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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Faculty: *DAVID SUNDERLIN*: Lafayette College, *CHRISTOPHER J. WILLIAMS*: Franklin & Marshall College
Students: *GARRISON LOOPE*: Oberlin College; *DOUGLAS MERKERT*: Union College; *JOHN LINDEN NEFF*: Amherst College; *NANCY PARKER*: Lafayette College; *KYLE TROSTLE*: Franklin & Marshall College; *BEVERLY WALKER*: Colgate University

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GEOLOGY OF THE HÖH SERH RANGE, MONGOLIAN ALTAI

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A. BAYASGALAN: Mongolian University of Science and Technology
KURT L. FRANKEL: Georgia Institute of Technology
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Research Advisor: Professor Ann Blythe
GANBAYAR RAGCHAASUREN: Mongolia University of Science and Technology

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GLACIATION OF RHYOLITE VALLEY, HÖH SERH RANGE, MONGOLIAN ALTAI

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Research Advisors: Bob Carson and Nick Bader

INTRODUCTION

The Altai Mountains of western Mongolia possess the only active glaciers in the entire country. Within the Altai Mountains, the Höh Serh Range reaches nearly 4000 m in elevation. Abundant glacial landforms, including cirques, glacial troughs, and moraines, evidence widespread glaciation in the Höh Serh Range during the Pleistocene.

Rhyolite Valley is a west-draining glacial trough in the Höh Serh Range. It was explored and geomorphically mapped to determine the extent and climatic significance of glaciation in the area. Numerous moraines in the valley, ranging from 2700 to 3400 m elevation, preserve a geomorphic history dating from the Last Glacial Maximum (LGM) to Neoglaciation (Fig. 1). While the neighboring valley to the north still possesses an active glacier, no ice is left in the southwest-facing cirque of Rhyolite Valley.

The last major glaciation in the area has been previously dated using thermoluminescence, and identified as the Sartan Glaciation at 32 ± 6 ka (Lehmkuhl, 1998), which will be referred to as the LGM in this paper.

METHODS

In order to recreate the shape of the former glacier occupying the valley, GPS locations were taken at significant landforms, including ice marginal channels, the crests of moraines, and boulder lines indicating potential ice limits. Moraines in Rhyolite Valley were identified and grouped together based on relative proximity, shape, and overall appearance. They have been named according to natural and anthropogenic features found nearby. Moraines with “complex” included in the name denote multiple moraine features that probably share a common origin. These moraine complexes are arcuate in places, but may also be more amorphous than other moraines in the valley, and have less distinct boundaries between features.

Russian topographic maps of the area were georeferenced using ArcGIS, and 3-D models of the glacier were generated. ArcGIS was also used to determine the Equilibrium Line Altitude (ELA) corresponding to each moraine complex, using the Toe-to-Summit-Altitude-Method (TSAM) and the Accumulation Area Ratio (AAR) method, with an AAR of 67%.

GEOMORPHOLOGY

OVERVIEW

The main branch of Rhyolite Valley is U-shaped, and contains many features typical of previously glaciated landscapes. A tributary of the main stream in Rhyolite Valley originates northwest of the cirque headwall. This northern fork of the stream is separated from the main drainage by a bedrock ridge, and the valley is predominantly V-shaped with no geomorphic evidence of recent glaciation. The north fork was explored but not extensively mapped. Moraines more than 100 m high are present near the mouth of Rhyolite Valley, with smaller moraines at higher elevations. From the cirque headwall, moving southwest toward the mouth of the valley, the moraines have been divided as follows: Neoglacial Moraine Complex, Canyon Moraine, Skull Moraine Complex (including Lake Moraine and Buttercup Moraine), Rock Jack Moraine Complex, and Eagle Moraine (Fig. 1). Most of the valley floor consists of vegetated till churned up by freeze-thaw processes,

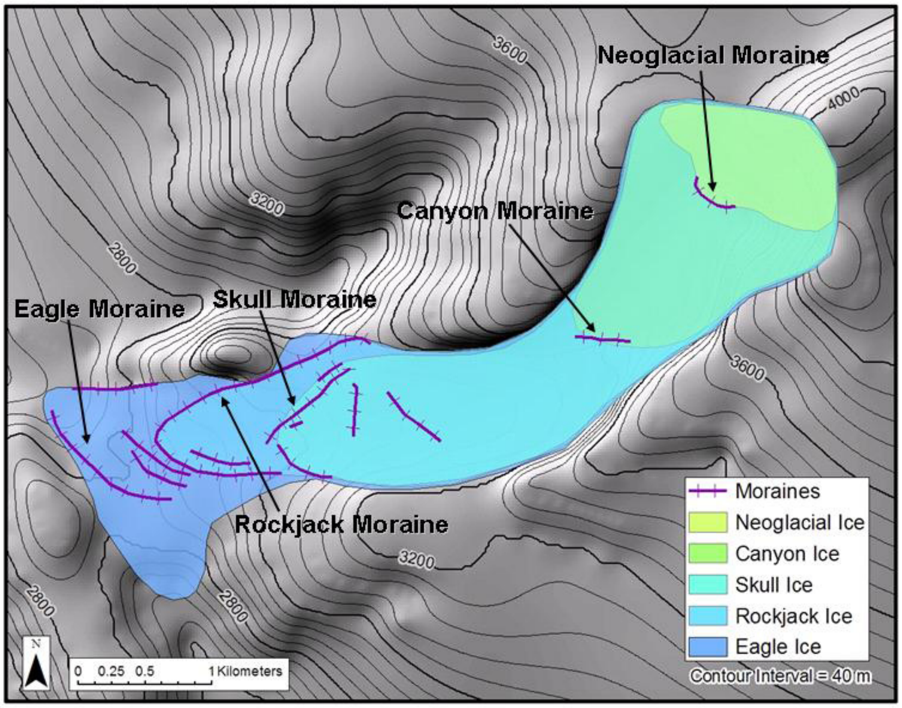

Figure 1. Ice extents in Rhyolite Valley corresponding to Eagle, Rockjack, Skull, Canyon, and Neoglacial moraines.

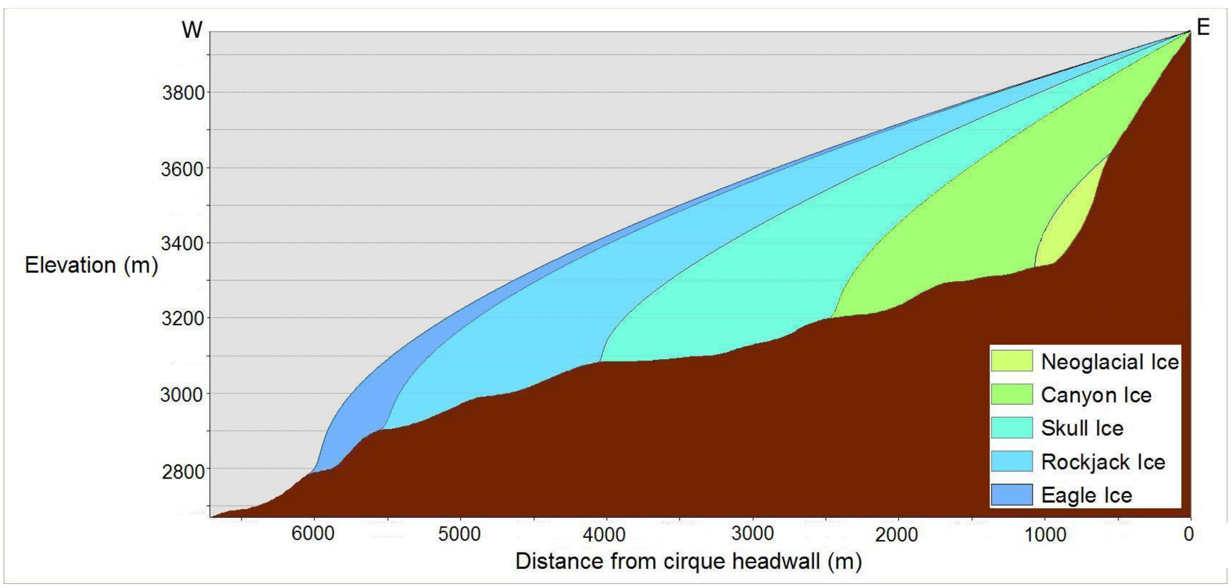

Figure 2. Longitudinal section of Rhyolite Valley with ice profiles.

with the exception of a rhyolitic bedrock step cutting across the valley just southwest of the Neoglacial Moraine Complex. An ice marginal channel was also identified near Rock Jack Moraine Complex, just south of the bedrock ridge separating the north fork from the main drainage of Rhyolite Valley. Cross Valley is a much smaller drainage connecting Rhyolite Valley to its southern neighbor, Yamaat Valley. Cross Valley runs parallel and about 1 km east of the Hoh Serh range front. There are several moraines and glacial features visible here, including Paddock Moraine Complex, Washboard Moraine Complex, and a distinct line of angular rhyolite boulders extending nearly 0.5 km down Cross Valley. This boulder line was used to determine the southwestern limit of the maximum ice extent (Fig. 1).

The results of periglacial processes are also prevalent throughout Rhyolite Valley, including a variety of patterned ground. Alternating circular hummocks and depressions roughly 1 m in diameter cover the relatively flat, vegetated portions of the valley. Near the large lake just upvalley of Lake Moraine are sorted polygons 2 to 4 m diameter with fines in the center and coarser material around the borders. Farther upvalley, at higher elevations where grass is sparse, sorted polygons of the same size are different: the fines in the centers of the polygons are surrounded by oblate pebbles and cobbles, with vertically-oriented long axes.

MORAINES

The Neoglacial Moraine Complex is composed of loose, angular boulders without any fines, soil, or vegetation. The sides of these young moraines are much steeper than those of other moraines in the valley. The base of the moraine complex is at 3340 m; the crest of the outermost moraine reaches 3420 m in elevation. Like the bedrock in the cirque headwall, most boulders in this deposit are rhyolite, but display varying degrees of metamorphism. Rhyolite (or some metamorphosed variant thereof) makes up roughly 90% of the rocks in the Neoglacial Moraine Complex. The remaining 10% are metasedimentary rocks, primarily greenish-grey phyllite with prolific quartz veins, and lesser amounts of pink iron-stained quartzite and a few cobbles of andesite.

Canyon Moraine is another mixture of rhyolite and metasediments, with the percentage of the latter slightly increased relative to the Neoglacial Moraine Complex. In addition to phyllite, cobbles and boulders of marble compose between 5 to 10% of the till. Canyon Moraine has its crest at 3150 m, and is slightly more vegetated than the Neoglacial Moraine Complex, with a much gentler gradient on both sides. The linear moraine crest extends from one valley side to the other, without the lumpy, disjointed shape typical of many moraines downvalley. The stream incised the bedrock on the northwest side of the valley after cutting through the till of Canyon Moraine, creating the 5-m-deep bedrock canyon for which the moraine was named.

Skull Moraine Complex includes three major portions: Lake Moraine, Buttercup Moraine, and the multiple crests of Skull Moraine. Lake Moraine has more fines and vegetation than Canyon Moraine, and even gentler slopes. Grass-covered with fewer large boulders, it lacks the jagged appearance of moraines upvalley. The modern crest of Lake Moraine reaches 3115 m; it has been fluvially dissected and cannot be traced across the valley. Buttercup Moraine and the crests of Skull Moraine have surface appearances similar to Lake Moraine, but the overall shapes vary depending on the chosen portion. Buttercup Moraine has a crest elevation of 3070 m. The base of Skull Moraine Complex begins at 2940 m, and rises to 3020 m in the center of the valley. Lateral moraines in Skull Moraine Complex rise even higher along the valley walls

Rockjack Moraine Complex and Eagle Moraine differ only in size from the moraines just upvalley. At the mouth of the main fork of Rhyolite Valley, Eagle Moraine has at least 160 m of relief, from its base to its maximum height at 2860 m. Rockjack Moraine Complex builds on Eagle Moraine, and its crest in the center of the valley is at 2940 m, though lateral moraines continue higher near the valley walls (Fig. 4). Paddock Moraine Complex and Washboard Moraine Complex in Cross Valley are much smaller, with average heights less than 30 m.

PALEOCLIMATE

The morphology and lack of soil development on the glacial features imply that all moraines in Rhyolite Valley are LGM in age or younger. Each recessional moraine or moraine complex marks the ice extent at the times the moraines were being deposited (Fig. 1). Cross sections of the ice are modeled in the longitudinal section of Rhyolite Valley (Fig. 2). At the maximum ice extent, the glacier covered more than 7 km^2, and had a volume of about

Figure 3. Looking upvalley at Canyon Moraine and the Neoglacial Moraine Complex from Skull Moraine Complex.

Figure 4. Looking downvalley along a right lateral moraine of the Rockjack Moraine Complex.

0.8 km^3.

The ELAs corresponding to the Eagle Moraine Complex are associated with the LGM, about 35,000 years ago (Table 1). The morphology and stability of the Neoglacial Moraine Complex, along with comparison to other moraines in neighboring valleys, suggest that this feature is Neoglacial (< 4 ka).

Striated bedrock in neighboring valleys indicate that the glaciers in the Höh Serh Range were at least partly warm-based. For warm-based glaciers, both TSAM and the AAR method (67%) can be used to theoretically determine the ELAs (Lehmkuhl 1998). In Rhyolite Valley, the ELAs calculated using TSAM and AAR sometimes differ by as much as 280 m for the same ice extent. The two methods are approximately equivalent for mid-elevation moraines. For moraines closer to the valley mouth the AAR method results in lower calculated ELAs; toward the headwall the AAR method results in higher ELAs (Table 1). The AAR ELA increased by 870 m between the LGM and Neoglaciation, while the TSAM ELA increased by only 350 m during the same period.

TSAM is a type of THAR (Toe to Headwall Altitude Ratio) designating the ELA as an elevation exactly halfway between the summit and the toe of the glacier, so both the TSAM and the AAR method depend on assumed ratios generalized for a certain type of glacier. The two sets of ELAs may differ because one or both of the ratios may not be appropriate for these glaciers. They may behave differently than the glaciers the methods were developed for, requiring a different balance of accumulation to ablation or a different division between the toe and the summit elevations to accurately determine the ELA.

Moraine	ELA (m)	
	TSAM	AAR 67%
Eagle (LGM)	3330	3050
Rockjack	3420	3300
Skull	3480	3360
Canyon	3600	3660
Neoglacial	3680	3920

Table 1. Equilibrium Line Altitudes (ELAs) corresponding to each moraine complex in Rhyolite Valley.

ELAs depend on both temperate and precipitation (Benn and Lehmkuhl, 2000). If we assume constant precipitation from the LGM to Neoglaciation, and a normal lapse rate of 0.65°C for every 100 m increase in elevation, the increase in temperature using these models from the LGM to Neoglaciation would be somewhere between 2.3°C (TSAM) and 5.6°C (AAR 67%).

CONCLUSION

In the summer of 2008, the ice cap above Rhyolite Valley had a summit elevation of approximately 3980 m, about 35 m lower than the elevation recorded on Russian topographic maps of the area produced in 1963. The present-day ELA for the region may consequently be greater than 4000 m, and above the highest peaks in the Höh Serh Range. If we assume constant precipitation and a current ELA of 4000 m, the mean annual temperature during the LGM was 4.3 °C to 6.2 °C cooler than it is today (determined by TSAM and AAR 67%, respectively). Previous studies done near the Altai assert that western Mongolia was also drier during the LGM (Grunert et al., 2000), meaning the temperatures would have been even lower to accommodate the same glaciers at equilibrium.

The rate of glacier retreat observed in the latter half of the past century is far greater than that documented in Rhyolite Valley from the LGM to Neoglaciation, and is a source of concern. Retreat and eventual disappearance of glaciers causes the loss of year-round streams, drastically reducing the water supply for plants, animals, and humans in the area.

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