



Utilizing StraboSpot as a teaching tool: an example from the Baraboo Hills, WI

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www.strabospot.org

Exercise description:

This exercise uses StraboSpot (www.strabospot.org) to recognize and describe deformation within Proterozoic metamorphosed and folded sediments exposed in south-central Wisconsin, and their relations to the overlying Cambrian rocks. This exercise can be tailored by adding more advanced (or more basic) questions for students with different backgrounds.

Learning Outcomes:

By completing this module, students should gain practice in:

1. Using StraboSpot as both a field and education tool – for students and instructors.
2. Using observations as a foundation for interpretations.
3. Identifying and differentiating some basic rock types in the field.
4. Recognizing and differentiating primary depositional features and overprinting structures.
5. Using structural measurements in the field to define large-scale structures.

Base knowledge to succeed:

Knowledge of strike/dip, right-hand rule

Exercise instructions:

Students should work through the following prompted virtual field activity, answering questions completely. The data are all on StraboSpot, which can be found by looking on the StraboSpot Search map near Baraboo, WI, or by following this [link](#). The dataset is called 'BarabooVirtualExperience - April2020'.

Tools required:

Protractor

Access to a web browser (www.strabospot.org/search)

Material for producing sketches, either on paper or electronically.

Approximate time to complete: 4 hours

Part I - Introduction:

Greetings and welcome to the Baraboo (WI) virtual fieldtrip!

All information about what do to will is detailed on the assignment sheet; instructions for each stop are also listed in the *NOTES* section on StraboSpot.

There are seven (7) stops made in the Baraboo area. The first set of four stops (Baraboo1-4) are in the south range. The second set of three stops (Baraboo5-7) are in the north range. Most of these places are well known and have place names. You should fill in all parts of the form, unless told otherwise by the instructor.

You will see photos of three rock types in Baraboo, WI. The Baraboo quartzite and phyllite are low-grade metamorphic rocks. The Cambrian sandstones are sedimentary rocks.

Geological background:

The Baraboo quartzite, and other quartzite exposures of similar age in the upper Midwest of the United States, are shown on Figure 1 as a band of yellow with tiny gray dots, contained within a green band. The green shows the extent of 1.76-1.72 Ga (giga annum, or 1.76-1.72 billion year old) juvenile crust, accreted to the Archaean core of the North American continent (shown in light gray and pink) during the Yavapai orogeny. The quartz arenite from which the Baraboo quartzite formed was deposited on this crust, specifically on 1.74 Ga rhyolite. It was subsequently deformed and metamorphosed, producing the features we will explore on this field trip.

The quartzite locally includes layers that once contained significant clay in addition to sand, subsequently metamorphosed to form phyllite or phyllitic rock, referred to here as 'phyllite'. The phyllite contains significant amounts of pyrophyllite, a phyllosilicate produced from clay at low metamorphic temperatures (*ca.* 300°C).

When the quartzite was deformed remains a hotly debated question, although it certainly occurred between 1.7 and 1.3 Ga. After deformation, the landscape was eroded. The next phase in the geological history is the deposition of Cambrian sandstone. In the Cambrian, Wisconsin was located near the equator and most of Wisconsin was covered in shallow seas. Minor deformation occurs in Wisconsin associated with the Appalachian orogenies.

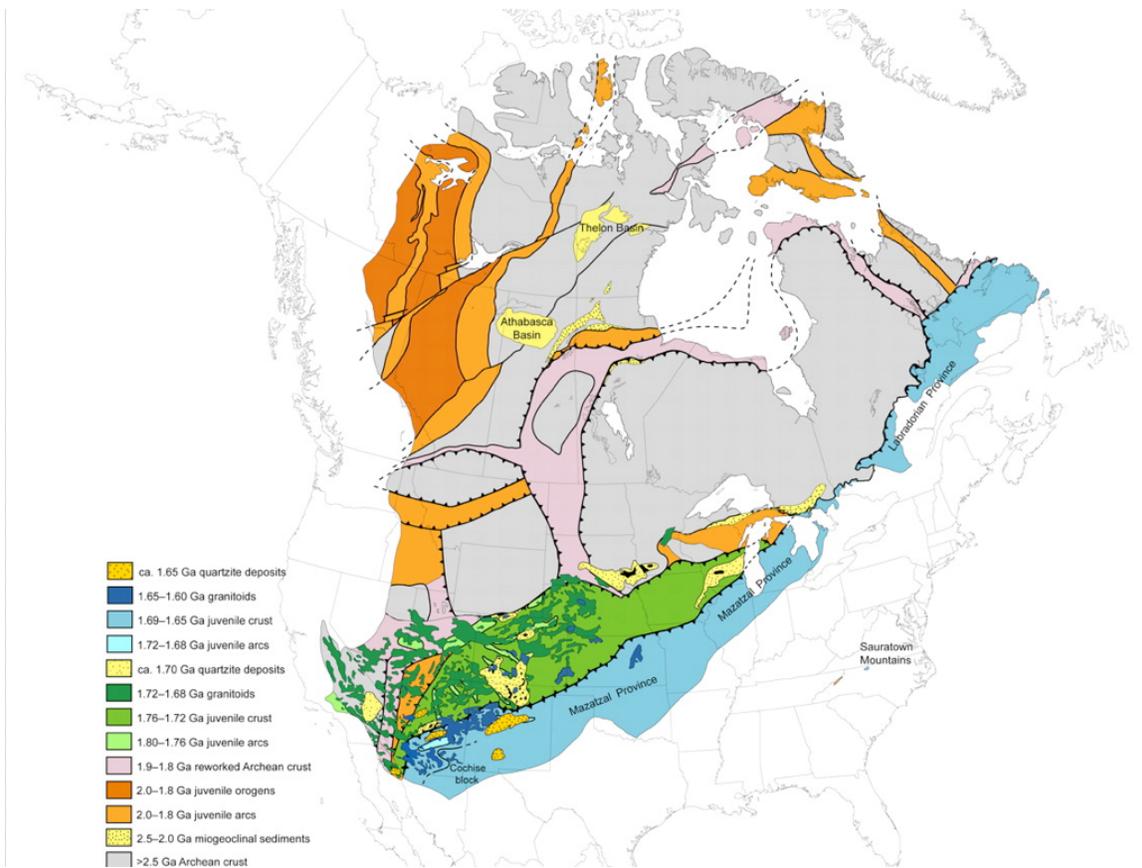


Figure 1. Tectonic map of North America highlighting Paleoproterozoic rocks. Diagram from Whitmeyer, S.J. & Karlstrom, K.E., 2007. Tectonic model for the Proterozoic growth of North America. *Geosphere* 3, 220–259.

Part II - Field Stops:

Stop Baraboo1: Point of Rocks – 43.4329N, 89.7758W

Description of lithology. The layering at this location is bedding.

This outcrop is called ‘Point of Rocks’. It is (barely) in the non-glaciated Driftless area of Wisconsin, as the terminal moraine of the Laurentide ice sheet stopped a couple of kilometers away near Devil’s Lake. Part of the outcrop was wind polished during the glacial era, but the other part was dynamited to make way for a road.

The learning goals at Point of Rocks are to explore the Baraboo quartzite and phyllite, and determine bedding orientations. Before you leave, you will want to:

1. Determine strike and dip of bedding for the outcrop, using right-hand rule.
2. Be able to list evidence to support your claim that you can determine bedding at this outcrop.
3. Start building a three-dimensional picture in your head of the orientation of bedding within the larger Baraboo area.

- b. Can you tell which direction is 'stratigraphically up' from this photo? Why or why not?

After the completion of this question, go back to Baraboo1. To navigate back to the Spot on the main basemap, click the back arrow on the left side toolbar.

Task #2. Return to the Baraboo1 Spot and navigate back to the 'PointofRocks' image. The camera was held level for this shot. You are looking due east, along the strike of the bedding.

- a. Using a protractor, determine the dip angle.

Dip:

- b. Write the dip direction as a cardinal orientation (N, NE, E, etc.).

Dip direction:

- c. Write down the strike and dip of bedding, using right-hand rule convention.

Strike/Dip (XXX/YY):

Ok, now on to Baraboo2, where things are going to get a bit more interesting.

Stop Baraboo2: East bluff of Devil's Lake – 43.4265N, 89.7266W

Description of lithology, difference between quartzite and phyllite; Foliation in both units

This outcrop is in Devil's Lake State Park, on the NE side of the lake where there is band of cliffs. You want to go to the 'LowerEastBluff' photo and click on the 'Image Basemap' symbol. This means you are using the image as a basemap. There are 3 points (labelled LowerEastBluff1-3).

Task #1: At this outcrop, there are *primary* and *secondary* structures. Primary structures are features that formed when the rock was originally deposited (for a sedimentary rock) or cooled (for an igneous rock). Secondary structures formed at a later time, typically as a result of deformation and/or metamorphism. It may or may not be obvious where bedding is. Moreover, at Baraboo, you have to be very careful, because sometimes things that look like bedding are deceptive.

Like the Baraboo1 stop, each of the points labelled LowerEastBluff1-3 is a Spot. You access them by clicking the Spot. At each of the Spots, you want to open the 'Images' tab to view the photos.

LowerEastBluff1:

- a. For Feature1. What is the orientation of bedding (a primary structure) and how do you know?

- b. For Feature1. The phyllite has a very prominent fabric within it. It is called a foliation (a general term) or a cleavage (a specific term for a type foliation in a fine-grained rock). The rock breaks (or cleaves) in a consistent direction because the small minerals (micas) are all aligned the same way. On a separate sheet of paper or your favorite e-drawing app, provide an annotated sketch of what you see. Include this sketch with the assignment when turning it in.

- c. For Feature1. Is the foliation in the phyllite parallel to the bedding, or oblique to it?

- d. For Feature1. The camera is held horizontally and is pointed due east. Measure and record the orientation of the bedding and the cleavage using the right-hand rule convention.

Strike/dip of bedding (XXX/YY):

Strike/dip of cleavage (XXX/YY):

- e. For Feature2. This photo is taken about 1 m above the Feature1 photo, in the middle of the quartzite unit. The camera is held horizontally and the black pen is pointed up. You know the orientation of bedding, because you wrote it down for 'Feature1'. Can you see any indication of bedding? Describe.

- f. For Feature2. On this face, there are thin white lines that are slightly wavy. This is a type of foliation called a stylolitic cleavage (different from the cleavage that we have been looking at in the phyllite). Stylolites occur when minerals are pushed together with enough force that they start to dissolve (it occurs most commonly in limestones, but also occurs in quartzites). On a separate sheet of paper or your favorite e-drawing app, provide an annotated sketch of what you see. Include this sketch with the assignment when turning it in.

- g. For Feature2. The camera was held horizontally. What is the strike and dip of the cleavage in the quartzite? Also, measure the strike and dip of bedding (you might need to think about the Feature1 photo to figure that out).

Strike/dip of bedding (XXX/YY):

Strike/dip of cleavage (XXX/YY):

- h. For Feature3 and 4. You are now looking at the same phyllite layer that you looked at in Feature1. In fact, Feature3 is just a close-up of the photo in Feature1. Feature 4 is in the same phyllite layer but located about 1 m to the N (left). In both cases, you see a white feature. What are these white features?

- i. For Feature3 and 4. Because it is a planar feature, it has a strike and dip. You are looking due East and the feature continues directly back into the rock face. What is the strike and dip of this feature?

Strike/dip of feature (XXX/YY):

- j. For Feature3 and 4. The material that forms the white feature is made of quartz. That quartz, which was once in a fluid, is deposited in this structure. Speculate on where this quartz might have originated?

- k. Using all Features. Which rock is more resistant to erosion: The phyllite or the quartzite? What is your evidence?

LowerEastBluff2:

- a. There is only one feature here. You are looking at the same phyllite layer as in LowerEastBluff1. There is also a close-up of the Feature, but the camera is not horizontal for that shot. On a separate sheet of paper or your favorite e-drawing app, sketch and compare it to Feature1 on LowerEastBluff1. Include this sketch with the assignment when turning it in.

- b. Does the phyllite or the quartzite look more deformed?

LowerEastBluff3:

- a. There is only one feature here. There is a prominent gap between the two rocks. What do you think caused that gap? Explain. (hint: think about your answer to LowerEastBluff1, part k.)

Stop Baraboo3: East bluff of Devil's Lake – 43.4254N, 89.7252W

The nature of the contact between the Proterozoic quartzite and the Cambrian sandstone

This outcrop is at the top of the cliff that you saw at the Baraboo2 stop, still on the NE side of Devil's Lake.

There are two photos – 060 face and 150 face - taken here, at right angles to each other. The top of both photos shows the orangish-tan Cambrian sandstone. The bottom of the photo shows purplish Proterozoic Baraboo quartzite (there is no phyllite here). So, there is a contact at this outcrop. Because we can't see into an outcrop, all we can do is draw the trace of the outcrop (where the 3D contact intersects the two-dimensional surface of the Earth).

Looking at both the 060 face (NE is on the left) and the 150 face (NW is on the right) photographs, answer the following questions:

- a. What is the orientation trace of layering of the Cambrian sandstone in this outcrop? Give the orientation using the right-hand rule convention.

Strike/dip of bedding (XXX/YY):

- b. Use the Quartzite Boulders photo, which is a close-up of the 150 face. There are large boulders of the quartzite in the middle of the photo. Were the boulders deposited like that during the deposition of the Baraboo quartzite or during deposition of the Cambrian sandstone (or, alternatively stated, what unit are the boulders part of)?

- c. The quartzite does not show clear bedding orientation in this photo, but it is the same as at the bottom of the cliff (Baraboo2). Name the type of contact between the quartzite and the sandstone exposed here. Be as specific as possible. This is a tricky question.

Stop Baraboo4: Entrance to Devil's Lake State Park – 43.4329N, 89.7376W

Minor structures in the phyllite layer.

This outcrop is near the entrance to the north part of Devil's Lake State Park. At this outcrop, there are large cliffs made of quartzite layers, but they alternate with phyllite layers. The phyllite layers include thin (~10-30 cm) layers of quartzite. The orientation of bedding is most accurately recorded by the orientation of the quartzite layers. The phyllite layers show a strong secondary fabric, so it is difficult to measure bedding.

This outcrop all has two faces, which are approximately perpendicular to each other. One is oriented N-S (NS Face) and one is oriented E-W (EW Face). You will see different geological structures on the two faces.

Task #1. Select 'Images' from stop Baraboo4. Navigate to the 'NS Face' Image Basemap. There are multiple Spots (labelled MinorFold or Foldhinge) all along the same quartzite layer.

NS Face (technically, you are looking in direction 260): This face has a minor fold within it. There are multiple strike and dip measurements and two lineation measurements (note, if you can't see the orientation measurements on the image basemap, go to the three-dot menu in the upper right and toggle 'Show Point Symbology').

- a. Characterize this structure with all the terminology you can think of that will characterize a fold (*e.g.* interlimb angle, folding style, etc.)

- b. In an asymmetric fold such as this, fold *vergence* refers to the apparent direction of shear. Does this fold have a vergence? If so, what is it?

- c. The Foldhinge measurements are given as trend and plunge, while the Minorfold measurements are given as strike and dips. Why is there the difference?
- d. Estimate the orientation of the fold axial plane. Record it using the right-hand rule convention.

Axial plane strike/dip (XXX/YY):

- e. What is the orientation of the 'bulk' foliation in the phyllite? Using the rest of the strike and dips on the quartzite bedding as a guide, approximate the orientation of the foliation in the phyllite.

Phyllite foliation strike/dip (XXX/YY):

- f. Compare the 'bulk' phyllite orientation to the axial plane of this small fold and describe the relationship. This relationship has a special name - what is it?

- l. On a separate sheet of paper or your favorite e-drawing app, provide an annotated sketch the fold and label the fold limbs, the fold hinge, fold crest, inflection points, and axial plane. Note the direction you are facing and label the cardinal directions of your sketch. Remember to add a scale bar. Include this sketch with the assignment when turning it in.

Navigate back to Baraboo4 and select the 'EW face' Image Basemap. This photo is taken ~90° to 'NS Face', just around the corner to the left (technically, you are looking in direction 340):

- a. What geological structure do you see on this surface? You might want to look at the image 'from EWFace'?
- b. This image has two linear orientations taken on it. What are these orientations recording?

- c. From that orientation, what can you say about how the rock was either shortened or elongated? What direction experienced the most shortening and what direction experienced the most extension?

- d. The same quartzite layer that is folding on the 'NS Face' image is doing something very different on this 'EW face'. Try and explain how that is possible?

Stop Baraboo5: Rock Springs quarry – 43.4836N, 89.91877W

Note that the next three outcrops are on the north side of Baraboo, west of Devil's Lake.

The learning goals at the Rock Springs quarry are to determine the orientation of bedding. Before you leave, you will want to:

1. Determine strike and dip of bedding for the outcrop, using the right-hand rule.
2. Describe the evidence that allows you to determine bedding orientation.

This stop is in an old quarry, where they mined quartzite for putting down under railroad tracks. This outcrop is against the wall on the south side of the quarry (the wall faces north and you are looking west), which is oriented almost exactly E-W.

- a. There are a few photos at this outcrop, some of which have a 12-year-old kid for scale. The close-up photo has a piece of masking tape that is put horizontally on the outcrop. How can you determine the orientation of bedding? What feature are you using?

b. This next fact is a mind-bender, but it is nonetheless true. The features you see are not the actual bedform, but rather the casts of the bedforms. If that is true, do the beds get younger to the south or younger to the north? Explain your answer with words and by drawing a small sketch. Remember to include this sketch with the assignment when turning it in.

c. The south wall of the quarry is nearly vertical. It dips 89° to the N. What is the strike and dip of the bedding?

Strike/dip of bedding (XXX/YY):

d. Is the bedding right side up (by one degree) or overturned (by one degree)? Explain your reasoning

Stop Baraboo6: Rock Springs quarry – 43.4836N, 89.91877W

The nature of the contact between the Proterozoic quartzite and the Cambrian sandstone

We can see the contact between the Proterozoic quartzite and the Cambrian sandstone in the quarry, just as you saw it on the East Bluff of Devil's Lake (a 'Baraboo3 contact' photo is included in the photos at this stop). The orange Cambrian sandstones make up only the very top of the cliff, although the orange color stains the underlying pink quartzite. There is one photo (Quarry Overview) of the entire face and a close-up (Baraboo6 contact) where you can see the horizontal layers of the Cambrian sandstones below a prominent evergreen tree.

Characterize the nature of the contact here (name it). Compare it to Stop Baraboo3 where you observed it previously.

Stop Baraboo7: Van Hise Rock – 43.4891N, 89.9157W

Where it all comes together. Small scale geological structures on the N limb.

Geologists have been coming to Van Hise Rock for over a century. It looks like it isn't attached (in place), but it is. One can observe the same features – although not as well exposed – in the nearby cliff. We are going to break this stop down in parts.

Part I - Measurements

The first issue with Van Hise Rock is to determine the orientation of bedding. There are two photos that help with this task. VanHiseLookingE is the view looking E towards the rock, and VanHiseLookingW is the view looking W towards the rock. (The looking E view is the better view, as the camera was held horizontally and you are looking directly E). Note that VanHiseLookingE also has some close-up photos – to view them, click on the 'Image Basemap' icon.

- a. What is the orientation of bedding in the quartzite? Give it below using the right-hand rule.

Strike/dip of quartzite bedding (XXX/YY):

- b. What is your evidence?

- c. What is the orientation of bedding in the phyllite? Give it below using the right-hand rule.

Strike/dip of phyllite bedding (XXX/YY):

- d. What is your evidence?

- e. What is the orientation of the foliation in the phyllite? Give it below using the right-hand rule. (Note that you have seen foliation in both the quartzite and phyllite, at Stop Baraboo2 and Baraboo4)

Strike/dip of phyllite cleavage (XXX/YY):

- f. What is your evidence?

- g. What is the orientation of the foliation in the quartzite? Give it below using the right-hand rule.

Strike/dip of quartzite cleavage (XXX/YY):

- h. What is your evidence?

- i. How does the orientation of foliation in the phyllite compare to what you saw at the Baraboo2 stop (you can use the VanHise1 close-up on the VanHiseLookingE map)?

- j. How does the orientation of foliation in the quartzite compare to what you saw at the Baraboo2 stop (you can use the VanHise2 close-up on the VanHiseLookingE map)?

- k. Describe the transition from the foliation in the phyllite to the foliation in the quartzite. Is it gradual or is it abrupt (you can use the VanHise3 close-up on the VanHiseLookingE Image Basemap)? This feature is called *cleavage refraction*, which occurs when layers have different strengths. Generally, the layer with the smaller angle between cleavage and bedding is less competent ('weaker') whereas the larger cleavage-bedding angle is characteristic of the more competent ('stronger') layer. Based on the cleavage-bedding angles, is the quartzite or phyllite stronger?

Part III - Synthesis:

- a. Compare the orientation of bedding on the north side of Baraboo (Stops 5-7) to the south side (Stops 1-4). What do you think happens to bedding between the Devil's Lake area and Rock Springs?

- b. Compare the orientation of foliation in the quartzite on the north side of Baraboo (Stops 5-7) to the south side (Stops 1-4). Is it more-or-less the same or different?

- c. Compare the orientation of foliation in the phyllite on the north side of Baraboo (Stops 5-7) to the south side (Stops 1-4). Is it more-or-less the same or different? What is the significance of this answer?

The following questions will require you to annotate and draw on the 'Baraboo x-section' image. Either save the image and use your favorite e-drawing app, print it out and draw by hand, or reproduce the image on a piece of scratch paper. Make sure to include your work when turning in the exercise.

- d. Take one more look at the VanHiseRockLookingW photo. Then, open the Baraboo x-section image (Fig. 2). This cross-section is oriented looking W. So, go ahead and put in the orientations of the bedding and foliation at Van Hise rock (looking W).

- e. From your notes, fill in the orientation of bedding and foliation on the south Baraboo (Baraboo1-4) stops on Figure 2.

- f. The 'Wisconsin School of Geology' was well known in the early 1900s. Much of their work was associated with mining the Proterozoic banded iron formation in the upper Midwest. Because they did not have very much exposure, they relied on using small-scale features to determine the orientation of large-scale features. Compare the small-scale fold at Stop Baraboo4 to the cross-section that you are currently making. Describe the similarities below.

- g. Using the small-scale fold at Baraboo4 as the model, draw a cross-section across the Baraboo region using the Baraboo x-section template. Assume that the quartzite layers by Devil's Lake connect to the quartzite layers by Van Hise Rock. Keep the layers at approximately the same thickness. Put in the foliation in the phyllite everywhere on the cross-section (and the foliation in quartzite, if you can figure out its pattern). Draw the Cambrian sandstones schematically on the cross-section.

