KECK GEOLOGY CONSORTIUM

PROCEEDINGS OF THE TWENTY-SECOND ANNUAL KECK RESEARCH SYMPOSIUM IN GEOLOGY

April 2009
Franklin & Marshall College, Lancaster PA.

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2008-2009 PROJECTS

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GEOLOGY OF THE HÖH SERH RANGE, MONGOLIAN ALTAI
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Keck Geology Consortium: Projects 2008-2009
Short Contributions – MONGOLIA

GEOLOGY OF THE HÖH SERH RANGE, MONGOLIAN ALTAI

NICHOLAS E. BADER and ROBERT J. CARSON: Whitman College
A. BAYASGALAN: Mongolian University of Science and Technology
KURT L. FRANKEL: Georgia Institute of Technology
KARL W. WEGMANN: North Carolina State University

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ELIZABETH BROWN: Occidental College
Research Advisor: Professor Ann Blythe
GANBAYAR RAGCHAASUREN: Mongolia University of Science and Technology

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***KRISTIN E. SWEENEY*: ** Carleton College
Research Advisor: Sarah Titus
TSOLMON ADIYA: Mongolia University of Science and Technology

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GEOMORPHOLOGY OF NARAN KHONDII, HÖH SERH RANGE, MONGOLIAN ALTAI

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ENKHBAYAR MUNK-ERDENE**:** Mongolia University of Science and Technology

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RECONSTRUCTING LATE HOLOCENE CLIMATE THROUGH TREE-RING ANALYSIS OF SIBERIAN LARCH: ALTAI MOUNTAINS, WESTERN MONGOLIA

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INTRODUCTION

The retreat of glaciers in Mongolia, as elsewhere, is a great concern because they provide water to millions of people for both drinking and irrigation. In an otherwise arid climate (Mongolian Institute of Meteorology and Hydrology, 2009; Kehrwald 2008; An, 2008), water stored in glaciers is a crucial resource that is quickly diminishing. The extent of this risk must be assessed and efforts of this and other research studies must be combined so that the effects of global climate change acting on the glaciers might be better understood.

The purpose of this study is to provide a detailed geomorphic description of Naran Khondii, a broad valley draining the Höh Serh range in the Mongolian Altai (Fig.1), and to assess the retreat of a glacier found in the southeastern part of the valley. The area in which the valley is located has been depicted on maps that were constructed from satellite imagery, but no field mapping had previously been conducted.
The weather in Mongolia is influenced by the Mongolian High Pressure System, westerlies from the North Atlantic, and East Asian summer monsoons (An 2008). Presently, the climate in western Mongolia is most heavily influenced by westerlies that bring precipitation from the Atlantic and the Mediterranean, not from the monsoons, which are blocked by the Karakorum and Himalaya (Gillespie, 2003). The varying influence of these two systems results in a precipitation decrease from west to east across Mongolia (Lehmkuhl, 2004). An (2008) also describes a general increase in temperature and decrease in humidity from north to south across Mongolia. The Naran Khondii Valley is located in the western part of Mongolia, and so receives more precipitation to aid in glacier development.

Within Mongolia, two late Pleistocene advances have been identified: the Early Zyrianka (Early Wurmian or OIS 4) 50-70 Ka and the Sartan (Late Wurmian or OIS 4) 15/20-32 Ka (Lehmkuhl, 2004). Records of Pleistocene glaciations in Mongolian mountain ranges can be found in the Khentey, Khangai, Mongolian Altai, and mountains surrounding Hovsgol Nuur. The maximum ice extent in the Mongolian Altai during the Pleistocene has been calculated to be between 20,700 km^2 and 28,750 km^2 (Lehmkuhl, 1998; 2004). The Mongolian Altai Pleistocene equilibrium line altitudes (ELAs) were depressed at least 500 m compared to present values (Lehmkuhl, 2004).

Two other glacial advances are those that correspond to the Late-glacial Wurmian (10-15 ka) and the Little Ice Age (LIA), which ended around 1850 AD (Lehmkuhl, 2004). This study also makes refer-

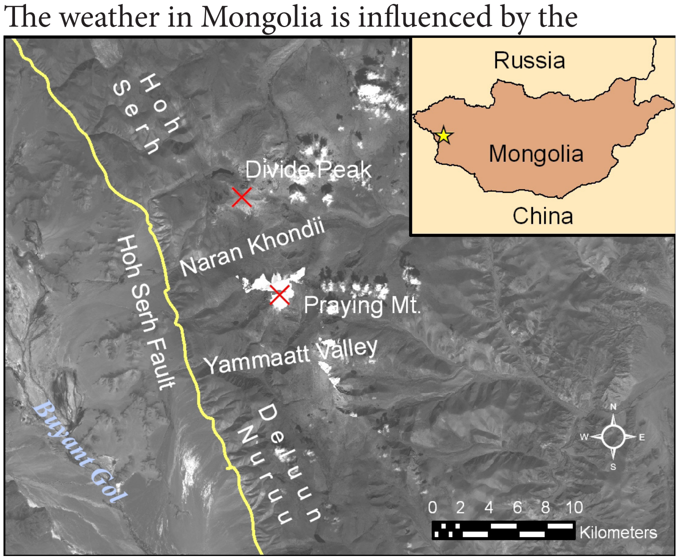

Figure 1 – Location of Naran Khondii and surrounding area.

ence to Neoglacial moraines, which formed during advances in the last 4000 yr.

METHODS

Notes, sketches, and photographs were collected in order to provide a geomorphic description of Naran Khondii. A GPS receiver was used to record the location of geomorphic features, such as moraines, erratics, and rockfalls. Relative moraine ages were approximated in the field based on their morphology, stability, and soils.

GIS was used to interpret collected waypoints over a digital elevation model (DEM) and SPOT satellite imagery, allowing one to constrain past ice limits based on the location of moraines and erratics. All data was projected as WGS 1984 UTM zone 46N. ELAs were estimated using both the toe to summit altitude (TSAM) method and the accumulation-area ratio (AAR) method. The TSAM method assumes that the ELA is halfway between the elevation of the terminal moraine and the elevation of the highest peak in the drainage. The AAR method places the ELA such that 67% of the total glacial area is above the ELA, where accumulation is occurring. Benn (2000) recommends the AAR method for clean, snowfall-fed glaciers in alpine environments and the TSAM method for Mongolian Pleistocene glaciers. Lehmkuhl (1998) suggests using an AAR of 67%, but warns that there are not detailed maps of Mongolia for an accurate measurement of this datum; however, we completed the necessary mapping to make accurate measurements. The TSAM method overestimates the ELA about by 100 m in the Alps but fits well with field observations in Mongolia (Lehmkuhl, 1998).

GEOMORPHOLOGY

The valley is U-shaped and consists of north and south forks that come together to form the main valley (Fig. 2). Streams in both forks of the valley converge to form a single flow in the center of the valley, which becomes a tributary to the Buyant Gol. Glacial landforms are evident to a varying degree throughout the valley. There are three moraine complexes preserved in the valley. The Cairn Com-

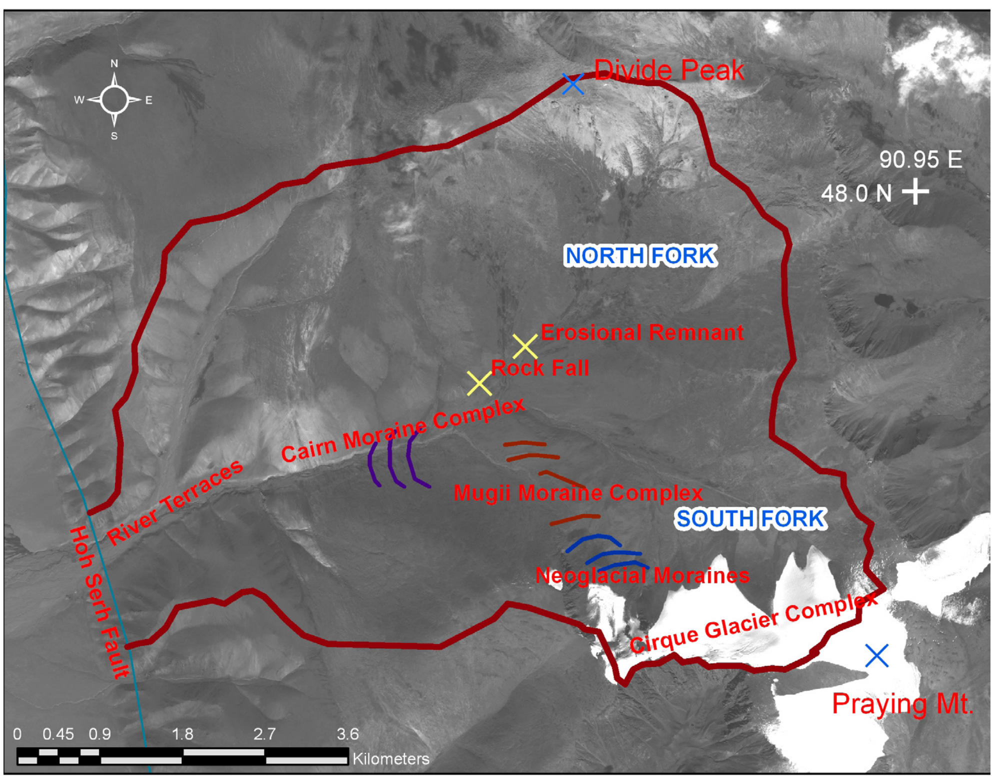

Figure 2 – Location of Naran Khondii and landforms within its drainage. The field camp is located approximately 7 km to the south of Naran Khondii.

plex contains the down-valley terminal moraine and is in the main, central valley. The Mugii complex is further up-valley, southwest of where the valley splits. A neoglacial moraine complex is present primarily in the vicinity of and down-slope from the westernmost extant glacier. The south side of the central valley lacks glacial landforms due to periglacial processes. This area now consists of a large solifluction apron that covers the valley wall.
A three-part cirque glacier complex lies on the southern headwall of the valley, against the north side of Praying Mountain. The cirque complex consists of eastern, central, and western glaciers. The eastern glacier has eastern and western lobes. Debris-covered, stagnant ice stretches several hundred meters below the western and eastern glaciers.

No ice remains on the north headwall of Naran Khondii, but the headwall has several cirques and tors that formed on it and the ridge between Naran Khondii and the valleys to the north and east. The highest point of elevation (3593 m), along the northern ridge is called Divide Peak. The summit of Divide Peak and the surrounding area are characterized by coarse-grained granite undergoing exfoliation and marked with tafoni. The surface is mostly covered by boulder sized clasts, but grus is found between the boulders and tors.

Near the mouth of the valley, along the creek that flows through it, there are four sets of Quaternary terraces named Qt1 though Qt4 from oldest to youngest. The formation of these terraces is related to the Höh Serh Fault. Following each episode of uplift along the fault, the nickpoint of the stream would retreat and the stream would downcut through alluvium and bedrock. Qt1 is estimated to correlate with the LGM. Qt2 and Qt3 are Holocene strath terraces. Qt4 was not included in the analysis. There are also two strath terraces in a side channel that branches off to the south of the main valley just east of the other terraces. However, these terraces could not be correlated with those of the main valley.

The center of the valley is filled with till, containing boulders up to 3 m across. Most boulders are subrounded granite, with some angular rhyolite metasedimentary rocks. The matrix is not compact and is nearly all sand with little clay present. Much of the fine sediment has been eroded from the surface. At the surface the till appears to be about 75% boulders and 25% matrix; however, the actual ratio underground could be as little as 50% boulders to 50% matrix.

GLACIAL HISTORY

The Cairn Moraine Complex consists of three visible moraines, all of which are LGM deposits based on the approximate boulder frequency (Pearson, 2007; Coggan, 2007). A small moraine comprises the westernmost glacial landform in the Naran Khondii. The presence of few granite boulders and the moraine's small size indicate that the ice margin was not here long. A larger recessional moraine a few m high is located 100 m east of the ice terminus. It has been mostly eroded by meltwater running across the recessional moraine, but many large boulders remain. There is a second recessional moraine in the complex that is located between 100 and 200 m east of the first recessional moraine. This moraine is a few m high and contains many large surficial boulders.

There is no evidence of a medial moraine in the central valley to compare the timing and extent of the glacial advance down the north and south forks. However, the bedrock of the north fork is granite while the south fork has rhyolite. Little granite in the moraines of the Cairn Complex indicates that glaciers from the south fork must have been the predominant source of ice. In addition, the glacier in the north fork would have faced southward absorbing more solar radiation than the north-facing glacier in the south fork. Assuming that the north and south headwalls obtained similar precipitation amounts, the south fork glacier should have been favored for snow preservation.

The Mugii Moraine complex contains two parts. Mugii A, the older part of the complex, extends farther down valley; Mugii B, the younger and steeper part of the complex, is located above Mugii

Figure 3 – The left side of this image shows the contouring of dark and light color rock around the base of the glacier in Naran Khondii. The right side is a close up image of the boundary line between light and dark material. The lighter rock is from an older neoglacial advance and the darker rock was likely ice-covered during the LIA.

A. Both parts of the complex are believed to be late Pleistocene in age. They consist of large lichen-covered boulders and both parts exhibit extensive soil development.

Above the Mugii moraine complex and in front of the western glacier of the cirque complex are Neoglacial moraines. These moraines consist of unstable deposits of angular, lichen-free rhyolite blocks that are up to three meters across, with few fines present. Several ice-cemented boulders jut out from the side of the moraine. The moraines closest to the glacier are probably Little Ice Age or more recent as their instability suggests that they have not been affected by activity of the nearby Höh Serh Fault.

In the upper parts of the valley, particularly along the headwall, striations and chatter marks suggest that the glacier must have been warm based for at least part of its history.

In the modern cirque complex, the central and eastern glaciers lack prominent moraine deposits, but are bordered down-valley by areas of rock that have been exposed more recently than the Pleistocene deposits (Fig. 3). The recently-exposed sediments around the perimeter of the glacier are dark-colored, unstable, and lichen free; farther from the ice, sediments are lighter in color, more stable, and sparsely colonized by lichens. The lighter area shows signs of solifluction, but the darker section does not. The lighter material may have been exposed since the early Neoglacial and the younger, darker material since the LIA.

Using an AAR of 67%, the ELA for the LGM glacier of the north fork was about 300 m lower than in the south fork (Table 1). In the south fork, the ELA rose to about 3550 m by the Neoglacial and to about 3600 m by the LIA. Using the TSAM method, ELAs were slightly higher (Table 1).

Lehmkuhl et al. (2004) estimated that modern ELAs in the Mongolian and Chinese Altai are between 3,000 m and 3,600 m. However, based on the

Age/Location of Ice	Area (m^2)	summit (m)*	toe (m)*	AAR 67% (m)	TSAM (m)	% total surface area lost (m^3)
LGM - South	10008843	4200	2683	3460	3440	78.971
LGM - North	8107879	3600	2683	3175	3140	100.000
Neoglacial	4322070	4200	3186	3550	3693	51.303
LIA	3388725	4200	3259	3600	3729	37.891
SPOT (2007)	2199434	-	-	-	-	4.307
Modern	2104710	4200	3278	-	-	-

*Elevations obtained from the DEM imagery used in analysis.

Table 1 – Summary of toe, summit, and ELA elevations as well as surface area retreat values for the glacier in Naran Khondii.

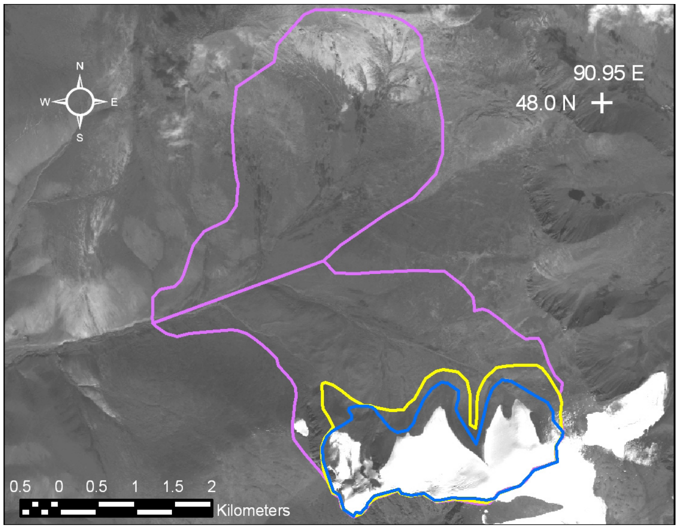

Figure 4: Reconstructed glacial ice boundaries in Naran Khondii. The purple line marks the LGM extent, yellow is the older Neoglacial extent, and blue is the LIA extent.

snowpack observed on top of Praying Mountain and an approximate 35 m drop in elevation at the mountain's summit from elevations listed on the 1963 topographic map to those observed during the summer of 2008, it is believed that the current ELA is located above the ice-covered mountain top, which was surveyed at 4019.3 m in 1963.

Based on the estimates of moraine ages, surface area of the glacier in the south fork of Naran Khondii has decreased by 79% since the late Pleistocene glacial maximum, 51% since the Neoglacial period, 38% since the Little Ice Age, and 4.3% between the 2008 and 2007 summer when the SPOT imagery was acquired (Fig. 4).

DISCUSSION

The glacier on Praying Mountain has lost 4.3% of its surface area since 2007. The loss of glaciers as a water resource is of great concern to those living in Mongolia and other parts of central Asia. In an arid climate, such as is found in western Mongolia, glacial melt is the major contributor to average daily stream flow. The reduction of glacial ice will reduce the delivery of meltwater to streams. In this area, meltwater is a particularly important water source for local nomadic people, who rely more heavily on streams than wells as their water source for much of the year.

The observations of significant ice loss on Praying Mountain may be part of a regional trend. Kehrwald et al. (2008) noted that Naimona'nyi, a glacier at 6050 m a.s.l. in the Himalaya, stopped accumulating snow by 1950 even though the region continues to receive between 200 and 1000 mm snow-water equivalent annually.

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