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

ISSN# 1528-7491

April 2010

Andrew P. de Wet
Editor & Keck Director
Franklin & Marshall College

Keck Geology Consortium
Franklin & Marshall College
PO Box 3003, Lanc. Pa, 17604

Lara Heister
Symposium Convenor
ExxonMobil Corp.

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

2009-2010 PROJECTS

SE ALASKA - EXHUMATION OF THE COAST MOUNTAINS BATHOLITH DURING THE GREENHOUSE TO ICEHOUSE TRANSITION IN SOUTHEAST ALASKA: A MULTIDISCIPLINARY STUDY OF THE PALEOGENE KOOTZNAHOO FM.
Faculty: Cameron Davidson (Carleton College), Karl Wirth (Macalester College), Tim White (Penn State University)
Students: Lenny Ancuta, Jordan Epstein, Nathan Evenson, Samantha Falcon, Alexander Gonzalez, Tiffany Henderson, Conor McNally, Julia Nave, Maria Princen

COLORADO – INTERDISCIPLINARY STUDIES IN THE CRITICAL ZONE, BOULDER CREEK CATCHMENT, FRONT RANGE, COLORADO.
Faculty: David Dethier (Williams) *Students: Elizabeth Dengler, Evan Riddle, James Trotta*

WISCONSIN - THE GEOLOGY AND ECOHYDROLOGY OF SPRINGS IN THE DRIFTLESS AREA OF SOUTHWEST WISCONSIN.
Faculty: Sue Swanson (Beloit) and Maureen Muldoon (UW-Oshkosh)
Students: Hannah Doherty, Elizabeth Forbes, Ashley Krutko, Mary Liang, Ethan Mamer, Miles Reed

OREGON - SOURCE TO SINK – WEATHERING OF VOLCANIC ROCKS AND THEIR INFLUENCE ON SOIL AND WATER CHEMISTRY IN CENTRAL OREGON.
Faculty: Holli Frey (Union) and Kathryn Szramek (Drake U.)
Students: Livia Capaldi, Matthew Harward, Matthew Kissane, Ashley Melendez, Julia Schwarz, Lauren Werckenthien

MONGOLIA - PALEOZOIC PALEOENVIRONMENTAL RECONSTRUCTION OF THE GOBI-ALTAI TERRANE, MONGOLIA.
Faculty: Connie Soja (Colgate), Paul Myrow (Colorado College), Jeff Over (SUNY-Geneseo), Chuluun Minjin (Mongolian University of Science and Technology)
Students: Uyanga Bold, Bilguun Dalaibaatar, Timothy Gibson, Badral Khurelbaatar, Madelyn Mette, Sara Oser, Adam Pellegrini, Jennifer Peteya, Munkh-Od Purevtseren, Nadine Reitman, Nicholas Sullivan, Zoe Vulgaropulos

KENAI - THE GEOMORPHOLOGY AND DATING OF HOLOCENE HIGH-WATER LEVELS ON THE KENAI PENINSULA, ALASKA
Faculty: Greg Wiles (The College of Wooster), Tom Lowell, (U. Cincinnati), Ed Berg (Kenai National Wildlife Refuge, Soldotna AK)
Students: Alena Giesche, Jessa Moser, Terry Workman

SVALBARD - HOLOCENE AND MODERN CLIMATE CHANGE IN THE HIGH ARCTIC, SVALBARD, NORWAY.
Faculty: Al Werner (Mount Holyoke College), Steve Roof (Hampshire College), Mike Retelle (Bates College)
Students: Travis Brown, Chris Coleman, Franklin Dekker, Jacalyn Gorczynski, Alice Nelson, Alexander Nereson, David Vallencourt

UNALASKA - LATE CENOZOIC VOLCANISM IN THE ALEUTIAN ARC: EXAMINING THE PRE-HOLOCENE RECORD ON UNALASKA ISLAND, AK.
Faculty: Kirsten Nicolaysen (Whitman College) and Rick Hazlett (Pomona College)
Students: Adam Curry, Allison Goldberg, Lauren Idleman, Allan Lerner, Max Siegrist, Clare Tochilin

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

Keck Geology Consortium: Projects 2009-2010
Short Contributions – MONGOLIA

PALEOZOIC PALEOENVIRONMENTAL RECONSTRUCTION OF THE GOBI-ALTAI TERRANE, MONGOLIA

Project Directors: ***CONSTANCE M. SOJA*****:** Colgate University
CHULUUN MINJIN: Mongolian University of Science and Technology
Project Faculty: ***PAUL MYROW*****:** The Colorado College
D. JEFFREY OVER**:** State University of New York at Geneseo

CHEMOSTRATIGRAPHY OF THE LOWER SILURIAN SCHARCHULUUT FORMATION, YAMAAN-US, SHINE JINST REGION, GOBI-ALTAI TERRANE, MONGOLIA

UYANGA BOLD**:** Mongolian University of Science and Technology
Research Advisor: Chuluun Minjin

GEOLOGIC MAP AND PALEOECOLOGY OF THE LOWER SILURIAN SCHARCHULUUT FORMATION AT "WENLOCK HILL", SHINE JINST REGION, GOBI-ALTAI TERRANE, MONGOLIA

BILGUUN DALAIBAATAR**:** Mongolian University of Science and Technology
Research Advisor: Chuluun Minjin

SEDIMENTOLOGY, DEPOSITIONAL HISTORY AND DETRITAL ZIRCON GEOCHRONOLOGY OF THE LOWER DEVONIAN TSAKHIR FORMATION, SHINE JINST REGION, MONGOLIA

TIMOTHY M. GIBSON**:** Colorado College
Research Advisor: Paul Myrow

BRACHIOPODS FROM THE LOWER SILURIAN SCHARCHULUUT FORMATION, YAMAAN-US, SHINE JINST REGION, GOBI-ALTAI TERRANE, MONGOLIA

BADRAL KHURELBAATAR**:** Mongolian University of Science and Technology
Research Advisor: Chuluun Minjin

CHEMOSTRATIGRAPHY AND MAGNETIC STRATIGRAPHY OF THE UPPER ORDOVICIAN DARAVGAI AND GASHUUNOVOO FORMATIONS, GOBI-ALTAI TERRANE, SHINE JINST AREA, SOUTHERN MONGOLIA

MADELYN METTE: Macalester College
Research Advisor: Ray Rogers

SEQUENCE STRATIGRAPHY AND PALEONTOLOGY OF THE UPPER ORDOVICIAN DARAVGAI AND GASHUUNOVOO FORMATIONS, GOBI-ALTAI TERRANE, SHINE JINST, MONGOLIA

***SARA E. OSER*:** University of Cincinnati
Research Advisor: Carlton E. Brett

PALEOECOLOGY OF LOWER DEVONIAN (EMSIAN) SHELF DEPOSITS IN THE CHULUUN FORMATION, GOBI-ALTAI TERRANE, MONGOLIA

***ADAM FRANCIS ANTONIO PELLEGRINI*:** Colgate University
Research Advisor: Constance M. Soja

TRILOBITE PALEOECOLOGY OF THE MIDDLE DEVONIAN TSAGAANKHAALGA FORMATION NEAR TSAKHIR WELL, SHINE JINST, MONGOLIA

***JENNIFER A. PETEYA*:** Mount Union College
Research Advisor: Lee Gray

GEOLOGIC MAP SHOWING EAST-TO-WEST FACIES TRANSITIONS IN THE LOWER SILURIAN SCHARCHULUUT FORMATION, SCHARCHULUUT, SHINE JINST REGION, GOBI-ALTAI TERRANE, MONGOLIA

***MUNKH-OD PUREVTSEREN*:** Mongolian University of Science and Technology
Research Advisor: Chuluun Minjin

PALEOECOLOGY AND CHEMOSTRATIGRAPHY OF THE AMANSAIR AND TSAGAANBULAG FORMATIONS, GOBI-ALTAI TERRANE, MONGOLIA

***NADINE G. REITMAN*:** Vassar College
Research Advisor: David P. Gillikin

THE EIFELIAN GIVETIAN BOUNDARY (MIDDLE DEVONIAN) AT TSAKHIR, GOVI ALTAI REGION, SOUTHERN MONGOLIA

NICHOLAS SULLIVAN: State University of New York at Geneseo
Faculty Advisor: D. Jeffrey Over

PALEOENVIRONMENTS AND DEPOSITIONAL HISTORY OF UPPER SILURIAN-LOWER DEVONIAN LIMESTONE IN THE AMANSAIR AND TSAGAANBULAG FORMATIONS AT ULAANSHAND AND TSAKHIR, GOBI-ALTAI TERRANE, MONGOLIA

***ZOE VULGAROPULOS*:** Oberlin College
Research Advisor: Dennis Hubbard

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

PALEOENVIRONMENTS AND DEPOSITIONAL HISTORY OF UPPER SILURIAN-LOWER DEVONIAN LIMESTONE IN THE AMANSAIR AND TSAGAANBULAG FORMATIONS AT ULAANSHAND AND TSAKHIR, GOBI-ALTAI TERRANE, MONGOLIA

ZOE VULGAROPULOS
Oberlin College
Research Advisor: Dennis Hubbard

INTRODUCTION

The Gobi-Altai terrane in Southern Mongolia, generally thought to be a backarc basin succession, consists of well-preserved Ordovician–Lower Devonian deep-to-shallow marine sedimentary rocks overlain by Devonian–Triassic breccia, limestone and volcanic-sedimentary units. The Tsagaanbulag and overlying Amansair Formations make up a total of over 550 meters of shallow marine limestone interbedded with siltstone (Minjin et al., 2001). Using conodont data, Wang et al. (2005) assigned the upper half of the Tsagaanbulag and the lower half of the Amansair to the Middle Lochkovian (Lower Devonian). A thick conglomerate unit at the bottom of the Tsakhir Formation unconformably overlies both units at two different sites near Shine Jinst (Fig. 1). The base of the Tsakhir is pre-Pragian or Pragian in age (Wang et al., 2005).

In this study I interpret the depositional environments of two sections within the Amansair and Tsagaanbulag Formations near Shine Jinst, and discuss how the environment and paleocommunities changed during the middle Lochkovian. Through examination of the abundance and composition of faunal and siliciclastic constituents, as well as analysis of sedimentary textures throughout the sections, I aim to interpret the paleoenvironmental context of strata preserved at the two sites. The goal is to form a better understanding of the environmental conditions leading up to the tectonic uplift that probably created the unconformity and initiated conglomerate deposition at the base of the Tsakhir Formation (Lamb et al., 1997). When compared to sections above and below these formations (studies by Reitman, Gibson, and others in this volume), this study will help to elucidate the depositional history and paleogeography of the Gobi Altai terrane, and help address the question of whether it actually represents a backarc basin or a dismembered part of the adjacent Mandalovoo island arc terrane (Soja et al., 2006).

METHODS

A detailed stratigraphic section was measured and described in two units at two sites: the Tsagaanbulag Formation at the Tsakhir Well (44.3616389°N, 99.4485278°E) and the Amansair Formation at the Ulaanshand Well (44.3373611°N, 99.53475°E). Both sections are situated beneath an unconformity with the Tsakhir Formation (Fig. 1). The Amansair section (UL1) is 64 m thick with the Tsakhir contact 63.5 m from the base. The Tsagaanbulg section (TSAV) is 10.1 m thick with the base approximately 70-80 m below the contact. Oriented samples were collected at approximately 1-m intervals across the overturned and exposed sections. They were slabbed perpendicular to bedding, and 58 were impregnated with resin at high pressure and made into thin sections. Each thin section was point-counted (200-250 points) to determine percent composition of different types of skeletal grains, as well as the relative importance of siliciclastic and carbonate grains in the largely micritic matrix. The grain-size range of the siliciclastic grains was recorded for each thin section. Selected hand samples were polished and etched in 10% HCl for about 1 minute to facilitate examination of internal fabrics and sedimentary structures. Data for skeletal components, grain size and sedimentary structures were used to infer changes in the paleocommunity, water depth, energy level and degree of siliciclastic sediment input over the time periods represented by the measured sections.

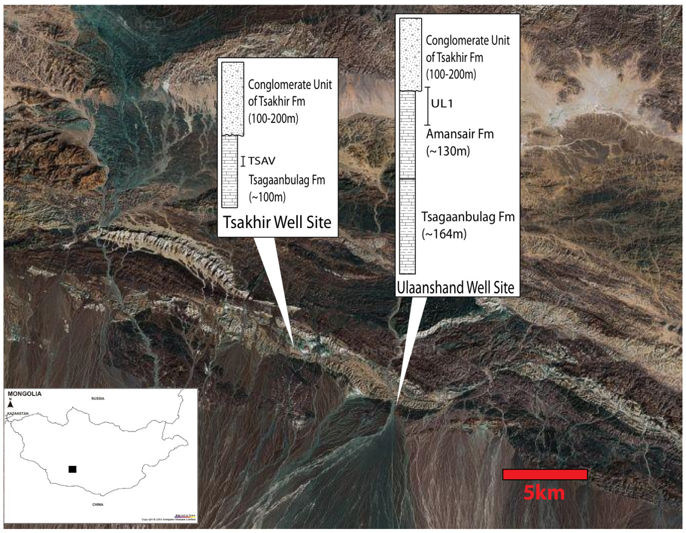

Figure 1. Locality map showing the sections examined (in brackets) at the Tsakhir Well and Ulaanshand Well sites.

In addition, samples were collected at 0.5- to 1-meter intervals for stable isotope analysis. Powder was collected from 63 samples using a Dremel tool; care was taken to avoid obvious calcite veins that would have post-dated deposition. Powder samples were sent to the Environmental Isotopes Laboratory at the University of Arizona for $\delta^{13}C$ measurement. Data were compared to published curves to chronostratigraphically correlate the sections with global records as well as those of other project members.

RESULTS

Data for the two measured sections are summarized in Figures 2 and 3. The 10.1-m section through the Tsagaanbulag Formation at the Tsakhir Well (TSAV) is made up of thinly interbedded wackestone and green, argillaceous calcilutite (Fig. 2). Brachiopods dominate the fossil assemblage in the lowermost meter of section; from 1 to 2 meters from the base brachiopods decrease to less than 2% of the allochems and gastropods become more prevalent. From 2.7 m onward, brachiopods increase again and along with crinoids make up over half of the fossils in the remainder of the section. Other common constituents throughout the section include trilobites and ostracodes. In hand sample and thin section, the brachiopods and other shells are generally intact or nearly intact. The samples through 2.7 m are wackestone consisting of relatively large (several millimeters) fossil fragments in a micritic matrix with less than 5% fine-grained (smaller than 0.1 mm) siliciclastic grains. The samples from 3.3 to 6 m are more grain supported and the intergranular space is primarily sparry calcite cement (Fig. 2). Above 6 m the rocks are again more micrite supported with fewer fossils, although fossil content and sparry cement increase upwards to 10.1 m, where fossils are largely packed once again.

In section UL1 at the Ulaanshand Well, fossil content in the Amansair Formation generally fluctuates between 0 (in shaley intervals) and 30%, except for a peak of over 70% around 50 m in the section (Fig. 3). Although some whole brachiopods and gastropods were found, most of these shells and other types of fossils are highly fragmented, a sharp contrast to section TSAV. The lower 43.7 m consist largely of thin (usually less than 1 m) intervals of silty micritic lime mudstone separated by more fossiliferous silty wackestone or packstone (Fig. 3). The most abundant skeletal grains in this part of the section are brachiopods, crinoids, ostracodes, and gastropods (Fig. 4a). From 43.7 to 54.2 m, the section is dominated by massive wackestone and packstone with thin (~10 cm) stromatoporoids. This part of the section also contains a few interbedded shaley units, all less than 1 m thick. The fossil constituents are mainly bryozoa, although brachiopods, ostracodes, and crinoids also exist in similar quantities as below. Trilobites also become somewhat significant (0.5 to 7% of the allochems). Above 54.2 m, until the unconformity at 63.5 m, there is a facies strata change to shaley, greenish, calcareous siltstone, which is interbedded with a few calcareous sandstone units with few to no fossils. The overlying conglomerate of the Tsakhir Formation is made up mainly of limestone clasts similar to facies found in

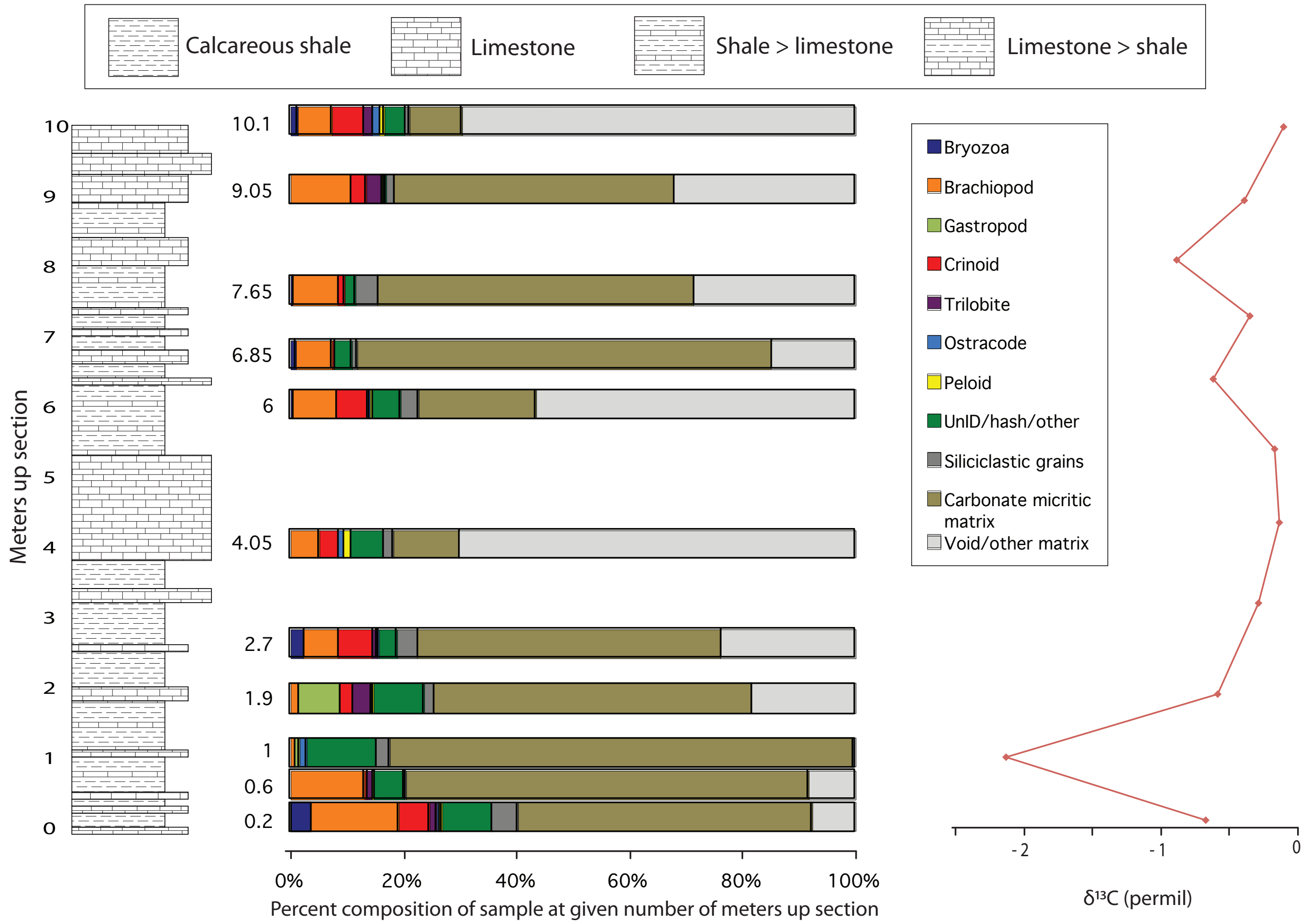

Figure 2. Stratigraphic section at TSAV within the Tsagaanbulag Formation at the Tsakhir Well site showing percentages of allochems and other components in the rocks. To the right, δ^{13}C data generally hover around -0.5‰.

the Tsagaanbulag and Amansair formations, as was the case at the Tsakhir site.

The matrix of the strata in UL1 generally consists of micritic limestone. Petrographic analysis also showed minor sparry cement and subangular siliciclastic grains, most commonly quartz, but also some feldspar and other minerals (Fig. 4a). Siliciclastic grains generally range from about 20 to 140 microns and make up between 10 and 30% of the rock throughout the section, with higher values occurring at 22 m (~50%) and above 54.1 m (over 30%) from the base. From 43.7 to 54.2 m, the packstone interval described above is characterized by lower siliciclastic content (1-5%) and smaller siliciclastic grain size (less than 100 microns). The percent of siliciclastic sediment in the rock tends to vary inversely with the number of allochems.

Evidence of both physical and biological disruption is present in the section. Small-scale cross-stratification exists in this outcrop, most notably between 18 and 22 m (Fig. 4b). Bioturbated textures and burrows are present at various fossiliferous beds throughout UL1.

Data for δ^{13}C fluctuate between -1 and 0‰ throughout the TSAV section, except for a minimum of less than -2‰ at 1.1m (Fig. 2). In the UL1 section, δ^{13}C data generally fluctuates between 1 and 2‰ in the lower 35 meters, after which they increase to over 3‰, decreasing again toward the top of the section (no data is available for the last ~10m below the unconformity) (Fig. 3).

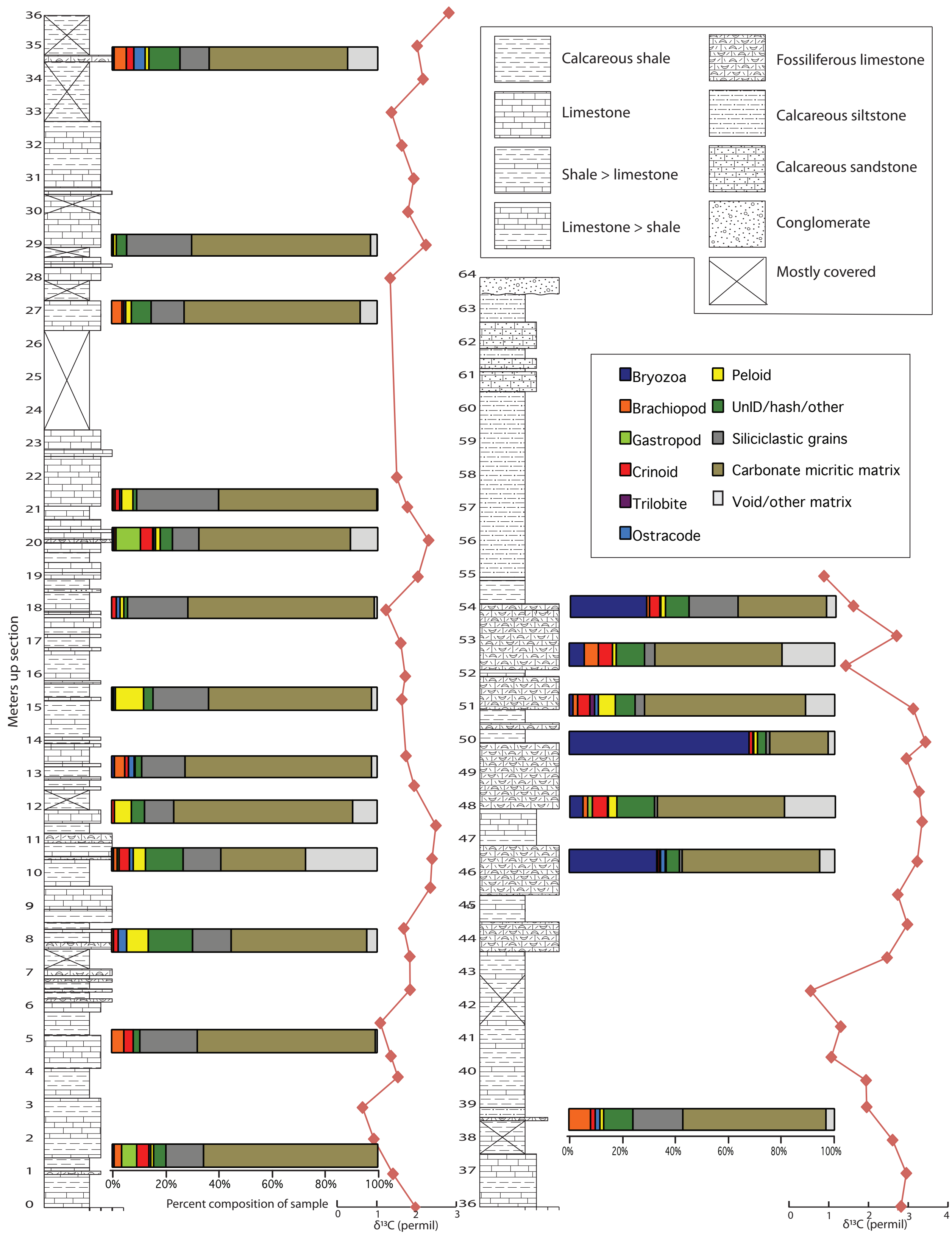

Figure 3. Stratigraphic section at UL1 within the Amansair Formation at the Ulaanshand Well site showing the percentage of allochems and other components. To the right, δ¹³C data show generally increasing values toward the top of the section, with peaks of around 3.0 to 3.5‰.

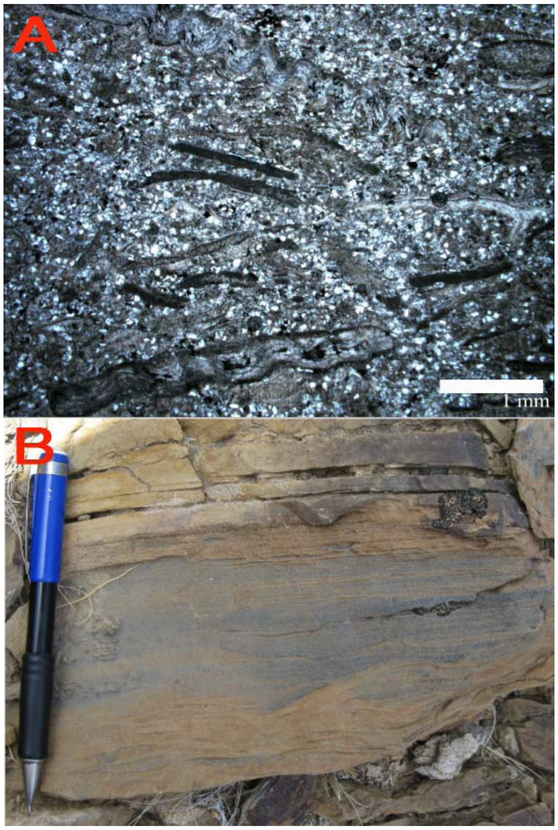

Figure 4. A. Photomicrograph of sample at 1.5 m above the base of the UL1 section, showing brachiopod, crinoid and other fossil fragments, along with silt-sized and fine sand-sized siliciclastic grains, which are relatively well sorted. B. Field photo at 19.5 m above the base of the UL1 section showing small-scale cross-bedding.

DISCUSSION

These two measured sections are similar in both their fossil content and the nature of the matrix. The angularity of the siliciclastic grains indicates that they were deposited close to their terrigenous source and were not extensively reworked by marine processes. Section UL1 probably represents an environment of at least moderate energy generated by waves, currents or storms. Skeletal grains seem to be largely transported and reworked, siliciclastic grains are fairly well sorted in the coarse silt to fine sand range, and cross-bedding is evident in some parts of the section. However, most of the rocks are largely unwinnowed, containing significant amounts of micritic carbonate. Periodic decreases in micrite that coincide with increases in sparry cement, as well as fragmentation and rounding of allochems, indicate deposition in an alternately high energy and quieter water environment: the energy is probably mainly provided by intermittent storms (Flugel, 1982). The TSAV section was probably deposited in a less energetic environment, based on the less abundant and finer-grained siliciclastic grains (coarse silt and finer), less fragmentation of skeletal grains, and a lack of current-generated sedimentary structures such as cross-bedding. This could reflect a deeper water site of deposition, or else a period of time with no storm-generated deposition. A study of a larger section of the Tsagaanbulag Formation The scarcity of siliciclastic grains in the TSAV section could infer a deeper environment removed from a terrestrial source; however it could also reflect a change in the intensity of erosion and sediment transport off the exposed landscape over the estimated 10-15 million years separating the two sections (based on data from Wang et al., 2005).

Facies analysis indicates subtle differences between the environments represented in the two sections. In the older strata of the Tsakhir Well section, abundance and diversity of organisms infers a shallow to deeper subtidal marine environment (Flugel, 1982). In the Ulaanshand Well section, higher overall interpreted energy, the higher amounts of siliciclastic sediment, the abundance of bioturbation, and the presence of stromatoporoids among abundant fossils of open marine fauna suggest a generally shallower subtidal environment (Flugel, 1982). Fossil content fluctuates within relatively constant limits until about 39 m, when it experiences a dramatic increase in mainly bryozoa and stromatoporoids, before dropping precipitously after 54 m. The sharp increase in faunal abundance near the top of the section may be attributed to a decrease in siliciclastic input and/or a decrease in energy, as it coincides with a drop in the amount and grain size of siliciclastic grains. Above 54 m, the lack of fossils and the dominance of siliciclastic sediment indicate a clear environmental change. One possibility is that increased uplift of the hinterland initiated higher siliciclastic erosion, transport, and deposition that limited the abundance of organisms and their fossil remains. Eventually this area was uplifted, exposed, eroded, and later overlain by the conglomerate of the Tsakhir Formation (Lamb et al., 1997; Gibson, this volume).

The carbon isotope data show a significant overall change from the negative $\delta^{13}C$ values in the lower Tsagaanbulag Formation section (TSAV: Fig. 2) and the generally increasing positive values in the Amansair Formation section (UL1: Fig 3). When compared with various local and global curves (Malkowski et al., 2009; Buggisch et al., 2006; Saltzman, 2002) the higher $\delta^{13}C$ values within the Amansair Fm (UL1) are consistent with a Middle Lochkovian age. However, isotopic signatures for the lower Tsagaanbulag Formation (TSAV) are more consistent with deposition just before the Silurian-Devonian boundary, contrary with the conclusions of Wang et al. (2005). Further examination of the curves is necessary to ascertain whether the peaks in the $\delta^{13}C$ curve for UL1 might help to better constrain the timing of deposition and to correlate among sections examined by the larger Keck-Mongolia project.

The results of this project suggest that both of these formations were formed in a somewhat shallow-water environment with fluctuating degrees of siliciclastic input from a nearby terrigenous source. UL1 represents a generally shallower facies than TSAV, although it is unclear whether there is a continuous shallowing-upward succession between the two formations. A shallowing-upward trend is inferred within the Amansair Formation at UL1. A study by my colleague of a ~110 m thick section of the Tsagaanbulg Formation at the Tsakhir site, laterally adjacent to TSAV, confirms that shallowing is occurring toward the top of this formation as well; TSAV may be conformable with a deeper-water facies within this section (Reitman, this volume). Further research and comparison of this study with those of other sections of the Gobi-Altai terrane may help to further constrain the larger paleoenvironmental and paleogeographic picture of this terrane.

REFERENCES

Buggisch, W. and Mann, U. 2004. Carbon isotope stratigraphy of Lochkovian to Eifelian limestones from the Devonian of central and southern Europe. International Journal of Earth Science, 93:521-541.

Flugel, E. 1982. Microfacies analysis of limestones. Berlin; New York: Springer-Verlag.

Lamb, M.A., and Badarch, G. 1997. Paleozoic sedimentary basins and volcanic-arc systems of southern Mongolia: New stratigraphic and sedimentologic constraints. International Geology Review, 39:542-576.

Malkowski, K. and Racki, G. 2009. A global biogeochemical perturbation across the Silurian–Devonian boundary: Ocean–continent–biosphere feedbacks. Palaeogeography, Palaeoclimatology, Palaeoecology, 276:244-254.

Minjin, C. and Soja, C.M. 2009. Geology of Shine Jinst area of South Mongolia: field guidebook.

Saltzman, M. R. 2002. Carbon isotope (NC) stratigraphy across the Silurian- Devonian transition in North America: evidence for a perturbation of the global carbon cycle. Palaeogeography, Palaeoclimatology, Palaeoecology, 187:83-100.

Soja, C.M., Minjin, C., and White, B. 2006. A tale of two terranes in Mongolia. G.S.A. Abstracts with Programs, v. 38 (7):90.

Wang, C., Weddige, K., and Minjin, C. 2005. Age revision of some Paleozoic strata of Mongolia based on conodonts. Journal of Asian Earth Sciences, 25:759-771.