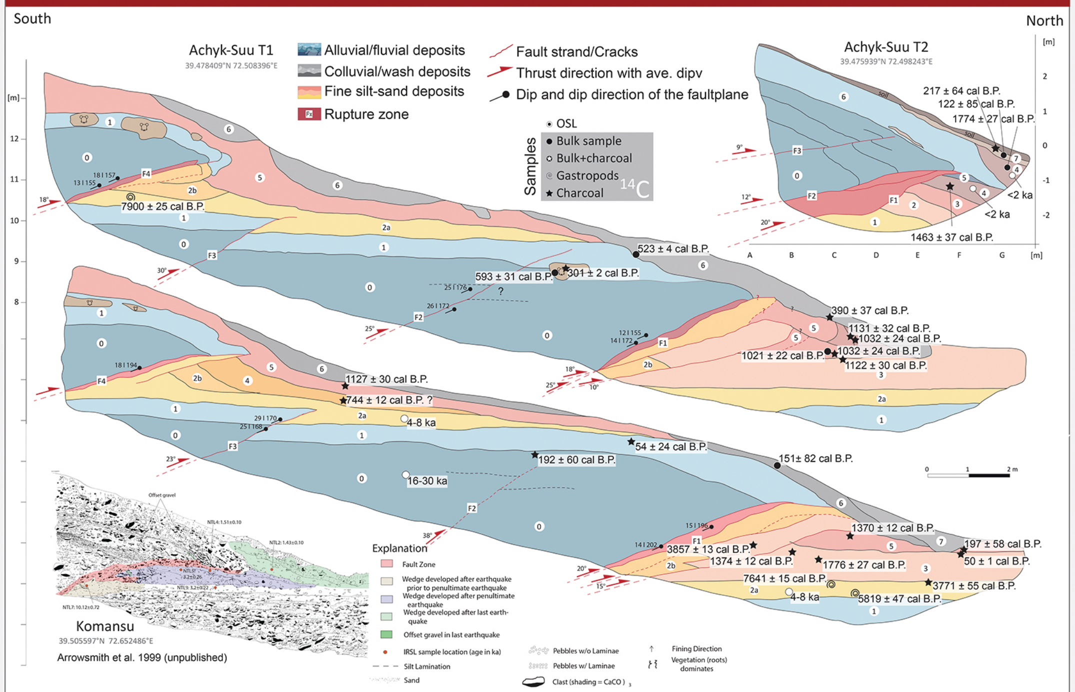

Figure 5. Trench logs of three excavations along the central segment of the PFT. From top: left: west wall and reflected east wall of trench 1 (T1); reflected east wall of trench 2 (T2) (Achyk-Suu Site, this study); west wall of Komansu trench ~15km further east on the central PFT segment from Arrowsmith et al. (1999) (unpublished). All trenches show fluvial deposits upthrusting over finer silty-sand deposits. T1 and T2 indicate evidence for at least one earthquake that ruptured across both trench sites (1 km apart). Assuming extended fault length rupture we suggest similar event chronology as at the Komansu trench.

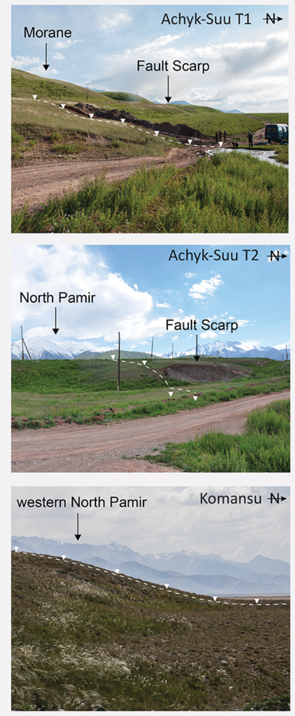

Figure 6. Overview photographs of the trenching sites

4 Results from the Achyk-Suu Excavations

Evidence for multiple paleoearthquakes including at least two surface-rupturing paleoevents.

- scarp heights of 5-10 m
- an alternation between hanging-wall collapse scarp and?
- multiple fault zones in two trenches: trench T1 = 2 main fault zones and at least 2 single rupture strands in between; trench T2 = 1 main fault zone and 1 single rupture strand out of the fault zone

Stratigraphic interpretation of identified event horizons and applied geochronology (14C and OSL) allows us to distinguish

- probable simultaneous co-seismic activity along multiple fault strands
- varying dip-slips between 0.4 and 2.0 m resulting in probabilistic paleomagnitudes of M6.0 to 7.0
- cumulative Holocene dip-slip rates at 3.4 - 6.8 mm/yr
- MRE in T1 at <1.0 ka, PE consistent in all three trenches, at <1.3 ka resulting in a rupture length of ~15 km along the central segment of the PFT
- at least one more seismic event before <4.0 ka

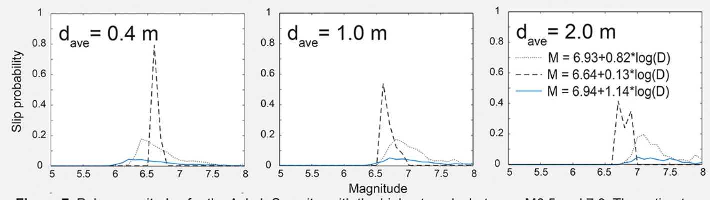

Figure 7. Paleomagnitudes for the Achyk-Suu site, with the highest peaks between M6.5 and 7.0. The estimates are based on individual average displacements d_{ave} following Biasi and Weldon (2006) and Wells and Coppersmith (1994).

CONCLUSIONS

- The PFT is seismically active with a complex history of several faulting events and co-seismic folding
- Historic earthquakes produced dip-slip events with limited vertical offsets, corresponding to magnitude ~M6 - 7 events. However, the complexity of the setting suggests that greater-magnitude events cannot be ruled out
- New Holocene slip rates decrease uncertainty over prior reported values, however still underestimate geodetically derived shortening rates by a factor of 2-3

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Acknowledgments

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