# PALSA FIELDS AND CRYOPLANATION TERRACES, HANGAY NURUU, CENTRAL MONGOLIA

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## INTRODUCTION

Periglacial geomorphology focuses on cold-climate landforms and processes. The term periglacial refers to primarily terrestrial, cold-climate, nonglacial processes and features regardless of date or proximity to glaciers (Washburn, 1973). The Chuluut Gol and Tsarang Sairin Gol valleys are located in the Hangay Mountains of central Mongolia and contain palsas and other periglacial features such as patterned ground and aufeis. In the surrounding hills, cryoplanation terraces, boulder pavement, and solifluction lobes are abundant. The purpose of this research is to compare and contrast the morphology and geochronology of two palsa fields and to evaluate cryoplanation terraces.

Palsas (Fig. 1) are peat-covered mounds up to a few meters high (Sollid and Sørbel, 1998) that contain a permafrost core of frozen peat and/or silt, small ice crystals and thin ice layers along with segregated ice, which can survive the heat of summer (Seppälä, 1986).


**Figure 1. Location and individual palsas in the Chuluut Gol and Tsarang Sairin Gol palsa fields. A) Chuluut Gol palsa with exposed ice core B) Tsarang Sairin Gol palsa C) Topographic map with palsa field locations (each square is 2 km x 2 km).**

An active palsa is one where visible ice is still present, while a mature or inactive palsa in one where there is no visible ice present. Palsas are almost exclusively associated with bogs, commonly occur in regions with long winters and thin snow cover (Washburn, 1973), and are found mainly in areas of sporadic and discontinuous permafrost (Worsley et al., 1995). A precondition for palsa formation is that the frost must penetrate the peat layers deep enough so that it does not thaw during subsequent summer melt seasons, and as a result forms a persistent frost horizon (Seppälä, 1986). Mean annual precipitation in the Hangay Mountains is 300-400 mm with an average January temperature of -30 to -34˚C in the valleys (Batima et al., 2005). Low winter temperatures contribute to ice-cored features as well as large-scale periglacial landforms.

Geologic structure and climate are the most important factors controlling the origin and development of cryoplanation terraces (Czudek, 1995). Cryoplanation terraces (Fig. 2A) have been predominately studied in Alaska and the former Czechoslovakia. Cryoplanation terraces are hillside benches that are cut into bedrock, lack predominant structural control, and are confined to regions of cold climate (Washburn, 1973). Cryoplanation terraces consist of two parts: the terrace flat and the terrace riser. The slope of the terrace flat varies mostly between 2 and 7° while the terrace riser can vary from 25 to 40° (Czudek, 1995). Snow accumulation at the terrace flat-riser transition is imperative to the development of cryoplanation terraces.

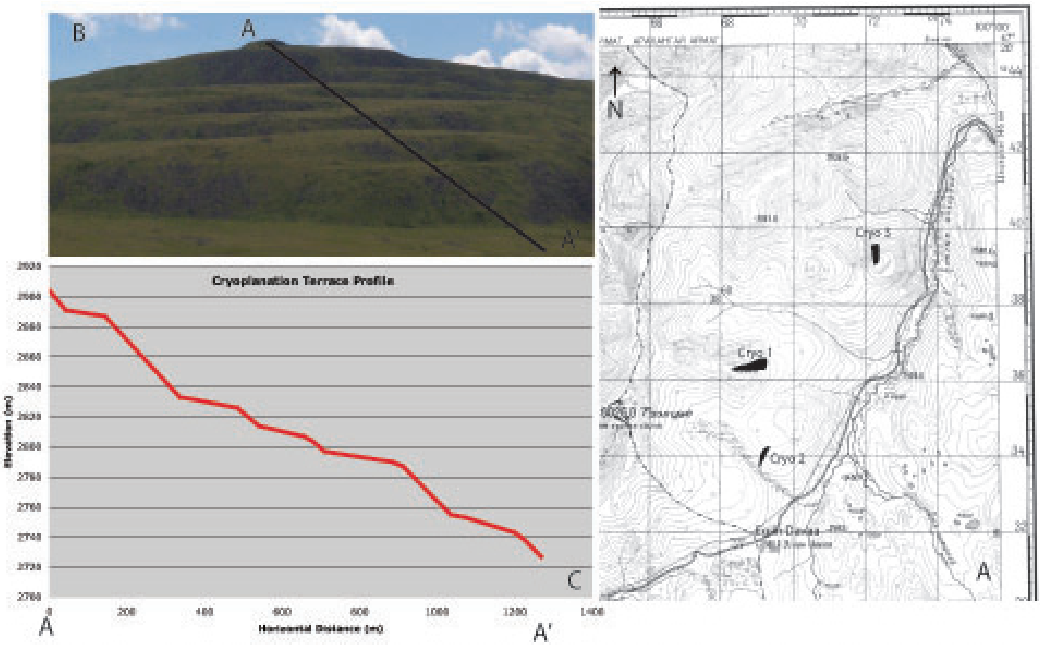


**Figure 2. Cryoplanation terrace sets near Eglin Davaa display various aspects as well as overall change in elevation. A) Topographic map (each square is 2km x 2km), (B) photo with visible block slopes and (C) surface profile of Cryo 1 near Egiin Davaa.**

# PALSAS

## RESULTS

Field data were used to analyze the geomorphic variation between the palsa fields in the Chuluut Gol (47.29°N, 100.07°E, 2283 m) and Tsarang Sairin Gol (47.23°N, 100.02°E, 2446 m) valleys (Fig. 1C). Potential sources of variation include: (1) type and extent of vegetative cover, (2) thickness and density of the peat-rich active layer, (3) climatic factors such as temperature, (4) growth rate of the segregated ice, and (5) exposure of the subsurface ice due to frost cracks.

Frost cracks form as a result of fractures within the active layer due to the subsurface expansion of ice (French, 1997). In the Chuluut Gol palsa field, there are four active palsas. The main palsa has three linear frost cracks that trend NW-SE. The other three palsas display radial frost cracks with a pseudo-polygonal pattern. The palsas in the Chuluut Gol field are covered with low grasses and sedges on a 6% slope in an open, treeless valley. This palsa field lies adjacent to patterned ground and is down gradient from a spring. Palsas in this field range from minimal surface expression up to 2 m high and are up to 20 m in diameter (Fig. 1A).

In the Tsarang Sairin Gol valley, individual palsas are difficult to discern as they lie beneath a mat of grasses, sedges, dwarf Salix sp. and other flowering plants. This palsa field is located in a narrow glacial valley, which drains north, and can be divided into an upper and lower section based on slope and the presence of water. The upper section slopes slightly south and has minimal surface water with granite and basalt boulders exposed beneath a 40-cm-thick dry peat layer. It has two ridges with prominant frost cracks that are parallel to the length of the palsa field. These ridges are accompanied by at least two inactive palsas. The lower section slopes north, has abundant surface water, and has no visible lithic fragments within or near the active layer. It has one active palsa and multiple mature palsas.

## PEAT SAMPLES AND AMS

Three peat samples were collected from the two valleys and submitted for radiocarbon dating (Table 1). Sample Chuluut Gol A (CGA) was taken at 25 cm depth from the crest of the highest palsa and yielded a radiocarbon age of 312 ± 35 ybp. Sample Chuluut Gol B (CGB) was taken from the perimeter of the highest palsa at the basal peat-permafrost boundary at 70 cm depth and yielded a radiocarbon age of 4,970 ± 20 ybp. In the Tsarang Sairin Gol palsa field, a sample was taken from an inactive palsa at 25 cm depth, which yielded a radiocarbon age of 79 ± 63 ybp.

**Table 1. Sample location, depth and $^{14}C$ age BP of each sample. Results from the Chuluut Gol valley suggest rapid accumulation, an erosional event, hiatus in peat deposition, or contamination. (*University of Arizona-AMS Lab; ** the University of California Irvine Keck Carbon Cycle AMS Lab)**

| Sample ID | Location | Depth | $^{14}C$ age BP |
|---|---|---|---|
| TSG P17-28-06 | Crest of inactive palsa: Tsarang Sairin Gol valley | 25 cm | 79 ± 63* |
| CGA P88-02-06 | Crest of active palsa: Chuluut Gol valley | 25 cm | 312 ± 35* |
| CGB 29773 | Perimeter of Chuluut Gol palsa field ~10 m from CGA | 77 cm | 4,970 ± 20** |

## DISCUSSION

The highest palsa in the Chuluut Gol valley displayed three conditions of peat: thawed, interstitial ice, and frozen, with a total thickness of 0.60 m. The only palsa with visible segregated ice in the Tsarang Sairin Gol valley had a completely thawed peat layer with a maximum thickness of 0.85 m. Field data suggests that frost cracks and the insulating properties of the active layer are important factors affecting the thermal stability of the palsas in the study area. Frost cracks are parallel to the present day water flow seen in each field, which suggests that the segregated ice lenses formed interstitially as well as between a layer of peat and another medium as a result of the downslope movement of trapped water. The underlying layer was never reached so it not known what the other medium was in the Chuluut Gol and Tsarang Sairin Gol valleys. Variation in vegetative cover may have also influenced the visible differences between the two palsa fields. The root system of the dwarf Salix sp. is more extensive and bulky than that of grasses and may have contributed to the overall transport of heat to the interior regions of a palsa. Conversely, a thick covering of vegetation might act to shade the active layer from the summer sun, thus keeping the active layer cooler in the summer. The lack of water in the upper section of the Tsarang Sairin Gol palsa field suggests stabilization or near complete degradation of any palsas in the area. No visible ice or domed features implies that the upper section is devoid of active permafrost and near complete degradation. The abundance of water in the lower section, however, hints at melting of the underlying permafrost.

The insulating property of the active layer influences the degree of heat passing through to the subsurface ice. Testing performed by Brovka and Rovdan (1999) shows that the thermal conductivity of peat soils depends mainly on the water content, bulk density and composition of the mixtures. Lab experiments with samples from each palsa field revealed a distinct difference in heat transport between the two fields with the Tsarang Sairing Gol peat transmitting heat more quickly (Figure 3); this difference in heat transport may have led to more rapid palsa decay during the summer season. In the experiment, there are three distinct changes in slope. Point A may have occurred as a result of stabilization within the samples. It is uncertain as to the cause of point B and point C represents the point in which heat was removed from direct contact with the samples.

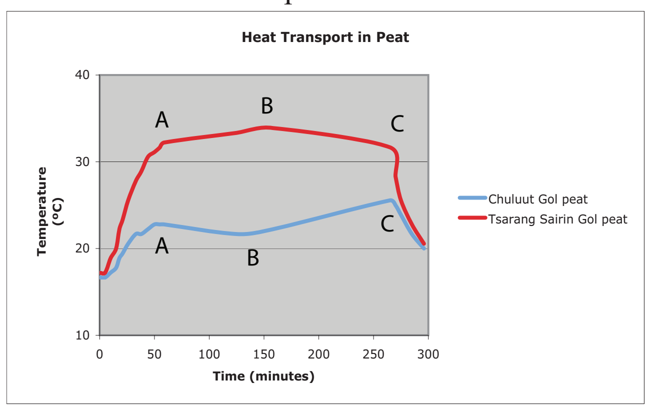


**Figure 3. Samples were collected from each palsa field and tested for effective heat transport. The peat sample from the Tsarang Sairin Gol palsa field had peat characteristics that included lower moisture content and a visible difference in density. Points A and B are not very well understood while point C represents the time in which heat was removed from the sampes. The Chuluut Gol peat sample acted as a better insulator when artificially heated.**

# CRYOPLANATION TERRACES

## DATA

Three sets of cryoplanation terraces were surveyed using a GPS receiver, an altimeter and a clinometer. The sets have different aspects and are at different elevations (Table 2). Cryoplanation terrace 1 is underlain by a metaconglomerate. Patterned ground was identified on some terrace flats while block slopes covered parts of most of the surveyed terrace risers.

**Table 2. Comparison of cryoplanation terraces sets, Egiin Davaa.**

| Terrace set | Cryo 1 | Cryo 2 | Cryo 3 |
|---|---|---|---|
| General Location (summit) | 47º 15.456' N 99º 54.244' E | 47º 14.188' N 99º 54.810' E | 47º 16.992' N 99º 57.308' E |
| Aspect | ENE | SSW | N |
| No. of Terraces Surveyed | 8 risers, 9 flats | 5 risers, 4 flats | 4 risers, 4 flats |
| Elevation Change | 173 m | 68 m | 87 m |
| Mean riser slope (º) | 15 | 14 | 17 |
| Mean flat slope (º) | 5 | 3 | 5 |

**DISCUSSION**

All three sets of terraces display slope steepness values consistent with results obtained by Czudek (1995) and Demek (1964) for the terrace flats, while terrace riser values are comparatively low (Fig. 2). The rock mass strength and jointing of the metaconglomerate are fundamental aspects of terrace development near Egiin Davva and may have contributed to the low riser values. As implied by Czudek (1995), patterned ground may have developed on the terrace flats due to removal of any snow by winter winds, while nivation hollows collected the snow. Both chemical and mechanical weathering has likely influenced the development of the cryoplanation terraces; however the degree to which each is involved is uncertain.

# CONCLUSION

Periglacial environments require low temperatures and low precipitation. Consequentially, when one of these parameters changes, it affects not only the development but also the overall appearance of periglacial features. Mean annual air temperatures are expected to increase significantly at high latitudes due to global climate change over the coming century (Alley et al, 2007), leading to degradation and thawing of permafrost, particularly on the southern boundaries of discontinuous permafrost (Ishikawa et al., 2005). As the northward and/or upward migration of the permafrost boundary continues, periglacial features transition from active to relict with a reduction in cold weather processes. Where the mean annual permafrost temperature in the ground is close to 0°C, even small-scale climate changes of short duration can be significant for growth and decay of ice-cored periglacial forms which could make palsas good geomorphological indicators of climate change (Zuidhoff and Kolstrup, 2000). The effects of a shift in local climate should not, however, be confused with natural palsa degradation. Although the overall properties of the peat seem to have played an important role, the frost cracks provided the most direct mechanism for heat transport and thus degradation. It is possible that the Tsarang Sairin Gol palsa field seems more developed as a result of multiple regenerations of palsas in the same area, moisture content of the peat-rich active layer, thickness of the peat and/or length of time of active layer accumulation. Palsa degradation in the Chuluut and Tsarang Sairin Gol valley can be attributed mostly to typical growth and decay patterns.

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