Field trip to the Winona Area
Leave: as early as possible on Friday. 5:00 p.m. at the latest.
Return: mid-day, Sunday.

We can either grab dinner on the way down to Winona, or cook something when we get there. As usual, we'll break into food and clean-up groups for meals on Saturday and Sunday morning.

Stuff needed for field trip:

The usual camping stuff:

- Tent
- Sleeping bag
- Sleeping pad
- Flashlight
- Warm clothes
- Raincoat
- Boots
- Hat
- Etc.

Plus:

- Camera (digital would be nice, if you have one)
- Rock hammer
- Fieldbook
- Hand lens and grain size card
- Clipboard

What should you record in your fieldbook, before even beginning to look at the rocks?

Take an hour to walk the entire length of the outcrop and do the following *on your own*.

What are the lithologies present here? Make a table with lithologies and their detailed descriptions in your fieldbook and list the lithologies, with brief descriptions, here. You may see some you've never encountered before; if you can't name them, describe them very thoroughly and leave the name blank.

Describe the *overall* style of bedding as you walk upward through the sequence. Remember: thickness, alternation of lithologies, beds versus bedsets, amalgamation, laminae, etc.

St. Lawrence Formation

Locate one of the resistant beds in this part of the outcrop and carefully describe how the rocks change upward to the base of the next resistant bed. You may need to dig around a bit with your rock hammer to figure out what's happening in the recessive interval. A small sketch might help here.

Seeing through weathering

Sometimes it is very difficult to tell what is a primary feature of the sedimentary rock (a feature that formed when it was deposited) versus a secondary feature that obscures the sedimentary features you want to look at. At this point in the section, make a sketch of what you think are the primary, sedimentary features in the outcrop and what are the features that formed later, most likely due to weathering.

This series of beds includes some very significant sedimentary features that are important clues to understanding one part of the story of the environment of deposition of this part of the Jordan Formation. First, sketch these beds as if viewed from a distance (from across the road, perhaps). Second, sketch a portion of the lower of these beds about 1.5 m long (left to right, when looking at the outcrop/bed).

Far view:

Closer up:

Session: The Jordan Sst. project **Sedimentology and Stratigraphy**	**Materials needed:** • **Large Post-it notes** • **Permanent markers**

Goals of the session:

- **To re-emphasize the methodology we're using/learning to interpret depositional sequences**
- **To re-focus on the Jordan Sst after a bit of a hiatus**
- **To get the students to come up with an appropriate outline for the final write-up on the Jordan:**
    - **what questions and sub-questions will we need to answer?**
    - **what will be the best approach to answering these questions?**
    - **what will be the best way to organize a write-up to answer these questions?**

Estimated time	**Session outline**
10 minutes	1. Re-focusing on the methodology we're using: a. How would you outline the methodology we used to interpret/ understand the JFG rocks? b. Can we, as a group, come up with an essential methodology for attacking the fundamental question of this class?
50 minutes	2. Re-focusing on the Jordan Sst: *gallery walk?* a. Using your field notes and measured section, list some similarities and/or differences between the JFG and Jordan Fm b. What sub-questions do you think we need to address with respect to the Jordan (and St. Lawrence) Formation if we are going to answer the fundamental question, "in what environment were these rocks deposited?" *Or:* what questions do you have about the Jordan Fm that we might need to tackle over the next few weeks? c. What features did you detect in the Jordan Fm that you think need explaining, in terms of understanding how these rocks were deposited? d. For one of the features that you detected in the Jordan Fm units: (1) list the feature and (2) suggest an approach we might take in trying to understand how it formed.
30 minutes	3. Devising an appropriate outline for the final write-up on the Jordan Fm. *Mini poster session, using four groups. Everyone looks at the posters, then we try to achieve consensus on what would be the **best** outline.* a. What will a rough outline of a final write-up look like? b. Can we fill in some details of this outline? c. Can you, as a class, come up with an appropriate outline for how to approach this next project effectively? d. If this goes too long: ask that the students use the course discussion board on the Blackboard site to come up with a consensus outline? I will also provide feedback.

Session notes

1. Section 1 should just be a quick discussion to refresh everyone's memory about observation, interpret the detailed processes, then interpret the dep environment.
2. Section 2 is a gallery walk that I want to use to get the students to summarize the main questions that we'll need to address to understand the Jordan Fm. The ideas generated here should dial into section 3 (below).
3. Section 3: I effectively want the students to write up the requirements for the next project and agree upon it.

1. Using your field notes and measured section, list some similarities and/or differences between the JFG and Jordan Fm.

2. What sub-questions do you think we need to address with respect to the Jordan (and other) Formation(s) if we are going to answer the fundamental question, “in what environment were these rocks deposited?”

3. What *specific* features did you detect in the Jordan Fm that you think need explaining, in terms of understanding how these rocks were deposited?

4. For one of the features that you detected in the Jordan Fm units: (1) list the feature and (2) suggest an approach we might take in trying to understand how it formed.

Session: How do water flows interact with a bed made of sand? A day at the St. Anthony Falls Lab **Sedimentology and Stratigraphy**	**Materials needed:** • **Velocity probes** • **Tape measures** • **Rulers** • **Overhead material** • **Tape** • **Vis-à-vis markers** • **Large pad of paper** • **Stopwatches** • **Calculator**

Goals of the session:

- **Students should be able to explain what happens to a sand bed as a unidirectional water flow above it is increased in velocity and/or depth.**
- **Students should be able to explain what happens to a sand bed as wave height, wavelength, and wave period change.**
- **Students should be able to relate these explanations to features encountered in clastic sedimentary rocks.**

Estimated time	**Session outline**
	1. Unidirectional flows a. Work up in velocity b. What should we take note of? c. At ripples: make some synthetic x-strat d. What would unidirectional flows produce in the rock record? 2. Oscillatory flows a. What can we control in the experiment? b. What more should we take note of? c. Pose the question: what would oscillatory flows produce in the sed record?

Session notes

- Point out that you have sheets of paper for note-taking. There will be a lot of discussion and you'll need to take notes.

Homework/write-up

Using your observations from today's lab, respond to the following in a well-written, 2-3 page write-up.

- **Explain what happens to a sand bed as a unidirectional water flow above it is increases in velocity.**
- **Explain what happens to a sand bed as wave height, wavelength, and wave period change.**
- **Relate these explanations to features encountered in clastic sedimentary rocks.**

GEOL 320, Sedimentology and Stratigraphy
How do water flows interact with a bed made of sand?
A day at the St. Anthony Falls Lab

Today we will be using one flume (an open-topped, man-made channel) and one tank with a wave generator to answer the question posed above. The idea is to have you come away from this lab with a strong sense of how moving water interacts with a sand bed and what this implies for understanding sedimentary rocks.

Playing with a flume

For the first set of observations/experiments, we will be running a unidirectional (one-way) water flow over a sand bed. We will start with a low velocity flow and gradually increase its velocity. We might also change flow depth and the tilt of the flume.

1. As a group, let's make a list of some of the things we might look for and measure as we do our experiment:

Playing with a wave tank

For the second set of observations/experiments, we will be running an oscillatory (bi-directional, two-way, etc.) flow over a sand bed.

2. What variables can we control in this experiment?

3. Once again, as a group, let's make a list of some of the things we might look for and measure as we do our experiment (in addition to the things we noted above):

Unidirectional flows

Mean flow velocity	Mean flow depth	Description of grain motion (how are grains moving?) and water motion.	Description and sketch of the bed state. Any sedimentary features that might be produced?

Oscillatory flows

Wave length and height (H)	**Wave period**	**Water depth (h)**	**Maximum orbital horizontal velocity** $U_{\max} = \frac{H}{2h}\sqrt{gh}$	**Description of grain motion (how are grains moving?) and water motion.**	**Description and sketch of the bed state. Any sedimentary features that might be produced?**

The space below is for you to make notes.
Through the course of the day we will likely stop to discuss the sedimentological and geological implications of what we're doing. You should try to stay focused on this aspect of the exercise.

Homework/write-up

Using your observations from today's lab, respond to the following in a well-written, 2-3 page write-up.

- **Explain what happens to a sand bed as a unidirectional water flow above it is increases in velocity.**
- **Explain what happens to a sand bed as wave height, wavelength, and wave period change.**
- **Relate these explanations to features encountered in clastic sedimentary rocks.**

Deriving bedform phase diagrams: in-class and homework assignment
Due Thursday, October 16, beginning of class.
Relevant reading in Boggs: pp. 37-44 & 97-102

Recall the first experiment we did in lab last week, with the unidirectional flume at SAFL. *Without looking at the remainder of this handout,* what three variables do you think play the *most* important role in shaping the bedforms we made (ripples, plane bed, etc.)?

Main variables that control the state of the bed:

1.
2.
3.

Part I: Initial relationships

You will find three Excel files on the course website (under "Assignments" and "Homer Project"):

0.10-0.14 mm.xls
0.5-0.64 mm.xls
1.3-1.8 mm.xls

Each of you will be randomly assigned one of these files. Note the name of the file you received here:

*Describe, in a well-written, **brief** paragraph, what your file contains.*

What is the relationship between flow velocity, flow depth, and the bedforms present under these conditions?

To answer this question, use Excel and its wonderful charting functions to make a plot that has mean flow velocity on the horizontal axis and flow depth on the vertical axis. For each bedform type, you need to plot a different symbol on this chart. Hint: you may have to use the "sort" function, move some columns around a bit, and you will have to use the "Add data" function when making the chart.

On your chart, you should try to divide the data into logical bedform "fields", or areas that define the conditions under which certain bedforms tend to occur.

Describe what your results tell you about this relationship for your set of data:

Print your chart and have it ready for part 2!!

Part II: How does grain size change things?

I will assign you to new groups of three or four. In your new groups, write a collective response (using Word) to the following:

Based on your data, what is the effect of changing grain size on the state of the bed (i.e. on the conditions under which certain bedform occur)? Be careful and in your response pay attention to the actual values under which certain bedforms occur and how they change with changing grain size.

Session: Interpreting cross stratification **Sedimentology and Stratigraphy**	**Materials needed:** • **Powerpoint on cross stratification** • **Rubin animations of cross strat**
Goals of the session: • **To forge a link between bedforms and the cross stratification they produce** • **Students should understand that cross stratification allows us to interpret specific flow conditions (velocity, depth, etc.)** • **Students should be able to describe unidirectional, oscillatory, and combined-flow bedforms**	

Estimated time	**Session outline**

30 minutes
 	
45 minutes
15 minutes
	1. Finish Part II of "Deriving bedform phase diagrams" jigsaw.
	    a. Re-arrange into groups with representative from each grain size class
	    b. Students should describe what happens as grain size varies, based on their own plots.
	2. Bedforms and cross stratification lecture
	3. Combined flow problem
	    a. What is a combined flow?
	    b. Using Myrow and Southard (1991) figure, interpret the trajectory
	4. Choose groups for lab demos.

Session notes	

<table>
<tr><td colspan="2">Session: Drafting a strat column in Adobe Illustrator
Sedimentology and Stratigraphy</td><td>Materials needed:
Strat column template (Adobe Illustrator document)
Student’s strat columns</td></tr>
<tr><td colspan="3">Goals of the session:
Students should have a basic idea of how to use Adobe Illustrator to draft a simple, grain size column by the end of the session.</td></tr>
<tr><td>Estimated time</td><td colspan="2">Session outline</td></tr>
<tr><td>2 minutes

1.5 hours (twice)</td><td colspan="2">1. Break the class into two groups, so that each student can have their own computer.
2. Basic Adobe Illustrator use
a. Download and open your template from Blackboard
b. Stroke and Fill control box
c. Drawing a line, changing its stroke weight and color
d. Drawing a box, changing its stroke weight and fill color
e. Selection arrows: closed versus open
i. Selecting an entire object, moving it
ii. Selecting part of an object, moving it, and deleting it
f. Drawing a box with one irregular edge
g. Using swatches: geology swatches
h. Sketching: using the pencil tool
i. Layers
3. Try drafting part of your strat column</td></tr>
<tr><td colspan="3">Session notes</td></tr>
</table>

Jordan Formation Project

In class last week we came up with the following outline for the Jordan Project. Recall also that I suggested you look over the paper on the Wheeler Gorge Conglomerate (Walker, 1985) and use it as a guideline for writing up the Jordan Formation Project. You do not have to use the precise outline below, but you should follow the spirit of it. Also, recall that there are figures that should be associated with some portions of this outline and that must appear in your write-up.

Outline

I. Introduction
- A. Problem
- B. Location
- C. Age
- D. General description of Jordan Outcrops (Homer and Stockton)

II. Observation
- A. Lithologies
- B. Bedding
  1. Contacts
  2. Lateral pinch-outs
- C. Grain size
- D. Primary sedimentary structures
  1. HCS
  2. cross strat
  3. Other lamination
  4. Other?
- E. Secondary structures
  1. Trace fossils
  2. Laminated sst clasts as breccia at Stockton
- F. Fossils?

III. Lithofacies: description and interpretation
- A. Lithofacies 1
  1. Description
  2. Interpretation
- B. Lithofacies 2, etc.

IV. Discussion/Interpretation
- A. Interpretation of depositional environment
- B. Supporting literature
- C. Time sequential history of deposition (evolution of the depositional system)

Project deliverables

- A project write-up that follows the outline we developed

Project milestones

- October 23: Individual measured sections due at beginning of class, in Adobe Illustrator format
- October 30: Draft of Introduction, Observations, and Lithofacies descriptions section due at beginning of class, ***with figures.***
- November 6: Draft of final write-up due at beginning of class (bring 3 copies)
- Thursday, November 13: Final write-up due at beginning of class.

Interpreting your individual strat columns in terms of primary and secondary sedimentary structures

You and your field partner should submit a write-up by the end of class today that includes the following:

- A written description of your individual measured section (this will be given to everyone in the class to accompany the overall measured section that I will compile from your individual sections). This should be a written description of your observations and *must* include a description of primary and secondary sedimentary structures, and their variation over your section (if any).
- An interpretation of the primary and secondary sedimentary structures in your measured section, based on our discussions of cross stratification in class, your textbook, and the Rubin bedforms site.
- In your interpretation, make sure that you address the following:
    - What kinds of bedforms made the cross strat you see? 2D or 3D? Unidirectional, oscillatory, or combined flow? What are reasonable depth and velocity conditions for these bedforms?
    - If you have trace fossils: what *trace fossil assemblage* do they belong to (see Boggs, pp114-123) and what is the significance of this assemblage?

This write-up should be done in Word, following the usual guidelines (12-point, Times font, double-spaced, 1.25" right and left margins and 1" top and bottom margins).

The group's measured section

While you are working on the above, I will attempt to piece together your individual measured sections in Adobe Illustrator, then make this section available on the course website. Once I have completed this (hopefully before the end of lab today), I will make hard copies of it for you. However, for your final copy, you will want to modify this section to make patterns, fonts, etc. consistent.

Toothy's Conodont Consultants
490 Slimefish Way
Leicester, England ORD151
United Kingdom

Conodont analytical report

To Whom It May Concern:

High resolution biostratigraphic dating through the entire thickness of the Jordan Formation and the lower portion of the Oneota Dolomite has been completed, per your order (Ref: HOM-03-0001). The attached table provides results, listing height in your measured section, formation name, conodonts encountered, and their conodont zone (based on Ross *et al.*, 1997).

Height (m)(in your measured section)	**Formation name**	**Conodonts encountered**	**Conodont zone (based on Ross *et al.*, 1997)**
0.5	Jordan Fm.	Proconodontus muelleri; Eoconodontus notchpeakensis	Eoconodontus nochpeakensis
3	Jordan Fm.	Eoconodontus notchpeakensis	Eoconodontus nochpeakensis
11.75	Jordan Fm.	Eoconodontus notchpeakensis	Eoconodontus nochpeakensis
13	Jordan Fm.	Proconodontus muelleri; Eoconodontus notchpeakensis	Eoconodontus nochpeakensis
14	Jordan Fm.	Proconodontus muelleri; Eoconodontus notchpeakensis	Eoconodontus nochpeakensis
21	Jordan Fm.	Proconodontus muelleri;	Eoconodontus nochpeakensis
22.25	Jordan Fm.	Proconodontus muelleri;	Eoconodontus nochpeakensis
26.5	Jordan Fm.	Proconodontus muelleri; Eoconodontus notchpeakensis	Eoconodontus nochpeakensis
27.5	Coon Vallye Mbr or the Oneota Fm.	*Acanthodus uncinatus; Aloxoconus iowensis; Aloxoconus propinquus; Aloxoconus sp.; Cordylodus intermedius; Cordylodus linstromi; Polycostatus oneotensis*	Cordylodus angulatus

Samples from the St. Lawrence Formation and the Jordan Sandstone contain only two conodont species, *Proconodontus muelleri* and *Eoconodontus notchpeakensis*. These species are widespread in North America and are diagnostic of the *Eoconodontus notchpeakensis* Subzone of the *Eoconodontus* Zone, approximately of middle Trempealeauan age. The Coon Valley Member of the Oneota Formaiton yielded a completely different conodont fauna.   This sample includes *Acanthodus uncinatus, Aloxoconus iowensis, Aloxoconus propinquus, Aloxoconus sp., Cordylodus intermedius, Cordylodus linstromi, and Polycostatus oneotensis*. Many of these species were named by Furnish (1938) from the Oneota in the Iowa-Minnesota area. This assemblage of species is at least as young as the *Cordylodus angulatus* Zone but could be from the

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overlying *Rossodus manitouensis* Zone. These two zones are from the middle to upper part of the Skullrockian Stage of the Ibexian Series (Lower Ordovician) in the Ibex area of western Utah (Ross *et al.,* 1997).

For your information, I have attached the conodont zonation from Ross *et al.* (1997). It looks like you may have some interesting results here!! I hope our analyses have been helpful.

Sincerely,

Theodore Hagburrow, esq. ("Toothy")

CONODONT ZONATION Ross and others (1997) Zone	Subzone	STAGE	SERIES
Rossodus manitouensis		SKULLROCKIAN	IBEXIAN
Cordylodus angulatus			
Iapetognathus			
Cordylodus lindstromi			
Cordylodus intermedius	*Clavohamulus hintzei*		
	Hirsutodontus simplex		
Cordylodus proavus	*Clavohamulus elongatus*		
	Fryxellodontus inornatus		
	Hirsutodontus hirsutus		
Eoconodontus	*Cambrooistodus minutus*	SUNWAPTAN	MILLARDAN
	Eoconodontus notchpeakensis		
Proconodontus muelleri			

Conodont zonation for the upper Cambrian, lower Ordovician

Session: Overall grain size trends and Walther's Law… Sedimentology and Stratigraphy	**Materials needed:**

Goals of the session:

- **To begin to develop an intuitive understanding of Walther's law and how it can control the overall grain size trend through a section.**
- **Progradation, aggradation, and retrogradation.**

Estimated time	**Session outline**

	1. What is overall grain size trend in section?
	2. How might you explain these trends?
	3. Walther's Law: laterally equivalent environments will stack vertically, in the absence of erosion/unconformities.
	  a. An example, using alluvial fans and lakes
	  b. Will lead to a discussion of sed supply, subsidence rate, and base level (the next project).

Session notes

1.

Lithology

The lithology of the Jordan Formation is quartz arenite sandstone. The sandstone framework is primarily made up of quartz. No thin section was available, so the identification of any other minerals that could be in this sandstone was not possible. There were places in the outcrop where the sandstone was well cemented, but there were also places where the sandstone was not as well cemented. The sand grains in this sandstone were well rounded and sorted. This sandstone is compositionally and texturally mature.

Bedding

The beds within the Jordan formation do not dip any direction. They are all horizontal beds. One thin that does change is bed thickness. Bed thickness of the Jordan ranges from to 0.1m-2m thick (see figure 2). The thickness of the beds follows a pattern. The pattern is a set of thick beds followed by a set of thinner beds. From 0-2 m a thick bed…

Session: Meandering and alluvial fan systems **Sedimentology and Stratigraphy**	**Materials needed:** • **Color photos of views of alluvial fans and meandering rivers (in sheet protector sleeves)**

Goals of the session:
I intend to do two things with this lab:

- Emphasize the connection between a geomorphic environment and the deposits they produce
- Demonstrate how a sedimentary facies is produced.

Estimated time	**Session outline**

In essence, you will be using photographs of modern depositional systems to come up with 'models' or 'hypotheses' about the kinds of deposits they will produce.

PART I: MEANDERING FLUVIAL SYSTEMS

IA: In this part of the lab you will work in groups. Each group should pick up an imagery packet from me (or I'll hand 'em to you). You will use the images of the two views of the Mississippi River. One is a black and white vertical air photo from Louisiana. The other is a Shuttle Imaging Radar (SIR) image; the different colors correlate with the polarity of the radar signal (ask me if you want more info on this). Notice that there are three sites, A, B, and C, labeled on each photo, with a red dot to more precisely locate the site.

Site A:
Site B:
Site C:

After a bit of lecture on meandering fluvial systems, ***on a separate sheet*** answer the following questions *for your site only*! I will be your primary resource, but I may toss a couple of books at you too.

- What processes dominate at your site? Cast the net wide: physical, biological, and chemical processes all may play a role.
- What might a short topographical profile look like at your site? Pick one that would show maximum change in relief and, if you're near the river, what the river cross-sectional shape would be.
- If you could drill a core at your site that was about 50' deep, what sequence of deposits do you predict you'd encounter? make a mini strat column, with grain size, sedimentary structures, etc.
-

IB: Now, break into the following groups:

Site A:
Site B:
Site C:

Notice that each group consists of someone with expertise in each site (A, B, and C). Using your expertise from part IA, each group should address the following:

- If you were looking at a vertical sequence of sedimentary rocks, what would you

	look for to discern whether the sequence was deposited as part of a meandering fluvial depositional system? You might call your answer to this question a type of "facies model." • How might you distinguish details of the depositional environment (i.e. could you recognize sub-environments within the broader picture of meandering fluvial depositional system)? **PART II: ALLUVIAL FAN/ BRAIDED FLUVIAL DEPOSITIONAL SYSTEMS** **IIA:** Again you will work in groups and use the same imagery packet. You will use the images of alluvial fans from Death Valley and China. One image is a National High Altitude Project color aerial photograph. One is an oblique view of a fan in Death Valley. The other two are Shuttle Imaging Radar (SIR) images. Your goal is do exactly the same thing that you did in part I. After a bit of lecture on alluvial fan processes, you will break into slightly different groups: …and answer the same questions for part IA. **IIB:** Once again, we'll play the same game with new groups, yet you will answer them questions as in part IB above: **FOR EACH PART OF THIS LAB EACH GROUP SHOULD HAND IN A WRITE UP WITH EACH GROUP-MEMBER'S NAME ON IT**
Session notes	

Your names:

Your site (A, B, or C):

1. What processes dominate at your site? Cast the net wide: physical, biological, and chemical processes all may play a role.

2. What might a short topographical profile look like at your site? Pick one that would show maximum change in relief and, if you're near a river, what the river cross-sectional shape would be.

3. If you could drill a core at your site that was about 50' deep, what sequence of deposits do you predict you'd encounter? Make a mini strat column, with grain size, sedimentary structures, etc.

Now, re-group such that you have a representative from each site (A, B, and C)

Who is in your group:

As a group, answer these questions:

1. If you were looking at a vertical sequence of sedimentary rocks, what would you look for to discern whether the sequence was deposited as part of this depositional system? You might call your answer to this question a type of "facies model."

2. How might you distinguish details of the depositional environment (i.e. could you recognize sub-environments within the broader picture of this depositional system)?