Field Trip to Enfield Glen, NY Finger Lakes Region

Alexandra Moore (afm113@gmail.com)
Department of Earth and Atmospheric Sciences, Cornell University, Ithaca, NY 14853

EAS 2200 – The Earth System
Lab #3: Enfield Glen

INTRODUCTION

Today we visit another of Ithaca's creeks. But now, instead of examining modern hydrologic processes, we will look at the Devonian-aged rocks exposed by Enfield Creek, which are themselves the product of 380-million-year-old river systems. Understanding the nature of the fluvial features preserved here allows us to interpret the nature of the Devonian environment and its paleogeography. We will also consider the processes that brought the sandstone and shale of the former ocean floor to its present position above sea level.

PART I - THE CATSKILL DELTA

In class we have discussed deltas – the sedimentary deposits that form when rivers enter the ocean or large lakes. When we think of deltas, we tend to visualize only the part that remains above sea level, the part that we see in photos, for example. Yet the majority of the delta deposit is actually below sea level. The upper Devonian sandstone and shale that make up the bedrock of central New York was originally deposited on the underwater portion of a large delta complex called the **Catskill Delta**. The Catskill Delta is not a single delta, but rather a series of deltas that formed from rivers draining a mountain range during late Devonian time (see Figures 4 & 16 at the back of this handout). That range was known as the **Acadian Mountains**, and may have rivaled the modern Himalayas in size. Given that the Earth is capable of great change over periods of hundreds of millions of years, we cannot take it for granted that ancient and modern mountain ranges were located in the same geographic position. Today, we'll examine the rocks closely for evidence that will help us determine the location of the ancient Acadian Mountains, and understand the paleogeography of ancient North America.

As we walk through Enfield Glen we'll look for "**paleocurrent indicators**" in the Devonian sedimentary rocks. These are features in the bedrock that formed at the time of deposition that allow us to infer the direction the water was moving when the sediment was deposited. Since we're looking at delta deposits, the current should be moving downstream, away from the mountains. Examples of paleocurrent indicators include *ripplemarks*, *sole marks,* and *crossbeds*. For our purposes sole marks – gouges formed by flowing water – will be the most useful. These can often be found on the bottom of sandstone layers. Ripplemarks are also common, and usually seen on the upper surface of bedding planes. Crossbeds are present in these deposits as well, but a little harder to spot, and harder to interpret in the timeframe of our trip. We will hunt for sole marks andrippemarks.

(1) Keep track of any paleocurrent indicators that you see, and note their orientation. We'll try to get exact measurements for as many features as possible.

(2) The total thickness of upper Devonian rocks in this area is approximately 6000 feet. These sedimentary rocks were deposited over approximately 14 million years.
   (a) What was the average sedimentation rate in inches/year?
   (b) Consider the "sand cylinder" experiment that we performed in the picnic area. Explain how alternating layers of sandstone and shale might form at the foot of the submarine Catskill Delta.
   (c) What is the relative time required to form a sandstone layer as opposed to a shale? When you calculated the sedimentation rate in part (a), do you think this rate is constant through time, or does this represent an average of very different rates? Explain.

SKETCH	TYPE OF PALEOCURRENT INDICATOR	ORIENTATION

PART II - OROGENY AND UPLIFT

Orogeny is the term used by geologists to label and identify events that create mountain ranges. The Acadian Mountains referred to above were formed during the Acadian Orogeny in early Devonian time. Orogenies occur when horizontal stress is applied to the Earth's crust. An analogy would be when you push the edge of a carpet with your foot. Your foot applies a horizontal stress to the carpet and the carpet responds by wrinkling and folding into "mountains." What could apply a large enough stress to the crust to "wrinkle it" and cause mountains to form? Plate tectonic processes--specifically the collision of one continent with another (if you've had no previous exposure to the subject of plate tectonics don't worry--we'll explore it in detail later this semester). In early Devonian time a large landmass collided with North America, folding and uplifting the rocks to create mountains. As the mountains began to erode, rivers carried sediment to the ocean and deposited the late Devonian sandstones and shales that we are standing on.

But wait, that's not all! The rocks here in Enfield Glen record the occurrence of not one but **two** orogenies! What is the evidence for this? The beautifully exposed vertical joints that make the upper gorge so scenic. Joints form when stress is applied to rocks. They can also form when that stress is released. These vertical joints must have been formed *after* the sandstone and shale solidified from water-logged sediment into hard rock, thus they *could not* have formed during the Acadian orogeny (because that produced the mountains that were the source of the sediment). In fact, the joints formed much later during the Permian period (see Geologic Time Scale). Thus there was another orogeny--another continental collision--during Permian time, in which the older Devonian rocks were fractured. This is called the Alleghenian Orogeny and was caused by the collision of both Europe and Africa with North America.

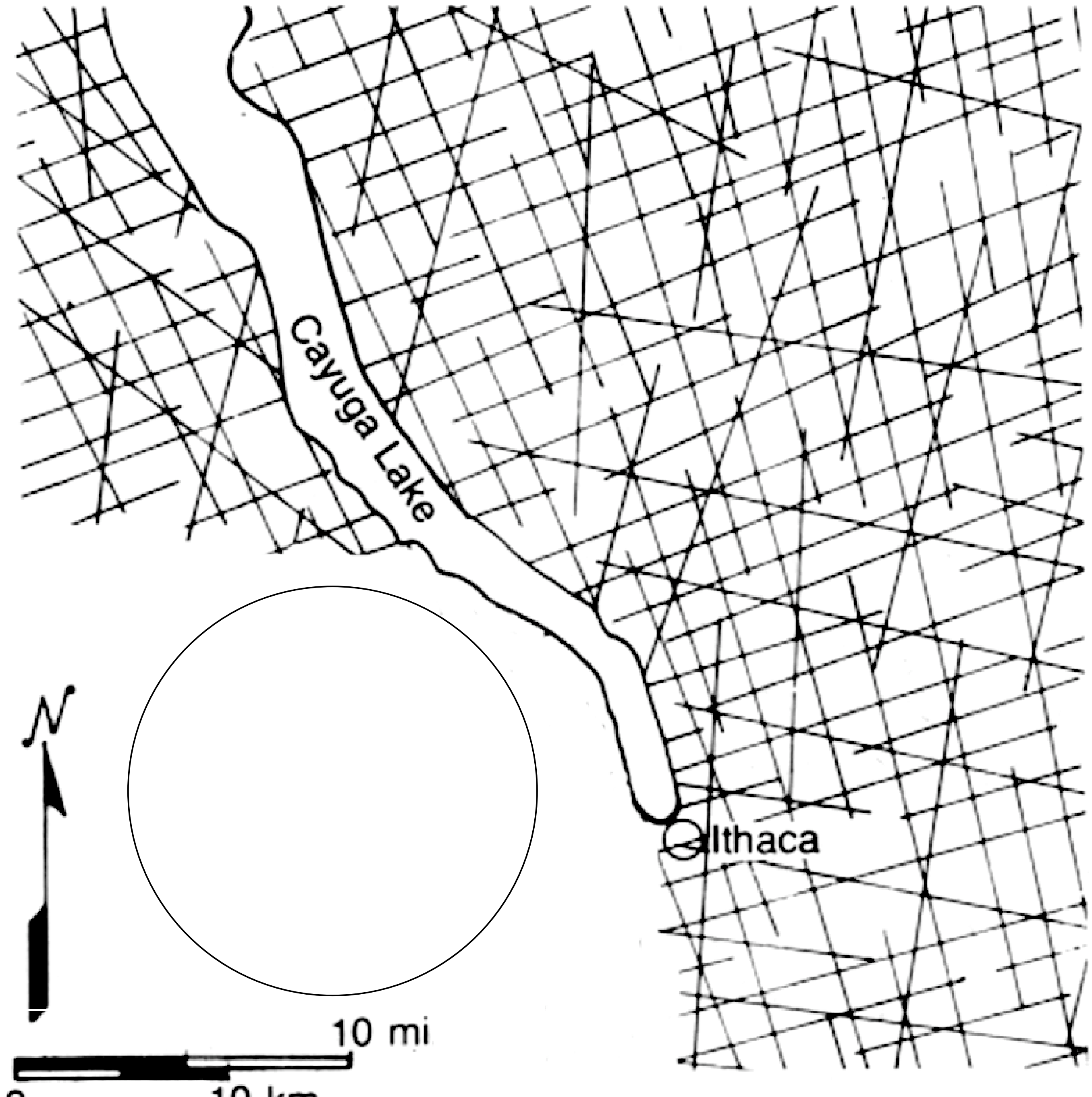
(3) Use your compass to measure the orientation (the **strike**) of 2 or 3 joint surfaces as we walk through the gorge. Use a protractor to plot your measurements in the circle on the regional joint map (next page). How do your measurements compare with the mapped joints?

PART III - GLACIAL HISTORY

The gorges in the Finger Lakes region – Cascadilla, lower Fall Creek, Taughannock, Enfield etc. – owe their origin to the recent ice ages. These gorges were not carved by ice. The large N-S trough-shaped valleys of the Finger Lakes themselves are the result of ice motion, but the narrow tributary gorges are not. The gorges are the result of erosion by water due to a large and rapid change in the base level of local streams. The base level for creeks around Ithaca is Cayuga Lake. At one time the elevation of ancestral Cayuga Lake (proglacial Lake Ithaca) was 980 feet above sea level. Cayuga Lake is currently 385 feet above sea level. The elevation of the rim of Enfield Glen is 1000 feet above sea level.

(4) Use the graph paper provided to make a sketch showing the river profile of Enfield Creek 13,000 years ago when it flowed into proglacial Lake Ithaca, and the river profile today as Enfield Creek flows into Cayuga Lake. The elevations and positions provided can be used as guides, and make your best estimate for gradients etc.

Many of the gorges near Ithaca show evidence of former stream channels that were filled with glacial sediment and then re-excavated by the modern creeks. In most cases the creeks haven't had time to remove all of the glacial debris – Fall Creek, which we will visit in two weeks – is an example of this. Often the modern creeks don't re-occupy their former channel, but instead erode a channel near-but-not-the-same-as the ancient one. Enfield Glen is an example of this. An ancient gorge was filled with glacial sediment *ca.* 18,000 years ago. The modern creek didn't follow the exact path of the ancient one, thus we see a glacial sediment-filled valley adjacent to modern Enfield Creek.


Cayuga Lake
Ithaca
N
10 mi
0
10 km.

(5) Form a hypothesis that would account for the change in position of Enfield Creek. What might have caused it to erode through the Devonian bedrock instead of in its old channel?

The fact that there are *two gorges* here at Enfield--the preglacial and the modern--is evidence that there has been more than one glacial advance across Ithaca. The sediment-filled gorge suggests that there was an even older proglacial lake that ancestral Enfield Creek was trying to reach. Thus this old gorge is better termed *interglacial* rather than preglacial since it seems to have formed between the most recent ice advance and a previous one. We have independent evidence from modern sea floor sediments that supports the multiple-glaciation hypothesis (examine the oxygen isotope graph in the Pppt folder).

- Make sure you can locate the path of the interglacial gorge on the colored topo map of Treman State Park in your Pppt folder.

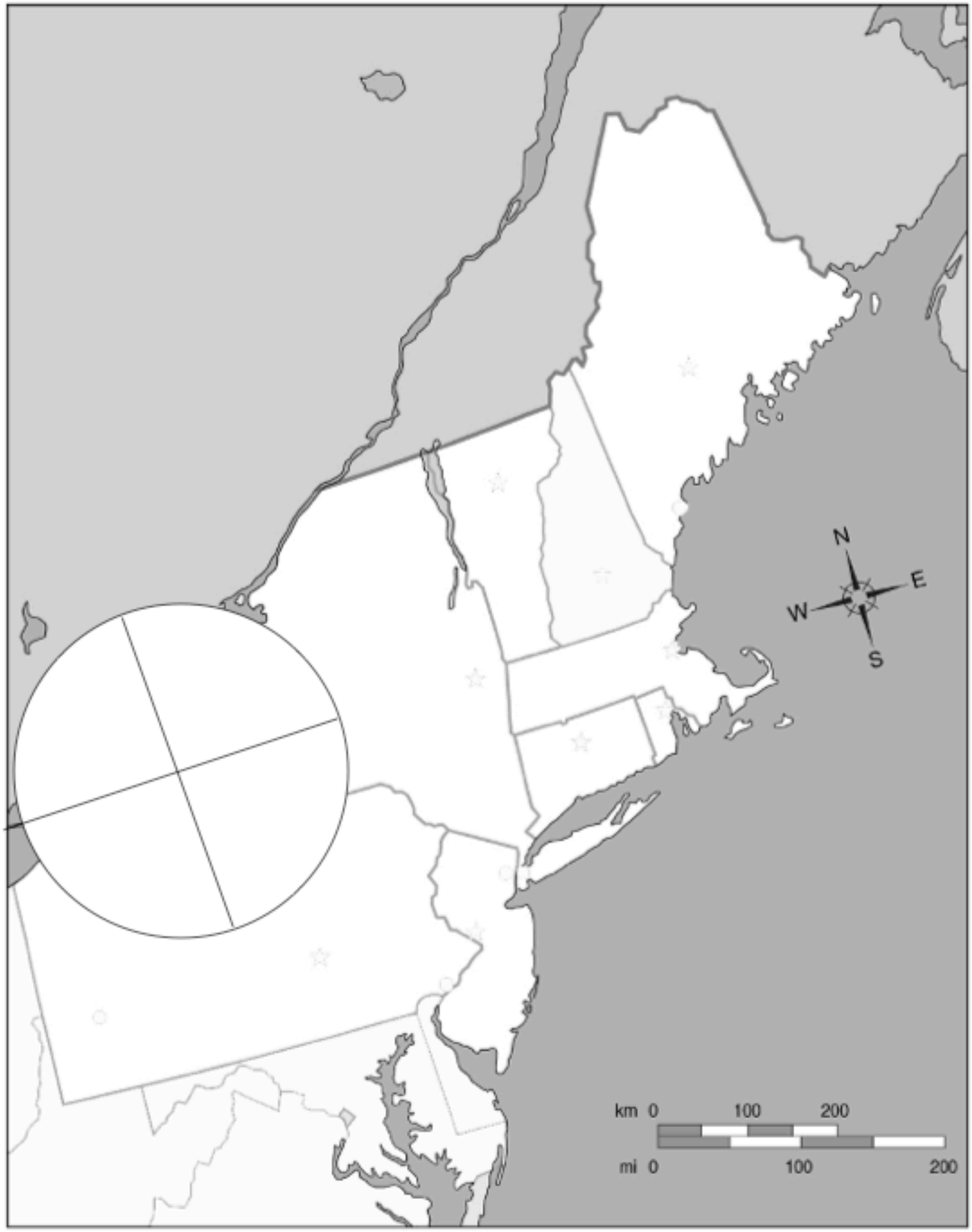
PART IV - DISCUSSION

We will stop to admire the view of Lucifer Falls, and take advantage of this time to review our measurements and plot them. It is important to do this while we're still in the field, so that we can more easily spot a mistake, and make sure that everyone is clear on everything. As a group we will answer the pre-lab question, "Where were the ancient Acadian Mountains?" and try to understand how and why the paleogeography of Ithaca and Enfield Glen has changed.

(6) Plot your paleocurrent data in the circle on the map of the NE US on the following page. For bi-directional data use a line segment, for unidirectional data use an arrow pointed in the downstream direction.

PART V - PUTTING IT ALL TOGETHER

(7) We've seen many different features here, whose formation is separated in time by millions of years! Now it's time to put all of your observations and measurements together. Your field report this week should be a lucid and compelling geologic history of Enfield Glen. Use maps and figures *as well as your own data* to tell your story. Give dates, positions, orientations etc. Take the point of view of the author of an informational pamphlet for the State Park. Can you explain everything you've learned to a park visitor? If so, you know you've got it wired. Good luck!


N
E
W
S
km 0
100
200
mi 0
100
200

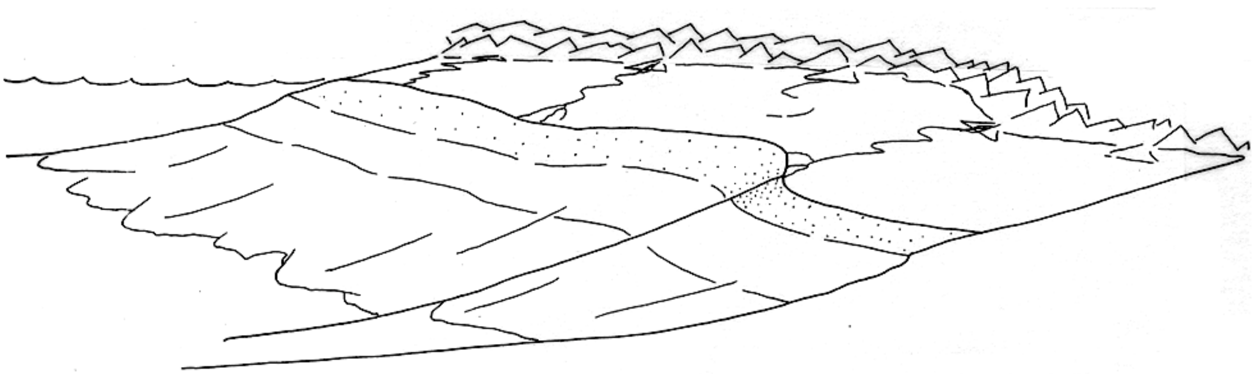


Figure 4. Panorama of the Catskill Delta and environs as seen from a vantage point above south-central Pennsylvania. Shoreline trends northeast. Length of shore: approximately 300 km. Basin margin and upper clinoform stippled.

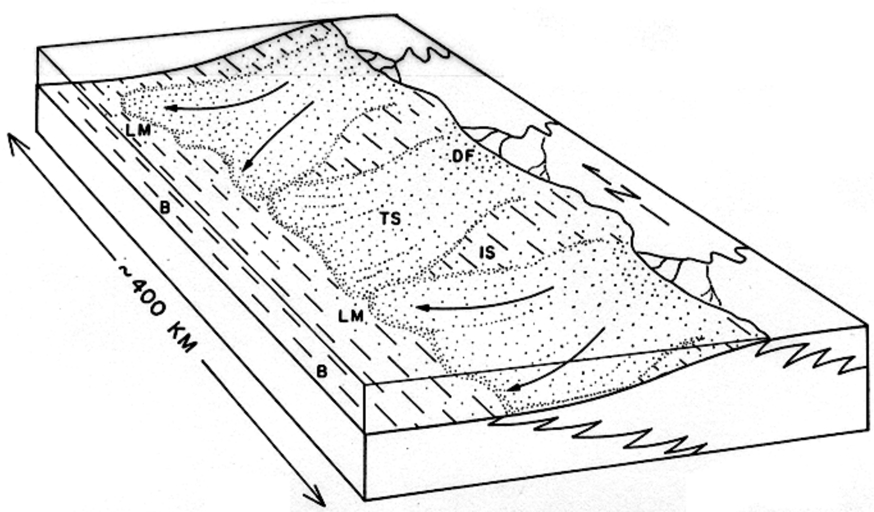
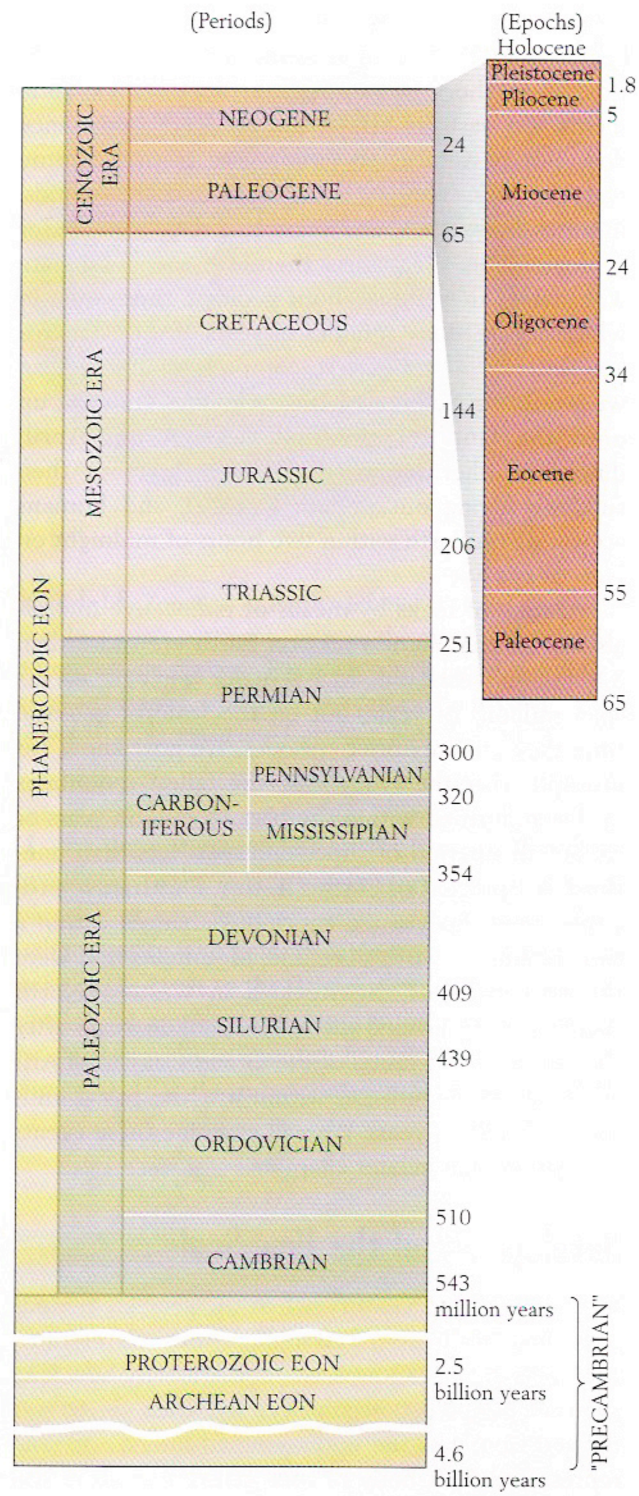
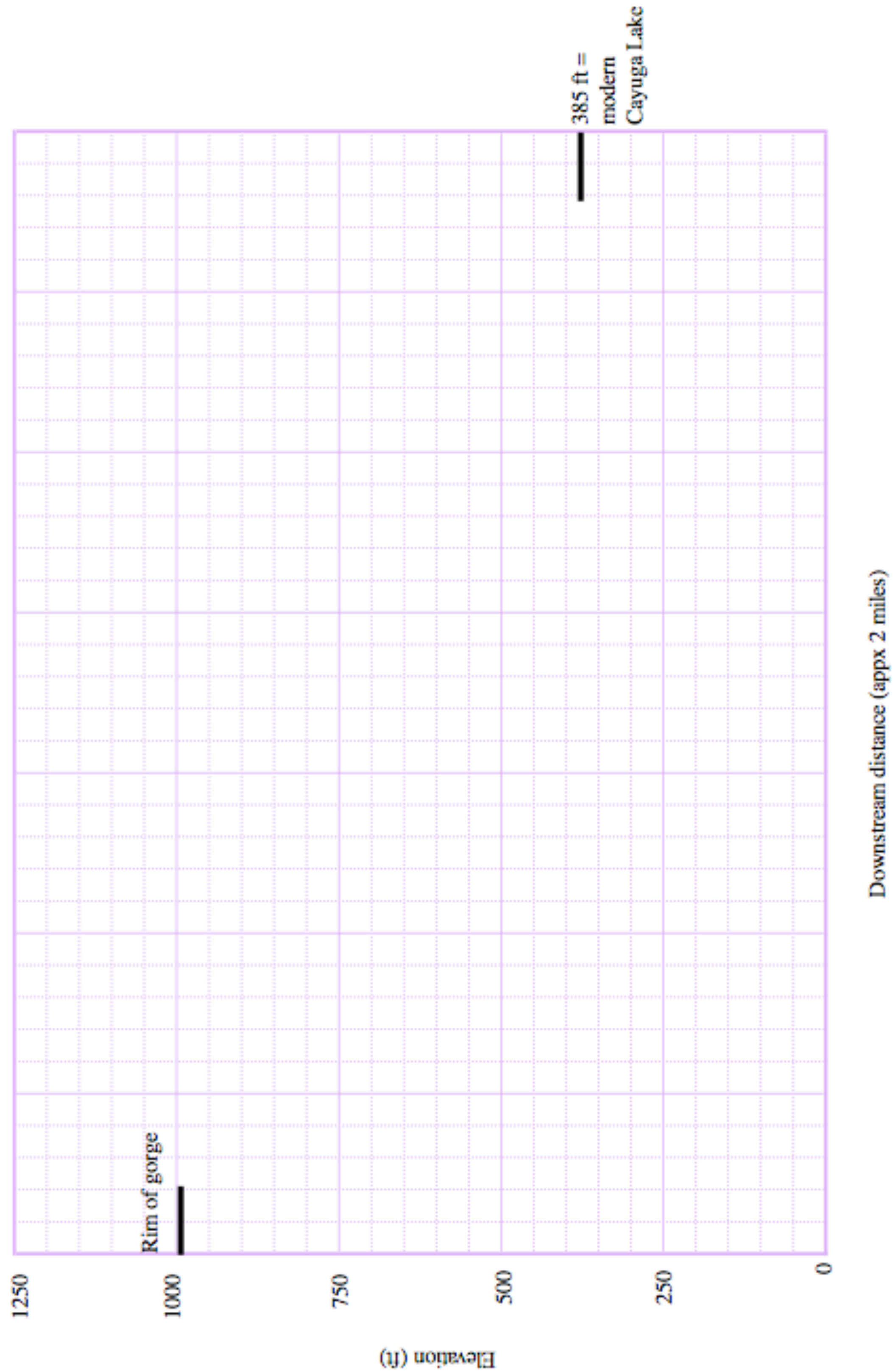


Figure 16. Interpretative reconstruction of the Late Devonian paleoslope. Turbidity currents had multiple point sources along the basin margin, resulting in more or less uniform progradation of the slope. Shortlived turbidite lobes were built and abandoned as the source of turbidity currents shifted. Abbreviations of facies discussed in text: DF, delta-front; TS, turbidite-slope; IS, interlobe-slope; LM, lobe-margin; and B, basinal.



Geologic Timescale


385 ft =
modern
Cayuga Lake
Rim of gorge
1250
1000
750
500
250
0
Elevation (ft)
Downstream distance (appx 2 miles)