EPS 10 Field Trip Guide
2021

By M. C. Brennan, modified from earlier versions by Sophie Coulson and MIT EAPS

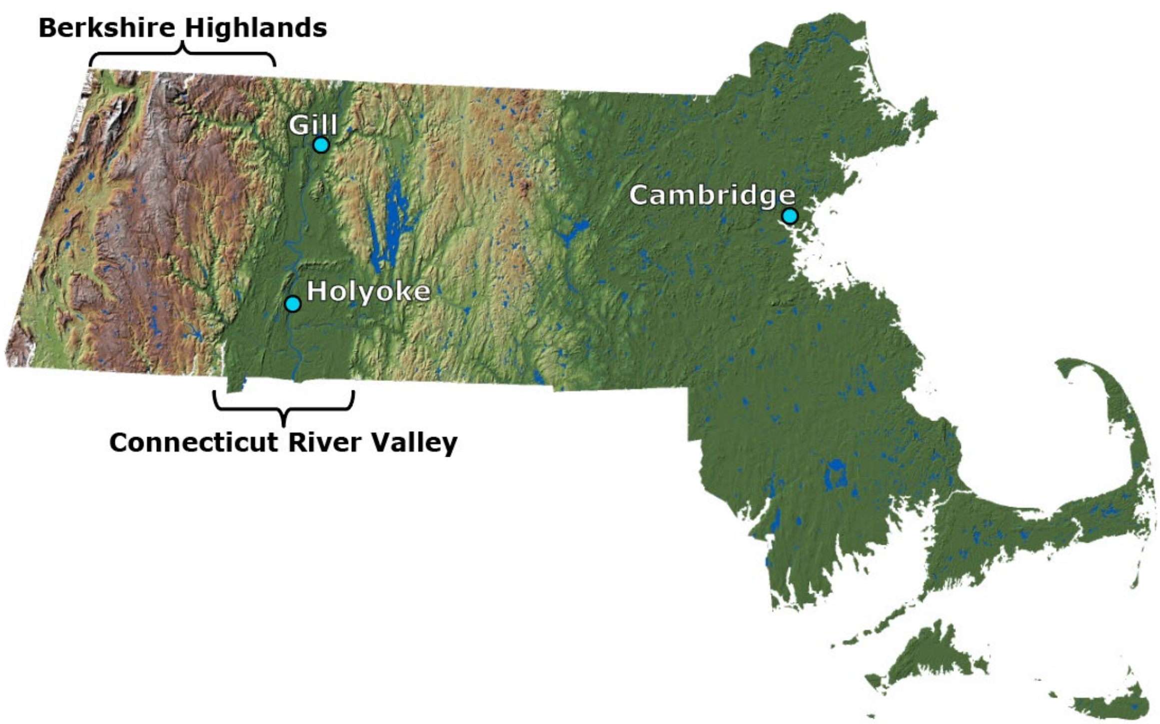


Figure 1 (Modified from USGS)

Overview of MA Geological History

Rocks to the west of the Connecticut River Valley, such as the Berkshire Highlands, have been part of the North American craton (the ancient, stable core of the continent) for billions of years. This craton is called Laurentia, and it has been part of numerous continents and supercontinents over geological history. About 550 million years ago (in the Cambrian Period), Laurentia was an independent continent separated from the continents of Avalonia (Western Europe) and Baltica (Central Europe) by the Iapetus Ocean. When this ocean closed, these and other small land masses collided with Laurentia, triggering several orogenies (mountain-building events like the modern Himalaya). The eroded remnants of these are the Appalachian Mountains. Another consequence of these collisions was that the incoming land masses became sutured (attached) to Laurentia, and now form the rocks of central and eastern Massachusetts.

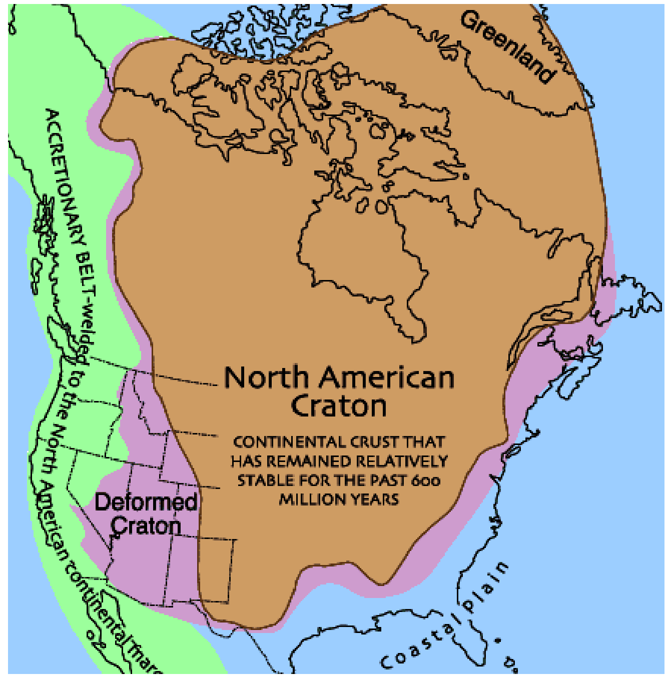


Figure 2 (USGS)

The combined landmass of Laurentia, Avalonia, and Baltica eventually collided with Siberia (Central Russia), Gondwana (Africa, South America, Antarctica, Australia), and the rest of the continents to form Pangea, the most recent supercontinent. Pangea finished forming during the late Permian (~250 million years ago), survived through the Triassic, and then began to drift apart during the early Jurassic (~200 million years ago). This continental breakup was accomplished by the formation of numerous rift valleys, much like the modern African Rift. The rift which eventually split Pangea became the Mid-Atlantic Ridge, and the Connecticut River Valley was its less-successful cousin. The rift generated large lava flows, now visible as basalt formations, and left behind a basin which filled with sediments and fossils as the continents began to drift into their modern configurations.

Later, there were glaciers.

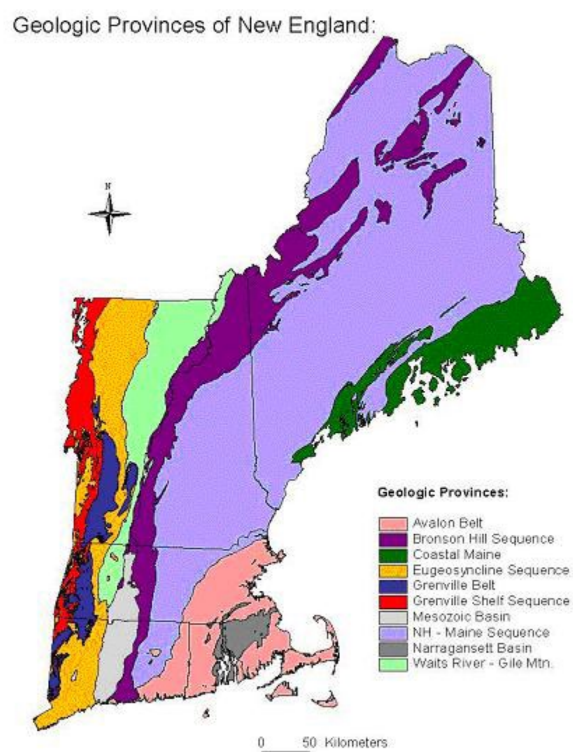


Figure 3 (USGS)

Stop 1: French King Bridge

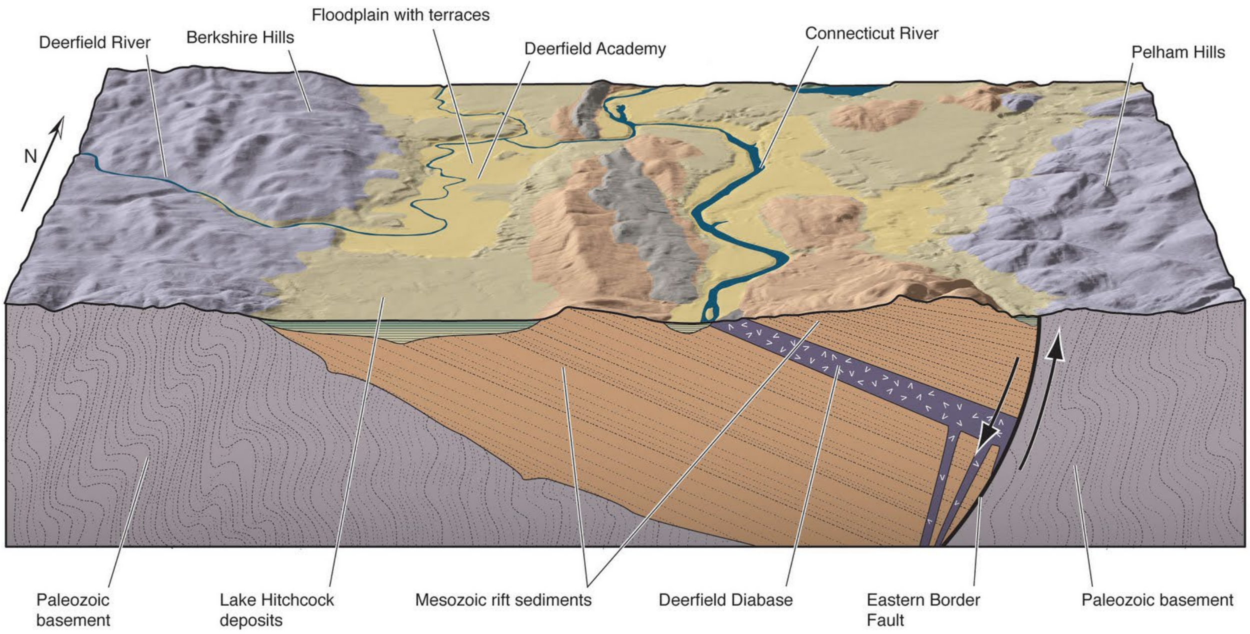


Figure 4 (Little & Sillin, 2011)

This bridge crosses the Connecticut River near the center of the rift basin (Figure 4). Notice the Eastern Border Fault. This is a "normal fault", which means the "hanging wall" on the west is moving down, a classic indication of divergence. This fault is the place where the ancient rocks of Laurentia (labelled "Paleozoic basement" in Figure 4) split apart to accommodate the spreading rift. Further movement on this fault over millions of years has caused the igneous and sedimentary rocks of the basin to tilt from their originally horizontal orientations. We will see evidence of these angled layers throughout the trip.

Stop 2: Barton Cove

a. Strike and Dip

Examine the dramatically tilted layers at the end of the picnic area peninsula. These are layers of Jurassic sandstone and siltstone, probably deposited at the bottom of a lake. The realization that these layers *angle down* toward the direction of the Eastern Border Fault revealed the fault's direction of motion and allowed geologists to conclude that this valley was caused by a diverging rift. In contrast, if the layers were *angling up* towards the Fault, it would mean that the western "hanging wall" was moving up, indicating convergence (try to convince yourself of this by examining Figure 4 above). Geologists quantify the orientation of features like this with "strike" (the orientation of the line where a layer intersects the horizontal plane) and "dip" (the angle at which a layer tilts). Both are measured with a special compass called a Brunton.

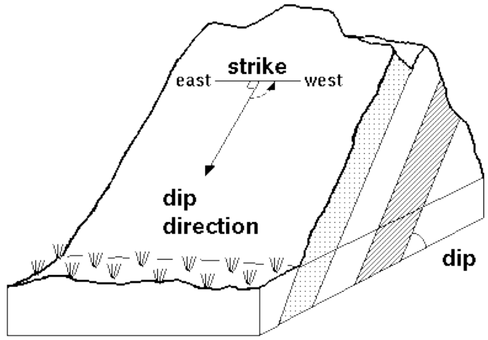
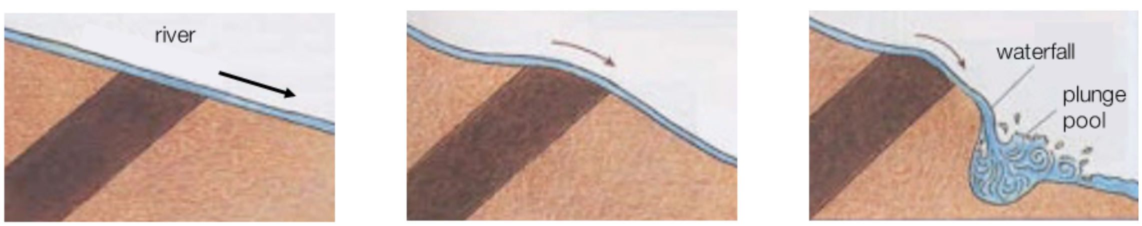


Figure 5: Strike and dip (University of Saskatchewan) *Figure 6: A Brunton (bruntonoutdoor.com)*

b. Lilly Pond Plunge Pool

Waterfalls in the Connecticut Valley were created after the most recent glaciation when rivers could not find their old preglacial channels due to the deposition of glacial and lake sediment. As rivers cut downstream, they sometimes encountered more resistant layers and a created a waterfall as illustrated in Figure 7.



A river flows across rocks of different resistance

The river erodes the less resistant rock more rapidly and this results in a change in the gradient.

A waterfall is formed where there is the sudden fall in height. The river plunges and hits the bottom of the river bed with great force. Rocks are swirled around to form a deep pool at the river bed known as a plunge pool.

Figure 7

This occurred in two places at the Lilly Pond Barrier between 9 and 14 thousand years ago, creating two extremely deep plunge pools before the river found a route to bypass the cliffs. Once the river cut through the Barrier, the waterfalls were abandoned. The river was once again free to erode downward and laterally, producing lower terraces including present-day floodplains adjacent to the river. The Lilly Pond pools were finally reconnected with the river in the early twentieth century when the nearby Turners Falls Dam raised the water level in Barton Cove.

Stop 3: Dinosaur Footprint Reservation

In 1836, Edward Hitchcock, professor of geology and theology at Amherst College, delivered a report about "remarkable footmarks in stone in the valley of Connecticut River, which have since awakened so much interest among intelligent men." Hitchcock collected over 20,000 fossil footprints and established a footprint museum at Amherst College, which remains the world's largest fossil footprint collection.

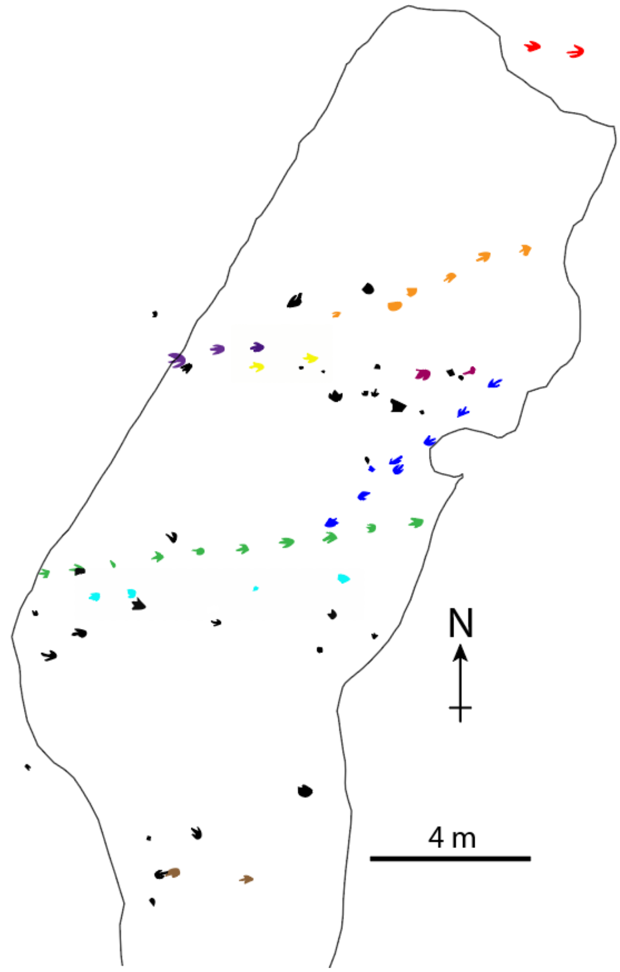


Figure 8: Map of visible footprints, colors indicate tracks of individual animals (modified from Aucoin & Hasbargen, 2011)

The footprints at this locality are preserved in sedimentary layers which were deposited in the rift basin during the Early Jurassic and dip about 15° toward the Eastern Border Fault. The sandstones contain ripple marks, formed by ancient slow moving currents, as well as worm trails and a few casts of salt crystals. Some beds have impressions of gymnosperm leaves (resembling firs) and stems (resembling reeds). Together, these probably indicate a lakeshore or even a slow-moving river like the modern environment.

Dinosaur footprints belong to a group of fossils known as ichnofossils (pronounced IK-no). These are trace fossils, such as footprints, dung, and stomach contents. It is nearly impossible to correlate an ichnofossil with a specific animal, so they are commonly named with a unique "ichnogenus". The footprints at this site almost all have three toes and appear to have belonged to bipedal or mostly bipedal animals. The largest footprints (*Eubrontes*) likely belonged to an animal like *Dilophosaurus*, while the smaller ones (*Anchisauripus*) possibly belonged to *Anchisaurus*, an ancestor of the long-necked sauropods.

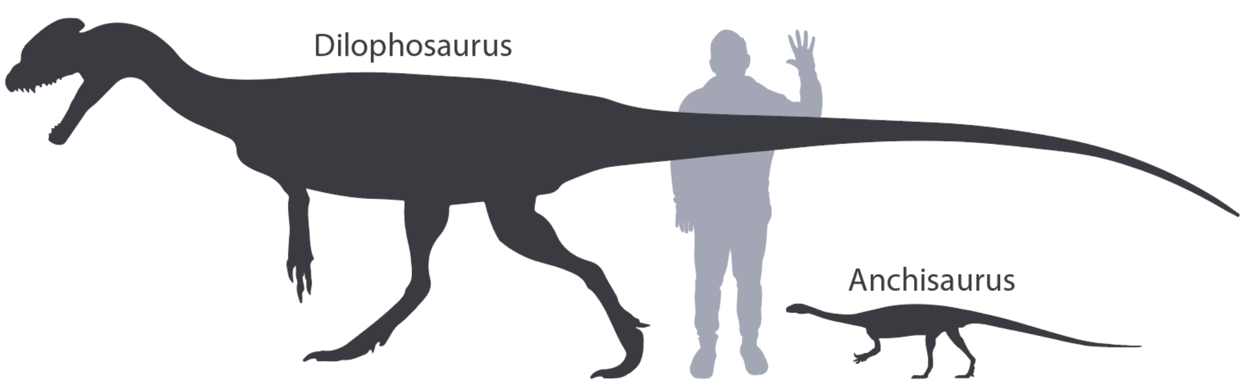


Figure 9 (based on Hartman, 2019 and Yates, 2010)

Stop 4: Skinner State Park

a. Titan's Piazza Columnar Basalt

Mount Holyoke is a "traprock mountain" created by a dipping igneous layer protruding from the ground. Basalt is harder and more erosion resistant than sedimentary rock, so these layers are worn down more slowly and create ridges.

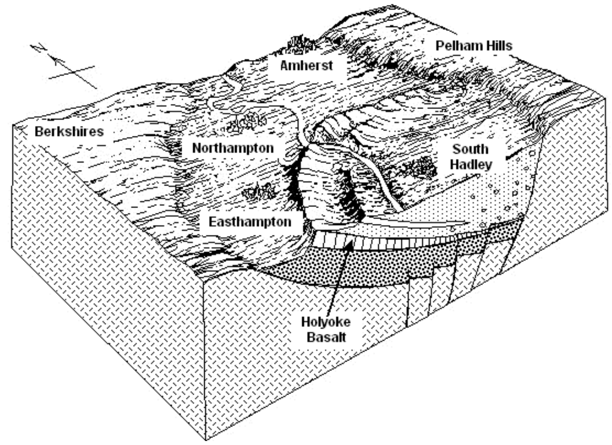


Figure 10 (DCR Massachusetts)

When the Holyoke Basalt was originally emplaced, it would have been a thick lava flow which cooled and crystallized from the top down. Rocks tend to shrink as they cool, so the cold upper layer contracted faster than the still-warm base. This differential caused stress cracks to develop in a characteristic hexagonal pattern, creating columns of basalt. Why hexagons? Of the three shapes which can tile a flat surface (triangles, squares, hexagons), the hexagonal tiling has the smallest total side length per unit area. This means that hexagons will require the least metal if you are an engineer designing a chain-link fence, and hexagons will require the least wax if you are a bee building a honeycomb. Since cracks require energy to produce, rocks tend to minimize the total crack length needed to alievate a given stress (this is why mud cracks and columnar basalt are both hexagonal).

Figure 11 (Hitchcock, 1823)

The most famous columnar basalt formation is the Giant's Causeway in Northern Ireland, where each column is about 20 cm in diameter. Here at Titan's Piazza, the columns are much larger. This is probably because the Holyoke basalt cooled more slowly, reducing the stress differential between the top and bottom of the flow.

b. Glacial Striations

During the Last Glacial Maximum (~20 thousand years ago), Boston was buried about 1 km below the Laurentide Ice Sheet, a massive contiental glacier which extended as far south as New York City.

As this glacier made its way southward, it abraded the underling rock. Fragments of rock carried along by the ice scraped across the bedrock, leaving deep scratch marks behind them. These scratches are called stiations, and are still visible on some of Mount Holyoke's basalt outcrops. One way to identify glacial striations is by their orientation. They should generally point North–South, alinged with the direction of glacial flow.

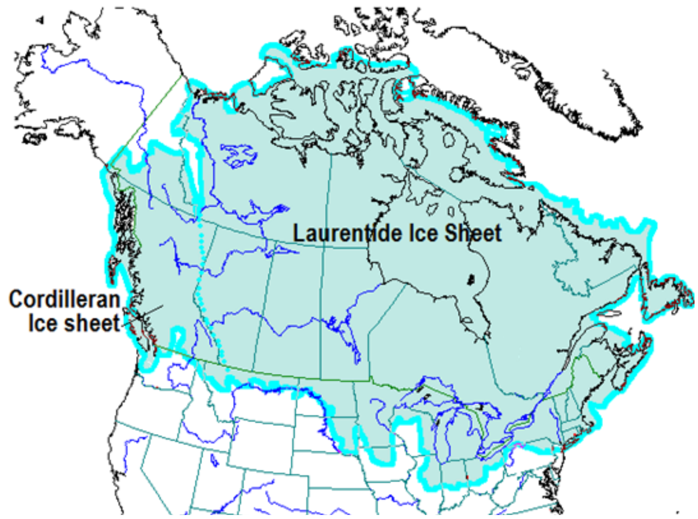


Figure 12

c. Glacial Erractics

When the Laurentide Ice Sheet finally melted, all those chunks of rock fell out of the ice as unsorted glacial sediments. The largest, boulder sized rocks are called glacial erratics, because they were plucked up by the glacier and transported far away from their point of origin. Essentially every large loose rock in New England is an erratic. The short stone walls you see all over the place are made from erratics that the longsuffering farmers of yesteryear pulled out of their fields each plowing season.

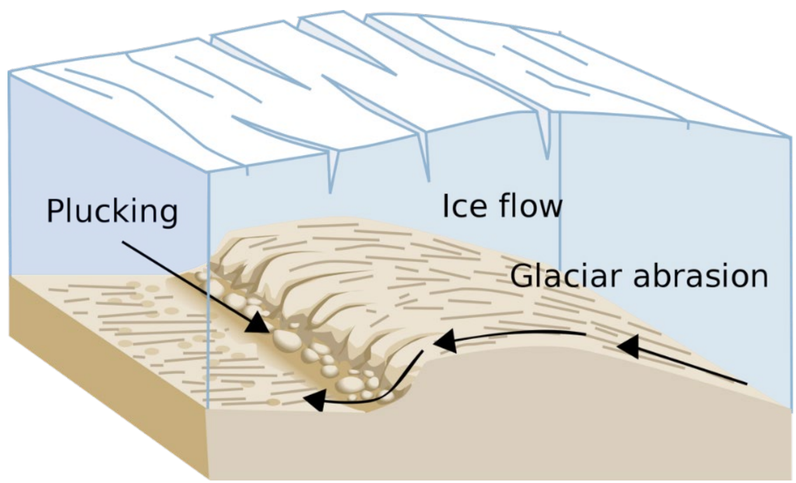


Figure 13 (Physical Geography UK)

Mount Holyoke is home to scattered white erratics (made of quartzite), as well as two particularly impressive ones: Conglomerate Rock and Devil's Football. The former is a conglomerate (!) and the latter is a very large chunk of basalt which has magnetic spots capable of deflecting a compass needle. Remember that these erratics are out of place, there's no easy way to tell whether they originated in local bedrock or from somewhere further to the north.