SLOPE INSTABILITY IN THE EASTERN KHARKHIRAA UUL, MONGOLIAN ALTAI

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INTRODUCTION

This study is located in the northwest corner of Mongolia, in the foothills and mountains of the eastern Kharkhiraa, Uul. The region is characterized by a steppe climate with cold, dry winters and moist summers. The temperature can range from -30ºC in winter to 20ºC in the summer.

Many large-scale mass wasting events occur in early spring during rain on snow events and as the active layer thaws. The field area is very susceptible to climate change due to its transitional nature between basin and mountain topography, as well as steppe, desert, and continental boreal climates.

MASS WASTING

This region is subject to intense physical weathering by freeze-thaw activity, producing abundant talus that is incorporated into colluvium. The finer component of the colluvium is loess derived from deflating glacial outwash plains and most recently (late-Holocene) from dried out lacustrine surfaces (Grunert and Lehmkuhl, 2001). The colluvium moves downslope via an array of different types of mass wasting processes:

- Debris flows characterized by natural levees travel from steep slopes (~30°) to valley floors and are common at all elevations (Fig. 1). Many debris flows show multiple generations of movement superposed on one another.
- Slump-earth flows are common on gentle slopes at 2200-2400 m of elevation. They typically display multiple, concentric convex scarps. The slump shown in Figure 2 is of particular interest because it dramatically demonstrates the importance of vegetation to soil cohesion. Flow occurred faster in the subsurface than in the topsoil, creating collapse. The turf then slid downslope as a unit, creating tectonic like compressional and extensional features as it buckled. Failure occurred along no obvious soil horizon or planar weakness at a depth of ~30-40 cm. This suggests that the depth of the frozen/saturated soil contact may control the depth of failure as the active layer thaws.

Figure 1. A recent, very long debris flow that started in colluvium on a 35° slope above the Burgastai River.

- Solifluction lobes, which are transitional to earthflows, are also closely connected with freeze-thaw processes. The wide seasonal temperature variation greatly accelerates solifluction rates in thick accumulations of silty colluvium (Serebryanny and Gravis, 1993). Many old earthflows overgrown with vegetation have toes that are vertical to overhanging at their base, evidence that they are currently undergoing solifluction.

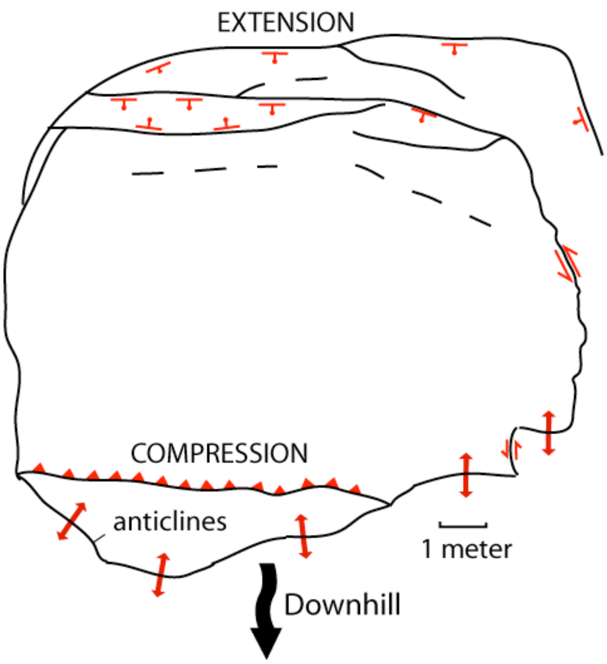

Figure 2. Slump-earthflow with miniature tectonic features.

Mass wasting processes also vary according to their position within a valley. On upper slopes talus partially mantles the bedrock. Middle slopes are characterized by earthflows, debris flows, and solifluction, often with terracettes. Lower slopes adjacent to downcutting streams are undergoing slumping and/or block topple as modern stream channels widen. These mass wasting processes supply sediment to the fluvial system.

STRATIGRAPHY

Stream cuts in several locations throughout the field area show alternating deposition of clastics (alluvium, colluvium, loess, and possible lacustrine sediment) and organics (soil and peat) over the last 2000 years (Fig. 3).

Figure 3. Photo of alternating clastics and organics just downstream of measured section 3 (see Figure 4).

Study and dating of stratigraphy was limited to one small tributary of Coal River. Radiocarbon dates of the organic-rich beds are internally consistent and indicate maximum and minimum dates of 1930 and 850 years BP, respectively (Fig. 4b). These dates constrain valley filling to sometime before 1930 yBP and incision to sometime after 850 yBP. However, incision may have occurred within the last several hundred years if the upper terrace does not represent an earlier cycle of cut and fill (Fig. 4a). The strata that display

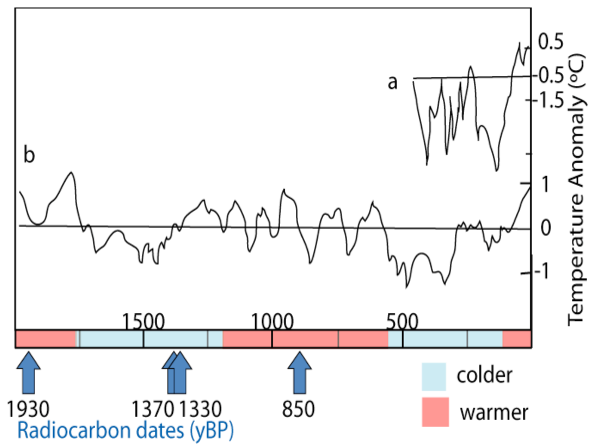

Figure 5. (a) Temperature reconstruction for central Mongolia based on tree rings (Jacoby et al., 1996), (b) Temperature reconstruction for China (Bao et al., 2002).

the greatest number and closest spacing of organic layers were dated to between ~1400 and 1300 yBP (Fig. 4b, column 1).

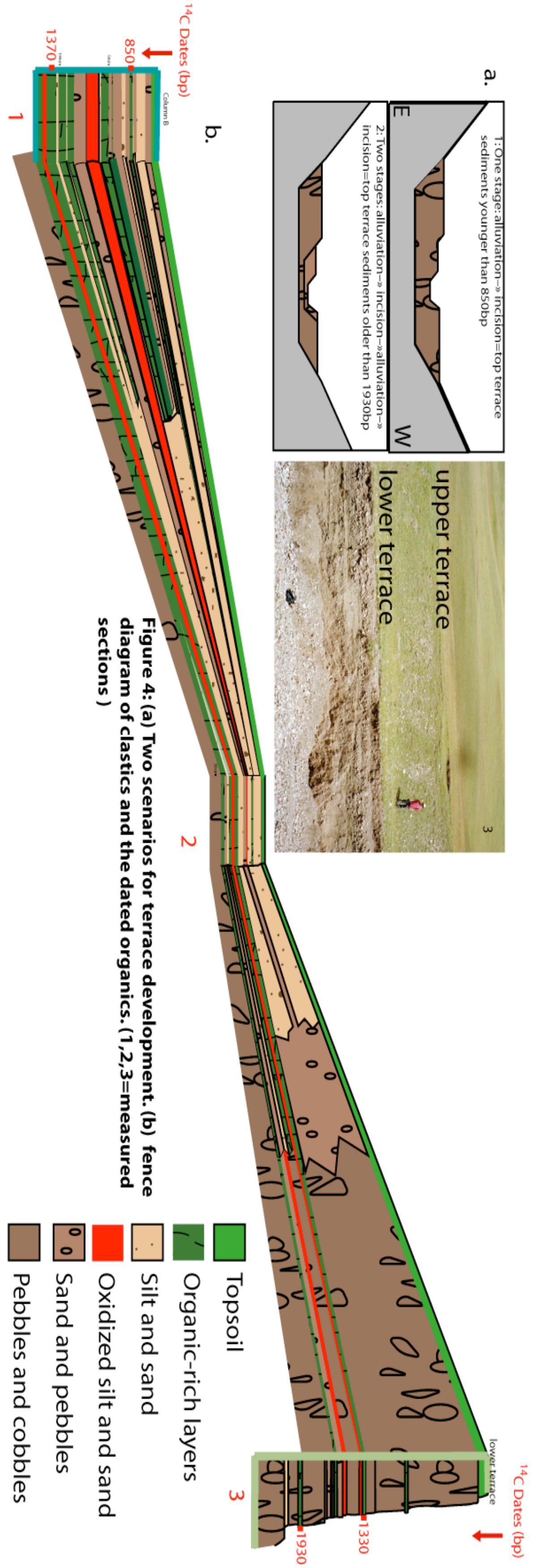

Figure 4: (a) Two scenarios for terrace development. (b) fence diagram of clastics and the dated organics. (1,2,3=measured sections)

PALEOCLIMATE

Temperature reconstructions for China show a warm stage between 2000-1760 yBP, a cold period between 1760-1200 yBP, a return to warmer temperatures from 1200-600 yBP, and finally a return to colder condition during the Little Ice Age between 600-100 yBP (Fig. 5a, Bao et al., 2002).

Temporal and spatial patterns of climate change specific to Mongolia are much more contentious. Grunert and Lehmkuhl (2000) interpret buried solifluction lobes to indicate more intense solifluction ~1500 years ago. Based on pollen analysis in Siberia, Serebryanny and Bravis (1993) inferred higher humidity since 2000 years ago. Pollen analysis from peat bogs of the Turgen-Kharkhirra area support this view (Grunert and Lehmkuhl, 2000). However, Pekala and Repelewska-Pekalowa (1993) state that that changing soil profiles indicate a tendency toward cooling and aridification.

DISCUSSION

The relationships between the observed stratigraphy and paleoclimate are unclear. Organic-rich horizons are dated to both warm and cool intervals (Fig. 4b). However, the concentration of organics at ~1300-1400 yBP suggests that they may be an indicator of cooler temperatures during this time. They may also correlate to enhanced solifluction activity dated at ~1500 yBP by Grunert and Lehmkuhl (2000). Many relict earthflows or solifluction lobes found on middle slopes may date to this period.

After ~1400 years ago, clastics increase relative to organics. This may correlate to a medieval warming period. Sometime after ~850 yBP, something triggers incision. This date agrees with work by Grunert and Lehmkuhl (2000) that shows an incision phase of rivers in the Uvs Nuur basin during the Little Ice Age.

An alternative explanation for the stratigraphy of the study area is anthropogenic impact. Such an interpretation has precedence in other studies of the region. For example, in Siberia overgrazing has been seen to provoke reactivation of slope processes even at long-stable localities (Serebryannny and Gravis, 1993). Pekala and Repelewska-Pekalowa (1993) argue that anthropogenic stress is a significant factor in the fossilization of many periglacial features in the Khangai and Khentai mountains of north-central Mongolia. Reactivation of dunes at the Uvs Nuur dunefield (located northeast of the field area) is also attributed to severe overgrazing (Grunert and Lehmkuhl, 2000).

Figure 6. A large herd grazing near location where peat was sampled.

The large population of livestock observed in the eastern Kharkhiraa is causing overgrazing (Fig. 6). Destruction of local vegetation is most likely contributing to increased runoff, triggering or exacerbating both incision and channel widening. Increased erosion from a local coal mine is also a factor, causing dramatic headward erosion of gullies which are currently destroying the access road to the mine (Fig. 7). Arroyo development in the western U.S. due to overgrazing may be analogous to the situation here (Vogt, 1997).

Figure 7. Gullying and headward erosion adjacent to coal mine.

CONCLUSION

The slopes of the eastern Kharkhiraa are currently undergoing a period of dramatic instability. Most slopes are undergoing multiple mass wasting processes, from creep to slip and flow and many streams are actively aggrading, deepening or widening their channels. Based on these observations of the most recent slope and fluvial processes, human impact seems to be at least partially to blame for recent slope instability. However, the relevance of the stratigraphic record to past climate change and/or anthropogenic stresses remains uncertain.

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REFERENCES CITED

Bao, Y., Braeuning, A., Johnson, K.R., Shi, Y., 2002, General characteristics of temperature variation in china during the last two millennia: on National Oceanic and Atmospheric Administration Website, http://www.ncdc.noaa.gov/paleo/pubs/yang2002/yang2002.html, visited 3/1/05.

Grunert, J., and Lehmkuhl, F., 2001, Aeolian sedimentation in arid and semi-arid environments of western Mongolia: Source Unknown.

Grunert, J., and Lehmkuhl, F., 2000, Paleoclimatic evolution of the Uvs Nuur basin and adjacent areas: Quaternary International, v. 65/66, p. 171-191.

Jacoby, G.C., D'Arrigo, R.D., Davaajamts, T., 1996, Mongolian tree rings and 20th-century warming: Science, v. 273, p. 771-773.

Pekala, K., and Repelewska-Pekalowa, J., 1993, Solifluction and related slope processes in the mountains of Central Asia (Mongolia): Palaeoclimate Research, v. 11, p. 87-102.

Serebryanny, L.R., and Gravis, G.F., 1993, Solifluction in northern Eurasia: a review: Palaeoclimate Research, v. 11, p. 103-123.

Vogt, B.J., 1997, The arroyo problem in the southwestern U.S.: U.S. Geological Survey, http://geochange.er.usgs.gov/sw/impacts/geology/arroyos.