KECK GEOLOGY CONSORTIUM

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

April 2011
Union College, Schenectady, NY

Dr. Robert J. Varga, Editor
Director, Keck Geology Consortium
Pomona College

Dr. Holli Frey
Symposium Convenor
Union College

Carol Morgan
Keck Geology Consortium Administrative Assistant

Diane Kadyk
Symposium Proceedings Layout & Design
Department of Earth & Environment
Franklin & Marshall College

Keck Geology Consortium
Geology Department, Pomona College
185 E. 6th St., Claremont, CA 91711
(909) 607-0651, keckgeology@pomona.edu, keckgeology.org

ISSN# 1528-7491

The Consortium Colleges The National Science Foundation ExxonMobil Corporation

KECK GEOLOGY CONSORTIUM
PROCEEDINGS OF THE TWENTY-FOURTH ANNUAL KECK RESEARCH SYMPOSIUM IN GEOLOGY

ISSN# 1528-7491

April 2011

Robert J. Varga
Editor and Keck Director
Pomona College

Keck Geology Consortium
Pomona College
185 E 6th St., Claremont, CA 91711

Diane Kadyk
Proceedings Layout & Design
Franklin & Marshall College

Keck Geology Consortium Member Institutions:
Amherst College, Beloit College, Carleton College, Colgate University, The College of Wooster, The Colorado College, Franklin & Marshall College, Macalester College, Mt Holyoke College, Oberlin College, Pomona College, Smith College, Trinity University, Union College, Washington & Lee University, Wesleyan University, Whitman College, Williams College

2010-2011 PROJECTS

FORMATION OF BASEMENT-INVOLVED FORELAND ARCHES: INTEGRATED STRUCTURAL AND SEISMOLOGICAL RESEARCH IN THE BIGHORN MOUNTAINS, WYOMING
Faculty: *CHRISTINE SIDDOWAY*, *MEGAN ANDERSON*, Colorado College, *ERIC ERSLEV*, University of Wyoming
Students: *MOLLY CHAMBERLIN*, Texas A&M University, *ELIZABETH DALLEY*, Oberlin College, JOHN *SPENCE HORNBUCKLE III*, Washington and Lee University, *BRYAN MCATEE*, Lafayette College, *DAVID OAKLEY*, Williams College, *DREW C. THAYER*, Colorado College, *CHAD TREXLER*, Whitman College, *TRIANA N. UFRET*, University of Puerto Rico, *BRENNAN YOUNG*, Utah State University.

EXPLORING THE PROTEROZOIC BIG SKY OROGENY IN SOUTHWEST MONTANA
Faculty: *TEKLA A. HARMS*, *JOHN T. CHENEY*, Amherst College, *JOHN BRADY*, Smith College
Students: *JESSE DAVENPORT*, College of Wooster, *KRISTINA DOYLE*, Amherst College, *B. PARKER HAYNES*, University of North Carolina - Chapel Hill, *DANIELLE LERNER*, Mount Holyoke College, *CALEB O. LUCY*, Williams College, *ALIANORA WALKER*, Smith College.

INTERDISCIPLINARY STUDIES IN THE CRITICAL ZONE, BOULDER CREEK CATCHMENT, FRONT RANGE, COLORADO
Faculty: *DAVID P. DETHIER*, Williams College, *WILL OUIMET*. University of Connecticut
Students: *ERIN CAMP*, Amherst College, *EVAN N. DETHIER*, Williams College, *HAYLEY CORSON-RIKERT*, Wesleyan University, *KEITH M. KANTACK*, Williams College, *ELLEN M. MALEY*, Smith College, *JAMES A. MCCARTHY*, Williams College, *COREY SHIRCLIFF*, Beloit College, *KATHLEEN WARRELL*, Georgia Tech University, *CIANNA E. WYSHNYSZKY*, Amherst College.

SEDIMENT DYNAMICS & ENVIRONMENTS IN THE LOWER CONNECTICUT RIVER
Faculty: *SUZANNE O'CONNELL*, Wesleyan University
Students: LYNN M. GEIGER, Wellesley College, KARA JACOBACCI, University of Massachusetts (Amherst), GABRIEL ROMERO, Pomona College.

GEOMORPHIC AND PALEOENVIRONMENTAL CHANGE IN GLACIER NATIONAL PARK, MONTANA, U.S.A.
Faculty: *KELLY MACGREGOR*, Macalester College, *CATHERINE RIIHIMAKI*, Drew University, *AMY MYRBO*, LacCore Lab, University of Minnesota, *KRISTINA BRADY*, LacCore Lab, University of Minnesota

Students: *HANNAH BOURNE*, Wesleyan University, *JONATHAN GRIFFITH*, Union College, *JACQUELINE KUTVIRT*, Macalester College, *EMMA LOCATELLI*, Macalester College, *SARAH MATTESON*, Bryn Mawr College, *PERRY ODDO*, Franklin and Marshall College, *CLARK BRUNSON SIMCOE*, Washington and Lee University.

GEOLOGIC, GEOMORPHIC, AND ENVIRONMENTAL CHANGE AT THE NORTHERN TERMINATION OF THE LAKE HÖVSGÖL RIFT, MONGOLIA
Faculty: *KARL W. WEGMANN*, North Carolina State University, *TSALMAN AMGAA*, Mongolian University of Science and Technology, *KURT L. FRANKEL*, Georgia Institute of Technology, *ANDREW P. deWET*, Franklin & Marshall College, *AMGALAN BAYASAGALN*, Mongolian University of Science and Technology.
Students: *BRIANA BERKOWITZ*, Beloit College, *DAENA CHARLES*, Union College, *MELLISSA CROSS*, Colgate University, *JOHN MICHAELS*, North Carolina State University, *ERDENEBAYAR TSAGAANNARAN*, Mongolian University of Science and Technology, *BATTOGTOH DAMDINSUREN*, Mongolian University of Science and Technology, *DANIEL ROTHBERG*, Colorado College, *ESUGEI GANBOLD*, *ARANZAL ERDENE*, Mongolian University of Science and Technology, *AFSHAN SHAIKH*, Georgia Institute of Technology, *KRISTIN TADDEI*, Franklin and Marshall College, *GABRIELLE VANCE*, Whitman College, *ANDREW ZUZA*, Cornell University.

LATE PLEISTOCENE EDIFICE FAILURE AND SECTOR COLLAPSE OF VOLCÁN BARÚ, PANAMA
Faculty: *THOMAS GARDNER*, Trinity University, *KRISTIN MORELL*, Penn State University
Students: *SHANNON BRADY*, Union College. *LOGAN SCHUMACHER*, Pomona College, *HANNAH ZELLNER*, Trinity University.

KECK SIERRA: MAGMA-WALLROCK INTERACTIONS IN THE SEQUOIA REGION
Faculty: *JADE STAR LACKEY*, Pomona College, *STACI L. LOEWY*, California State University-Bakersfield
Students: *MARY BADAME*, Oberlin College, *MEGAN D'ERRICO*, Trinity University, *STANLEY HENSLEY*, California State University, Bakersfield, *JULIA HOLLAND*, Trinity University, *JESSLYN STARNES*, Denison University, *JULIANNE M. WALLAN*, Colgate University.

EOCENE TECTONIC EVOLUTION OF THE TETONS-ABSAROKA RANGES, WYOMING
Faculty: *JOHN CRADDOCK*, Macalester College, *DAVE MALONE*, Illinois State University
Students: *JESSE GEARY*, Macalester College, *KATHERINE KRAVITZ*, Smith College, *RAY MCGAUGHEY*, Carleton College.

Funding Provided by:
Keck Geology Consortium Member Institutions
The National Science Foundation Grant NSF-REU 1005122
ExxonMobil Corporation

Keck Geology Consortium: Projects 2010-2011
Short Contributions— Hövsgöl Rift, Mongolia

GEOLOGIC, GEOMORPHIC, AND ENVIRONMENTAL CHANGE AT THE NORTHERN TERMINATION OF THE LAKE HÖVSGÖL RIFT, MONGOLIA
Project Faculty: KARL W. WEGMANN: North Carolina State University, TSALMAN AMGAA: Mongolian University of Science and Technology, KURT L. FRANKEL: Georgia Institute of Technology, ANDREW P. deWET: Franklin & Marshall College, AMGALAN BAYASAGALN: Mongolian University of Science and Technology

MAPPING AND RELATIVE AGE DATING OF MORAINES IN THE HOROO GOL VALLEY, HÖVSGÖL RIFT, MONGOLIA
BRIANA BERKOWITZ, Beloit College
Research Advisor: Susan Swanson

PALEOLIMNOLOGY AND PALEOCLIMATE ENVIRONMENT REVEALED THROUGH HOLOCENE LAKE SHORE SEDIMENTS FROM HÖVSGÖL, MONGOLIA
DAENA CHARLES, Union College
Research Advisor: Donald Rodbell

A MULTI-PROXY STUDY OF HOLOCENE PALEOCLIMATE AND DEPOSITIONAL ENVIRONMENT, HÖVSGÖL, MONGOLIA
MELLISSA CROSS, Colgate University
Research Advisor: Bruce Selleck

CORRELATION OF TREE RING ANALYSIS AND CLIMATOGICAL RECORDS IN THE LAKE HÖVSGÖL REGION OF MONGOLIA
JOHN MICHAELS, North Carolina State University
ERDENEBAYAR TSAGAANNARAN, Mongolian University of Science and Technology
BATTOGTOH DAMDINSUREN, Mongolian University of Science and Technology
Research Advisor: Karl Wegmann

LATE PLEISTOCENE GLACIATION AND TECTONICS AT LAKE HÖVSGÖL
DANIEL ROTHBERG, Colorado College
Mongolian Participants: Esugei Ganbold, Aranzal Erdene
Research Advisor: Eric Leonard

TIMING AND EXTENT OF LATE QUATERNARY GLACIATIONS NEAR LAKE HÖVSGÖL, MONGOLIA: IMPLICATIONS FOR CLIMATE CHANGE IN CENTRAL ASIA
AFSHAN SHAIKH, Georgia Institute of Technology
Research Advisor: Kurt L. Frankel

THE PALEOSEDIMENTARY ENVIRONMENT AND PALEOCLIMATIC CONDITIONS REVEALED BY STRATIGRAPHY IN HOLOCENE BOG AND TERRACE SEDIMENTS, NORTHWEST OF LAKE HÖVSGÖL, MONGOLIA
KRISTIN TADDEI, Franklin and Marshall College
Research Advisor: Dr. Andy deWet

PLEISTOCENE GLACIATION OF THE EASTERN SAYAN RANGE, NORTHERN MONGOLIA
GABRIELLE VANCE, Whitman College
ESUGEI GANBOLD, Mongolia University of Science and Technology
Research Advisors: Bob Carson and Nick Bader

LATE-CENOZOIC VOLCANISM IN THE HÖVSGÖL RIFT BASIN: SOURCE, GENESIS, AND EVOLUTION OF INTRAPLATE VOLCANISM IN MONGOLIA

ANDREW ZUZA, Cornell University
ARANZAL BAT-ERDENE, Mongolian University of Science and Technology
Research Advisor: Christopher Andronicos

Keck Geology Consortium
Pomona College
185 E. 6th St., Claremont, CA 91711
Keckgeology.org

CORRELATION OF TREE RING ANALYSIS AND CLIMATOLOGICAL RECORDS IN THE LAKE HÖVSGÖL REGION OF MONGOLIA

JOHN MICHAELS, North Carolina State University
ERDENEBAYAR TSAGAANNARAN, Mongolian University of Science and Technology
BATTOGTOH DAMDINSUREN, Mongolian University of Science and Technology
Research Advisor: Karl Wegmann

INTRODUCTION

The Lake Hövsgöl region receives most of its annual precipitation during the mild summer months of July and August, while winter is harsh and typically very cold and dry. Climatic data sets from 3 meteorological monitoring stations (MMS) near Lake Hövsgöl reveal a 1°C increase in mean annual temperature over the past 20 years. The findings of Batima et al. (2005), with similar data, agree that the mean air temperature has increased by 1.66°C for the last 70 years, with distinct warming from the beginning of the 1970s increasing toward the end of the 1980s and 1990s. This indicates that both the summers and winters of Lake Hövsgöl are warming. Do the nomadic and semi-nomadic herders of Lake Hövsgöl (or for that matter all Mongolians) have reason to be concerned about a 1°C increase in temperature over the past 20 years? What is the impact of this temperature change on the Mongolian ecosystem? Changes in weather patterns may disrupt the growth of grasses which are key to the survival of foraging livestock upon which the majority of the Mongolian populous depends. Nearly 50 percent of Mongolia's population is reliant on animal husbandry with an additional 35% of the population dependent upon agricultural gross production, which accounts for 30% of Mongolia's export. Climatic changes may adversely impact pasture availability, threatening forage yield, endangering livestock productivity, and ultimately adversely impacting the food production capacity of local and national food producers.

The goal of this project is to characterize the variability of precipitation and temperature change through the construction of native tree ring chronologies and ring-width indices spanning several hundred years for the northern Lake Hövsgöl region and perform stable isotopic analysis of extracted alpha-cellulose in an effort to validate the instrumented climatic observations over longer time periods. Analysis of the ratios of stable isotopes (O, H) in cellulose can be used as "palaeothermometers" to help reconstruct a climatologic record (Wilson and Grinsted, 1977). For this project, analysis was performed on a single wood component, cellulose, in order to minimize the variability of the ratio of wood constituents like lignin-to-cellulose as noted in (Wilson and Grinsted, 1977).

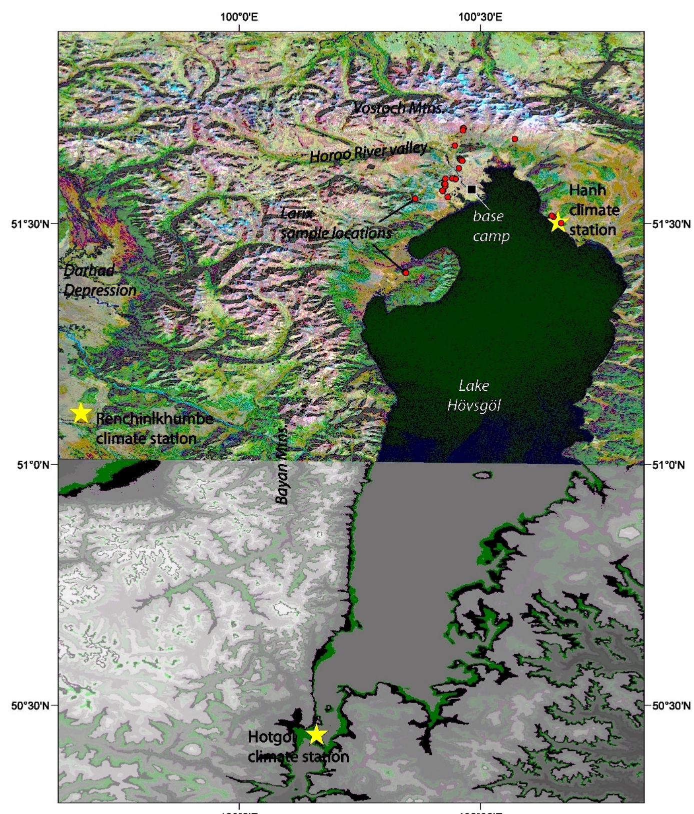

Figure 1. Study areas and meteorological monitoring stations (MMS) near Lake Hövsgöl

STUDY SITES

The Hövsgöl basin lies at the southern limit of the continuous Siberian boreal (taiga) forest. At the latitude of northern Lake Hövsgöl, forest stands are naturally composed almost entirely of Siberian larch (Larix siberica). The tree core samples for this study were gathered from several sites that lie along the northern shores of Lake Hövsgöl in the Horoo Gol valley (51.570° N; 100.462°E). Siberian larch chosen for this study are growing on south facing slopes, widely separated from other trees in the stand, and have large diameters (> 2 m) and heights (>18 m). Southern slopes were chosen because they are moisture-limited, making the stable-isotope analysis more feasible. Additionally, the selected trees were screened to avoid those with signs of burn scars, insect infestation or outward signs of heart-rot (to which L. Siberica is prone) and those with obvious anthropogenic influence. The slope aspect of the selected trees ranged from 0 to 31° (mean = 8°) and are covered with thin mantles and solifluction debris composed of granitic and balsatic rocks. The position of the tree line and the diversity and distribution of species in northern Mongolia are climatically controlled by humidity (total effective moisture) and temperature gradients (Jacoby et al., 2003).

Tree	Longitude	Latitude	Elevation(M)	C(m)	Slope(°)	Aspect	Species	Ht(m)	Age
T01	100.44733	51.59362	1780	2.6	0	None	L.Siberica	20	240
T02	100.44261	51.59357	1762	2.33	22	ESE	L.Siberica	20	246
T03	100.42793	51.59314	1807	2.23	0	None	L.Siberica	19	213
T04	100.42724	51.57721	1727	2.7	0	None	L.Siberica	23	272
T05	100.43301	51.75526	1699	2.3	0	None	L.Siberica	15	247
T10	100.36591	51.55217	1938	1.45	28	S	L.Siberica	18	63
T11	100.45828	51.63493	2001	1	0	None	L.Siberica	18	96
T12	100.45866	51.63438	1990	2.35	0	None	L.Siberica	21	202
T13	100.46047	51.63243	1998	2.25	0	None	L.Siberica	19.6	215
T14	100.46282	51.63102	2036	0.91	30	S	L.Siberica	8	87
T15	100.45638	51.61506	1771	1.7	25	S	L.Siberica	8	162
T16	100.34314	51.39939	1842	1.95	15	SE	L.Siberica	26	217
T17	100.34504	51.4003	1822	1.55	0	None	L.Siberica	25	90
T18	100.34566	51.40007	1816	1.36	0	None	L.Siberica	23	134
T19	100.34594	51.39968	1819	1.63	0	None	L.Siberica	21	126
T20	100.34578	51.3995	1826	1.8	0	None	L.Siberica	22	172
T21	100.34653	51.39848	1815	0.95	10	SW	L.Siberica	16	91
T22	100.34673	51.39793	1821	1.78	0	None	L.Siberica	27	170
T23	100.65257	51.51411	1675	1.83	31	SE	L.Siberica	20	155
T24	100.64892	51.51596	1766	1.88	0	None	L.Siberica	21	250
T25	100.66776	51.50119	1686	1.86	20	SW	L.Siberica	18	175
T26	100.57224	51.67605	2019	2.17	25	SE	L.Siberica	22.7	223
T27	100.42569	51.58205	1847	2.52	17	SE	L.Siberica	18	241
T28	100.42716	51.58239	1838	2.6	0	None	L.Siberica	18.9	177
T29	100.46481	51.69844	2306	0.58	0	None	L.Siberica	7.3	75
T30	100.46496	51.6983	2307	0.67	0	None	L.Siberica	7	90
T31	100.4659	51.69783	2301	0.6	0	None	L.Siberica	7	93
T32	100.46474	51.69411	2258	0.98	10	SW	L.Siberica	7	94
T35	100.44798	51.66182	1938	2.32	0	None	L.Siberica	14	174
TS02	100.44993	51.59249	1836	0.68	0	None	L.Siberica	N/A	245

Table 1. Trees cored by location, elevation, circumference, slope, aspect, species, height and age

METHODS AND MATERIALS

This study was conducted in two phases, tree ring analysis to construct chronologies and ring-width indices and the stable-isotope analysis of the core samples.

Tree Ring Analysis

During the months of July and August 2010, a total of thirty-one tree cores were taken from twenty-nine L. Siberica using a 5 mm increment borer at breast-height (Table 1). For those trees with non-zero slope aspects, the cores were taken parallel to the slope contour thereby avoiding reaction wood (Speer, 2010). Two cores were taken from selected trees in order to obtain a full diameter core section. The cores were stored in plastic straws to avoid damage in transit and storage prior to preparation.

Cores were prepared using Speer's methodology (Speer, 2010). The cores were removed from the straws and placed in wooden sample holders; some samples showed evidence of mold. The cores were glued into the concave slot of the sample holders using wood glue and allowed to dry for at least 24 hours. The protruding upper half of the core was then removed down to the level of the sample holder by both belt and hand sanding with progressively finer grit sandpaper until a smooth surface was obtained. The orientation (bark-ring) of the sample was denoted on the sample holder for reference.

The prepared samples were then visually analyzed under a binocular microscope at 30x magnification and the width of individual rings measured and recorded with a Velamex Rapid Advance Unislide linear encoder that interfaces between the microscope and a PC using the ring counting procedure outlined by Speer (Speer, 2010). This process starts by assigning the year of the core acquisition to the bark end of the sample and then counts rings backwards in time to the sample pith. Total ring widths (including early and late wood) were measured to within 0.01 mm using the MeasureJ2X software package interfaced to the Velamax encoder. The ring width was exported from MeasureJ2X into a text file per core sample. Text files were manually edited to correct data format problems. These files were then imported into the

TSAPWin software package (Rinntech GmbH, 2011) for cross-dating of time series. This step is critical to eliminate false rings, allow for insertion of missing rings and determine correlation between sites.

Figure 2. A. Field methods B. alpha cellulose extraction lab methods

Stable Isotope Analysis of Alpha Cellulose

Because of reaction tissues and growth disturbances, most of the trees sampled were not dateable by dendrochronology. These tissues and disturbances disrupt the expected environmental signal of wide and narrow rings that enable cross-dating. Of the dated trees, three trees were selected for the hydrogen and oxygen isotopic analysis, however due to time limitations, only one tree was used. Selection criteria was based on three criteria used by (Loader et al., 2007): wood quality based on the absence of reaction tissue or rot, chronology (no partial/false rings) and age (to avoid potential isotopic 'juvenile' effects, samples chosen were greater than 150 years old). Alpha-cellulose was extracted and purified from the wood samples using a slightly modified Brendel method (; Fig. 3; Brendel et al., 2000) and placed in a desiccator filled with anhydrous silica gel prior to isotopic analysis. Oxygen and Hydrogen isotopes from the extracted alpha-cellulose were measured on an isotope ratio mass spectrometry (IRMS) in the North Carolina State University Stable Isotope Laboratory. At the time of writing, these analyses were ongoing.

RESULTS AND DISCUSSION

Although the results of the isotope analysis are not yet complete, the project intends to perform correlation analysis between dendroclimatic and stable isotope $\delta^{18}O$ data with the data sets obtained from

Step 1
• Take 10-100 mg milled sample
• Add 2 mL 80% v/v acetic acid
• Add.2mL 69% v/v nitric acid
• Seal and vortex
• Boil gently at 120ºC for 20 minutes
Step 2
• Allow to cool
• Add 2.5 mL of 99% v/v ethanol
Step 3
• Seal and vortex
• Centrifuge for 5 minutes at 2000 rpm
• Decant supernatant
Step 4
• Add 2 x 2.5 mL of 99% v/v ethanol
• Repeat Step 3
Step 5
• Add 2 x 2.5 mL deionized water
• Repeat step 3
Step 6
• Add 2 x 2.5 mL of 99% v/v ethanol
• Repeat Step 3
Step 7
• Add 2 x 2.5 mL acetone
• Repeat Step 3
Step 8
• Add .4 mL acetone
• Add.6 ml L acetone
• Transfer sample to 1.5 mL microfuge tube
• Vacuum dry

Figure 3. The modified protocol for purification of alpha cellulose from Micro-samples of tree cell wall material using acetic acid: nitric acid for simultaneous delignification and removal of non-cellulose polysaccharides, after Brendel et al., 2000.

3 meteorological monitoring stations (MMS) around Lake Hövsgöl. Climatic data sets were obtained from Hotgol at the south end of lake, Hanh at the northern end of lake, and Renchinlkhumbe to the west in the Darhad depression. The mean annual, summer and winter temperature was plotted. A 0.05°C per year increase in temperature for the 3 stations equaling a 1°C increase in the past 20 years is observed as shown in Figure 5. Batima et al. (2005), using shorter temperature records from these three stations came to

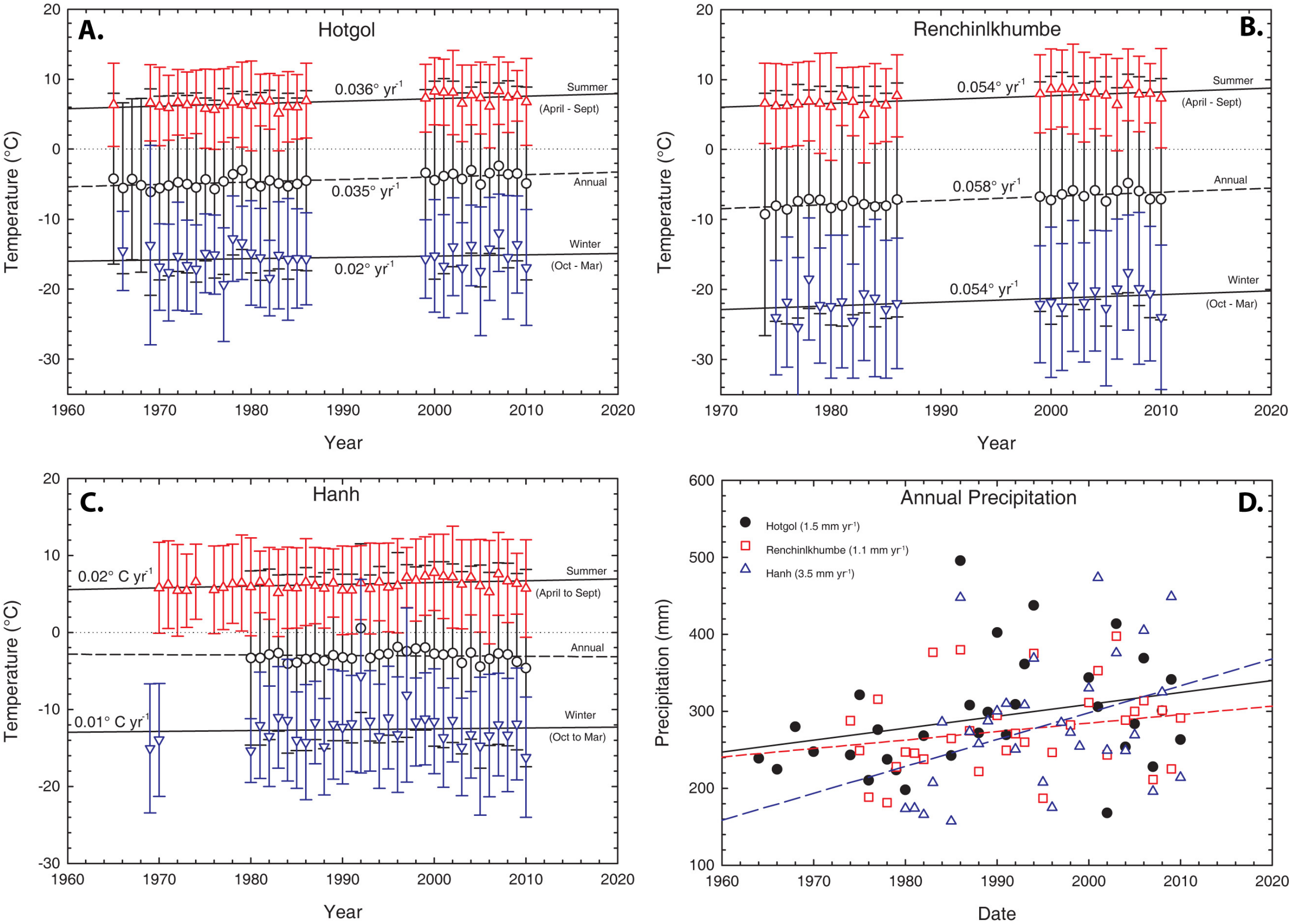

Figure 4. Recorded Temperature and precipitation as a function of time, 1960-2010 as reported from 3 meteorological monitoring stations (MMS) A. Hotogol B. Renchinlkhumbe C. Hanh. D. Recorded of precipitation amounts from Hotgol, Renchinlkhumbe, and Hanh.

similar findings that the mean annual air temperature has increased by 1.66 °C for the last 70 years, with distinct warming from the beginning of the 1970s increasing toward the end of the 1980s and 1990s. The warming has been most pronounced and evident by a mean winter (October – March) temperature increase of 3.6 °C. Annual precipitation has increased by 1 to 3.5 mm/yr as recorded by the three meteorological stations, as might be expected for a warming atmosphere.

CONCLUSION

Further discussion of the results and the conclusions based upon them are pending completion of the ongoing stable isotope analysis of the extracted alpha-cellulose. However, from the available recorded climatic data observations, it is evident that the mean annual temperature and the annual precipitation are both increasing. Because of the agrarian-basis of much of the Mongolian economy, changes to the climate, which potentially affect the growth of both fodder and forage are likely to have a bigger impact than they would on a more industrial-based economy. It might seem counter-intuitive that an increase in precipitation and temperature would have a negative impact on the continental climate of Mongolia, but historic flooding in 2009 which devastated even populated areas like Ulaanbaatar illustrates that such changes often result in negative outcomes.

ACKNOWLEDGEMENTS

I would like to thank RINNTECH for making their TSAPWin software available to me at a reduced cost.

I would also like to thank Battogtoh Damdinsuren, "Togii", for making the Mongolian field trip much easier, more productive and culturally enlightening by lowering the language barrier between myself and the Mongolian team members and providing translation assistance. I'd also like to acknowledge Dr. Karl Wegmann's contributions to this project, not the least of which was his patience and invaluable guidance in the laboratory work.

REFERENCES

Batima, P., Natsagdorj, L., Gombluudev, P., and Erdenetsetseg, B., 2005, Observed climate change in Mongolia: Assessments of Impacts and Adaptations to Climate Change Working Paper Number 12, p. 1–26.

Brendel, O., Iannetta, P.P.M., and Stewart, D., 2000, A Rapid and Simple Method to Isolate Pure Alpha-Cellulose: Phytochemical Analysis, 11, p. 7-10.

D'Arrigo, R., Jacoby, G., et al., 2000, Mongolian tree-rings, temperature sensitivity and reconstructions of Northern Hemisphere temperature: The Holocene, v. 10, no. 6, p. 669-672.

Jacoby, G., Pederson, N., et al., 2003, Temperature and precipitation in Mongolia based on dendroclimatic investigations: Chinese Science Bulletin, v. 48, no. 14, p. 1474-1479.

Loader NJ, McCarroll D, Gagen M, Robertson I and Jalkanen R (2007) Extracting climatic information from stable isotopes in tree rings. In: Dawson T, Siegwolf R (eds) Isotopes as Indicators of Environmental Change. Elsevier, 23–44.

Loader, N. J., Helle, G., et al., 2010, Twentieth-century summer temperature variability in the southern Altai Mountains: A carbon and oxygen isotope study of tree-rings: The Holocene, v. 20, no. 7, p, 1149-1156.

Rinntech GmbH, TSAP-Win software brochure, http://www.rinntech.de/images/stories/PDF/TSAPWin_brochure.pdf.

Speer, J. H., 2010, Fundamentals of tree-ring research, Tucson, University of Arizona Press, p. 78.

Sternberg, T., 2007, Environmental challenges in Mongolia's dry land pastoral landscape, Journal of Arid Environments, v. 72, no. 7, p. 1294.

Wilson, A.T. and Grinsted, M.J., 1977, 12C/13C in cellulose and lignon as palaeothermometers: Nature, v. 265, p. 133-135.