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

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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
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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

SEAFLOOR VOLCANIC AND HYDROTHERMAL PROCESSES PRESERVED IN THE ABITIBI GREENSTONE BELT OF ONTARIO AND QUEBEC, CANADA
Faculty: *LISA A. GILBERT,* Williams College and Williams-Mystic and NEIL R. BANERJEE, U. of Western Ontario
Students: *LAUREN D. ANDERSON*: Lehigh University; *STEFANIE GUGOLZ*: Beloit College; *HENRY E. KERNAN*: Williams College; *ADRIENNE LOVE*: Trinity University; *KAREN TEKVERK*: Haverford College

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Students: *EVEY GANNAWAY*: The U. of the South; *KENNETH NELSON*: Macalester College; *MIGUEL RODRIGUEZ*: Colgate University

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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; *MAIJA 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
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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

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 SPRAJCAR*: ** 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 KHONDII, HÖH SERH RANGE, MONGOLIAN ALTAI

KATHRYN LADIG: Gustavus Adolphus College
Research Advisor: Laura Triplett
ENKHBAYAR MUNK-ERDENE**:** 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**:** Mongolian 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
BATTOGTOKH DAVAASAMBUU: Mongolia University of Science and Technology

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
DELGERTSEGTSEG BURENDELGER: Mongolia Univ. of Science and Technology

Visitors:

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

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

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

CHELSEA C. DURFEY: Whitman College
JARGAL OTGONKHUU: Mongolian University of Science and Technology
Research Advisors: Nick Bader and Bob Carson, Whitman College

INTRODUCTION

Right-lateral slip along northwest-trending ranges in western Mongolia is 10 mm/y due to the collision of India and Eurasia and extension from the Baikal rift system; this activity has resulted in 4 historic M>8 earthquakes in western Mongolia (Baljinnyam et al., 1993). The northwest-trending, right-lateral, oblique Höh Serh Fault (HSF), which accommodates a portion of this right-lateral slip, is exposed along the western edge of the Höh Serh range. We conducted a detailed survey on the Praying Mountain Fault Segment (PMFS), the 10-km segment of the HSF between Naran Khondii Valley in the north and Debris Flow Valley in the south (Fig. 1). We described and measured visible offsets along the PMFS in order to better understand its slip rate and mechanism of deformation and to quantify offset distances.

METHODS

After examining satellite imagery and conducting reconnaissance drives, we walked along the PMFS looking for signs of deformation, including breaks in slope on the mountain front, variation in vegetation, offset channels and alluvial fans, shutter ridges, changes in lithology, and fault fabrics. We measured offset in 23 locations. To measure vertical offset, we surveyed profiles perpendicular to the fault with a tape and clinometer (Fig. 2B). Lateral displacement, which we identified by offset drainages and shutter ridges, was measured along the strike of the PMFS with a tape and Brunton compass (Fig. 2D). We surveyed offset and fault features with a differential GPS in 27 locations. GIS was used to compile vertical and lateral displacement at various locations along the fault.

To estimate the timing of the last rupture along the PMFS, we compared the geomorphic expression of the fault exposures to other fault segments of known age in the Mongolian Altai (Walker et al., 2006). We combined this estimate with our measurements of horizontal and vertical offsets to calculate slip rate along the PMFS.

FAULT EXPRESSION

The average strike and dip of the PMFS is N 15-20° W, 80° E and its mean elevation is 2470 m (Fig. 1). Mean right-lateral offset of late Quaternary landforms is 31 +/- 26 m. Mean vertical offset is 3 +/- 3m, with the segment's maximum vertical offset of 12 m between Naran Khondii Valley and Rhyolite Valley (Table 1).

Measured lateral offsets vary along the PMFS (Table 1). This variability is unsurprising for four reasons. First, not all offset features are the same age; an old stream that experienced more fault ruptures should be offset more than a younger stream. Second, differential stress along the fault generates local differences in thrust or slip amounts. Third, a thrust fault does not always continuously intercept the surface; variation in the extent that it intercepts the surface causes variation in its geomorphic expression. Fourth, soils vary in their ability to preserve fault scarps, and in some places scree has covered the rupture site; thus post-movement erosive processes have dulled the fault's geomorphic expression and made offset impossible to observe in many places.

Shallow, discontinuous normal faults are found at a number of localities, such as 25 m above the thrust

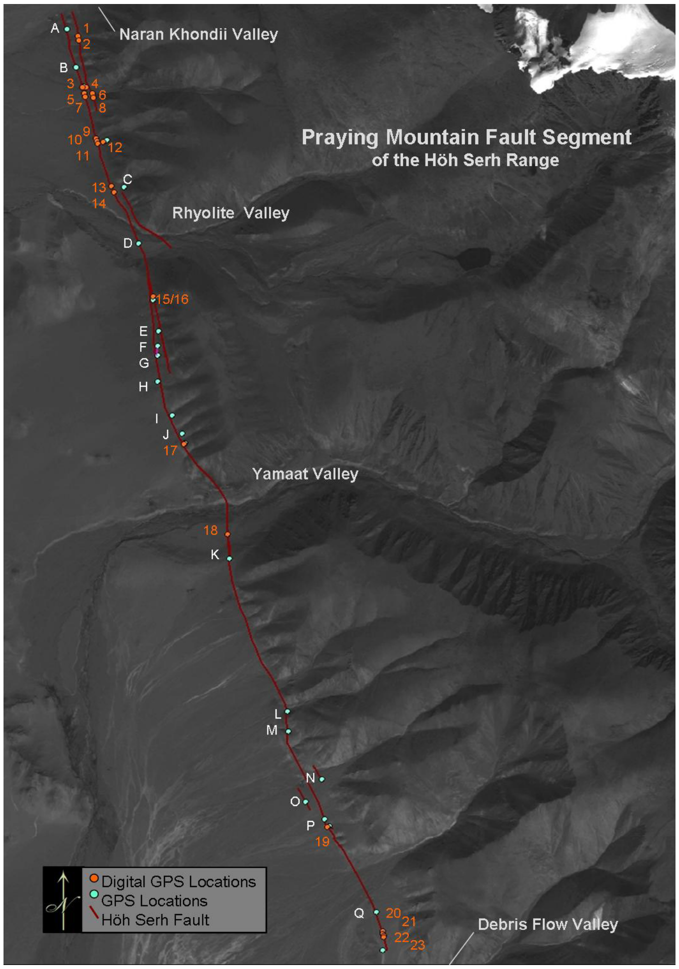

Figure 1: Map of the Praying Mountain Fault Segment between Naran Khondii Valley and Debris Flow Valley. Labeled points correspond with points in Table 1. Lettered points indicate observations of offset and/or geomorphic expression. Numbered points indicated observations measured with a digital differential GPS. Some labels are not shown due to overlap.

fault at point 1 on Figure 1. Two thrust faults, 113 m apart, extend from point C to just after point D (Fig.1). South of Rhyolite Valley, burrows and a break in slope indicate the lower fault. Three generations of terraces in Rhyolite valley and distinct notches in the south wall of Rhyolite Valley (Fig. 2A) indicate the HSF's reverse component. A ridge, point E and F (Fig. 1), 10° off strike is approximately 120 meters long. At the south end of the ridge is a 34 m by 32 m depression, at point G. This anomalous morphology may be related to a step in the fault.

En echelon tension gashes cross the Yamaat Valley terminal moraine (Fig. 2C). Here, the fault strikes N

Reference Points	Approximate Fault Elevation	Description of movement and/or feature	Lateral offset (m)	Vertical offset (m)	Total offse t (m)
1	2445	thrust, offset alluvial fan	na	3	3
2	2426	oblique, offset alluvial fan	19	5	19.6
3	2456	thrust, fan profile	na	1	1
4	2455	thrust, fan profile	na	2	2
5	2458	thrust, fan profile	na	1.5	1.5
6	2459	thrust, fan profile	na	1	1
7	2460	oblique, drainage profile	37	1.5	37
8	2458	thrust, fan profile	na	1	1
9	2450	thrust, fan profile	na	0.5	0.5
10	2486	thrust, fan profile	na	5	5
11	2486	thrust, drainage profile	na	5	5
12	2486	thrust, offset drainage	60	5	60.2
13	2500	thrust, drainage profile	na	12	12
14	2502	oblique, offset fan	20	10	22.4
15	2622	strike-slip, shutter ridge	86.5	na	86.5
16	2580	profile through lower fault	5	na	5
17	2461	oblique, shutter ridge	42	na	42
18	2419-2480	oblique, tension gashes	na	na	na
19	2400	oblique, offset drainage	20	2	20.1
20	2418	thrust fault profile	na	1	1
21	2419	thust fault profile	na	2	2
22	2416	thrust fault profile	na	na	na
23	2415	thrust fault profile	na	4	4
A	2424	thrust, offset drainage	na	3	3
B	2449	oblique, offset fan	45	na	45
C	2540	parallel thrusts, 110 m apar	na	na	na
D	2509	thrust, offset fan	na	2	2
E	2591	oblique, ridge	na	4	4
F	2580	oblique, ridge	na	4	4
G	2566	depression	na	2	2
H	2468	oblique, offset drainage	11.5	4	12.2
I	2549	oblique, offset drainage	na	1	1
J	2555	oblique, offset drainage	3.5	2	4
K	2440	oblique, offset drainage	12	na	12
L	2444	oblique, offset drainage	8.1	na	8.1
M	2446	oblique, offset drainage	65	na	65
N	2414	thrust, offset fan	na	3	3
O	2414	thrust, offset fan	na	4	4
P	2416	thrust fault profile	na	na	na
Q	2416	thrust fault profile	na	na	na
R	2412	spring	na	na	na

Table 1: Measured offsets along the PMFS. Points correspond with points in Figure 1.

15°. The orientation of the tension gashes indicates right-lateral motion. Dextral and reverse movement from Yamaat Valley to Debris Flow Valley is apparent in the satellite images. Baljinnyam et al. (1993) suggested that tension gashes are a common rupture style in the Altai and that their presence is preserved and further expanded by freeze-thaw conditions. As the tension gashes at Yamaat valley are at between 2420 m and 2480 m elevation, less than 2 km below the extant ice cap, freeze-thaw mechanisms are plausible.

Flat benches, parallel to the PMFS, are prominent immediately north of Debris Flow valley, at approximately 2500 m elevation. Here, vague fault scarps, dipping nearly vertical are discernable.

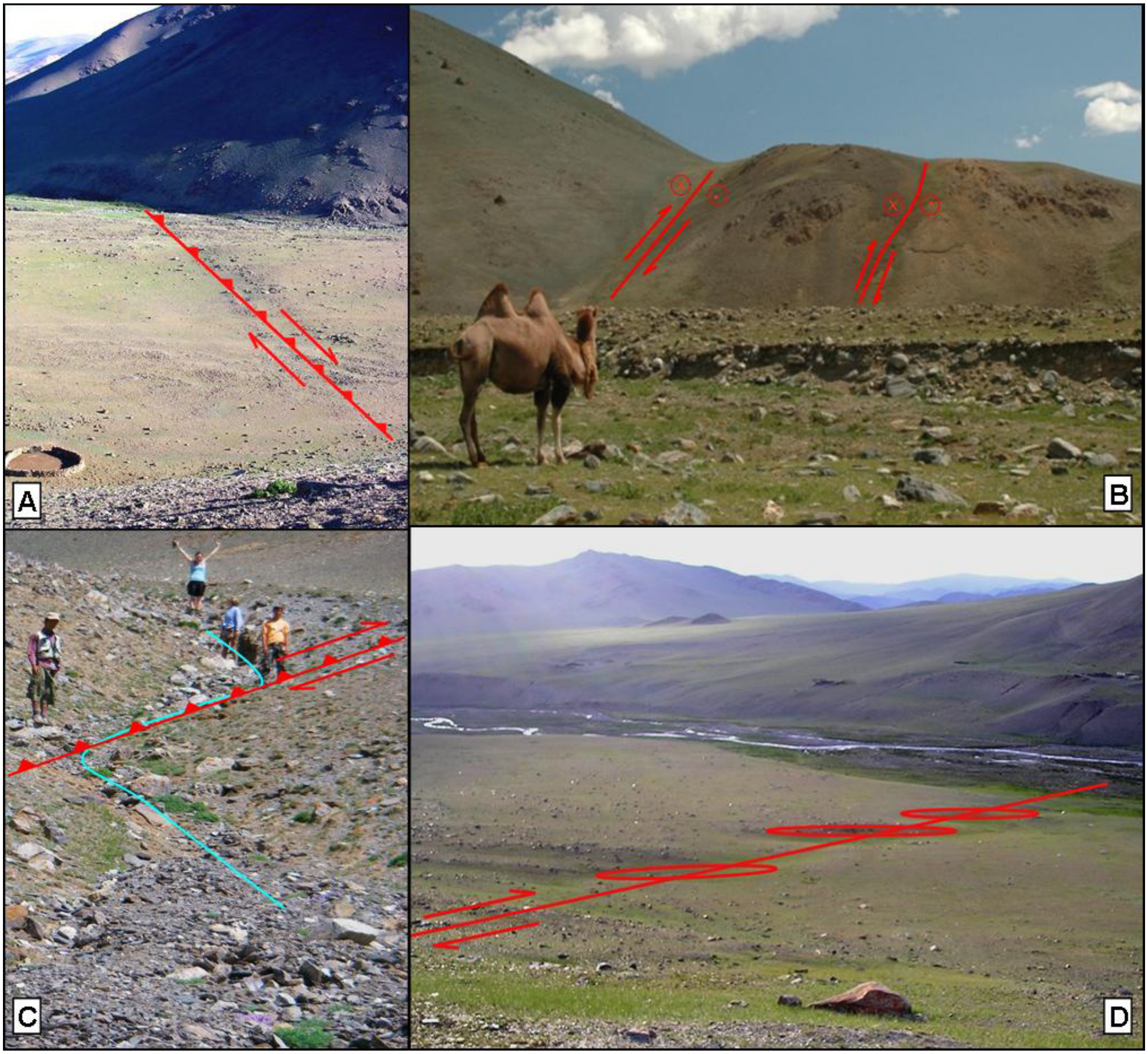

Figure 2: Tectonic geomorphology along the Praying Mountain Fault Segment. A: vertically offset scarp in Rhyolite Valley; B: dextrally offset drainage in Rhyolite Valley; C: two Rhyolite Valley fault scarps 113 m apart; D: tension gashes on Yamaat Valley's terminal moraine.

TIMING OF MOTION

Slow erosion rates in the Altai enable rupture scarps to be preserved for thousands of years (Walker et al., 2006). Cosmogenic dates indicate that the Deluun Debris Flow is around 13 ka; since the debris flow crosscuts the PMFS, the last rupture occurred >13 ka. Lake Valley Offset, a segment of the HSF to the north, last ruptured around 15 ka (Sprajcar, this volume). In comparison with the Lake Valley Offset, the PMFS rupture is poorly preserved; we thus estimate that the last movment occurred more than 15 ka.

Three strath terraces in Naran Khondii Valley indicate three separate fault ruptures. The uplift of the mountains during each rupture caused the river to downcut at the mountain front, resulting in the formation of strath terraces downstream that project into nickpoints upstream.

CONCLUSIONS

Steep mountain fronts along the PMFS make vertical offset apparent. The dextral component of the PMFS was confirmed by multiple offset drainages. Average strike along the PMFS is N 20° W, which is roughly perpendicular to the direction of convergence between India and Eurasia. Our principal results are consistent with Baljinnyam et al. (1993) and Cunningham et al. (2003), who concluded that the HSF is a right-lateral fault with a strong reverse component.

The consistent vertical offset throughout the segment (Table 1) is in agreement with previous assessments of western Mongolia's oblique faults: the reverse component of the HSF uplifted the Höh Serh Range and tilted it eastward.

Baljinnyam et al. (1993) calculated that lateral offset for the for the Western Altai is (6-10 mm y-1). Our estimation of lateral slip along the HSF (1 and 2 mm y-1 and vertical slip is about 0.5 mm y-1) is consistent this Baljinnyam calculation because the HSF accommodates only a portion of the total Altai strain.

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