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

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

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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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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
Students: *ELIZABETH BROWN*: Occidental College; *GIA MATZINGER, ANDREA SEYMOUR, RYAN J. LEARY*, *KELLY DUNDON* and *CHELSEA C. DURFEY*: Whitman College; *BRITTANY GAUDETTE*: Mount Holyoke College; *KATHRYN LADIG*: Gustavus Adolphus College; *GREG MORTKA*: Lehigh U.; *JODI SPRAJCAR*: The College of Wooster; *KRISTIN E. SWEENEY*: Carleton College.

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

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Research Advisor: Shelley Judge
ERDENEBAT BOLOR : Mongolia University of Science and Technology

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

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

ICE LAKE VALLEY GLACIATION, HÖH SERH RANGE, MONGOLIAN ALTAI

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GLACIATION OF RHYOLITE VALLEY, HÖH SERH RANGE, MONGOLIAN ALTAI

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GLACIATION OF YAMAAT VALLEY, HÖH SERH RANGE, MONGOLIAN ALTAI

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

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

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

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Laura Gregory	Oxford University
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APATITE FISSION TRACK THERMOCHRONOLOGY OF THE HöH SERH RANGE, MONGOLIAN ALTAI

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

INTRODUCTION

This study uses fission track thermochronology to determine the exhumation history of the Höh Serh Range in the Mongolian Altai. The Altai are an active mountain range, characterized by historical seismicity and Quaternary fault ruptures along major strike-slip faults, such as the Höh Serh fault. Very few low-temperature thermochronologic data exist for the Altai, and there are no published data for the Höh Serh Range. The exhumation history of these mountains is important for understanding the formation of intercontinental orogens and the distribution of far-field strain related to the Indo-Asia collision. Deformation in the interior of Asia is largely driven by the continuing Indo-Eurasian collision 2500 km to the south and the Mongolian Altai are thought to be evidence of northward propagation of stress from the Indo-Eurasian collision (e.g., Molnar and Tapponnier, 1975). The results of this study shed light on our understanding of intercontinental orogens and the geologic evolution of western Mongolia.

METHODS

Apatite Fission Track Thermochronology

Fission tracks are formed by the spontaneous fission of ^{238}U. Uranium occurs in trace amounts in all rocks, but is more concentrated in a few minerals, including apatite, which is found in most rocks in small quantities. When ^{238}U undergoes fission, its nucleus splits in half and the particles repel each other, forming a damage zone in the surrounding mineral lattice. These damage zones in the apatite crystal lattice, known as "tracks", are erased when the apatite grains are exposed to temperatures greater than ~110°C. The tracks undergo partial annealing between ~110°C and ~60°C. Below ~60°C, in shallow crustal levels of 1-2 km depth, the tracks are retained (Green et al., 1986). By comparing the amount of spontaneous fission tracks to the amount of uranium in the grain of apatite (determined by inducing fission in ^{235}U), the age at which the rock cooled through ~110°C can be determined; assuming a geothermal gradient allows the exhumation rate of the rock over the specified time period to be estimated.

Sample Analysis

The Mongolian Altai are composed of metasedimentary and metavolcanic rocks with extensive Paleozoic to Mesozoic intrusions of coarse-grained granite. These granite bodies are present from a local base level of about 2.4 km to the top of peaks higher than 3.7 km. This widespread distribution of granite allowed us to collect fission track samples with a total vertical relief of about 1.5 km, covering a distance of about 30 km along the Höh Serh fault. We collected samples in three vertical transects and in each case the lowest samples was within 2 km of the fault. This sampling strategy was employed so that the fission track cooling ages can be compared with the relative elevation of each sample.

Of the twelve samples collected, six were chosen for analysis, including one vertical transect and the two lowest-elevation samples. Apatite grains from each sample were separated and then mounted in epoxy. Sample surfaces were ground for 20 seconds with 400 grit paper and then for another 20 seconds with 600 grit paper. The slides were then polished for 3-5 minutes with 6 micron diamond paste, and then 3-5 minutes with 1 micron diamond paste. The apatite mounts were then etched in 5.5 molar HNO_3 for 21 seconds at room temperature. An "external

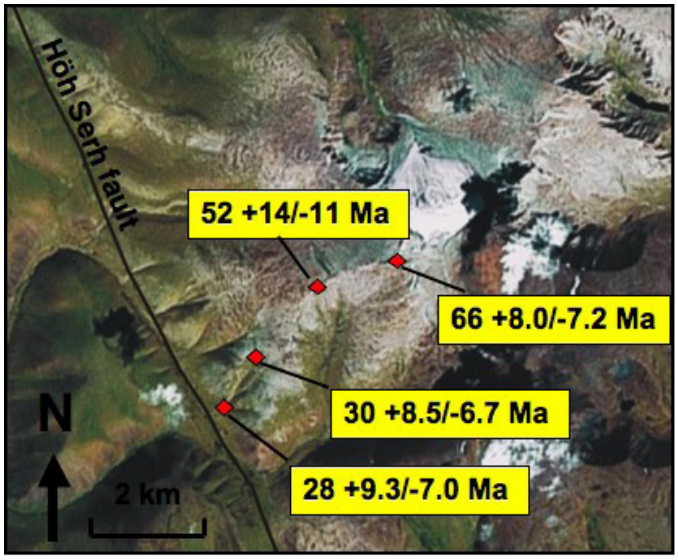

Figure 1. Aerial photograph showing sample ages and distance from the Höh Serh fault. Ages increase with elevation, which is predicted theoretically. The large change in FT age with elevation suggests that these samples are part of an exhumed PAZ.

detector" (e.g., Naeser, 1979), consisting of low-U (<5 ppb) Brazil Ruby muscovite, was used for each sample, which were irradiated in the Oregon State University TRIGA nuclear reactor.

After irradiation, the muscovite detectors were etched in 48% HF for 30 minutes to reveal the induced ^{235}U fission tracks. Tracks were counted only in apatite grains with well-etched, clearly visible tracks and sharp polishing scratches using a 100X dry lens and 1250X total magnification. Lengths of horizontal tracks were measured in each sample. A Kinitek microscope stage and track length modeling software written by Dumitru (1993) were used for analyses. Ages were calculated using my pre-determined zeta of 348 ± 32 for dosimeter CN5 (e.g., Hurford and Green, 1983). The apatite fission track ages and errors were calculated with the program Binomfit (Brandon, 1992).

RESULTS

Four samples we analyzed using fission track thermochronology. Sample ages ranged from 28 +9.3/-7.0 to 66 +8.0/-7.2 Ma (Fig. 1). Ages increase with elevation, which is predicted theoretically. An inverse thermal model was produced from the distribution of measured track lengths for the sample at the highest elevation using HeFTy (Ketcham et al., 2005). The model is consistent with major cooling and exhumation through ~60 Mya, followed by relatively stability to the present day (Fig. 2). A small pulse of late stage cooling and exhumation beginning at ~10 Ma may be indicated by the model but needs further work to confirm.

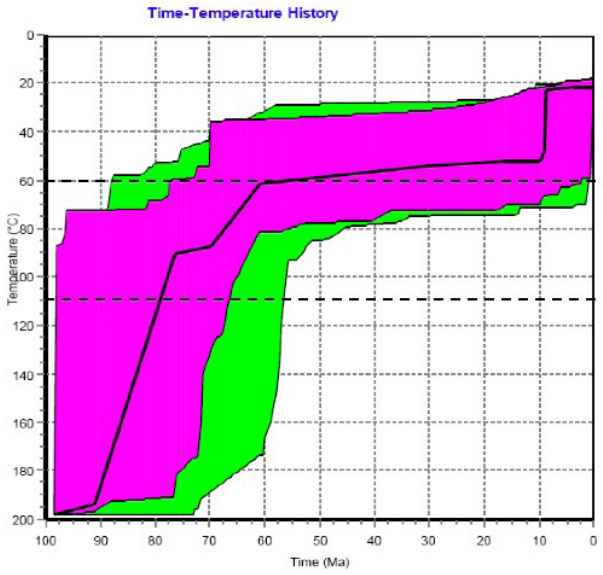

Figure 2. Inverse thermal model produced with HeFTy (Ketcham et al., 2005) for sample MA-3. The exterior envelope corresponds to 2σ uncertainty, the internal envelope corresponds to 1σ uncertainty. The validity of the models is limited to the areas above and below the PAZ, between about 40° and 120.

DISCUSSION

Previous fission track thermochronology studies on areas near the Höh Serh Range found that the mountains in western Mongolia have a two-phase exhumation history. Results from both De Grave et al. (2002) and Vassallo et al. (2007) suggest that these ranges were initially exhumed during the Jurassic, with fission track ages of about 150 Ma. Thermal modeling of sample ages and track lengths reveal a more recent period of exhumation during the Miocene. The first stage of exhumation correlates to the widespread denudation of a low-relief landscape during the Jurassic (Jolivet et al., 2007).

As found in other locations by De Grave et al.

(2002) and Vassallo et al. (2007), while the Höh Serh Mountains were exhumed during the Miocene, there has not been enough exhumation for the rocks that are currently at the surface to have been "reset". More work, including inverse thermal models of the samples at lower elevations, will better capture a signal of Cenozoic exhumation of the Höh Serh Range.

CONCLUSIONS

The large change in fission track age with elevation suggests that these samples are part of an exhumed partial annealing zone (PAZ). However, the data do not capture the lower break in slope of the PAZ and therefore do not provide us with exhumation onset timing. Thermal models of the lowest-elevation sample might capture a more robust signal of exhumation over the last 10 Ma, as is predicted by previous research and the regional geology (e.g. Vassallo et al., 2007). (U-Th)/He dating of these samples might better capture any Late Cenozoic exhumation. Based on the final pulse of cooling in the thermal model, and a geothermal gradient of 30˚C/km depth, the exhumation rate over the last 10 Ma is 175 ± 25 m per My.

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