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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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
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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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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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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.

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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

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***JARGAL OTGONKHUU*:** Mongolian University of Science and Technology

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ANDREA SEYMOUR: Whitman College
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ENKHBAYAR MUNK-ERDENE**:** Mongolia University of Science and Technology

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

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

INTRODUCTION

Active tectonics in Mongolia is dominated by transpression in the NNW-striking Mongolian Altai and EW-striking Gobi Altai, caused by NNE-directed shortening due to the Himalayan orogeny (Cunningham, 2005). In parts of Mongolia, this oblique motion is partitioned onto purely strike-slip and dip slip faults; in other areas the motion is accommodated on a single fault strand. In the Mongolian Altai, faults tend to strike NNW and have both dextral and thrust offsets.

This study considers a segment of a dextral strike-slip fault, the NNW-striking Höh Serh fault and the associated Tsagaan Salaa thrust in the Mongolian Altai near the village of Deluun (Fig. 1). Though the Höh Serh fault system has been surveyed at a fairly coarse resolution (Cunningham et al., 2003), this study adds detail regarding fault kinematics and regional fault slip rate estimates along a ~25 km partitioned section of the fault. South of the field area, both strike-slip and thrust motion of the Höh Serh fault system is accommodated along a single fault strand (Cunningham et al., 2003). Field observations and analytical techniques such as differential GPS and ^{10}Be cosmogenic dating are used to characterize fault motion.

METHODOLOGY

The Höh Serh and Tsagaan Salaa faults are most easily recognized by geomorphic and physiographic features. In addition to field observations, differential GPS was used to survey strath terraces in Big Gorge (48.05398N, 90.76556E) and an offset alluvial fan along the Tsagaan Salaa fault (48.09798N, 90.71220E). Three SW-NE profiles, separated by

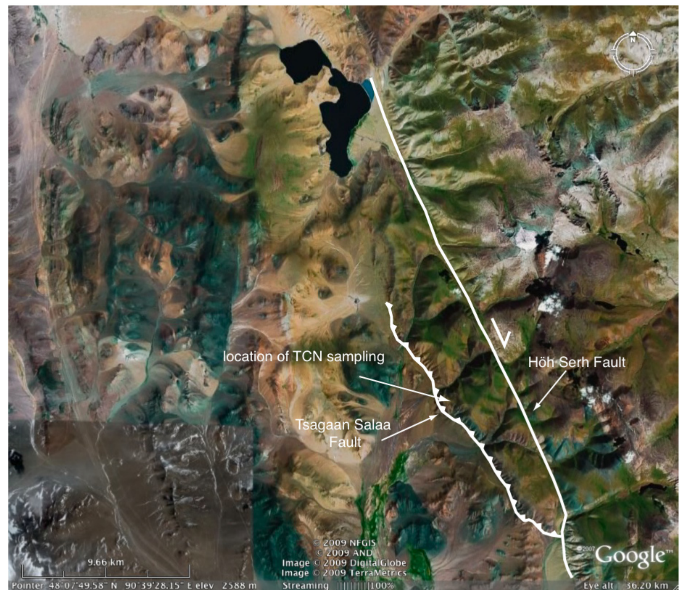


Figure 1. Map of study area showing Höh Serh fault and Tsagaan Salaa fault. The location of TCN sampling is also labeled. Note the offset of drainages along the Höh Serh fault. Modified from Google Earth.

about 20 m, were measured perpendicular to the strike of the fault scarp plane across the alluvial fan The offset for each scarp profile was calculated by averaging the hillslope above and below the scarp. The vertical distance between the hillslope projection lines of best fit for each profile corresponds to the vertical offset of the alluvial fan (Fig. 2).

Samples were collected for ^{10}Be terrestrial cosmogenic nuclide (TCN) dating from six quartz-rich boulders in a single alluvial fan offset by the Tsagaan Salaa fault (Fig. 1). Cosmogenic dating estimates the surface exposure age of geomorphic features by measuring the accumulation of radiogenic isotopes produced in near-surface grains of quartz upon bombardment by cosmic radiation. Boulders are ideal sampling targets because their size increases

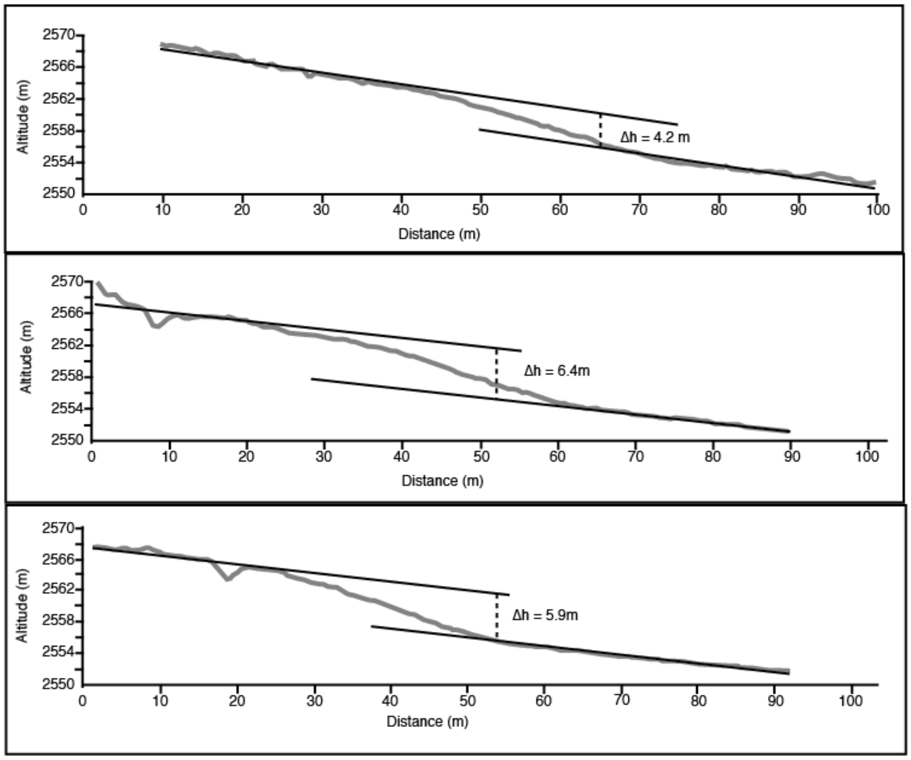


Figure 2. Three cross-sectional differential GPS profiles of a single offset alluvial fan along the Tsagaan Salaa Fault. The thick grey line is a smoothed curve of the GPS data. The black lines are linear regressions of the downslope data and translated upslope data.

the probability of a constant exposure history and decreases the likelihood of movement or cover by younger sediments. TCN age calculations were corrected for the following factors as suggested by Gosse et al., (2001): altitude, latitude, and topographic shielding, using the model of Lal (1991). Site-specific topographic shielding (angle to the horizon) was determined in the field with a handheld clinometer.

OBSERVATIONS AND RESULTS

The Höh Serh fault strikes NNW and dips steeply to the NE. The fault trace was inferred from several different geomorphic and topographic features. The fault is expressed topographically as either a depression (at high mountain passes) or as defining the course of local drainages (in valleys). The surface trace is suggested in one exposure by a sharp vertical contact between metasediments and a granite intrusion. Mole tracks (small push-up ridges) and tension gashes are also present along the trace of the strike-slip fault. This pattern of left-stepping alternating small-scale (< 5 x 5 m) depressions and topographic highs is a typical expression of dextral strike-slip faulting (Sylvester, 1988; Walker et al., 2006). The most obvious large-scale expression of the Höh Serh fault in the study area is the dextral offset of three rivers by as much as 2 km (Fig. 1). These multi-kilometer offsets record multiple ruptures, as indicated by smaller offsets further south on the fault (Sprajcar, this volume)

The Tsagaan Salaa fault is subparallel to the Höh Serh fault (strike 332), but dips shallowly (25°) to the NE. The fault is expressed in the field by vertical offset of alluvial fans at the base of the range front (Figs. 3a, b). In addition, there are several cross-strike drainages running between the Höh Serh and Tsagaan Salaa faults that pass through steep, narrow canyons, suggesting rapid rock uplift and contemporaneous river incision just upstream from where these streams exit the mountain range (Vassallo et al., 2007). The Tsagaan Salaa fault is exposed in cross-section in “Big Gorge” as a zone of fault gouge about 20 m wide (Fig. 3c) from which the dip of the thrust is estimated to be between 22–30° NE (Cun-

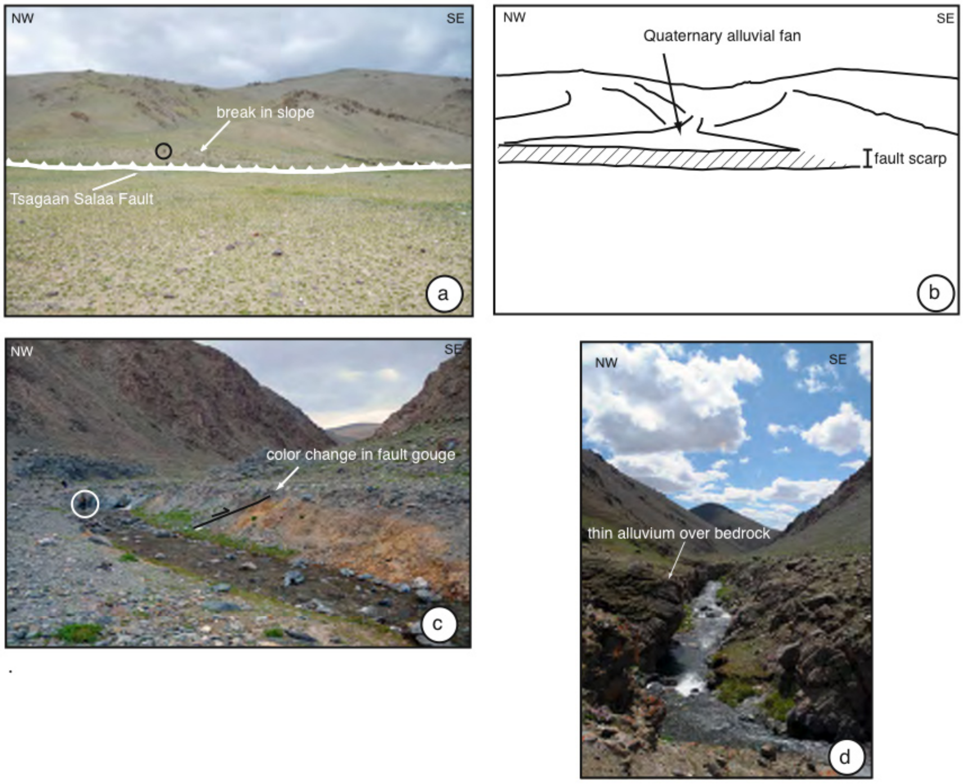


Figure 3. Field expression of Tsagaan Salaa Thrust. a. Offset alluvial fan. White line is approximate trace of fault. The circle encloses another student (for scale) b. Line drawing of a. Dashed area shows increased slope of fault scarp. c. Exposure of fault along Big Gorge. Gouge zone is around 50 m long. The circle highlights another student. d. Youngest strath terrace in Big Gorge. Strath is approximately 3 m high

ningham et al., 2003).

Upstream from the fault exposure, Big Gorge contains three fluvial strath terraces where the alluvium above the bedrock is < 3 m thick (Fig. 3d). The Tsagaan Salaa Fault runs perpendicular to the course of the drainage. Straths form in response to local or regional base-level fall, usually the result of climate change or tectonics (Burbank, 2001). This study follows the example of previous authors in using such terraces to estimate the rate of tectonic uplift, as indicated by incision rate (Vassallo et al., 2007; Wegmann and Pazzaglia, 2002).

The bedrock strath terraces in Big Gorge are a record of vertical offset along the Tsagaan Salaa fault. At the range front, there are three terraces that successively increase in height above the modern channel by ~2.5 m. The GPS survey shows that each terrace terminates in an abrupt convexity in the channel longitudinal profile (knickpoint), with the lowest terrace terminating at the down-stream most knickpoint, and the highest terrace at the upstream-most one (Fig. 4). Because of this pattern of termination, it is inferred that the straths formed as a result of local base-level fall due to tectonic uplift (Keller, 2002)and each terrace is interpreted as the

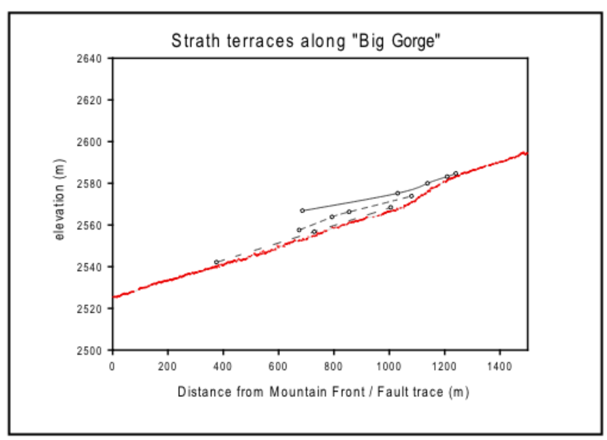
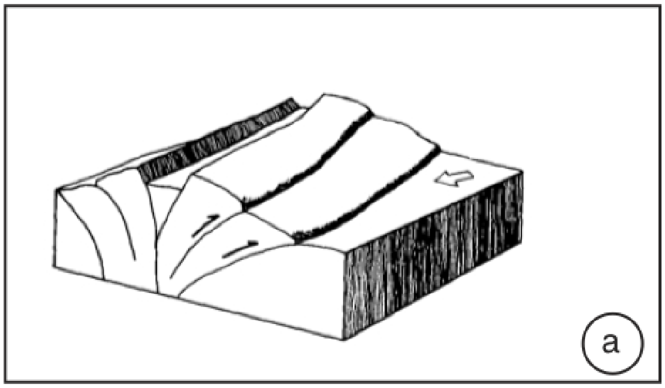


Figure 4. GPS profile of strath terraces in Big Gorge. Red points show location of channel bed. The solid grey line is the oldest strath terrace, the line with short dashes is the next youngest, and the line with long dashes is the youngest of all.



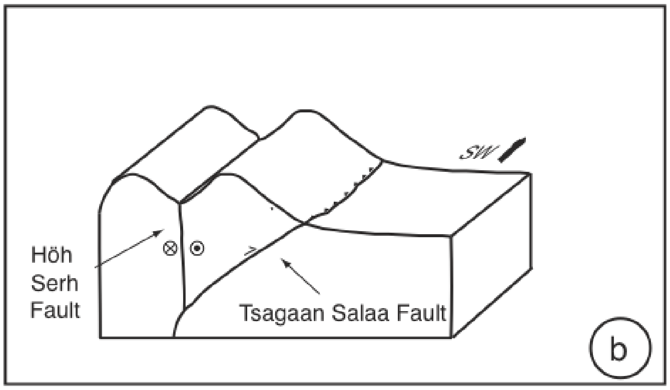


Figure 5. Flower structures a. Typical flower structure, adapted from Sylvester (1988). b. Hypothetical subsurface structure of Höh Serh fault system.

record of a single rupture of the fault, suggesting an average vertical component of rupture of ~2.5 m.

Based on the GPS survey detailed above, the offset alluvial fan along the Tsagaan Salaa Fault shows 5.5 ± 0.5 m of vertical displacement. TCN samples collected from the fan surface were prepared in Kurt Frankel's lab at Georgia Tech University.

Mass spectrometry analysis on the six samples, carried out at the Lawrence Livermore National Laboratory, returned an age of 35 +/- 5 ka. In contrast, based on the extent of stream dissection, the weathering of cobbles, and the relative surface roughness (Bull, 1991; Frankel and Dolan, 2007; Ritter et al., 1993), the fan dates to the mid-Holocene.

DISCUSSION

Based on an estimated alluvial fan age of 35 ± 5 ka, vertical throw across the Tsagaan Salaa Fault is 0.15 ± 0.02 mm/yr. The NE to SW-directed horizontal shortening rate across the fault is 0.23 ± 0.07 mm/yr, based upon the measured fault dip of 22°-30°.
The Tsagaaan Salaa and Höh Serh faults are most likely a single structure at depth. South of the field area, faults accommodate strike-slip and dip-slip motion, whereas within the field area, strain is partitioned. The distribution of strain often takes the form of a flower or palm tree structure, where a single subvertical feature at depth is expressed at the surface as a subvertical strike-slip fault and several subparallel shallow thrust faults (Bayasgalan et al., 1999; Sylvester, 1988). In this particular case, it appears that the structure is asymmetric, with only the Tsagaan Salaa fault branching off of the main Höh Serh fault (Fig. 5b).

Though the offset of the alluvial fan on the Tsagaan Salaa fault appears continuous, the scarp may actually be the result of multiple ruptures. Another alluvial fan surveyed south of the field area (on the unpartitioned section of the Höh Serh fault) is vertically offset by 2.75 ± 0.5 m, about half the offset measured on the Tsagaan Salaa fault (Sprajcar, this volume). Similarly, the strath terraces in Big Gorge are separated by ~2.5 m. Assuming that the Höh Serh and the Tsagaan Salaa faults are a single structure at depth, these offsets suggest that the scarp surveyed in this study records at least two rupture events.

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