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ACTIVE TECTONICS OF WESTERN TURKMENISTAN; IMPLICATIONS FOR THE ONSET OF SOUTH CASPIAN SUBDUCTION

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ABSTRACT

The Kopeh Dagh and Balkan mountain ranges of West Turkmenistan are actively deforming as a result of Arabia-Eurasia collision. Between 55-57.5°E, partitioned (north-vergent) thrust and right-lateral strike-slip fault segments comprise the Ashkabad fault zone. Reconstruction of displaced geology indicates 35 km total right-lateral motion across this fault zone. The Balkan region lies along-strike of the Ashkabad fault zone, west of 55°E. Fault plane solutions indicate shortening is partitioned onto the Balkan thrust and right-lateral Kum Dagh fault zones. Thrust earthquakes are relatively deep (30-45 km) and lie along a north-dipping plane which extends ~40 km north beneath the south-vergent Balkan anticline. Recent uplift is also indicated by extensional faults which displace Quaternary geomorphology along the range crest. South of the Balkan range, right-lateral shear occurs across the Kum-Dagh fault zone, which is expressed as a series of right-stepping anticlines (affecting Pliocene Red Series and younger sediments), forming important traps for hydrocarbons. The unstable geometry of north-vergent thrusting east of 55°E and south-vergent thrusting west of 55°E has resulted in the right-lateral Kum Dagh and Ashkabad fault zones becoming offset by ~40 km. Resolving estimates for South Caspian-Eurasia motion onto thrust and strike-slip components indicates a NNE-shortening rate of 4-6 mm/yr and right-lateral slip-rate of 5-7 mm/yr across the Balkan region. If the Kum Dagh-Ashkabad right-lateral shear zone becomes offset at the rate of shortening across the Balkan thrust, ~40 km offset would be accommodated in 6-11 Ma, suggesting the present-day kinematics of the region, and the onset of South Caspian subduction beneath Eurasia, may be older than previously thought (>5.5 Ma).

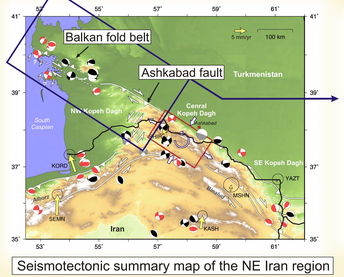
INTRODUCTION

1

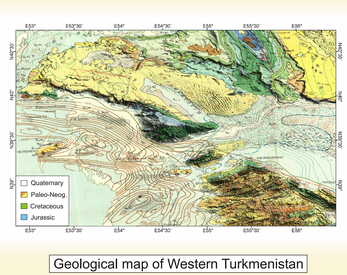
• We combine remote observations of the geomorphology and geology, with published GPS velocities and seismicity, to identify major active faults in Western Turkmenistan.

• The NNW-motion of the South Caspian-NW Kopeh Dagh block, relative to Eurasia, is accommodated across the NW-SE Ashkabad fault zone, and Balkan fold-and-thrust belt.

• This work investigates exactly how this motion is accommodated by active faults at the Earth's surface, as well as the implications the Balkan and Ashkabad regions pose to the regional tectonic evolution.



Seismotectonic summary map of the NE Iran region



Geological map of Western Turkmenistan

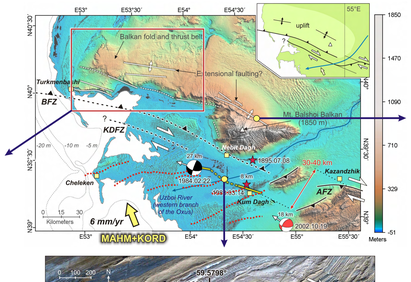
BALKAN ANTICLINE

3

• The Ashkabad fault system forms the northern margin of the Kopeh Dagh, west of 57°E.

• NW shortening across the system is partitioned onto right-lateral strike slip and parallel thrust fault segments.

Summary seismotectonic map of the Balkan fold-and-thrust belt

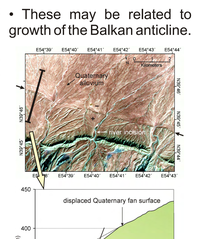


S-vergent Neogene fold; normal faults on crest

Distributed right-lateral shear along the Kum Dagh fault

• Extensional features in the Quaternary geomorphology are visible along the crest of the Balkan anticline.

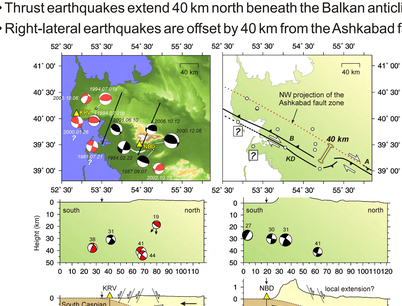
• These may be related to growth of the Balkan anticline.



Displaced Quaternary fans - extension along the fold crest?

• Thrust earthquakes extend 40 km north beneath the Balkan anticline.

• Right-lateral earthquakes are offset by 40 km from the Ashkabad fault.



• Thrust earthquakes lie on a N-dipping plane between 20-40 km depth, beneath the South-vergent Balkan fold-and-thrust belt.

ASHKABAD FAULT

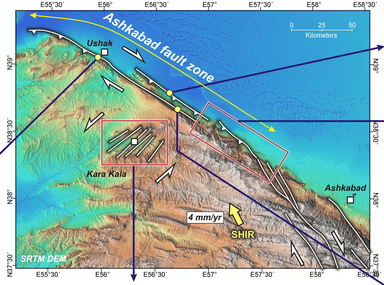
2

• The Ashkabad fault system forms the north margin of the Kopeh Dagh, west of 57°E.

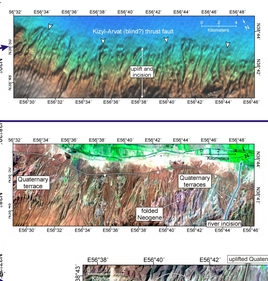
• NW shortening across the system is partitioned onto right-lateral strike slip and parallel thrust fault segments.

• NE-SW left-lateral faulting also occurs near Kara Kala accommodates alonAg-strike elongation of the Kopeh Dagh).

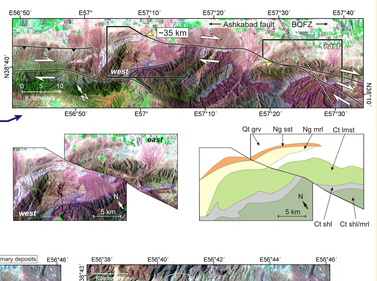
Summary tectonic map of the Ashkabad fault zone

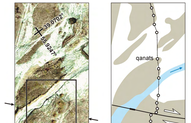


Uplifted Quaternary deposits - thrusting

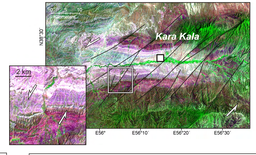


Ashkabad fault reconstruction; 35 km total right-lateral slip



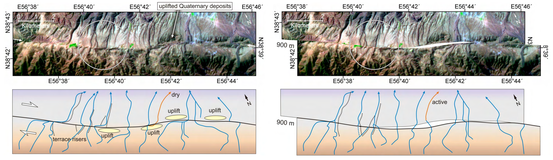


Recent right-lateral slip at Ushak



Satellite image of the left-lateral Karak Kala fault system

• The GPS velocity of station SHIR indicates 4 mm/yr NW-directed shortening, relative to Eurasia, which must be accommodated across the Ashkabad fault system (see Discussion).



Right-lateral displaced geomorphology - reconstruction of Quaternary fans indicates 900 m displacement

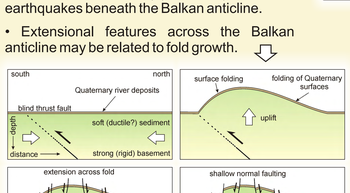
DISCUSSION

4

• The NW motion of the South Caspian-NW Kopeh Dagh block, relative to Eurasia, is accommodated by partitioned right-lateral strike-slip and thrust faults in the Ashkabad and Balkan-Kum Dagh fault zones.

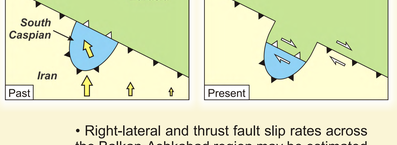
• The change in polarity of thrusting (S-vergent in the Balkan region, N-vergent in the Ashkabad region) results in the 40 km offset of the right-lateral Kum Dagh-Ashkabad fault zone, and the northward extension (by 40 km) of thrust earthquakes beneath the Balkan anticline.

• Extensional features across the Balkan anticline may be related to fold growth.

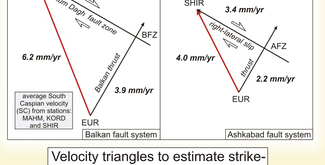


Model showing how extensional faults may form in the crest of the Balkan fold -and-thrust belt.

Due to the changing polarity of thrust motion, the Caucasus-Apsheron-Kopeh Dagh zone (initially linear) will gradually become offset with time



• Right-lateral and thrust fault slip rates across the Balkan-Ashkabad region may be estimated from published GPS velocities.

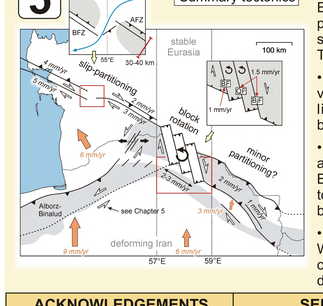


Velocity triangles to estimate strike-slip and thrust fault slip rates

CONCLUSIONS

5

Summary tectonics



• The NW motion (~6 mm/yr) of the South Caspian block, relative to Eurasia, is accommodated by partitioning onto right-lateral strike-slip and thrust faults in Western Turkmenistan.

• The change in polarity of thrust vergence has resulted in the once-linear Balkan-Ashkabad zone becoming offset by ~40 km.

• At present day rates of shortening and strike-slip, the tectonics of the Balkan-Ashkabad region, and the total slip on the Ashkabad fault may be accommodated in 6-11 Ma.

• Present day kinematics of the West Turkmenistan, and the onset of South Caspian subduction, may date from ~6-11 Ma.

ACKNOWLEDGEMENTS

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SELECTED REFERENCES

Hollingsworth, J., Jackson, J., Walker, R., Gheitanchi, M., & Bolourchi, M., 2006. Strike-slip faulting, rotation, and along strike elongation in the Kopeh Dagh mountains, NE Iran. Geophysical Journal International, 166, 1161–1177.

Jackson, J., Priestley, K., Allen, M., & Berberian, M., 2002. Active tectonics of the South Caspian Basin, Geophysical Journal International, 148, 214–245.

Masson, F., Anvari, M., Djamour, Y., Walpersdorf, A., Tavakoli, F., Daigni`eres, M., Nankali, H., and van Gorp, S. (2007). Large-scale velocity field and strain tensor in Iran inferred from GPS measurements: new insight for the present-day deformation pattern within NE Iran. Geophysical Journal International, 170, 436440.

Raven, K. (2005). The nature of 'oceanic' basins trapped within the Alpine-Himalayan Belt, and their relationship to Tethys. Ph.D. thesis, University of Cambridge.

Ritz, J.-F., Nazari, H., Ghassemi, A., Salamati, R., Shafei, A., Solaymani, S., and Vernant, P. (2006). Active transtension inside central Alborz: A new insight into northern Iran-southern Caspian geodynamics. Geology, 34(6),477480.

Trifonov, V. (1978). Late Quaternary Tectonic Movement of Western and Central Asia. Geological Society of America Bulletin, 89, 10591072.