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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

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

PALEOZOIC PALEOENVIRONMENTAL RECONSTRUCTION OF THE GOBI-ALTAI TERRANE, MONGOLIA

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

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

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

TIMOTHY M. GIBSON**:** Colorado College
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BRACHIOPODS FROM THE LOWER SILURIAN SCHARCHULUUT FORMATION, YAMAAN-US, SHINE JINST REGION, GOBI-ALTAI TERRANE, MONGOLIA

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

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

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

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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

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

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

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

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

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INTRODUCTION

In the Gobi-Altai Terrane, Paleozoic rocks, ranging in age from Late Ordovician to Middle Devonian, were studied near Shine Jinst, southwestern Mongolia. My research focused on an outcrop of the Middle Devonian (Eifelian) Tsagaankhaalga Formation exposed near the Tsakhir well. The goals were to collect and describe trilobites found within the section and to describe the paleoenvironments they inhabited based on the rock and fossil constituents. This was the first in-depth study of trilobites in Mongolia. From July 29 through August 6, 2009, the outcrop was measured, lithologies were described, and hand samples and fossils were collected. These samples were later analyzed at Mount Union College to gain understanding of their paleoenvironmental significance.

Figure 1. Basal portion of the Tsagaankhaalga Formation at Tsakhir Well, Shine Jinst, Mongolia. Rocks are progressively younger to the right of the figure. Dog for scale.

LOCALITY DESCRIPTION

The Tsagaankhaalga Formation is approximately 335 meters thick. The Devonian (early Eifelian) age of the Tsagaankhaalga Formation is validated by the presence of several species of the conodont genus *Caudicriodus* (Wang et al. 2005). This age could not be confirmed on the basis of the 2009 field season. Conodonts of the genus Icriodus were collected and found to be a potentially new species (J. Over, 2010, personal communication).

The formation disconformably overlies the limestone, claystone, and sandstone of the 124 meter-thick Lower Devonian (Emsian) Chuluun Formation. The Tsagaankhaalga Formation is overlain by the 1170 meter-thick Devonian (Givetian) Govialtai Formation, which consists of volcanic rock, black claystone, siltstone with sandstone, and sandy limestone (Minjin and Soja 2009). The nature of the Eifelian-Givetian contact is unknown.

The Tsagaankhaalga Formation is subdivided into two brachiopod zones: the 165 meter-thick basal *Leptodontella zmeinogorskiana* Zone and the overlying 170 meter-thick *Leptagonia reticulata* Zone. Lithologies within the *L. zmeinogorskiana* Zone consist of dark gray calcareous conglomerate, grayish-brown coarse-grained calcareous sandstone interbedded with dark-gray limestone, dark-gray sandy nodular limestone, and gray limestone. The basal portion of this zone was studied during the 2009 field season. The *L. reticulata* Zone consists of dark gray crinoidal limestone, gray siliceous limestone, and alternating siltstone and sandy limestone (Minjin and Soja 2009).

All beds are vertically oriented to slightly overturned, dipping steeply 65˚ to 80˚ SW. A right lateral strike-slip fault cuts perpendicular to the beds at the top of the cliff where the measured section is exposed. Pressure solution marks and calcite veins of varying thickness cross-cut the entire section. Many of the calcite grains and fossils within the rocks are recrystallized.

MATERIALS AND METHODS

Thirty-nine meters of the Tsagaankhaalga Formation were measured and studied. The base of the stratigraphic section was defined by the first occurrence of measurable rocks above a conglomerate unit belonging to the basal Tsagaankhaalga Formation (Minjin and Soja, 2009). The uppermost part of the measured stratigraphic section occurred after the last occurrence of trilobites in the measurable part of the exposure. Hand samples were extracted at every meter, with the exception of the thickest unit, which was sampled at 28.5 meters. Samples for geochemical analysis were collected every 0.5 meters. Fossils were noted throughout the section with emphasis on trilobite communities. These were collected and photographed when observed in the rock. Photographs of the rock beds were taken every two meters within the section and were also taken of any well-preserved fossils within those beds.

Data collection then continued at Mount Union College. Forty thin-section billets were prepared. Hand samples and thin-sections were analyzed to determine the lithology, taxonomy of fossils, and the state of fossil preservation. Geochemical samples may be used for future analysis.

RESULTS

Stratigraphy

A 15 meter-thick basal conglomerate serves as the base of the Tsagaankhaalga Formation exposed at Tsakhir Well. It is overlain by approximately six meters of shale and sandstone, which is in turn overlain by a light gray, thin to medium-bedded, cross-bedded, calcareous sandstone interbedded with gray,

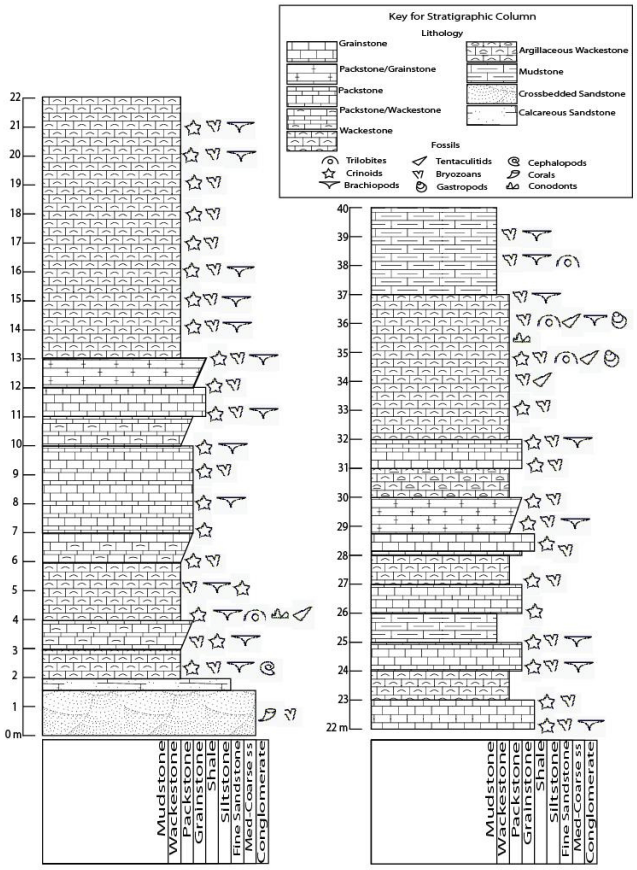

Figure 2. Stratigraphic column of the 39 m measured section.

silty shale. This grades upward into a very thin, light gray calcareous sandstone.

A majority of the beds in the basal-most limestone section (from 2 to 12 m) are 5-15 centimeters thick. Lithologically, they range from dark gray and medium gray brachiopod wackestone and crinoidal packstone beds in the first nine meters to a crinoidal grainstone at 11 m and a crinoidal packstone/grainstone at 12 m. Most units in this section are interbedded with very thinly bedded mudstone that is mostly devoid of fossils.

The middle limestone section (from 13 to 28.75 m) contains the thickest beds, which range in thickness from 8-22 centimeters. Meters thirteen through twenty-one are composed of bryozoan-dominated wackestone beds. These are overlain by alternating crinoidal grainstone, bryozoan-dominated wackestone, and crinoidal packstone beds. Most of the coarser beds are interbedded with a finer, thin-bed-

ded skeletal wackestone. This section also includes the thickest bed of the entire measured area - a 60 cm-thick crinoidal grainstone that forms the top of the middle limestone section.

The uppermost limestone section (28.75 to 39 m) is characterized by generally thinner beds. They range from less than 4 cm to 13 cm in thickness. The lowermost portion is a bryozoan packstone/wackestone, which is overlain by a silty, argillaceous, crinoidal wackestone. Overlying these are crinoidal packstone beds, which is overlain by tentaculitid wackestone beds. The wackestone beds are overlain by trilobite mudstones. Many of these beds are interbedded with very thin-bedded mudstone that is mostly devoid of fossils. Primary sedimentary structures were not observed in any of the limestone beds of the 39 meter section.

Sedimentology

The basal sandstones of 0 to 1.55 m contains fine sand-sized quartz embedded in micrite. The overlying 0.45 meters contain calcite-cemented fine sand-sized quartz grains.

The basal limestone contains sand-sized fossils in micrite with less than 1% siliciclastic minerals. The wackestone beds in this section contain sand-sized fossils in silty matrix with less than 1% siliciclastic minerals. These minerals have a hardness of greater than 5.5 based on a scratch test with rocks containing heavy siliciclastic concentratons (27 m and 30 m). Mineral type could not be determined due to recrystallization. The packstone/wackestone beds within the section contain fine sand-sized calcite grains. The three meters of thin packstone beds contain fine to medium-sized fossils with calcite spar cement. The one meter-thick grainstone beds contain medium to fine sand-sized fossils with no visible cement. The uppermost beds of this section contain coarse to fine sand-sized fossils in calcite cement and micrite.

Wackestone beds of the middle limestone section are comprised of sand-sized fossils in micrite. These contain less than 1% siliciclastic grains, except for the beds at 15 m and 18 m, which contain 1-3% siliciclastic minerals. The overlying grainstone contains coarse to fine sand-sized fossils with no visible cement or matrix. Packstone beds contain medium to fine sand-sized calcite grains in micrite matrix. Mudstones at 25 m contain few fossils surrounded by a micrite matrix. The wackestone at 27 m contains greater than 10% siliciclastics.

The basal packstone/wackestone of the upper-most limestone section contains medium to fine sand-sized calcite grains in silty matrix with less than 1% siliciclastics. The overlying silty, argillaceous, wackestone contains coarse to fine sand-sized calcite grains and over 20% siliciclastics surrounded by micrite. Packstones contain coarse to fine sand-sized calcite grains in micrite. These are overlain by wackestones with sand-sized fossils in micrite containing less than 1% siliciclastic minerals. Lime mudstone beds at the top of the section contain micrite with few sand-sized fossils.

Fossils

High biodiversity is evident throughout the measured section. Common fossils, listed in descending order of abundance, include crinoids, bryozoans, brachiopods, trilobites, tentaculitids, bivalves, gastropods, cephalopods, and conodonts.

Bryozoans and crinoids are the most abundant fossils noted throughout the section. Bryozoans include branching, fenestrate, encrusting, and mound varieties. These are abundant throughout the entire section, except in many of the grainstones. Crinoid segments were found throughout a vast majority of the section and are characterized by having a diameter ranging from less than 1 mm to greater than 1 cm (see Figure 3).

Pedunculate brachiopods, namely rhynchonellids, were collected between 1.6 to 4 m above the base of the section. Few strophomenids were found within this interval, but increased in number and diversity from 34.73 to 35.5 m. *Leptaena* is the sole strophomenid identified. Spiriferid brachiopods were sparse throughout all three limestone sections (see

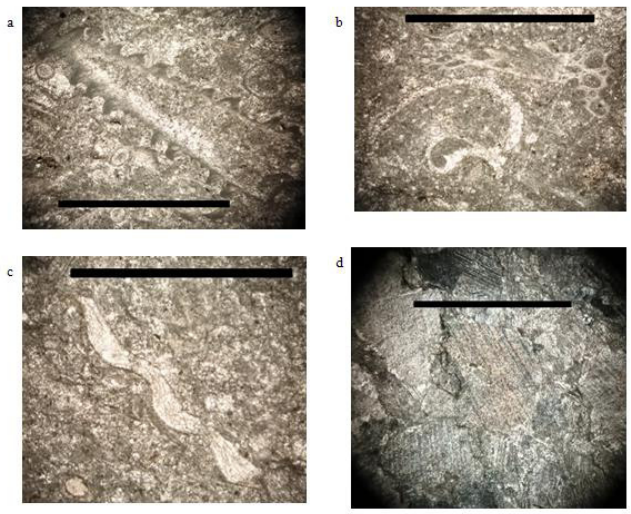

Figure 3. a) Tentaculitid (center) and small, cone-like fossils at 35.0 m in reflected light. b) Gastropod (bottom left) and bryozoan (top right) at 36.0 m. c) Brachiopod in reflected light at 20.0 m. d) Crinoidal grainstone at 11 m in cross polarized light. 1.5 mm scale.

Figure 3).

Small (less than 1 cm), cone-like fossils were noted throughout the section. These are not seen in hand sample and do not have visible shell ornamentation when viewed in thin-section. Tentaculitid fossils occur between 34 and 38.5 m (see Figure 3).

Conodonts are very sparse throughout the section. Specimens of a possible new species of *Icriodus* were collected at 4 m and 35.5 m (J. Over, 2010, personal communication).

A small coiled snail shell was collected at 34.75m. The only other petrographic evidence of gastropods was viewed in thin section at 36 m (see Figure 3). Bivalves are represented by small, dark shell fragments between meters 35 and 38.5. Cephalopods were the sparsest megascopic fossils in the section. Very poorly preserved orthocone nautiloid fragments were collected in float 1.6 meters above the base of the section.

Trilobite fossils mostly consisted of nearly complete and fragmented pygidia. Over 50 trilobite fossils were collected between 2.1 and 4.0 m and 34.75 and 38.5 m above the base of the section. Five cephalic fragments were collected. One poorly preserved smooth glabellum was collected from 35.0 m. A genal spine was collected from 34.85 m, and a partial librigena was collected from 34.8 m.

Fossil preservation is generally poor. Most specimens are fragmented, recrystallized, and compressed slightly.

DISCUSSION

Paleoenvironment

This section of the Tsagaankhaalga Formation contains evidence of a low energy environment. The small grain size of the dominant lithologies – skeletal wackestones and mudstones – suggests a low energy environment (Boggs, 2006). This low energy is also evident in the lack of primary sedimentary structures, such as cross bedding or ripple marks. Fossils are mostly coarse fragments with few complete brachiopods, suggesting that reworking by waves and currents was low.

Many of the coarser-grained beds found in the middle and upper parts of the section may be the result of high energy events that may have rbeen caused by temporary shallowing of the environment. Due to the lack of visible primary sedimentary structures, these beds may not have been influenced by physical processes, such as storms (Kidwell and Bosence, 1991). The high abundance of crinoids and low biodiversity indicated by a lack of other invertebrate fossils within these beds suggests a higher sedimentation rate. Higher sediment input may also explain the increased thickness of these beds, including the 60 cm grainstone bed in the uppermost limestone section.

A lower sedimentation rate is evident throughout the rest of the section. For example, there is some evidence of encrusting organisms within the section. A few of the brachiopods from 16 m have micritic coatings, which appear to represent encrustation by microbial organisms. Encrustation also occurs at 19 m; a bryozoan had encrusted on and grown around half of the circumference of crinoid seg-

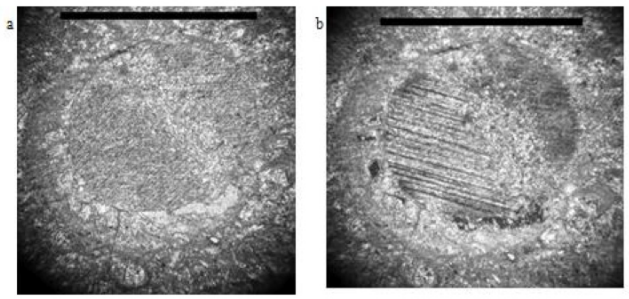

Figure 4. Crinoid encrusted by bryozoan at 19 m. a) viewed with reflected light. b) viewed in cross polarized light. 1.5 mm scale.

ment (see Figure 4). Encrustation suggests a lower sedimentation rate. Fragmentation may also be due to bioturbation. Predators and scavengers may have destroyed living and dead shells, making them responsible for an unknown amount of shell fragmentation, disarticulation, and movement (Kidwell and Bosence, 1991).

Evidence of bioturbation within wackestone and mudstone beds includes a lack of primary bedding structures, fossils that are uniformly concentrated throughout the beds, and a lack of evidence of preferred orientation. There is a lack of visible evidence of burrows due to low sedimentation rate. Long exposure causes taphonomic features such as burrows to be gradually destroyed (Kidwell and Bosence, 1991).

The beds of this section of the Tsagaankhaalga Formation contain evidence that the rocks formed in a shallow marine shelf environment as a part of the Paleo-Asian Ocean (Buslov, et. al, 2001). Such evidence includes the highly diverse communities, comprising of many types of bryozoans, brachiopods, and crinoids and to a lesser extent trilobites, gastropods, conodonts, nautiloids, and bivalves. Other evidence includes the cycling between low energy and high energy environments. Restricted shelf environments generally contain transgressive intervals, indicated by the skeletal packstones and grainstones that occur episodically within the section. Shelf environments can also lack evidence of burrowing (Enos, 1983).

The interbedded thin mudstone beds and interbedded thinly-bedded wackestone beds occurring throughout the section between thicker beds may represent episodic mud deposition. These could be the results of temporary deepening events. A lack of shell fossils suggests that mud deposition stopped shell accumulation (Speyer and Brett, 1991).

Siliciclastic minerals are found in varying concentrations throughout the section. The best example of high siliciclastic concentration is the argillaceous wackestone at 30 m. Due to the high amount of mineral recrystallization throughout the beds, these siliciclastic minerals may have formed by the alteration of clay minerals (Carson, 1991).

Trilobites

The trilobites are highly fragmented and poorly preserved. A vast majority of the trilobite fossils collected were pygidia. These trilobites may belong to the Order Proetida, as suggested by the pygidia found in the field and the librigena specimen from 34.8 m (see Figure 5) (Fortney, 1997). Both the Tsagaankhaalga trilobites and many of the proetids have wide pygidial borders and generally few (4 to 10) pygidial segments. The pygidium is also semielliptical in outline and is small in size (Harrington, 1959)

The main evidence that these trilobites could be proetids is the high likelihood that the Tsagaankhaalga trilobites had opisthoparian sutures. While the facial suture itself was not preserved in the librigena specimen, the suture does not appear to be proparian or gonatoparian. A genal spine was found in the section, which eliminates the possibility of a gonatoparian suture. The librigena also contains a very small portion of the ridge underneath the eye, which would be separated from the genal angle in a proparian suture. Part of the genal angle is preserved in the specimen. The ridge is very close to the genal angle, suggesting that the posterior suture was very short – a common characteristic of proetid trilobites (Harrington, 1959).

CONCLUSION

In summary, the rocks of the Eifelian Tsagaankhaalga

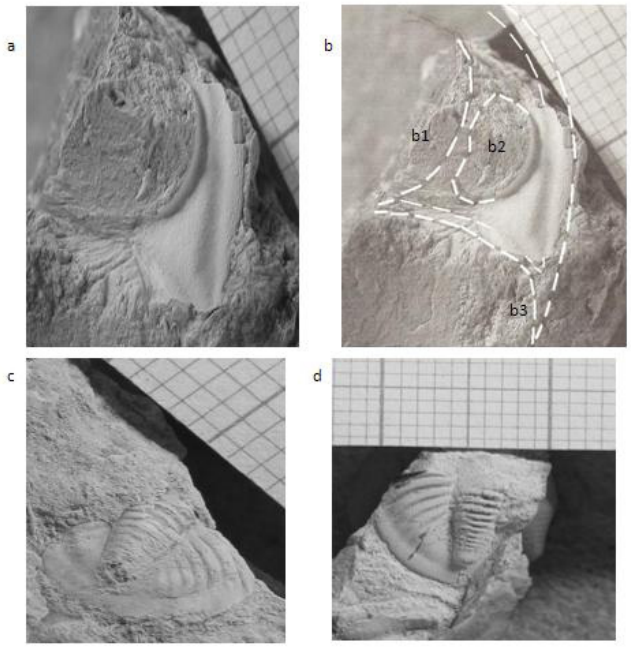

Figure 5. a) Trilobite librigena from 34.8 m. b) Trilobite librigena from 34.8 m with interpretation of cephalic morphology. b1 represents glabellum. b2 represents eye. b3 represents the genal spine. c) Partial trilobite pygidium at 4.0 m. d) Partial trilobite pygidium at 35.75 m. Small squares = 1 mm scale.

Formation near Tsakhir Well, Shine Jinst, Mongolia, contain much evidence revealing their history. Small grain size coupled with larger, fragmented fossils suggests a low energy shallow shelf environment with a low sedimentation rate. During periods of deeper-water environment, Takhir Well was inhabited by a highly diverse group of organisms, including small proetid trilobites. During shallowing periods, it was inhabited by many crinoids and a variety of bryozoans. Future research will hopefully reveal more about these diverse creatures.

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