KECK GEOLOGY CONSORTIUM

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

April 2009
Franklin & Marshall College, Lancaster PA.

Dr. Andrew P. de Wet, Editor
Keck Geology Consortium Director
Franklin & Marshall College

Dr. Stan Mertzman
Symposium Convenor
Franklin & Marshall College

Kelly Erb
Keck Consortium Administrative Assistant

Diane Kadyk
Academic Department Coordinator
Department of Earth & Environment
Franklin & Marshall College

Keck Geology Consortium
Franklin & Marshall College
PO Box 3003, Lancaster PA 17604-3003
717 291-4132 keckgeology.org

ISSN # 1528-7491

The Consortium Colleges National Science Foundation
2008-2009 PROJECTS

THE BLACK LAKE SHEAR ZONE: A POSSIBLE TERRANE BOUNDARY IN THE ADIRONDACK LOWLANDS (GRENVILLE PROVINCE, NEW YORK)
Faculty: WILLIAM H. PECK, BRUCE W. SELLECK and MARTIN S. WONG: Colgate University
Students: JOE CATALANO: Union College; ISIS FUKAI: Oberlin College; STEVEN HOCHMAN: Pomona College; JOSHUA T. MAURER: Mt Union College; ROBERT NOWAK: The College of Wooster; SEAN REGAN: St. Lawrence University; ASHLEY RUSSELL: University of North Dakota; ANDREW G. STOCKER: Claremont McKenna College; CELINA N. WILL: Mount Holyoke College

PALEOECOLOGY & PALEOENVIRONMENT OF EARLY TERTIARY ALASKAN FORESTS, MATANUSKA VALLEY, AL.
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

SEAFLOOR VOLCANIC AND HYDROTHERMAL PROCESSES PRESERVED IN THE ABITIBI GREENSTONE BELT OF ONTARIO AND QUEBEC, CANADA
Faculty: DAVID DETHIER: Williams College and MATTHIAS LEOPOLD: Technical University of Munich
Students: LAUREN D. ANDERSON: Lehigh University; STEFANIE GUGOLZ: Beloit College; HENRY E. KERNAN: Williams College; ADRIENNE LOVE: Trinity University; KAREN TEKVERK: Haverford College

INTERDISCIPLINARY STUDIES IN THE CRITICAL ZONE, BOULDER CREEK CATCHMENT, FRONT RANGE, CO
Faculty: DAVID P. DETHIER: Williams College and MATTHIAS LEOPOLD: Technical University of Munich
Students: EYEN GANNAWAY: The U. of the South; KENNETH NELSON: Macalester College; MIGUEL RODRIGUEZ: Colgate University

GEOARCHAEOLOGY OF THE PODERE FUNGHI, MUGELLO VALLEY ARCHAEOLOGICAL PROJECT, ITALY
Faculty: ROB STERNBERG: Franklin & Marshall College and SARA BON-HARPER: Monticello Department of Archaeology
Students: AVERY R. COTA: Minnesota State University Moorhead, JANE DIDALEUSKY: Smith College; ROWAN HILL: Colorado College; ANNA PENDLEY: Washington and Lee University; MAJA SIPOLA: Carleton College; STACEY SOSENKO: Franklin and Marshall College

GEOLOGY OF THE HÖH SERH RANGE, MONGOLIAN ALTAI
Faculty: 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

BLOCK ISLAND, RI: A MICROCOSM FOR THE STUDY OF ANTHROPOGENIC & NATURAL ENVIRONMENTAL CHANGE
Faculty: JOHAN C. VAREKAMP: Wesleyan University and ELLEN THOMAS: Yale University & Wesleyan University
Students: ALANA BARTOLAI: Macalester College; EMMA KRAVET and CONOR VEENEMAN: Wesleyan University; RACHEL NEURATH: Smith College; JESSICA SCHEICK: Bryn Mawr College; DAVID JAKIM: SUNY.

Funding Provided by: Keck Geology Consortium Member Institutions and NSF (NSF-REU: 0648782)
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

APATITE FISSION TRACK THERMOCHRONOLOGY OF THE HÖH SERH RANGE, MONGOLIAN ALTAI

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

CHARACTERIZATION OF THE HÖH SERH AND TSAGAAN SALAA FAULTS, HÖH SERH RANGE, MONGOLIAN ALTAI

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

CALCULATING THE RATE OF DEXTRAL STRIKE-SLIP MOTION ALONG THE HÖH SERH FAULT, MONGOLIAN ALTAI

JODI SPIRAJCAR: The College of Wooster,
Research Advisor: Shelley Judge
ERDENEBAT BOLOR: Mongolia University of Science and Technology

MOVEMENT AND TECTONIC GEOMORPHOLOGY ALONG THE HÖH SERH FAULT, MONGOLIAN ALTAI

CHELSEA C. DURFEY: Whitman College
Research Advisors: Nick Bader and Bob Carson
JARGAL OTGONKHUU: Mongolian University of Science and Technology
ICE LAKE VALLEY GLACIATION, HÖH SERH RANGE, MONGOLIAN ALTAI

ANDREA SEYMOUR: Whitman College
Research Advisors: Bob Carson and Nick Bader

GALBADRAKH SUKHBAATAR: Mongolia University of Science and Technology

GEOMORPHOLOGY OF NARAN KHONDI, HÖH SERH RANGE, MONGOLIAN ALTAI

KATHRYN LADIG: Gustavus Adolphus College
Research Advisor: Laura Triplett

ENKHBAIGAL BADRAG: Mongolia University of Science and Technology

GLACIATION OF RHYOLITE VALLEY, HÖH SERH RANGE, MONGOLIAN ALTAI

KELLY DUNDON: Whitman College
Research Advisors: Bob Carson and Nick Bader

ESUKHEI GANBOLD: Mongolia University of Science and Technology

GLACIATION OF YAMAAT VALLEY, HÖH SERH RANGE, MONGOLIAN ALTAI

GIA MATZINGER: Whitman College
Research Advisors: Bob Carson and Nick Bader

GLACIATION OF DEBRIS FLOW AND LAKE VALLEYS, HÖH SERH RANGE, MONGOLIAN ALTAI

RYAN J. LEARY: Whitman College
Research Advisor: Robert J. Carson

TAMIR BATTOGTOKH: Mongolia University of Science and Technology

A LARGE GLACIAL-OUTBURST DEBRIS FLOW DEPOSIT, HÖH SERH RANGE, MONGOLIAN ALTAI

GREG MORTKA: Lehigh University
Research Advisor: David J. Anastasio

NARANCHIMEG MERGEN: Mongolia University of Science and Technology

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

BRITTANY GAUDETTE: Mount Holyoke College
Research Advisors: Al Werner

DELGERSEGTSEG BURENDELGER: Mongolia Univ. of Science and Technology

Visitors:
Tsolman Amgaa
Steven Boettcher
Laura Gregory
Richard Walker
Mongolia University of Science and Technology
University of Bayreuth
Oxford University
Oxford University

Funding provided by: Keck Geology Consortium Member Institutions and NSF (NSF-REU: 0648782)

Keck Geology Consortium
Franklin & Marshall College
PO Box 3003, Lancaster Pa, 17603
Keckgeology.org
INTRODUCTION

Yamaat Valley is a Y-shaped, west-draining glacial trough (between 200 and 500 m deep) (Fig. 1). The north fork (8 km long) maintains a modern glacier at the summit of Praying Mountain, and the south fork (5.7 km long) has a moraine-bound lake at its drainage divide with the adjacent valley to the south (Debris Flow Valley). Elevations of the valley range from 4,019 m to 2,340 m a.s.l. The bedrock is Paleozoic metasedimentary rocks and granitics. The large terminal moraine at the mouth of the valley marks the maximum extent of Pleistocene glaciation, which was probably deposited during the Last Glacial Maximum (LGM). A probable recessional moraine is positioned 1 km upvalley of the mouth. No other moraines are exposed, possibly because of extensive and abundant mass-wasted material. The goal of this project was to map glacial features in Yamaat Valley in order to reconstruct its Pleistocene glacial history.

METHODS

Ice limits were determined by locating moraines and granitic erratics with topographic maps and a GPS. Glacial erratics were collected for cosmogenic 10Be surface exposure dating. Collected field data included GPS locations, measurements, and photographs of landforms, sediments, and boulders for dating.
GIS was utilized to compile field data to estimate LGM ice area, volume and Equilibrium Line Altitude (ELA).

Paleodischarge of a possible jökulhlaup was estimated using topographic maps and the Manning equation:

\[ Q = AR^{2/3} S^{1/2} n^{-1} \]

where \( A \) is the channel cross-sectional area, \( R \) is the hydraulic radius, \( S \) is the slope and \( n \) is the Manning resistance factor. For this analysis we estimated \( n = 0.035-0.100 \) resistance.

**GEOMORPHOLOGY**

A modern glacier (ELA > 4000 m) caps Praying Mountain, and several cirques rim the north fork of Yamaat Valley. From Praying Mountain, Pleistocene ice flowed southwest into the main valley (Fig. 2). Presence of a moraine-dammed lake at the south fork drainage divide (elevation 3129 m) indicates that ice covered this area. Ice flowed both northwest into the main valley and south along the Höh Serh Range ridge crest in the vicinity of the moraine-dammed lake (Fig. 2). Granitic bedrock along the ridge crest is the source of glacial erratics found downvalley. Ice from both forks merged (at an elevation of 2640 m) and flowed west to Delüün Valley. Ice volume within the valley at this time was approximately 10 km\(^3\) and covered an area of approximately 40 km\(^2\). Striated boulders preserved in drift deposits suggest that the glacier was at least partially warm-based.

The LGM glacier was up to 500 m thick in places. The thickest sections occurred where ice from the two forks merged 8 to 10 km downvalley of Praying Mountain summit.

A prominent terminal moraine (57 m high) lies at the mouth of Yamaat Valley, recognized by hump- mocks topography, kettles, and high concentrations of granite boulders (1-3 m in diameter) (Fig. 3). The south side moraine till is thicker, suggesting that more of the ice exiting the valley mouth probably flowed to the southwest, perhaps because the elevation of the bajada was lower here.
A recessional moraine 1 km upvalley from the terminal moraine is distinguished by hummocky topography, a rise in local elevation, kettles and an increased concentration of granitic boulders (Fig. 2). No other recessional moraines are exposed; either (1) no other moraines were deposited, or (2) moraines were later covered by colluvium. Ice deepened and steepened the preexisting valley, carving a trough up to 0.5 km deep and 2 km wide. Glacier retreat greatly reduced lateral support of the steep valley sides, causing extensive mass-wasting of weak metasedimentary rocks. Colluvium from slumps and rockfalls cover both sides of the valley. Solifluction lobes line part of the south side of Yamaat Valley (Fig. 2). Abundant rockfall also explains the existence of several large probable protalus ramparts. Individual ramparts vary significantly in age based on differences in vegetation and lichen cover (Fig. 4).

Granite cobbles were found 3.5 km southwest of the terminal moraine, partly up a ridge in Delüün Valley (anomalous granitic erratics in Fig. 2). Because the entire ridge is made of metasedimentary rocks, a jökulhlaup or moraine burst may have deposited these granitic cobbles. We calculated that such a flood would require a paleodischarge of roughly $1 - 3 \times 10^3$ m$^3$/s, depending upon the range of probable Manning’s resistance factors utilized (from 0.035 to 0.1).

**DISCUSSION**

ELAs were determined using GIS analysis and the Accumulation Area Ratio Method (assuming accumulation was 67%) and the Toe-To-Summit Method (assuming 50% distance from the summit of Praying Mountain to the terminal moraine). Calculated LGM ELAs for Yamaat Valley are 3300 m (AAR Method) and 3170 m (TSAM Method). Table 1 summarizes ELAs found for Yamaat Valley and nearby glaciated valleys within the Höh Serh Range. Lehmkühl et al. (2004) calculated LGM ELAs of 2800 to 3000 m in the northern Mongolian Altai and 3000 to 3600 m present ELAs in the Chinese and Mongolian Altai; he estimated an ELA depression of 500 m within the latter region during the Late Pleistocene (Lehmkühl et al., 2004). The 2008 Keck group calculated an average ELA of 3160 m for five LGM glaciers in the Höh Serh (Table 1).

While no single factor determines the ELA of a glacier, winter precipitation and summer temperatures account for 90% of ELA variance in the Colorado...
Rockies (Leonard, 1989). Mongolia has low mean annual precipitation (200 mm/yr at 2000 m). Mean annual temperatures can drop to around -20°C to -30°C in the winter while summer temperatures can exceed 20°C (Lehmkuhl, 1998). Paleoclimate research suggests that LGM climate was associated with a dry and cold period in western Mongolia, resulting in low-reaching glaciers and low lake levels (Grunert et al., 2000). Based on past and present ELAs, approximate rise in mean annual temperature since the LGM can be estimated at 2.5ºC using a temperature lapse rate of 1ºC/300 m and assuming constant precipitation.

**DATING**

Cosmogenic $^{10}$Be nuclide samples taken from the crest of the terminal moraine yield exposure ages of 31 +/- 3 ka, 33 +/- 3 ka, and 44 +/- 4 ka (mean 36 +/- 7 ka). This is consistent with the 32 +/- 6 ka estimate of the age of the last (Sartan) glaciation in central Mongolia (Lehmkuhl, 1998). Also, the measured boulder density of 0.12 boulders per m$^2$ is comparable to the boulder density of 0.18 boulders per m$^2$ from a probable LGM moraine in the Hangay Range 700 km east of the Altai (Coggan, 2007).

**WATER RESOURCES**

Present glacial retreat in this part of the Mongolian Altai is an order of magnitude greater than the long-term average retreat from 1963 to LGM. In Central Asia, increasing temperatures are speeding the rate of glacial retreat despite increasing precipitation. In China and the Tibetan Plateau, meltwater-supplied lake levels are increasing while those predominantly supplied by precipitation are dropping (Yao et al., 2007). The majority of precipitation falls in the summer months, which will reduce winter glacier accumulation and reduce stored water. Mongolia’s nomadic people have historically relied on glacial meltwater for subsistence in areas of sparse vegetation. Temporary benefits from increased discharge of meltwater-charged rivers will be offset by the negative effects of precipitation variability, seasonal shifts in water supply, and flood risks (Batima et al., 2005).

**CONCLUSIONS**

The maximum extent of glacial ice in Yamaat Valley occurred during the LGM. This late Pleistocene, partially warm-based glacier deposited a large terminal moraine at the valley mouth and a recessional moraine partially concealed by abundant mass-wasted material further upvalley. GIS analysis of reconstructed glacial topography indicates that about 10 km$^3$ of ice covered and area of approximately 40 km$^2$ during the LGM. A longitudinal profile indicates that ice thickness reached 500 m in places. The LGM ELA was at about 3200 m, somewhat higher than ELAs reported in Lehmkhul et al. (2004), either due to poorly constrained ice limits or to anomalous temperatures and/or precipitation during the LGM. The loss of ice mass from glacial retreat has social repercussions: nomadic groups will have limited access to consistent and reliable water sources as global temperatures rise and more precipitation falls as rain instead of snow.

**REFERENCES**

Batima, P., Natsagdorj, Gombluudev, P., and Erdenetsetseg, B., 2005, Observed climate change in Mongolia: AIACC (Assessments of Impacts and Adaptations to Climate Change) working paper no. 12, p.18; 23.


Lehmkuhl, F., Klinge, M., and Stauch, G., 2004, The extent of Late Pleistocene glaciations in the Al-
