RIVER SUMMER CURRICULUM: Natural Sciences

Geology

Geology of the Hudson Highlands Region

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Abstract

- The Hudson Valley of New York State has a complicated 1.3 billion year geologic history represented by several geologic provinces located between New York City and Albany. While there are a number of accessible areas where students can be exposed to the rocks and structures geologists have used to unravel the complicated history of the Valley, they are often separated by distances which make it impossible to visit them all in one day. This module will therefore focus on the geology of one selected area, the top of Bear Mountain in the Hudson Highlands, and relate this to the larger picture of the Hudson Valley’s geologic history.

Activity Summary

This write up will describe a geologic field trip to the top of Bear Mountain in Bear Mountain State Park in Orange County, NY. The field trip will introduce students to the origin of the continental crust of New York State, the geological evolution of the Hudson Highlands region, and the importance of the Highlands region to the course of the Hudson River and the historical development of New York State.

Learning Goals

Upon completion of this field activity, students will be able to:
- delineate the Hudson Highlands region on a map of New York State.
- describe the sequence of tectonic events that led to the Grenville Orogeny and the development of the supercontinent of Rodinia.
- recall the age of the Grenville Orogeny.
- recognize the Storm King Granitic Gneiss and understand how this type of high-grade metamorphic rock forms in the core of ancient mountain belts.
• describe how gneiss physically and chemically weathers into sediments to provide material for clastic sedimentary rocks.
• recognize evidence for glaciation at Bear Mountain including erratics, glacial striations and polishing, and chatter marks and understand the processes that led to the formation of these features.
• Relate the important role the Hudson Highlands played in the geological development of the Hudson River and the historical development of New York State.

Insights Gained
Upon completion of this field activity, students will have better insight into:
• The order of events in the formation of New York State topography as we see it today
• How geologic time relates to other mechanisms for measuring time such as the Julian calendar

Advance Preparation
Trip participants should be dressed appropriately for geologic fieldwork and have field notebooks. The instructor should provide the New York State Geological Highway Map (NYS Museum Educational Leaflet 33) and several hand lenses for students to examine mineral grains and compasses to measure orientations. Perkins Memorial Drive to the top of Bear Mountain is closed during the winter months and periodically for repairs. Before embarking on a trip you may wish to contact the Palisades Interstate Park Commission to ascertain its current status. A half-day should be allotted for this field trip. This area can be crowded on weekends during nice weather.

Required Concepts
Before beginning this activity, students should have a conceptual understanding of:
• the 4.6 billion year age of the Earth.
• the basic principles of plate tectonics, with an emphasis on the types of geologic structures and processes associated with convergent plate boundaries. These structures and processes include subduction zones and associated seismic activity, partial melting of subducting plates and the generation of magma, the formation of oceanic and continental volcanic arcs, and folding and faulting associated continental collision.
• the three basic rock types – igneous, sedimentary, and metamorphic – and how each form in the Earth’s environment.
• the common rock-forming minerals such as quartz, feldspar, and micas.
• the basic physical and chemical weathering processes which act over time to reduce rock to sediments.
• the growth and movement of continental ice sheets during the Pleistocene Ice Age and how moving ice is important in eroding, transporting, and depositing sediments thus modifying the landscape over time.
Suggested Resources

The following resources are suggested for instructors to learn more about the geology of the Hudson Highlands as well as the surrounding Hudson Valley Region of eastern New York State.


For those with a strong geological background, the following resources will provide more detailed information.


A number of websites currently provide accurate information about the geology of the Hudson Highlands.


A Brief Geologic History of the Hudson Highlands

The Hudson Highlands is a belt of igneous and high-grade metamorphic rocks running from the Housatonic Highlands of Connecticut southwestward across the Hudson River into New Jersey where it becomes the New Jersey Highlands and from there extending into Pennsylvania where it’s known as the Reading Prong.

While the Earth formed 4.6 billion years ago, the continental crust that forms the deep basement rocks of New York State did not exist prior to 1.3 billion years ago. At that time, this area was a muddy seafloor near the coast of a smaller Proto-North America – a block of continental crust geologists call Laurentia.

Slowly approaching Laurentia at this time was another block of continental crust called Amazonia (today comprising part of the present-day South American continent). These blocks of continental crust were approaching each other due to the presence of a subduction zone between them and the consumption of the intervening ocean floor. Volcanic activity near the subduction zone resulted in periodic falls of volcanic ash into the muddy seafloor sediments (and thus governing the geochemistry of the resulting rocks which formed from this sediment).

Between 1.3-1.1 billion years ago, Amazonia and Laurentia collided resulting in the Grenville Orogeny (an orogeny is a mountain-building event). This continent-continent collision folded, faulted, and heavily metamorphosed the sediments...
caught up between these colliding blocks to form a mountain belt running from present-day Canada down the eastern seaboard of the United States to Georgia and then westward into Texas. Igneous intrusions, some also metamorphosed, were common as well. A modern-day analogy to this event is the northward movement and collision of India with Asia to form the Himalayan mountain belt.

About this same time, other continents were colliding and accreting (growing or fusing together) (Antarctica with the western coast of Laurentia, for example) forming a supercontinent known as Rodinia (from the Russian word for “Motherland”). During the late stages of the Grenville Orogeny, large-scale faults developed as the Grenville Mountains began to break down. Hot water circulating through these fault zones precipitated economically-viable deposits of magnetite ($\text{Fe}_3\text{O}_4$) iron ore. Rodinia lasted for hundreds of millions of years during the latter part of the Precambrian (Late Proterozoic Eon). During this time, the once-mighty Grenville Mountains were eroded down exposing rocks which formed deep in the core of the mountain belt. These were eventually covered by younger (Paleozoic Era) sedimentary rocks.

A more recent collision of African with eastern North America formed the supercontinent of Pangaea around 250 million years ago. This collision, the Alleghanian Orogeny, also formed Himalayan-scale mountains and thrust up the already ancient rocks of the Hudson Highlands to punch through overlying younger sedimentary rocks. This event formed the present-day ridge of the Hudson Highlands which has been eroding to this day. Most recently, the Hudson Highlands was affected by the Pleistocene Ice Age. Glacial polishing, striations, and chatter marks are common on many areas of exposed bedrock as well as glacially-deposited erratic boulders. The glacial carving of a fjord through the Highlands governs the course of the present-day Hudson River. The geology and geomorphology of the Highlands has played a huge role in the early history of New York settlements, the battles of the Revolutionary War, and the economic development of the area.
Directions to Field Trip Locality

Exit from the New York State Thruway at Harriman and follow signs for Route 6 East. Route 6 will climb into the Highlands and pass through Harriman State Park. Just after passing the Palisades Parkway, you'll see a sign off Route 6 for Seven Lakes Drive to Perkins Memorial Drive. Following the signs will lead to a narrow road which winds its way to the top of Bear Mountain. Proceed past the observation tower and parking area, bear to the right, and follow the road to a pull-off providing a spectacular view of the Hudson River below.

Perkins Memorial Drive and field stops A, B, and C (http://maps.google.com)
Field Stop A

Field Stop A is an excellent place to introduce students to the geomorphology of the Hudson Highlands. The New York State Geologic Highway Map (NYS Museum Educational Leaflet 33) can be used to delineate the extent of the igneous and metamorphic rocks of the Highlands as they extend southwestward across the region from Connecticut to New Jersey. The Highlands are bounded on both sides by faults (including the well-known Ramapo fault to the south) and the hard, resistant nature of its rocks controls the narrow width of the Hudson River here. To the north and south of the Highlands, softer shales and sandstones enabled the Pleistocene glaciers and subsequent Hudson River to erode a wider channel.

Fort Montgomery is situated below, where the Popolopen Creek enters the Hudson, and its location was clearly chosen for its strategic view down the river. The hill of Anthony’s Nose is across the river on the other side of the Bear Mountain Bridge and is the location for a number of mines. Philips Mine, just north of Anthony’s Nose above the Appalachian Trail is an important site where acid mine drainage has turned the local area into a wasteland of rock tailings with little vegetation. Just to the south, on the west side of the river, is Dunderburg Mountain, the southern gateway to the Highlands.

To identify other geomorphic features from this viewpoint, the Cornwall, West Point, Popolopen Lake, and Peekskill USGS 7.5 minute series topographic map quadrangles are helpful. Driving back toward the peak of Bear Mountain, there is space to pull-off the road on the right next to a large, open outcrop of rock.

Field Stop B

A short walk from the road will lead to a large expanse of rock that makes up Bear Mountain. This rock is the Storm King Granitic Gneiss which formed from the high-grade metamorphism of a granitic intrusion just over a billion years ago during the Grenville mountain-building event. This rock formed at temperatures approaching 800°C at over 20 km of depth. It’s presently exposed at the surface because miles of overlying rock were eroded away for hundreds of millions of years after these rocks had formed.

This location is an excellent place for an outdoor lecture on the geologic history of the Grenville rocks which comprise the Hudson Highlands. The amount of information conveyed would, of course, depend upon the background of the students but could range from fairly basic to quite complex. The major minerals (quartz, feldspars, amphibole, and micas) which comprise the gneiss are easily visible with a hand lens and gneissic layering can be identified on the eroded corners of the outcrop. Several joints and quartz veins can be identified running across the outcrop. Students could be asked to sketch selected features visible in this outcrop and to hypothesize about the formation of the fractures and veins.

The large boulders sitting on the surface of the outcrop (unfortunately marred by graffiti) are locally-derived glacial erratics of gneiss and careful examination of the outcrop will reveal some patchy areas of glacial striations and polishing. These features are also seen at outcrops just south of the observation tower parking area.

Field Stop C

Along the paved path from the parking area to the overlook just south of the observation tower, nearby outcrops display a number of glacial features such as polishing, striations, and crescent-shaped chatter marks. A number of glacial erratic boulders are visible here
as well, some with exotic lithologies. The purple conglomerate, for example, is a Devonian sedimentary rock from Schunnemunk Mountain 10 miles to the northwest. Students can use a compass to measure the orientation of glacial striations and chatter marks at various locations around this area and compile a rose diagram showing the dominant direction of ice advance or spend some time trying to identify the lithology of some of the other glacial erratics.

The rounded nature of the outcrops here is typical for the erosion of granitic rocks. It’s worth taking some time to examine the sediments collecting within low areas of the rock outcroppings under the magnification of a small hand lens. The dominant mineral grain is, of course, quartz and this can lead into a discussion on the chemical and physical weathering of gneiss. Just to the south, in Rockland County, arkosic redbeds in the Newark Rift were derived from the weathering of Hudson Highlands gneiss during the rifting of Pangaea. The presence of feldspar in these redbeds attests to their relatively short transport distance.

The trip can be concluded with a climb up the observation tower and its 360° view of the area.

**Supplementary Activities**

If more time is available, there are numerous other outcrops which can be examined in the nearby area. Interesting outcrops of Storm King Granitic Gneiss and Canada Hill Granite exist along the side Route 9W north toward Storm King. There are a number of different metamorphic and igneous rock bodies exposed throughout Harriman State Park. The Trailside Museum at Bear Mountain has a number of geological and biological displays. There are a number of abandoned magnetite iron mines in the Highlands that are accessible via the many trails running though the Harriman State Park.

For ideas on other outcrops to visit in the area, the New York State Geological Highway Map has a listing of field trip guidebooks available for the Hudson Highlands region (at least up through 1991). Iron mines can be located in the book *Iron Mine Trails* by E.J. Lenik (1996, NY-NJ Trail Conference).

**Interdisciplinary Opportunities**

This field trip could be combined with other activities allowing for interdisciplinary collaboration. Trips can be taken to sites of some of the abandoned mining towns in Harriman State Park to discuss early settlement in the area and the economics of the iron mining industry. Fort Montgomery and the U.S. Military Academy at West Point are located nearby easily leading into a discussion on the strategic importance of the Highlands during the Revolutionary War (and the chains across the Hudson were forged with Hudson Highlands iron). Trips to old iron mining areas, for example the Philips Mine on the east side of the River, can be combined with geochemical sampling and analysis of acidic water still draining from these mines. Biological field work is also possible in the forests of the area as well as a study of the impact of human development on ecosystems with the Highlands.
# The Geologic Time Scale

<table>
<thead>
<tr>
<th>Eons</th>
<th>Eras</th>
<th>Periods</th>
<th>Age (Ma)</th>
<th>Hudson Valley Events</th>
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<tbody>
<tr>
<td>Phanerozoic</td>
<td></td>
<td>Quaternary</td>
<td>0 – 1.8</td>
<td>Post-glacial lakes</td>
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<td></td>
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<td>Neogene</td>
<td>1.8 – 23</td>
<td>Pleistocene ice age</td>
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<td></td>
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<td>Paleogene</td>
<td>23 – 66</td>
<td>Uplift of Adirondacks</td>
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<td></td>
<td>Cenozoic</td>
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<td></td>
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<td>Cretaceous</td>
<td>66 – 146</td>
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<td></td>
<td>Mesozoic</td>
<td>Jurassic</td>
<td>146 – 200</td>
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<td></td>
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<td>Triassic</td>
<td>200 – 251</td>
<td>Palisades sill</td>
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<td>Newark Rift sediments</td>
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<td>Rifting of Pangaea</td>
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<td>Permian</td>
<td>251 – 299</td>
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<td>Pennsylvanian</td>
<td>299 – 318</td>
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<td>Mississippian</td>
<td>318 – 359</td>
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<td>Devonian</td>
<td>359 – 416</td>
<td>Iroquois forming Catskill delta</td>
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<td>Acadian orogeny</td>
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<td>Helderberg Sea carbonates</td>
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<td>Silurian</td>
<td>416 – 444</td>
<td>Rondout Formation</td>
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<td>Shawangunk conglomerate</td>
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<td>Erosion of Taconics</td>
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<td>Ordovician</td>
<td>444 – 488</td>
<td>NYC metamorphism</td>
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<td>Taconic orogeny</td>
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<td>Cambrian</td>
<td>488 – 542</td>
<td>Hudson River shales</td>
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<td>Passive margin sediments</td>
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<td>Proterozoic</td>
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<td>542 – 2,500</td>
<td>Laurentia rift/pl off Rodinia</td>
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<td></td>
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<td>The Precambrian</td>
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<td>Formation of Rodinia</td>
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<td>(88% of Earth’s History)</td>
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<td>Greenville orogeny</td>
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<td>Archean</td>
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<td>2,500 – 4,000</td>
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<td>Hadean</td>
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<td>4,000 – 4,550</td>
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Ma = mega annuus or million years ago  
Data from the International Commission on Stratigraphy (2004)

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# A Geologic Time Scale focused on major Hudson Valley Events
A section of the Geologic Map of New York State showing the Hudson Highlands from the New York State Geological Survey, Isachsen, Y. W., T. D. Mock, R. E. Nyahay, and W. B. Rogers. 1990, Educational Leaflet No. 33,
A section of the Legend from the Geologic Map of New York State showing the Hudson Highlands area information. From: New York State Geological Survey, Isachsen, Y. W., T. D. Mock, R. E. Nyahay, and W. B. Rogers. 1990, Educational Leaflet No. 33,