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*Students: Lenny Ancuta, Jordan Epstein, Nathan Evenson, Samantha Falcon, Alexander Gonzalez, Tiffany Henderson, Conor McNally, Julia Nave, Maria Princen*

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*Students: Livia Capaldi, Matthew Harward, Matthew Kissane, Ashley Melendez, Julia Schwarz, Lauren Werckenthien*

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*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*

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*Students: Alena Giesche, Jessa Moser, Terry Workman*

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*Students: Travis Brown, Chris Coleman, Franklin Dekker, Jacalyn Gorczynski, Alice Nelson, Alexander Nereson, David Vallencourt*

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*Faculty: Kirsten Nicolaysen (Whitman College) and Rick Hazlett (Pomona College)*

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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  
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MONGOLIA**

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**JENNIFER A. PETEYA:** Mount Union College  
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**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-  
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# THE EIFELIAN GIVETIAN BOUNDARY (MIDDLE DEVONIAN) AT TSAKHIR, GOVI ALTAI REGION, SOUTHERN MONGOLIA

NICHOLAS SULLIVAN

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## INTRODUCTION AND PURPOSE

The Devonian System ( $418.1 \pm 3.0 - 365.7 \pm 2.7$  Ma) is subdivided into three epochs, Lower, Middle, and Upper, which are further subdivided into seven stages. The Middle Devonian is subdivided into the Eifelian ( $391.9 \pm 3.4 - 388.1 \pm 2.6$  Ma) and the Givetian ( $388.1 \pm 2.6 - 383.7 \pm 3.1$  Ma; Kaufmann, 2006). The stage boundary is defined by the first appearance of *Polygnathus hemiansatus* at the Eifelian-Givetian Stage Global Stratotype Section and Point (GSSP), which is a section at Jebel Mech Irdane in the Tifilalt of Morocco (Walliser et al. 1995). At some sections, the appearance of the goniatite *Maenioceras undulatum* has been used as a proxy for the boundary (Kutcher and Schmidt, 1958).

The Eifelian-Givetian stage boundary occurs just above a globally recognized hypoxic episode called the Kačák Event (House, 1995). Due to its association with the Dacryoconarid *Nowakia otomari*, the Kačák Event is also referred to as the Kačák-otomari Event. Crick et al. (2000) discovered a period of low magnetic susceptibility values associated with the Kačák-otomari Event, reflecting a lower detrital iron concentration within the sedimentary record. Lower concentrations of detrital iron are interpreted as the result of a transgressive episode and consequent migration of clastic input landward. The end of the Kačák-otomari Event coincides with a sharp rise in magnetic susceptibility levels roughly concurrent with the Eifelian-Givetian boundary (Crick et al. 2000). Travis et al. (2009) have used the positive magnetic susceptibility spike to approximate the Eifelian-Givetian boundary in eastern North America. The purpose of this paper is to analyze and approximate the Eifelian-Givetian stage boundary of the Tsakhir Section, which is located near Shine Jinst in the Gobi Altai Region of southern Mongolia.

## GEOLOGIC SETTING

Badarch et al. (2002) argued that Mongolia consists of numerous terranes that were accreted onto small Precambrian cratonic blocks in the Hangay Region during the Paleozoic and Mesozoic. The focus of this investigation are strata in a region recognized as part of one of these accretionary wedges, which is referred to as the Gobi Altai Terrane (Figure 1; Badarch et al., 2002; Minjin and Soja, 2009a). Badarch et al. (2002) characterized the Gobi Altai Terrane as a backarc basin, as evidenced by abundant volcanoclastic sedimentary rocks. The volcanics within the Gobi Altai Terrane are believed to be derived from a prehistoric island arc represented by the Mandalovoo Terrane, which was active throughout the Lower and Middle Devonian (Badarch et al., 2002).

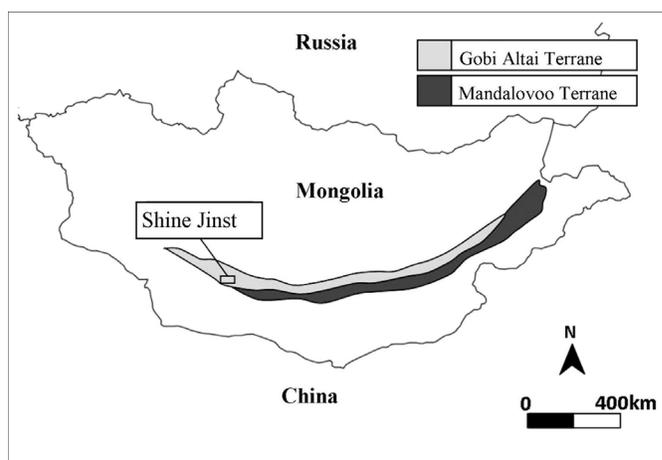


Figure 1 – Simplified tectonostratigraphic terrane map for Mongolia with the Gobi Altai and Mandalovoo Terranes highlighted. (modified from Badarch et al. 2002)

The study area near Shine Jinst (Fig. 1) represents a series of relatively continuous and mildly deformed rock strata, ranging from the Ordovician to the

Carboniferous (Minjin and Soja, 2009b). Wang et al. (2005) argued that the Eifelian-Givetian boundary lies either near the top of the Tsagaankhaalga Formation, or near the bottom of the overlying Govialtai Formation, suggesting the possibility of a gap in the stratigraphic record that includes the stage boundary.

Alekseeva (1993) described the Tsagaankhaalga Formation as predominantly massive, bedded limestones and associated conglomerates and sandstone layers. Wang et al. (2005) reported the conodonts *Caudicriodus angustus cauda*, *Caudicriodus stelcki*, and *Caudicriodus unwoschmidti*, within the Tsagaankhaalga Formation, thereby constraining its age to the Eifelian.

Alekseeva (1993) subdivided the Govialtai Formation into two members. The lower or Tentaculite Member is characterized by black siltstones and claystones with occasional sandstone and sandy limestone layers. The upper or Khar Member is characterized by volcanoclastic sediments with occasional interbedded basalts. Conodonts of the Upper *ensensis* Zone were reported by Alekseeva (1993) in the Tentaculite Member, thereby constraining its age to the Givetian.

The Eifelian-Givetian Stage boundary is believed to fall within the upper Tsagaankhaalga or lower Govialtai. Alekseeva (1993) suggested that the Tsakhir section is incomplete and the two formations are unconformable, a sentiment shared by Wang et al. (2005).

## LITHOLOGY AND LOCATION OF THE TSAKHIR SECTION

From 3 August 2009 to 6 August 2009, the section at Tsakhir was measured and sampled. The approximate location of the section is 44° 22' 53" N and 99° 28' 46" E. The outcrop lies on a ridge that trends roughly northwest-southeast between two drainage divides that contain dirt roads. The crest of the ridge consists of massively bedded, fossiliferous carbonates. A small sample of these carbonate beds, believed to correspond to the base of Unit 18 from

Alekseeva (1993), was collected for microfossils and thin section production.

The primary focus of this study was an outcrop that can be found on the third hill east of the drainage divide that crosses the ridge to the west (Fig. 2). The strata were found to have a trend of 058 with a dip of 50 to the south. However, they were determined to be overturned; indicating stratigraphic up was to the northeast.

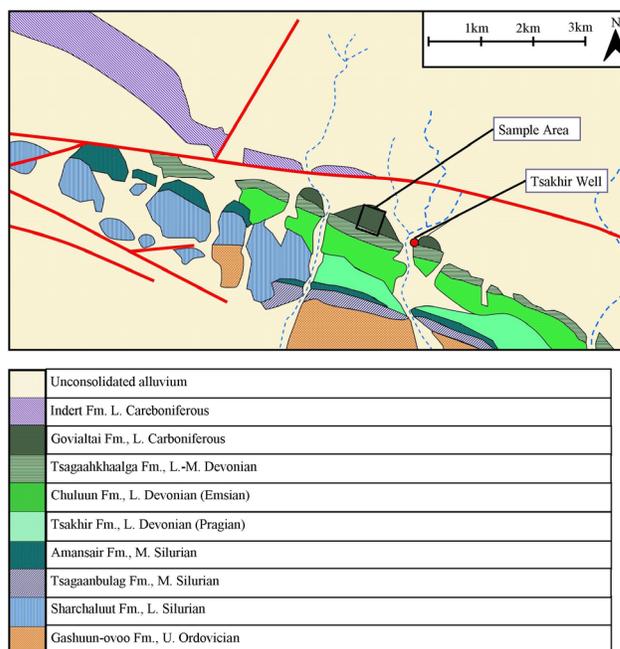


Figure 2 – Location of the Tsakhir section (outlined in the black box) on a simplified geologic map of the study area. Faults are indicated by red lines. Drainage channels are indicated by dotted blue lines. The Tsakhir Well is represented by a red dot. Geologic units are labeled below (modified from Wang et al. 2005; and Minjin and Soja, 2009).

A 103 meter section of rock was studied with zero established at the level where a light pinkish gray siltstone is overlain by a light gray silty shale (Fig. 3). The 3.6 m–25.0 m, 28.8 m–43.0 m, and 49.0 m–53.0 m section intervals were obscured by alluvium and therefore were not recorded. Magnetic susceptibility samples were collected at half meter intervals through the section. Five bulk samples were collected for thin sections and microfossil analysis at 65.2 m, 68.8 m, 76.5–77.0 m, 87.0 m and 96.0–97.0 m (Fig. 3).

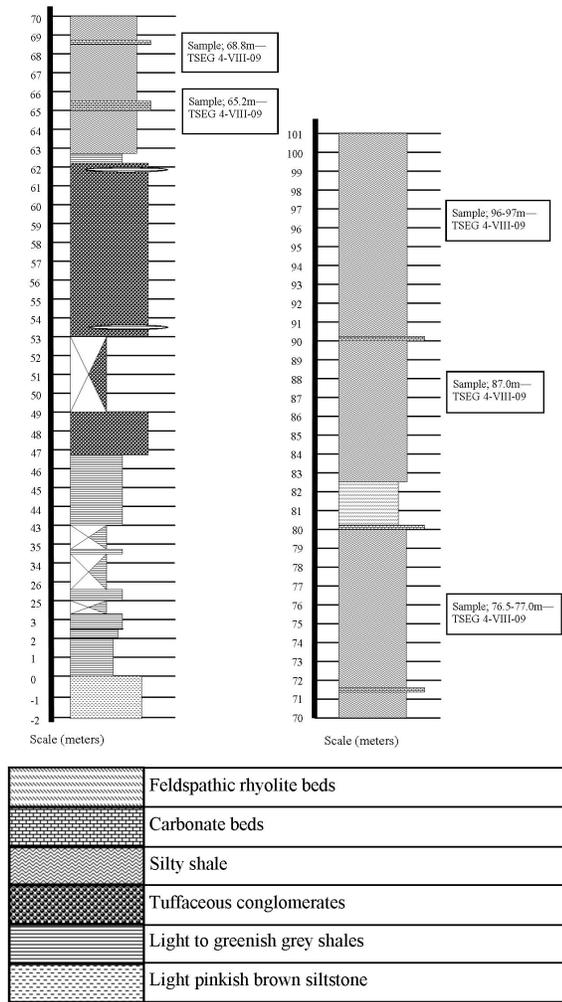


Figure 3a – Stratigraphic column compiled from data collected from the Tsakhir Section. Figure 3b – Key to lithologies

The stratigraphic section consists primarily of fine grained siliclastics; mostly dark blue to dark gray silty shales. Also present are greenish gray tuffaceous conglomerates, medium green to gray feldspathic rhyolite silicious beds, and interbedded carbonates which were sampled for microfossils.

### MICROFOSSIL DATA AND SYSTEMATICS

The carbonate bed sampled at 68.8 m, 76.5-77.0 m, 87.0 m, and 96.0-97.0 m were processed for conodonts using a solution of formic acid. Conodonts were recovered from the 68.8 m interval and imaged using a scanning electron microscope (Fig. 4).

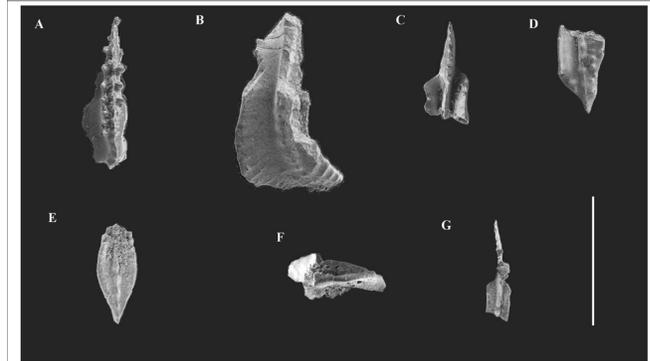


Figure 4 – Conodonts from the sample collected at 68.8 m carbonate bed. Images were acquired using the scanning electron microscope. White bar represents two millimeters. *Icriodus* sp.

A; Upper view of TSEG 01726, (long axis; 1.19 mm), *Polygnathus linguiformis linguiformis*

B; Upper view of TSEG 01734 (long axis; 1.45 mm) *Polygnathus* sp.

C; Upper view of TSEG 01730 (long axis 0.84 mm)

D; Upper view of TSEG 01736 (long axis 0.72 mm), most likely the posterior end of sample TSEG 01730

*Polygnathus ensensis*

E; Upper view of TSEG 01736 (long axis 0.77 mm)

F; Oblique view of TSEG 01731 (long axis 0.77 mm)

*Polygnathus xylus xylus*

G; Upper view of TSEG 01735 (long axis .78 mm)

### *Icriodus* sp.

Remarks: The main P<sub>1</sub> element of *Icriodus* is characterized by three longitudinal rows of nodes with some forms including transverse ridges (Clark et al., 1981). The stratigraphic range is between the Pridolian and the Famennian. Specimen 4A is a P<sub>1</sub> element displaying by the three longitudinal rows of nodes characteristic of *Icriodus*. The nodes of the central row are connected by a longitudinal ridge. Transverse ridges are present, running between lateral and central nodes.

### *Polygnathus linguiformis linguiformis*

Remarks: *P. linguiformis linguiformis* is defined by an elongate plate with one extremity produced into a tongue like projection which is marked by transverse ridges. The anterior portion of the platform is characterized by adcarinal troughs straddling the blade (Hinde, 1879). This taxon is known to have a stratigraphic range between the late Eifelian and early Givetian (Ziegler et al., 1979). Although Figure

4B does not represent a complete and undamaged conodont, it is intact enough to view the tongue like projection and lateral ridges characteristic of *P. linguiformis linguiformis*.

#### *Polygnathus* sp.

Remarks: The genus *Polygnathus* is defined by carminiplanate  $P_1$  elements.  $P_1$  elements of *Polygnathus* consist of a flat platform extending away from the posterior section of a blade. Figures 4C and 4D are believed to represent two fragments of the same conodont. The specimens were not identified to the trivial level. The straight outer margins of the blade and distinct adcarinal troughs are reminiscent of *P. linguiformis*. However, the specimens lack the lateral ridges and tongue like projections. Relatively flat but discrete protrusions on the platform are also visible. The specimen bears resemblance to specimens identified as *Polygnathus pseudofoliatus* by Walliser (1996, Fig. 4A, 4B) from Morocco.

#### *Polygnathus ensensis*

Remarks: *P. ensensis* (synonymous with *P. xylus ensensis*) is defined by distinctly serrated platform margins just posterior to the geniculation point (Zeigler et al., 1976). *Polygnathus ensensis* first appears in the upper Eifelian, ranging into the early Givetian (Bultynck and Hollevoet, 1999). Figure 4E is fragmented and the blade is not intact. However, the distinctly serrated margins in the posterior margin of the platform are visible. Figure 4F shows an oblique view of the platform.

#### *Polygnathus xylus xylus*

Remarks: *P. xylus xylus* is characterized by platform margins just posterior to the geniculation point that are not significantly serrated. The taxon appears in the upper Eifelian, ranging into the *Lower varcus*-Subzone of the early Givetian (Ziegler et al. 1976). Figure 4G shows the specimen which displays the unserrated margin characteristic of *P. xylus xylus*. The specimen also shows an elongated blade which is also characteristic of the taxon.

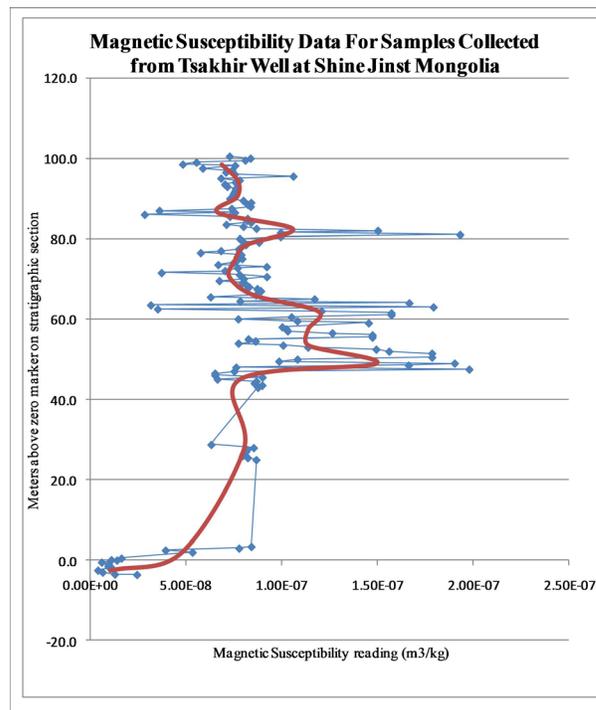


Figure 5 –Magnetic susceptibility ( $m^3/kg$ ) of samples collected at Tsakhir Section plotted against stratigraphic thickness in meters. Blue line represents magnetic susceptibility of individual samples. Red curved line represents mean magnetic susceptibility for sets of eight samples.

## MAGNETIC SUSCEPTIBILITY DATA

Magnetic susceptibility data was acquired using an AGICP Kappabridge housed in the SUNY Geneseo Department of Geology. Data were compiled and organized in Microsoft Excel and magnetic susceptibility ( $m^3/kg$ ) was plotted against stratigraphic thickness in meters (Fig. 5A). Magnetic susceptibility data show an overall positive trend moving up the section. There are three major positive spikes in magnetic susceptibility at approximately 0.0 m, 47.0 m, and 63.0 m.

These positive spikes over short intervals, combined with the overall positive trend of magnetic susceptibility moving up section, is similar to data collected from the Eifelian-Givetian GSSP at Jbel Mech Irdane in Morocco (Crick et al., 2000) and from Middle Devonian strata sampled in New York (Travis et al., 2009).

## CONCLUSIONS

The siliclastic and volcanic sediments at the Tsakhir Section are assigned to the Tentaculite Member of the Govialtai Formation. This is consistent with the geologic map produced by Wang et al. (2005) and the observations of Alekseeva (1993).

The lithology of the section shows many significant similarities to Middle Devonian outcrops in North America. The massive carbonates of the Tsagaankhaalga Formation overlain by the more finely bedded siliclastic shales of the Govialtai Formation are strikingly similar to outcrops in eastern North America where carbonates of the Onondaga Formation are overlain by the Marcellus and Skaneateles shales. The abundance of volcanoclastics throughout the section is consistent with the conclusions of Badarch et al. (2002) who defined the Shine Jinst area as a backarc terrane that had formed behind a volcanic island arc that was active during the Devonian.

The presence of *Polygnathus xylus xylus* and *Polygnathus linguiformis linguiformis* indicate that the carbonate bed found at 65.8 most likely represents the Lower *varcus*-Zone of the lower Givetian. The Eifelian-Givetian boundary is tentatively placed above the positive magnetic susceptibility shift observed at approximately 0.0 meters, where the measurements appear to stabilize at a level between  $6.00 \times 10^{-8}$  and  $9.00 \times 10^{-8}$  m<sup>3</sup>/kg. However, biostratigraphic control is not sufficient to constrain the boundary interval and thick intervals of the section are obscured by alluvium, thus limiting the resolution of magnetic susceptibility trends.

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