Tectonic geomorphology of the Tuzgölü fault zone: combining morphometrics and structural geology to assess changes in deformation rate and pattern over time

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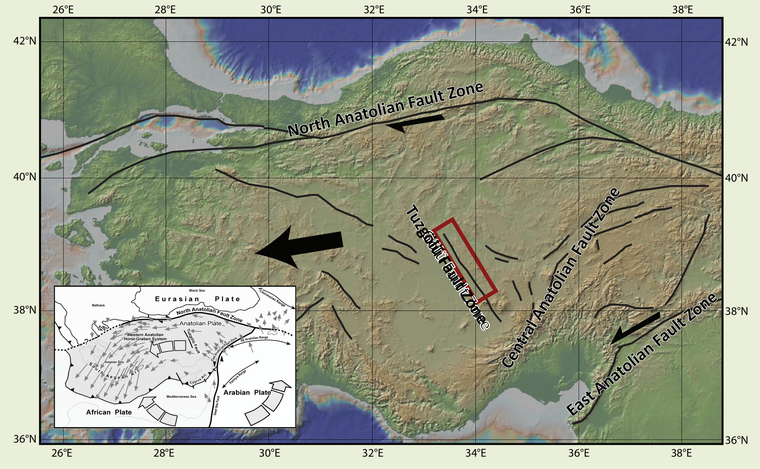
Introduction

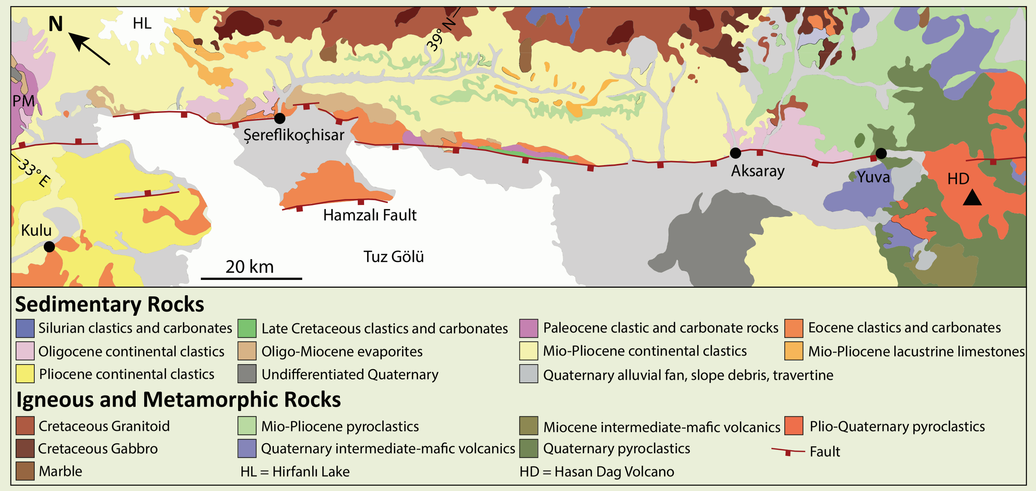
Situated within the interior of the Central Anatolian Plateau (CAP), the 200 km-long Tuzgölü fault zone offers first-order constraints on the timing and pattern of regional deformation and uplift. In this study, we utilize morphometric analysis of 92 catchments along the Tuzgölü range-front and the parallel, basinward Hamzalı fault, measuring mountain front sinuosity, basin asymmetry, basin elongation, basin-fault azimuth, hypsometry, river steepness, and knickpoint location, coupled with regional geomorphic observations and longitudinal profile analysis. In addition, we use field and remote mapping to constrain the geometry of two key marker beds, a Mio-Pliocene ignimbrite (5.02 ± 0.2 Ma; Özsayin et al., 2013) and the Pliocene Kışladağ limestone (~3.7 Ma; Meijers et al., 2019), in order to investigate deformation in the footwall of the Tuzgölü fault zone.



Tuzgölü fault zone

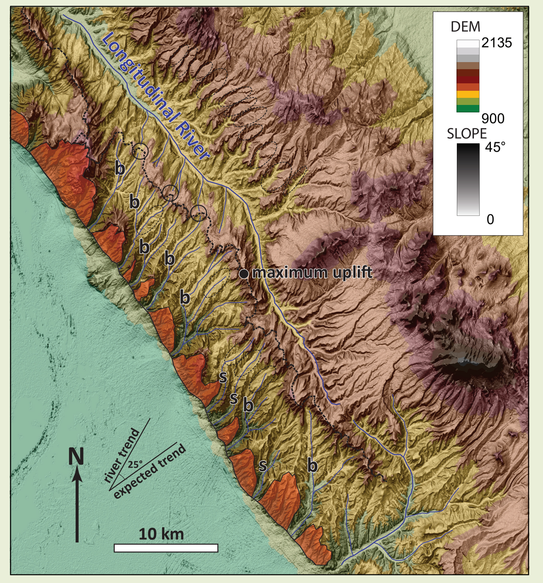
This Tuzgölü fault formed as early as the Late Maastrichtian (Özsayin et al., 2013), and was reactivated as a strike-slip fault in the Eocene (Çemen et al., 1999) and under compression in the Late Miocene to Early Pliocene (Fernandez-Blanco et al., 2013); it is currently dominated by extension, with a possible right-slip component (Özsayin et al., 2013). The southern end of the Tuzgölü fault crosses and interacts with the Central Anatolian Volcanic Province, slicing through the northeast edge of the Hasan Dag volcano (Dhont et al., 1998).

Because the potential drivers of deformation in Anatolia are interacting complexly and evolving over time, it is not surprising that The Tuzgölü fault zone has experienced profound kinematic changes over the course of its history.



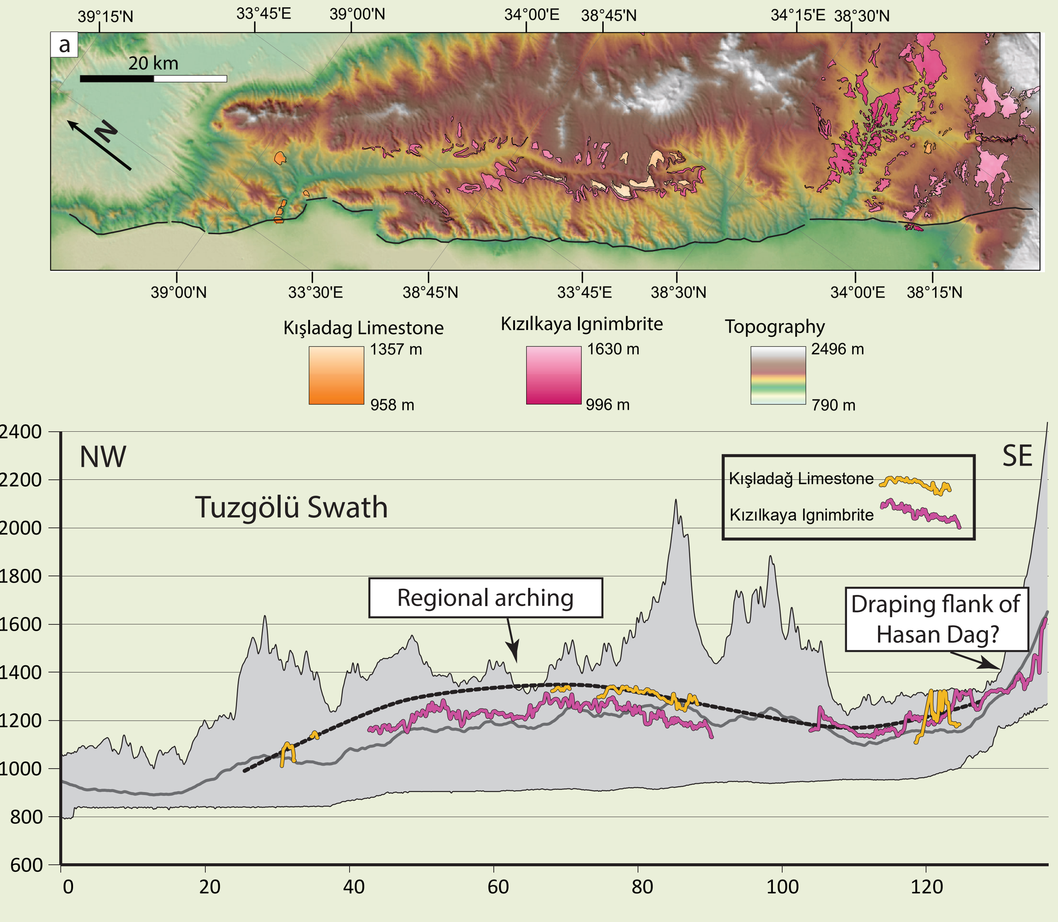
Regional Geomorphology - Northward Tilting

There is consistent evidence for north or northwest tilting in the footwall of the Tuzgölü fault. Larger rivers that reach the divide are oriented ~25° CCW with respect to the range front and are frequently s-shaped or branching. This pattern could be explained by northwest tilting; if the outlets are fixed, the headwaters of a catchment may drift in the direction of down-tilting. Asymmetric erosion patterns, with shorter, more deeply dissected south-southeast facing slopes suggests north or northwest tilting. Basin Asymmetry Factor (AF) is dominated by catchments with greater areas to the southeast of the trunk stream, suggesting rivers are migrating laterally to the northwest. There is a tendency toward a counterclockwise orientation of catchments along the Tuzgölü fault (Acf). The similarity of AF and Acf along the Tuzgölü and Hamzalı faults suggests regional tilting affecting both the footwall and hanging wall of the Tuzgölü fault zone.



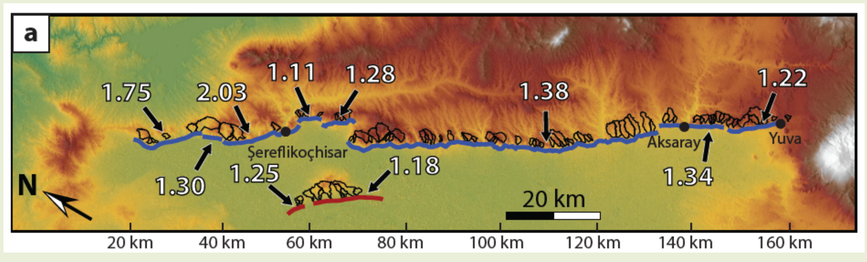
Deformation of Marker Beds - post 3.7 Ma Displacement

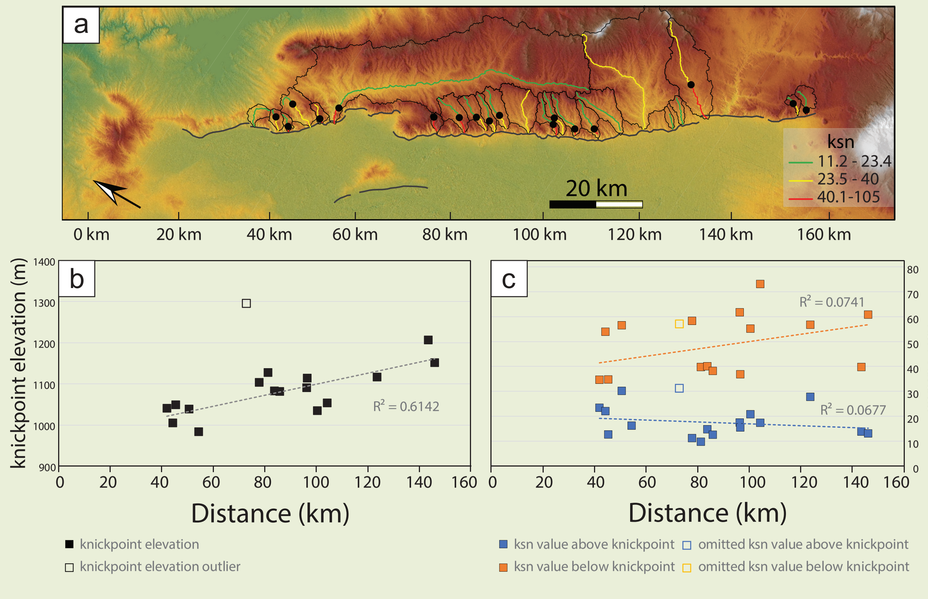
We use the Kışladağ limestone (~3.7 Ma; Meijers et al., 2019) and Kızılkaya ignimbrite (5.02 ± 0.2 Ma; Özsayin et al., 2013) as markers for regional deformation. Although the ignimbrite could drape existing topography, we find close agreement in deformation between both units, suggesting regional deformation since 3.7 Ma. Thus, the Tuzgölü fault was likely reactivated after 3.7 Ma and experienced displacement with a maximum of ~300 m footwall uplift in the center of the fault. Increase in elevation of the marker beds to the southeast could reflect a later phase of deformation or interaction with the Hasan Dag volcano.

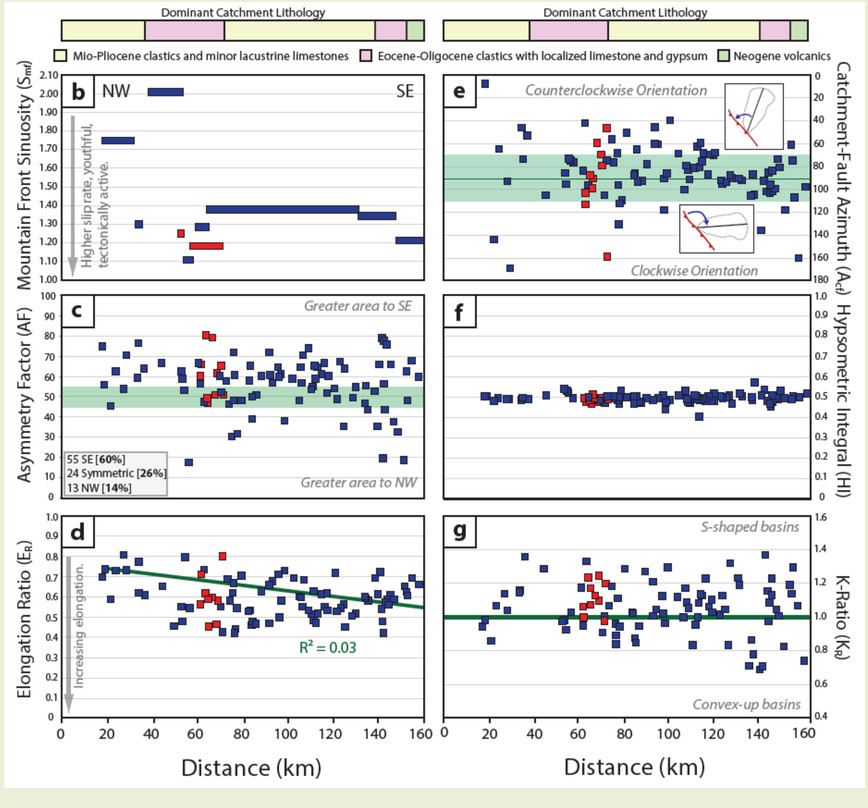


Morphometrics and River Profiles - Shift to Higher Uplift to the Southeast

Catchment morphometrics and river profile analysis indicate a change from earlier displacement focused on the center of the fault to higher uplift rate to the southwest. Smf decreases to the southeast, implying higher uplift rates or possibly propagation towards the Hasan Dag volcano. Elongation Ratio (ER) records catchments that are more elongated towards the southeast, indicating higher uplift rate or fault propagation. While Hypsometric Integral (HI) is insensitive to along-strike changes, minimum K-Ratio (KR) values decrease to the southeast, indicating less-adjusted catchments that formed more recently or are experiencing higher uplift rates. River steepness clearly reflects this change, with an increase in ksn to the southeast suggesting higher uplift rate. Finally, knickpoint elevation may increase to the southeast as well, although this increase could partially be explained by a change in base level. If the increase in knickpoint elevation does reflect tectonics, it could indicate an earlier onset of the change in uplift rate or a higher rate of uplift towards the Hasan Dag volcano.







Conclusions

- Deformation of the marker beds indicates greatest cumulative displacement along the central part of the fault zone, suggesting Late Miocene to Early Pliocene extensional reactivation of the Tuzgölü fault with a typical fault displacement profile.
- A change in deformation pattern is marked by transient knickpoints along river channels; morphometric indicators sensitive to shorter timescales, including river steepness, basin elongation, K-ratio, and mountain front sinuosity indicate an overall southeastward increase in footwall uplift rate of the Tuzgölü fault zone which could reflect block rotation or interaction with the Quaternary Hasan Dag volcano.
- Basin asymmetry and basin-fault azimuth measurements indicate north-northwest tilting of footwall catchments, which may be linked to regional tilting across the CAP interior.
- Our data suggest the influence of multiple sources of deformation and varying behaviors along the length of the Tuzgölü fault zone, likely due to the interference of crustal and lithospheric-scale processes, such as rotation of crustal blocks, extrusion of the Anatolian microplate, crustal heating due to the presence of the Central Anatolian Volcanic Province (CAVP), gravitational collapse associated with plateau uplift, and mantle-driven vertical displacements.

References

Çemen, I., Göncüoglu, M. C., and Dirik, K., 1999, Structural evolution of the Tuzgölü basin in Central Anatolia, Turkey: The Journal of Geology, v. 107(6), p. 693-706, doi:10.1086/314379.

Dhont, D., Chorowicz, J., Yürür, T., Froger, J. L., Köse, O., and Gündogdu, N., 1998, Emplacement of volcanic vents and geodynamics of Central Anatolia, Turkey: Journal of Volcanology and Geothermal Research, v. 85(1), p. 33-54, doi:10.1016/S0377-0273(98)00048-1.

Fernández-Blanco, D., Bertotti, G., and Çiner, T. A., 2013, Cenozoic tectonics of the Tuz Gölü Basin (Central Anatolian Plateau, Turkey): Turkish Journal of Earth Sciences, v. 22(5), p. 715-738, doi:10.3906/yer-1210-5.

McClusky, S. et al., 2000, Global Positioning System Constraints On Plate Kinematics and Dynamics in The Eastern Mediterranean and Caucaus, Journal of Geophysical Research, 105:83, 5695-5719.

Meijers, M.J.M., Brocard, G.Y., Whitney, D., and Mulch, A., 2019, Paleoenvironmental conditions and drainage evolution of the central Anatolian lake system (Turkey) during late Miocene to Pliocene surface uplift: Geosphere.

Özsayın, E., Çiner, A., Rojay, B., Dirik, K., Melnick, D., Fernández-Blanco, D., Bertotti, G., Schildgen, T.F., Garcin, Y., Strecker, M.R., and Sudo, M., 2013, Plio-Quaternary extensional tectonics of the Central Anatolian Plateau: a case study from the Tuz Gölü Basin, Turkey: Turkish Journal of Earth Sciences, v. 22, p. 691-714,