YARDANGS AND DOME DUNES NORTHEAST OF TAVAN HAR, GOBI, MONGOLIA

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INTRODUCTION

A variety of eolian landforms, including dome and longitudinal dunes, yardangs, and coppice dunes, characterize a 5-km^2 area in a region of the Gobi where dunes and yardangs are otherwise uncommon. Yardangs are wind-eroded, aerodynamic hills that form under conditions of strong unidirectional winds or seasonally opposite winds with one stronger than the other. Longitudinal dunes typically represent obtusely bimodal or unimodal wind directions and form parallel to the prevailing wind direction. Dome dunes, however, are small dunes without slipfaces that form under variable winds. Although yardangs and dome dunes form from different wind patterns, in this region of the Gobi they do not exist independently of each other.

The purposes of this study are: to determine prevailing wind directions based on yardang and longitudinal dune orientations and dome dune bedding; to analyze yardang proportions and erosional processes affecting shape and distribution; to determine the relationship

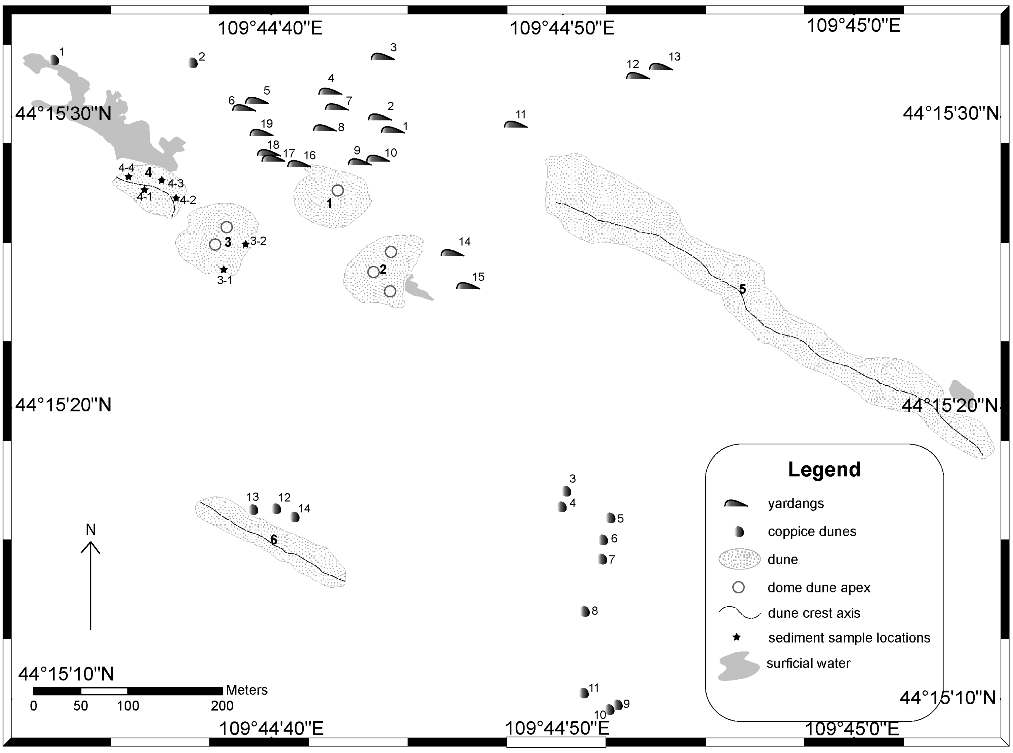

Figure 1. Map made with Trimble GeoXT of landforms in study area. Modified from map by Karl Wegmann.

between the yardangs and dome dunes; and to determine the source area for dune sands.

METHODS

We used a Trimble GeoXT GPS receiver with ESRI ArcPad software to map the landforms in this area with accuracy of less than one meter. Both the Trimble and an altimeter were used to record elevations of the landforms. We used an inclinometer to measure yardang and dune slopes and a tape measure for yardang and coppice dune dimensions. We dug six pits in two of the dome dunes for sediment sampling and to measure and describe the internal bedding of the dunes.

RESULTS

Yardangs

Dozens of yardangs are distributed along the northern edge of the study area amongst a group of dome dunes (figure 2). They are eroded from Upper Cretaceous weakly consolidated sandstone and mudstone. Many have a steep northwest side with a moat, relatively steep northeast and southwest sides, and a gently sloping southeast side, but there is significant variation in shape and slopes. Of 19 yardangs studied, sizes range from 3.85 m long and 0.74 m high to 10.9 m long and 3 m high. The maximum length-to-width ratio of the yardangs is 3.6:1, the minimum is 0.73:1, and the mean is 1.8:1. This average is significantly lower than the "ideal" aerodynamic yardang shape, which is 3 or 4 to 1 (Grolier et al. 1980; Ward and Greeley 1984). This may be a factor of yardang maturity, variation in the cross-bedded sands, or fluvial erosion. The long axes range from 270 to 020 (upwind azimuths), but the average indicates prevailing winds from about 310 (figure 3).

Laity (1994) outlines abrasion, deflation, fluvial erosion, and mass wasting as important processes in yardang development. Abrasion, or sand-blasting, of the yardangs in this area is likely given the abundance of sand in the surrounding dunes. There are no yardangs outside of the dune area, which implies a direct relationship between the two landforms. Abrasion is the primary process that leads to a steep, or even undercut, upwind face. Many of the yardangs in the study area have vertical and overhanging upwind faces, although some have very gently sloping upwind sides, which may be a result of the structural variation in the weakly consolidated rock.

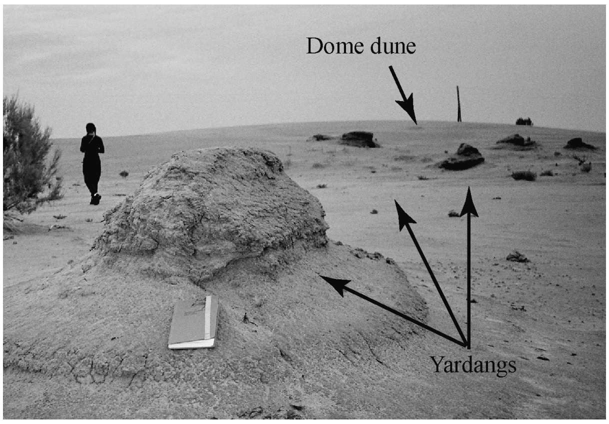

Figure 2. Yardangs and dome dune 1 (figure 1), looking south.

The importance of deflation as a process contributing to yardang formation depends on yardang lithology, but no research has definitely verified deflation as a process impacting yardangs (Laity 1994). Deflation likely contributes as an erosional force in this area, carrying away fine sand and silt from the yardangs. One yardang has a tree growing atop it with exposed roots indicating at least 67 cm of deflation. Deflation in the areas between yardangs is clearly seen in root exposures up to 70 cm above the current ground surface. The average deflation distance measured from seven trees among the yardangs is 43.8 cm.

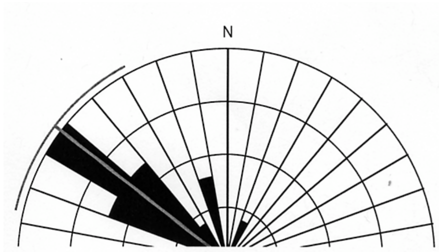

Figure 3. Rose diagram of yardang orientations indicating wind from the northwest.

Water can be another important process impacting yardang formation. While yardangs only form in places where wind is the dominant erosional force, the lack of vegetation in deserts can contribute to significant fluvial erosion during occasional rainstorms. In the Gobi study area, gullies may have contributed to some of the yardang initiation, but some of the yardangs are situated near the top of a gentle slope where the impact of runoff is minimal.

Mass wasting has yet to be studied by other researchers as a process involved in yardang formation, but it clearly was prevalent amongst the yardangs in this study area. Failure may be along joints or as a result of undercutting by wind or water erosion. Slump blocks were found on all different sides of at least four yardangs. The size of mass wasted blocks ranged from very small clods to 20% of a yardang's entire volume.

Due to the variable cross-bedded sands from which the yardangs are eroded and perhaps in part due to localized changes in wind direction and velocity, some of the yardangs have very strange and grotesque shapes, and are more accurately called demoiselles.

Dome Dunes

Dome dunes are rare features that have not been studied much. In this study area the presence of dome dunes, which require variable winds, along with yardangs, which require unidirectional winds, is very perplexing. McKee (1982) notes in his study of a dome dune in the Namib Desert of southwest Africa that dome dunes, when found among other types of dunes, probably occur in areas of locally variable winds. Our team measured and described four dome dunes (figure 1), and dug pits around dunes 3 and 4. The dunes ranged in height from 2.3 to 5.9 meters. The slopes of the dune sides ranged from 2.3˚ to 12.5˚. Dune 2 had three humps, 3 had two humps, and 4 had a unique barchan-like shape, indicating that these are slightly more complex than singular dome dunes. Perhaps they are coalesced dome dunes, or they may be transitioning to another kind of dune. Evidence that the dunes are migrating, despite the absence of slipfaces, is obvious in dune 1, which has buried at least two meters of an electric pole.

Pits dug on all sides of dune 4 show beds dipping out from the dune center in all directions, indicating winds from various directions. Most of these beds, with true dips between 10˚ and 25˚ do not represent slipfaces. Beds that dip between 8˚ and 14˚ in a dome dune usually represent the upwind side of the dune, whereas beds dipping above 20˚ indicate the downwind side (Reineck and Singh 1980). Beds in pits 4-4 and 4-3 had dips of 10 and 11˚, which indicates an upwind side in the same direction as the upwind faces of the yardangs. Pit 3-2 contained beds dipping at 25˚, indicating that the southeast side of the dune is downwind. In all of the pits, the beds within the dune dip in the same direction as the surface slopes.

Longitudinal Dunes

During the first part of field work, there was a series of long, parallel, slipfaceless dunes extending across the study area. These dunes are oriented in the same northwest-southeast direction as the yardangs. After a severe wind storm, these dunes developed slipfaces similar to those on transverse dunes and barchans (figure 4). The slipfaces developed on the northeast side of the longitudinal dunes, and semi-consolidated beds representing previous slipfaces dipping both to the southwest and northeast were exposed on the southwest side. The presence of beds dipping away from the dune crest in both directions verifies that these are longitudinal dunes.

Figure 4. Longitudinal dune 5 (figure 1) with new slipface after storm (left) and semi-consolidated beds (right) dipping in same direction to the northeast.

There is also a series of parallel, semi-consolidated, eroding longitudinal dunes (figure 5). These dunes are oriented along the same axis as the yardangs and active longitudinal dunes. They are only 1 to 1.5 meters high, and about 70% of the dune area is covered with a thin veneer of non-consolidated, rippled sand. Erosion of these dunes is essentially forming dune yardangs;

although the dune orientation already aligns with the prevailing wind direction, the dunes are steeper on the upwind side than the downwind.

Figure 5. Eroding, semi-consolidated longitudinal dune.

Coppice Dunes

When vegetation traps eolian sand, a positive-feedback landform known as a coppice dune may begin to form (figure 6). These dunes range from small bumps of less than a meter high to 10 meters tall, and are often streamlined according to the prevailing wind direction. Coppice dunes form where there is sparse vegetation and usually contain cross-beds dipping at or near the angle of repose (McKee 1982).

Figure 6. Coppice dune with low-growing shrub.

In the study area, coppice dunes are distributed among the yardangs and in the areas surrounding the dome and longitudinal dunes. The coppice dunes tend to concentrate in arroyos, possibly because there is more moisture in these areas, which allows for more vegetation. We measured and mapped 13 of these dunes and noticed no obvious streamlining of their shapes. The maximum length-to-width ratio is 1.48:1 and the average is 1.18:1, or essentially equidimensional. The dunes have formed under a variety of plants, including low-growing shrubs and tamarisk trees. Vegetation density varies greatly but does not seem to impact dune size. Some of the dunes are semi-consolidated, and some of these are now undergoing eolian erosion on the sides, resulting in exposure of cross-bedded sands and buried branches.

DISCUSSION

The prevailing winds in Mongolia come from the southwest as part of the prevailing westerlies, yet all of the landforms in the study area indicate a prevailing northwest wind. There are two possibilities for this variation. One is that the Tavar Har mountains to the southwest of the study area act as a barrier to wind and redirect wind flow such that it bends around and hits this area from the northwest. Another possible explanation is that the winds vary seasonally, along with moisture levels and temperatures, and that the combination of wind strength, direction, temperatures, and moisture levels renders one of these winds more effective in yardang erosion and in sand transport on the longitudinal dunes.

The northwest winds in this area suggest that an extensive area of Quaternary sediment to the northwest may be the source area for dune sands. The absence of dunes and yardangs in surrounding areas indicates that there is a direct relationship between these two landforms, but the nature of this interdependence remains unclear.

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