Geology

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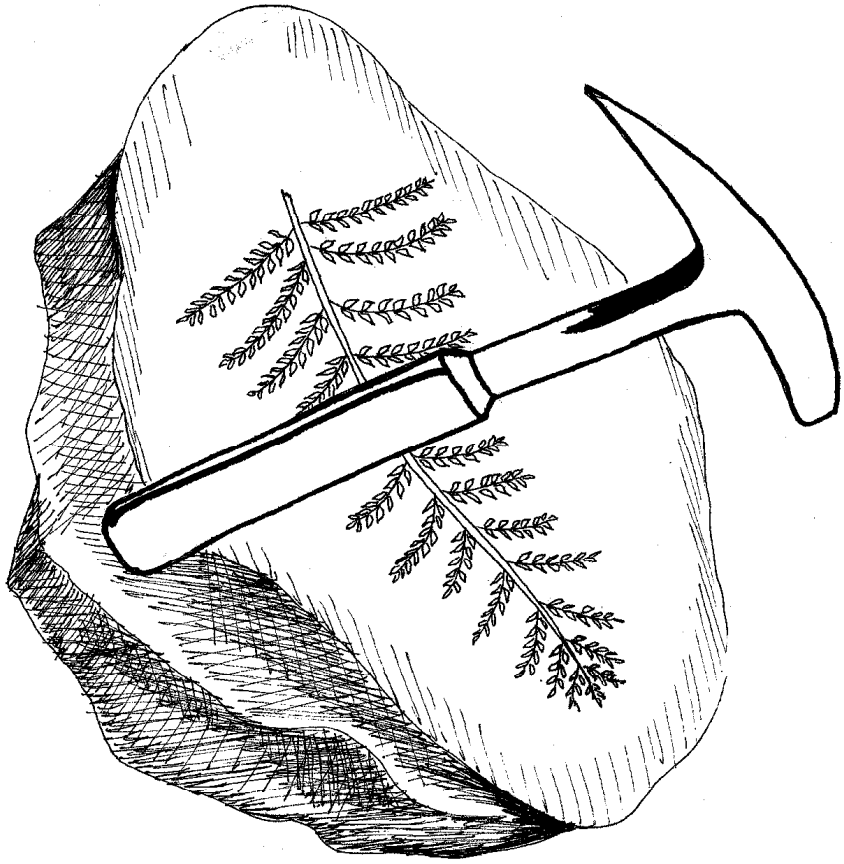

Scientists believe the Earth was formed about 4,600 million years ago. The amazing story of the formation of the Earth and the evolution of plants and animals is written in the rocks that surround us.

By examining rocks, this fascinating and often violent history can be unveiled. From rocks and the fossils they contain, we know that at one time all the continents were joined together in a single land mass called Pangea, and that dinosaurs once roamed the Earth.

In eastern Pennsylvania, the rocks reveal several violent events that forced mountains upward to the sky and then eroded them away only to thrust deposited sediments to the sky again and again.

Rocks often carry in their shape, texture, content, and appearance, a record of the conditions and events which occurred before, during, and after they were formed. By dating rocks, geologists can then place these events in time. The building blocks of rocks are minerals. The minerals in rocks also have a story to tell.

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Minerals

A mineral is a homogeneous solid comprised of specific chemicals, its atoms typically arranged in an orderly pattern called a crystal. For example, quartz is made of molecules containing two atoms of oxygen and one atom of silicon (SiO_2), and ice is made of molecules containing one atom of oxygen and 2 atoms of hydrogen (H_2O).

Some mineral crystals grow rapidly while others require years to **crystallize** completely. In addition to time, several other factors control the growth of a crystal, including temperature, pressure and the quantity of chemical atoms present.

Hardness Test: One mineral is harder than a second if the first can scratch the second.

Hardness Scale for Minerals

(10 is hardest)

Hardness	Mineral	Test
1	Talc	
2	Gypsum	Fingernail
3	Calcite	Copper coin
4	Fluorite	
5	Apatite	Penknife or glass plate
6	Orthoclase	
7	Quartz	Steel file
8	Topaz	
9	Corundum	
10	Diamond	

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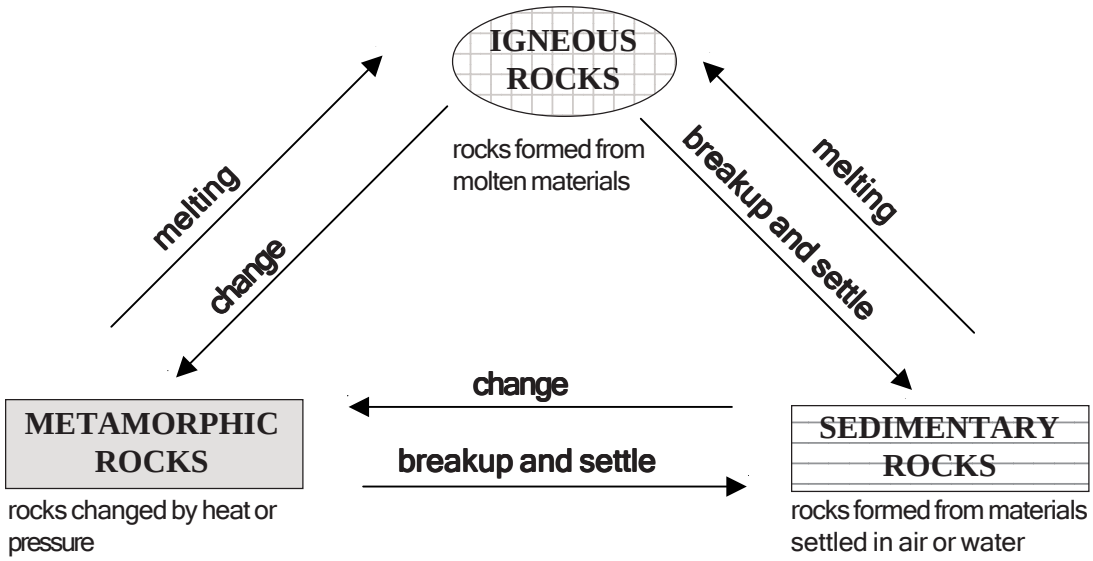
Rocks: Although some rocks may contain only one type of mineral, for example, limestone that is composed of calcite, most consists of combinations of minerals. There are many different types of rocks but these can be grouped (based on how they were formed) into three categories, **igneous**, **sedimentary** and **metamorphic** rocks.



Igneous rocks are formed as a result of the cooling and solidifying of molten **magma** rising from within the Earth's liquid core. As **magma** rises to the surface, it can solidify before it reaches the surface or it can reach the surface and then solidify. Molten magma at the surface is called **lava**. Igneous rocks often have high iron and magnesium contents. The rate of cooling determines the type of igneous rock produced. Granite and basalt are igneous rocks. Igneous rock does not occur at Hawk Mountain.

Sedimentary rock is made of sedimentary material. Sediments are produced when other rocks erode, and are deposited in layers called **bedding planes**. If the layers are thick enough, sediments become compacted and cemented into an aggregate sedimentary rock. Sediments may vary in size from clay (≤ 0 .00015 of an inch) to boulders (greater than 10 inches in diameter). Sedimentary rocks often contain fossils. By examining sedimentary rock, we can answer questions related to the origin of the sediments, the way they were transported, and what led to their deposition. Shale, sandstone, and limestone are examples of sedimentary rocks.

Metamorphic rock is formed when sedimentary and igneous rocks are subjected to high pressures or temperatures that cause them to undergo physical and chemical changes that alter the appearance of the minerals in the earlier rock type. New minerals form that arrange themselves in new patterns. This change is called recrystallization. Metamorphic rocks are quite different from their parent sedimentary, igneous or event metamorphic formations. Because the forces that bring about recrystallization are intense, metamorphic rocks can be heavily folded and faulted. Marble and slate are examples of metamorphic rocks.

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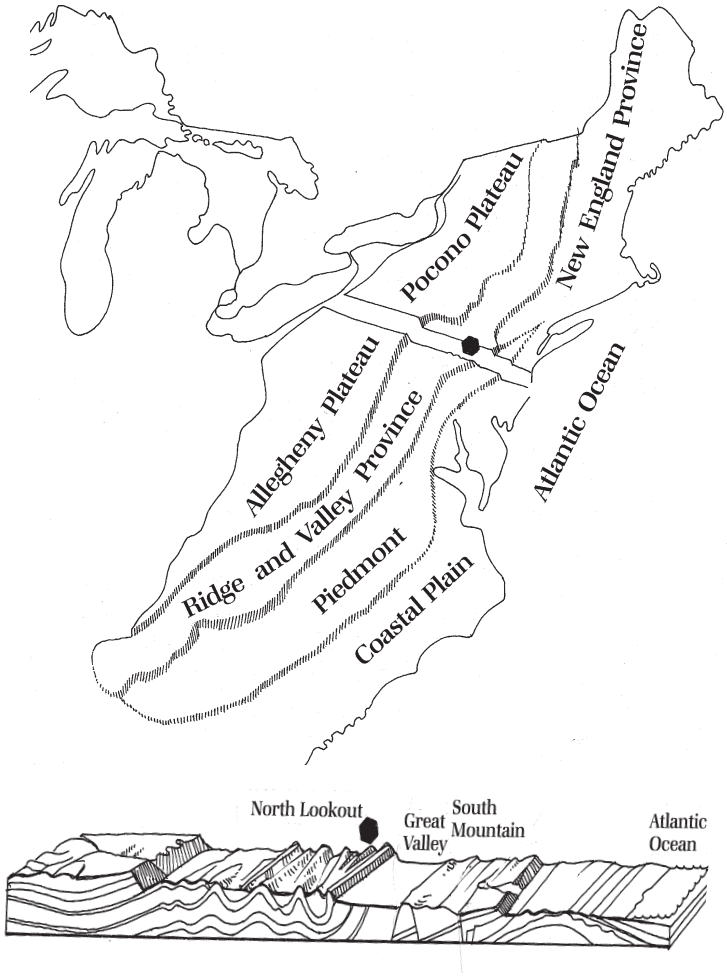
The Geological History of Hawk Mountain

Although most Sanctuary visitors cast their eyes skyward to observe the spectacle of hawk migration, there is as fascinating a story to be found underfoot. The geological history of the Hawk Mountain is written in its rocks and soils.

Hawk Mountain is part of the Appalachian Mountain system in eastern Pennsylvania. The Kittatinny ridge or Blue Mountain of which Hawk Mountain is a part, extends from 60 miles north of New York City to 20 miles west of Chambersburg. The North Lookout, the tallest point on the Sanctuary, rises to 1,521 feet. Stretching to the north and west of the Lookout is a series of folded ridges and valleys called the Valley-and-Ridge Province. The northernmost ridge, Broad Mountain, is 25 miles distant. The Pocono Plateau is north of Broad Mountain. To the west, the Valley-and-Ridge Province is bounded by the Allegheny Plateau.



South of the Great (or Lehigh) Valley is South Mountain, which is composed of igneous rocks. The igneous rocks of South Mountain are some of the oldest on the American continent, dating back to the **Pre-Cambrian** period more than a billion years ago.

The oldest rocks on the Sanctuary, shales and mud stone from the **Ordovician Period** more than 500 million years ago, are best observed at Aspen Cut, east of the Mountain Summit. Younger rocks, include the shales that comprise the reddish brown soil that covers farmlands to the north. This soil is from the **Bloomsburg** Period some 450 million years ago. **Tuscarora Sandstone** along the ridge top at Hawk Mountain was formed in the Silurian Period over 440 million years ago.

The Appalachian Mountains, as we know them today, are a relic of several mountain building periods, or **orogenies**. The earliest of these, the **Taconic Orogeny,** occurred some 450 million years ago. The Taconic Orogeny was followed some hundred million years later by the **Acadian Orogeny** and, more recently, by the **Alleghenian Orogeny** about 250 million years ago.

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During each mountain-building period, forces resulting from the very slow collision of continents, thrust rocks upward forming towering peaks that were subsequently eroded away by nature–water, wind, rain, snow and ice. Again and again, lowlands were thrust up and eroded away. Today, although only a remnant of the once majestic Appalachian Mountain remains, the rocks and soils left behind gives us a picture of past events and the processes that have affected them. Our story begins 500 million years ago.

The Taconic Orogeny

5 hundred million years ago eastern Pennsylvania was covered with a huge shallow inland sea called **the Iapetus Ocean**. Layers of sediments thousands of feet thick were eroded by rivers from the surrounding highlands and deposited on the floor of this sea. The weight of overlying sediments put great pressure on lower deposits, reducing the space between individual particles and squeezing air and water out. Minerals dissolved in this water slowly precipitated out and cemented the remaining sediments together, forming sedimentary rocks called rock-shale or mudstone. This process of rock formation is called **lithification**. **Martinsburg** shale formed during the Ordovician period can still be found at the Sanctuary at the Aspen Cut Campgrounds.

We know that the rocks that make up the Mountain were formed in the sea because the fossilized remains of many sea animals, including trilobites, molluscs, bryozoa, corals and graptolites, are found in them.

Following the deposition of the Martinsburg shale at the end of the Ordovician Period 430 million years ago, the sea bottom was elevated, folded, and deformed by continental collisions that pushed the rocks together like a rug. This was the **Taconic Orogeny**. Erosional forces eventually reduced these folded beds to more or less a level surface. The eroded sediments were carried eastward and deposited in a shallow inland sea.

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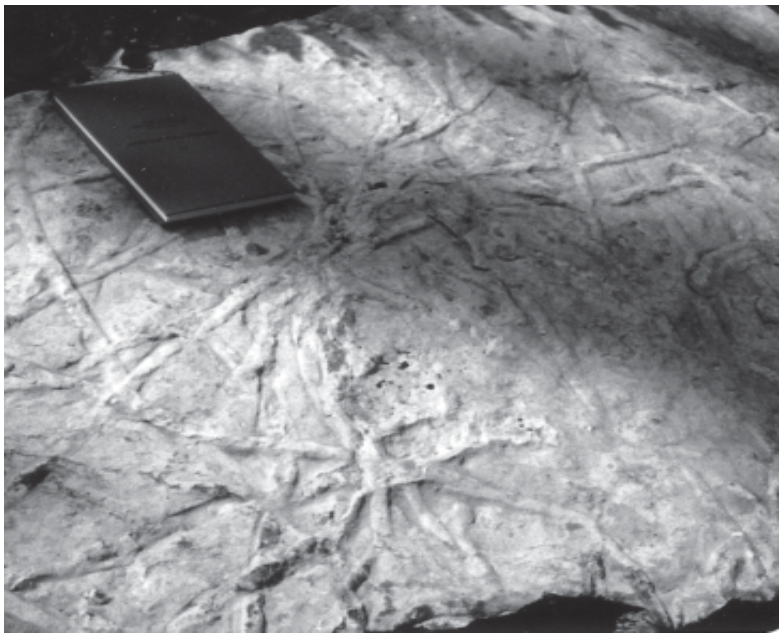
The Acadian Orogeny



4 hundred thirty million years ago, at the beginning of the Silurian Period, large streams from the southeast deposited quartz-rich gravelly sand across the region's Ordovician landscape. The gravel was eventually compressed to form a conglomerate sandstone, called **Tuscarora Formation**. Although Tuscarora sandstone lacks the abundant fossils found in Martinsburg shale, fossil tracks of worm-like organisms, known as "arthrophycus" can be seen in rocks along the Sanctuary's trails and lookouts. A particularly good specimen is part of the counter at the Information Pavilion.

During the middle of the Silurian period, olive green **Clinton Formation** shale was deposited in horizontal layers above the Tuscarora formation. The Clinton formation in turn was overlain by the younger **Bloomsburg Formation**, which consists of red sandstone and shales. Small amounts of green shale are inbedded within this thick red-bed deposit.

At the end of the Devonian period (405-365 million years ago) continental collisions again pushed up a new mountain range in an event known as the **Acadian Orogeny**. The new mountain was capped by marbled sandstone (Bloomsburg Formation) underlain by shale (Clinton Formation) and sandstone (Tuscarora Formation). The new range lay just east of Pennsylvania. In the Late Devonian, the mountains eroded and sediments deposited in the Appalachian basin west of the Acadian Mountains.

3 hundred sixty-five million years ago saw the beginning of the Carboniferous Period, Pennsylvania's famous coal fields were formed during this time. In the western part of the state, the alluvial plain was covered by large swamps of lush ferns and tree forests. Pennsylvania, which lay just south of the equator, had a moist tropical climate. Large trees called lycopsids, together with the fern trees, produced large amounts of organic matter that fell into the swamp. The water prevented oxidation and the material did not rot. Vegetation eventually accumulated and formed peat. Layers of peat eventually were buried by river sediments. Heat and pressure from the overlying sediments eventually turned the peat into coal.

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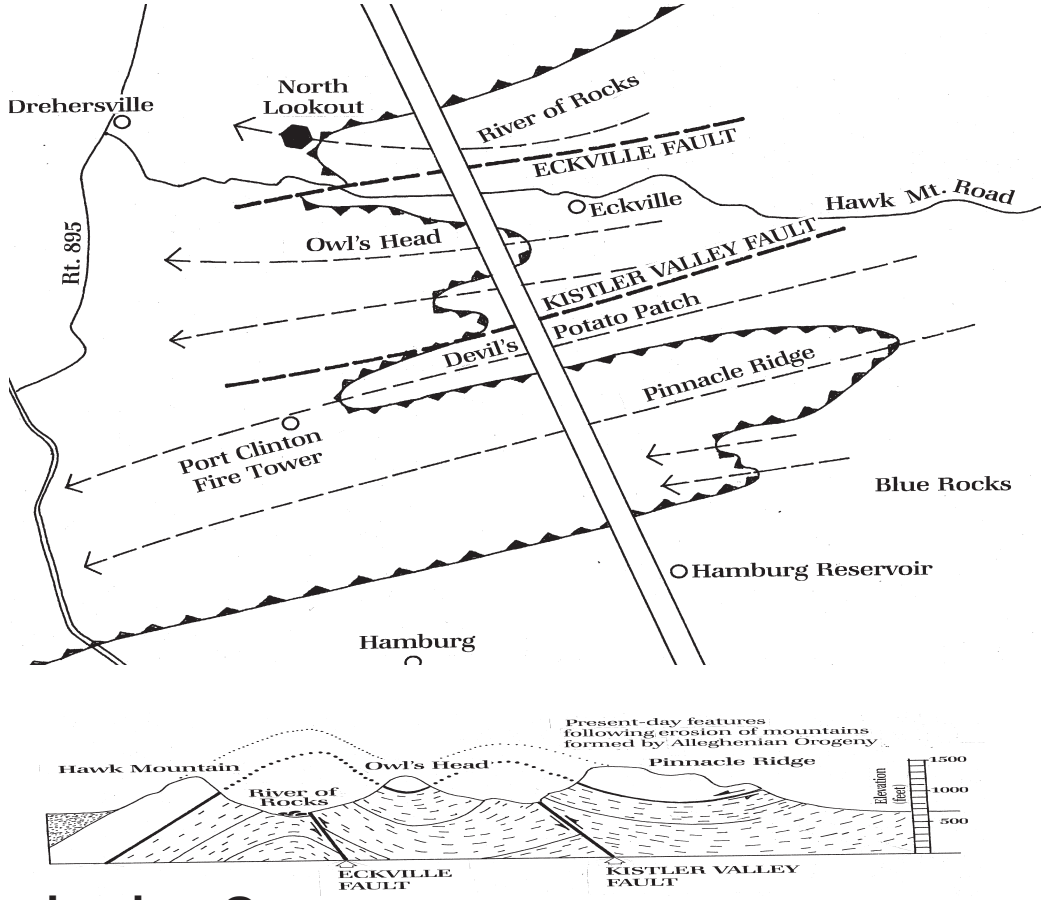
Geologic map and cross-section of Hawk Mountain vicinity



The Alleghenian Orogeny

2 hundred twenty five million years ago, at the close of the **Carboniferous Period**, thick sediments were again strongly deformed and uplifted for the final time during the **Alleghenian Orogeny**. Rocks were displaced thousands of miles from their origins. By reconstructing the fold patterns of these ancestral mountains we know that the young Appalachian Mountains were more than 20,000 feet high and more impressive than mountains produced by earlier Taconic and Acadian orogonies. The mountains we know today as the Appalachians are remnents of once majestic peaks.

The long period of erosion that started 250 million years ago produced the landscape that we are familiar with today. Since then, North America has drifted northward, taking Pennsylvania to its present position north of the equator. The continents have drifted apart and created new rock to fill the void created between them. Erosion by rain, wind, ice over the past 250 million years has eroded away most of the overlaying younger formations, revealing Tuscarora sandstone formed during the earlier Silurian period. Rocks from this formation are harder and resistant to erosion, because of their high quartz content. These rocks can be found on the ridgetops while much eroded material covers the valley floors. Following this most recent orogeny, glaciers scoured the landscape.

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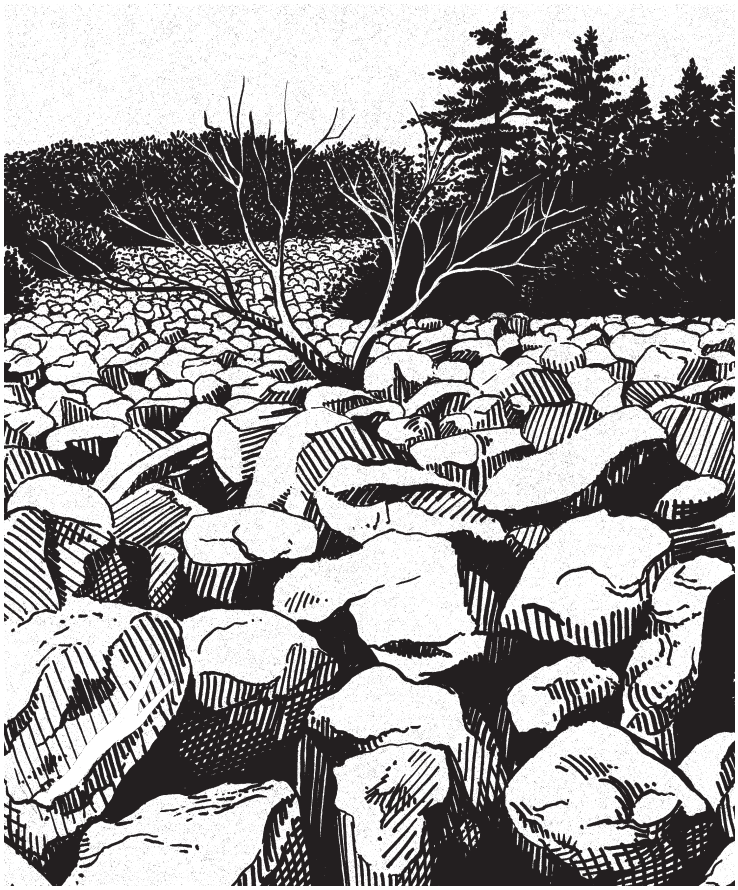

The Glacial Age

1 million years ago, continental glaciers began playing a significant role in shaping the North America landscape. After the Alleghenian orogeny, continents drifted apart and North America drifted closer to the North Pole, and a cooler climate. About 800,000 years ago, the first continental glacier advanced through Pennsylvania. Since then, glaciers have advanced for a second and third time, with the last advance occusing 10,000-12,000 years ago. Advancing glaciers sculpted deep, wide valleys and scoured soil and rock. Eroded materials were later deposited at the edge of ice sheets as the ice melted. Surrounding the continental ice sheet was a transistion zone of **periglacial conditions**. Ice sheets *never* covered the area in and around Hawk Mountain. (The furthest ice advance was to the Poconos, 50 miles to the north of Hawk Mountain.)

The **River of Rocks** lies in the valley below South Lookout. The field is a mile long, 30-400 feet wide, and lies at a gradient of 3-12 degrees. The field formed during the last Ice Age. During this time, local vegetation was sparse and extreme climate conditions resulted in repeated freeze and thaw cycles. Under periglacial conditions, water seeped into fractures in the rocks and expanded upon freezing. Eventually the cracks enlarged and broke up the Tuscorora sandstone into large boulders. These boulders alowly slid wit h mud and ice downslope to their present position by a process known as **solifluction**. This process occurs when boulders slide on a water-logged surface underlain by perfanently frozen ground (permafrost). With time some of the boulders became covered with debris and plant life. A small stream under the rocks has removed finer particles leaving areas of bare rock exposed. The materials being washed away are being deposited in the ocean and may be the source of materials for another mountain building period.

Boulder fields like the River of Rocks are common in the area. Blue Rocks in Lenhartsville, and the Hickory Run Boulder field in Hickory Run State Park near White Haven are similar examples. These relics of the Ice Age climate are common along the Appalachians as far south as Virginia. Some boulder fields are still moving.

Hawk Mountain Sanctuary
Geological Time Scale

ERA	Years Ago	PERIOD	Fossils Records	Hawk Mountain Geological Events
Cenozoic	The present to 2 million	**Quatarnary**	**Mammals including humans**	Erosion over 225 million years reduced the towering peaks of the Alleghenian orogeny to their present height and appearance. At Hawk Mountain, the highest point is 1521 feet at Borth Lookout. The Pinnacle, the highest peak in Berks County, is 1635 feet. River of Rocks formed under periglacial conditions resulting from the advance of the ice sheet some 10-12,000 years ago.
	2 million to 67 million	**Tertiary**	**AGE OF MAMMALS**	
Mesozoic	67 million to 140 million	**Cretaceous**	**Dinosaurs, mammals, birds**	
	140 million to 208 million	**Jurassic**		
	208 million to 250 million	**Triassic**	**AGE OF REPTILES**	
Paleozoic	250 million to 290 million	**Permian**	**Trees, ferns, ambhibians, reptiles, insects**	**Alleghenian Orogeny** continues. Appalachian Mountains pushed up to its maximum hieght over 20,000 feet
	290 million to 365 million	**Carboniferous**	**AGE OF AMBHIBIANS**	Erosion of the Acadian Mountains. Sediments to be the ingredient of the last mountain building period, the Alleghenian Orogeny that began during the late Carboniferous and continuing into the Permian period
	365 million to 405 million	**Devonian**	**Fish, ambhibians, insects, land plants**	**Acadian Orogeny** pushes up the Tuscorora overlain by the Bloomsburg and Clinton Formations.
	405 million to 430 million	**Silurian**	**AGE OF FISHES**	During the early Silurian rivers deposited white quartz and rich gravelly sand that become the **Tuscorora Formation**. Shale of the Clinton Formation then overlay the sandstone. The lowering of sea level during the mid Silurian resulted in the deposition of red mud which later became part of the **Bloomsburg Formation**.
	430 million to 500 million	**Ordovician**	**Molluscs, bryozoa**	**Taconic orogeny** (uplifted Martinsburg Formation)
				During early Ordovician, Hawk Mountain is covered by the shallow depositional **Iapetus Sea**. Thick layers of sediment deposited in this sea lithified forming shale or mudstone rocks called **Martinsburg Formation**.
	500 million to 570 million	**Cambrian**	**Trilobites, brachiopods**	
Pre Cambrian				
Origin of the Earth				

How Hawk Mountain Was Built

INSTRUCTIONS:
Cut along dotted lines and staple cards together to form a book. Hold book in one hand and flip pages from front to back with thumb of other hand.