Plio-Quaternary Wind Erosion in the Qaidam Basin, Central Asia: Records, Rates, and Broader Implications

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Liquid water and ice are the dominant agents of erosion and sediment transport in most actively growing mountain belts. An exception is in the western Qaidam Basin along the northeastern margin of the Tibetan Plateau. Here, northwesterly to westerly winds and wind-blown sand have sculpted enormous fields of mega-yardangs, with up to 60 m of relief, in actively folding sedimentary strata (Figure 1). Located downwind of the Qaidam Basin is the Loess Plateau, one of the most voluminous and best exposed accumulations of Plio-Quaternary loess on Earth. Here, loess accumulation occurred primarily during glacial and stadial periods when climatic conditions were colder and drier in central Asia and alternated with episodes of paleosol development during wetter interglacial and interstadial periods (e.g., Porter, 2007).

Figure 1. Mega-yardangs with up to 60 m of relief sculpted into mainly lacustrine, Pleistocene strata within the west-central Qaidam Basin.

We speculate that the Qaidam Basin experienced alternating episodes of sediment accumulation and wind erosion in phase with Loess Plateau paleosol development and loess accumulation, respectively. A supporting preliminary investigation of Plio-Pleistocene basin fill in the west-central Qaidam Basin shows that lacustrine sedimentation was punctuated by periodic episodes of sub-aerial exposure and wind erosion. The latter is evidenced by the presence of salt paleosols/crusts, deflation lag deposits, wind-storm deposits, paleopans filled with lacustrine and/or eolian deposits, and paleoyardangs separating meter-scale lacustrine parasequences. Except for perhaps along the crests of large anticlines, which parallel topographic highs in the basin, sediment accumulation during periods of lacustrine deposition must have exceeded the thickness of material removed when wind erosion was active in order to lead to the observed, positive net Plio-Pleistocene sediment accumulation in the region. The ongoing folding in the Qaidam Basin coupled with the most recent episode of severe wind erosion led to the preservation and exposure of this stratigraphic record of episodic wind erosion.

Rates of wind erosion have not been quantified in the Qaidam Basin, but must be significant. The modern Qaidam yardangs must have developed since the basin was largely occupied by lakes ~200,000 years ago

(Mischke and others, 2006) and possibly as recently as ~25,000 years ago. The development of mega-yardangs with 50 m of relief since these times yields time-averaged erosion rates in the 0.25-2.0 mm/yr range in the troughs between the yardangs, assuming an initial flat surface into which the yardangs were sculpted. Time-averaged erosion rates can also be estimated over a longer time scale. Seismic-reflection profiles show that sediment accumulation was continuous across the entire Qaidam Basin until ~2.8 Ma, when fold growth accelerated based on growth strata (Zhou and others, 2006). This suggests that the erosion of Qaidam Basin folds has occurred since 2.8 Ma. Geometric constraints provided by published regional cross sections and our own, more local cross sections show that hundreds of meters to thousands of meters of strata have been eroded from above the Qaidam Basin folds since 2.8 Ma. Given stratigraphic evidence for closed-basin conditions since 2.8 Ma, this material could only have been removed from the basin by wind. We estimate that the average erosion rate across the sandblasted part of the Qaidam Basin is ~0.29 mm/yr, with localized erosion hotspots above the crests of large anticlines (~1.4 mm/yr). These estimates are minima for when wind erosion was active, as they are averaged over a time interval when erosion was not continuously active (excluding perhaps along the crests of the largest anticlines) but alternated with episodes of sediment accumulation.

Our estimates of wind-erosion rates are comparable to rates of fluvial and glacial erosion in tectonically-active mountain ranges, and at least locally above anticline crests, comparable to those in other orogens where positive tectonic-climate feedback relationships have been suggested. The possibility that wind erosion may have exerted a positive feedback relationship with fold growth in the Qaidam Basin is intriguing. An observation supporting this hypothesis is the presumably not coincidental, coeval acceleration of wind erosion in central Asia (based on the Loess Plateau record) and fold growth in the Qaidam Basin (based on imaged/mapped growth strata) at 2.8-2.5 Ma.

The Qaidam Basin is presently not thought to be a major source of Loess Plateau deposits, despite its proximity, upwind geographic position, and vast exposure of wind-eroded landforms. Rather, and strongly influencing popular thinking, in the modern climatic conditions the Gobi and adjacent sand deserts are the locus of major northwesterly wind storms that transport dust over the Loess Plateau. In the modern winter-to-spring climate, the main axis of the polar jet stream is located over the Gobi region- the locus of modern dust storms. During glacial and stadial periods, global climate models suggest that the main axes of the high-level westerlies in both hemispheres shift ≥10° in latitude toward the equator (e.g., Toggweiler and Russell, 2008). This places the main axis of the jet stream directly over the Qaidam Basin during glacial and stadial periods, when wind erosion was most severe. A corollary of this hypothesis is that the strong winds that produced the exposed Qaidam yardangs are not active during the modern interglacial climate. This is consistent with the relative scarcity of major, documented dust storms in the Qaidam and our observations that in many places, the Qaidam yardangs are armored with a decimeter-scale-thick crust/soil of strongly indurated salt, indicating landform stability. A testable prediction is that the provenance of Loess Plateau deposits should shift back-and-forth between the Gobi Desert and Qaidam regions, with the bulk of the accumulated loess being sourced from the Qaidam during glacial and stadial episodes.

References

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