PROMISED LAND STATE PARK, PIKE COUNTY

ANCIENT RIVERS AND AGES OF ICE

Promised Land State Park is located on a broad upland surface known as the Pocono Plateau. The highs and lows of the land surface are separated by only a few tens of feet of elevation and the slopes are gentle. However, the gentleness of the slopes does not necessarily mean that it is easy to walk on the surface. One of the outstanding features of the park is the abundance of rocks which lie in jumbled disarray throughout the area (Figure 1). In order to understand how these rocks came to their present position, we must consider several different aspects of geology which combined to create the present landscape.

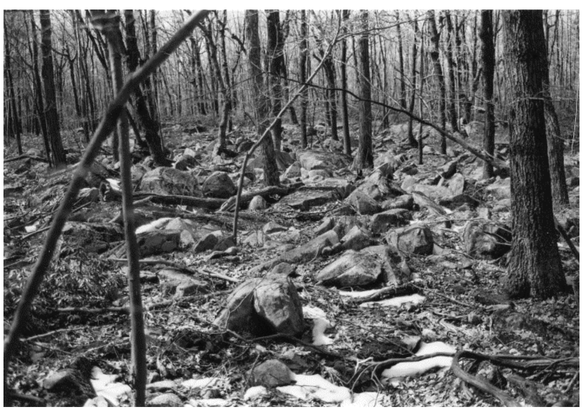


Figure 1. Boulder-strewn surface at site 12.

Breaks in the Rock

If we look at some of the rock ledges present within the park, such as the ledge in Figure 2, or those located at sites 2 and 6 on the map, we see that the rock is broken in many places. If we examine these breaks carefully we see that the breaks (partings) have a pattern. Many of the partings are more or less horizontal and are called *bedding-plane partings.* The bedding-plane partings are

Figure 2. Various partings in rock at site 8.

separated from one another by a few feet of rock that has smaller, more closely spaced, curved partings, called *crossbeds.* The crossbeds occur at various angles to the bedding planes (Figure 3). There are also large, nearly vertical partings, called *joints,* which cut through the bedding planes and crossbeds. The joints in the park trend approximately north-south and east-west. The north-south joints are often very straight and smooth (Figure 3), but the east-west joints are irregular. Individual joints are usually spaced from 1 to 10 feet apart. These bedding

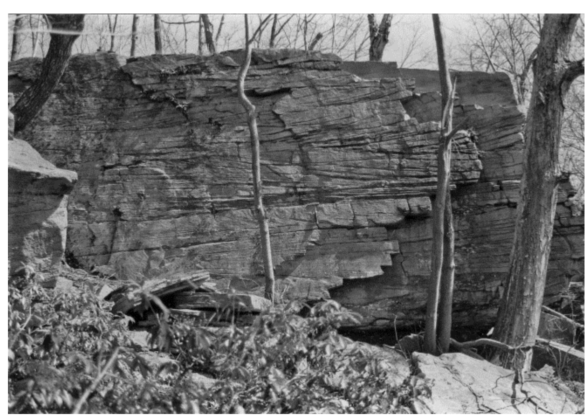


Figure 3. Joint face and crossbedding at site 15.

planes, crossbeds, and joints are the surfaces along which the rock separates into smaller pieces. All of the ledges in the park have these partings. The spacing of the partings controls the size and shape of blocks and slabs broken from a ledge. Thus, when rock is separated along widely spaced partings, large, cube-shaped blocks are formed, but separation along more closely spaced partings results in small, platy or slabby pieces. These partings and their contribution to natural rock breakup are one part of the origin of the rock-strewn surface. Let us now consider the second part.

Ages of Ice (Glaciation)

About 21,000 years ago, a large sheet of ice (glacier) of continental proportions entered northeastern Pennsylvania from the north and moved slowly southward into the state. This ice continued to move southward until about 19,000 years ago, when the front of the glacier extended from Northampton County northwestward to McKean County. Promised Land State Park was probably covered by 2,000 to 3,000 feet of ice and perhaps even more. Our explanation of the jumble of rocks in the park begins to unfold as we examine what happened to the land beneath several thousand feet of slowly moving ice. Figure 4 will help us to understand the following explanation.

As a glacier moves across the land surface, loose materials such as soil and rock become frozen to the bottom of the ice. These materials make the bottom of the ice similar to a large sheet of sandpaper. As the glacier moves slowly forward, perhaps only a few inches per day, these materials scrape the rock beneath the ice and create well-defined scratch marks called striations (Figure 5) which parallel the direction of ice movement. Although the tools for this erosive action are the rock materials frozen to the base of the ice, the erosion is aided by the pressure due to the weight of the ice. This pressure also forces some of the ice into the underlying rock partings previously discussed. The force of the ice within the partings combined with the forward movement of the ice causes some of the rock to be broken from a ledge, by a mechanism called *plucking,* thus adding to the rock being moved along at the base of the ice (Figure 4).

Larger pieces of rock plucked from the ledges are frequently left on the ground near the ledge, such as at sites 6 and 12. Some of the rocks being moved by the ice are also deposited in small depressions, such as at site 11, or on the north-facing sides of hills, such as at site 2. Once these rocks have been

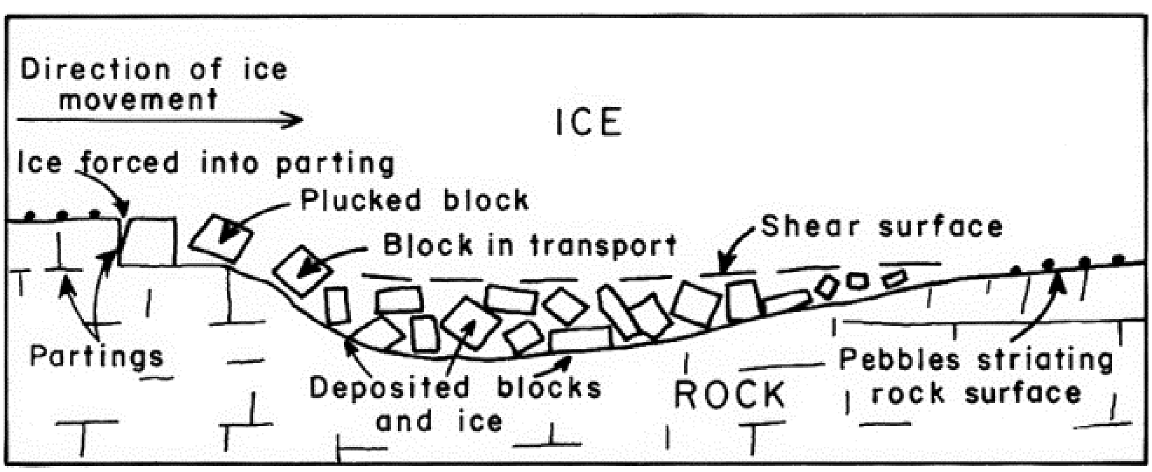


Figure 4. Model for erosion and deposition of strewn rocks.

Figure 5. Glacial striations at site 14.

lodged on the ground surface and ice fills in around them, the main mass of ice slides over them and they remain undisturbed. Thus we have an explanation for the rocks we see strewn around the park. What explanations are there for other materials and features?

Between 18,000 and 15,000 years ago the glacier melted. As the ice melted, much of the rock material contained within the ice settled directly to the ground as an unsorted mixture of boulders, gravel, sand, silt, and clay. This material, called till, occurs in many places in the park, but is probably best exposed in the road bank at site 1. Some of the material in the ice was washed away by the water (meltwater) produced by the melting ice. Most of these materials were transported down the stream valleys, but sometimes meltwater on top of the ice emptied into holes in the ice and filled the holes with sand and gravel such as the material at site 4.

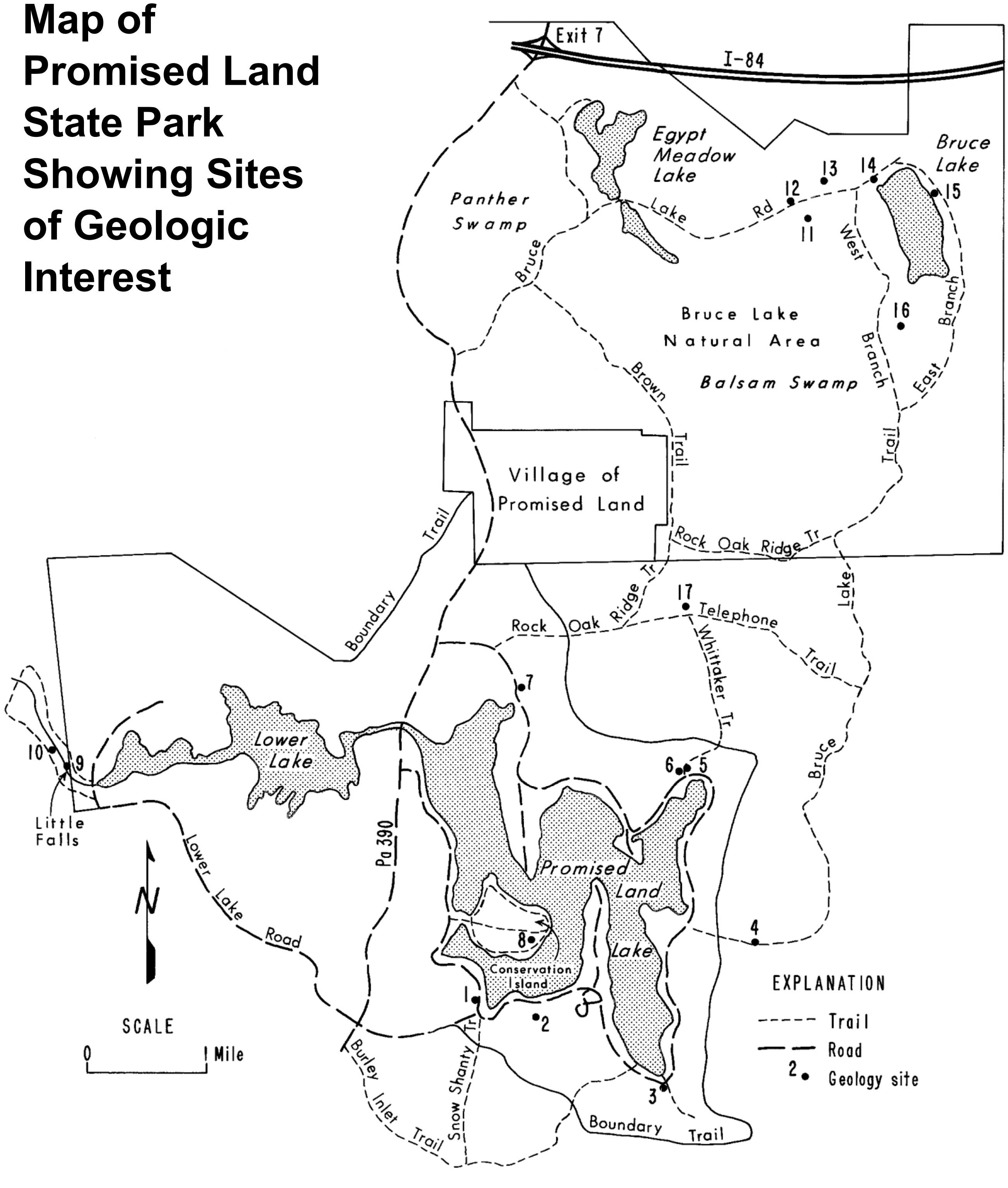
As might be expected, huge amounts of water and debris were produced by the melting of a continental ice sheet over 2,000 feet thick. After they were free of ice and open to water flow, valleys such as the East Branch Wallenpaupack Creek valley probably flowed at flood level continuously during the summer months when ice melting was the greatest. The sediment (sand and gravel) carried by the meltwater caused some abrasion of all of the streambeds, but also sometimes got caught in irregularities on the channel-bottom surfaces. Circular water motions, like whirlpools, developed at these irregularities, and the gravel, swirling around in one place, gradually eroded a hole in the streambed and created a pothole (Figure 6) such as the ones that occur at site 9. The potholes at this site are not being made today; they were formed at the end of the ice age, when greater volumes of water flowed frequently in the stream.

Figure 6. Pothole in rock at site 9.

After the Ice Age

After the ice had melted from northeastern Pennsylvania, there were many depressions on the newly exposed surface. A few of these, such as Bruce Lake, filled with water and have remained as natural lakes. Some of the depressions were very shallow and became swamps. Many of the depressions went through a series of plant growth changes to become peat bogs. In a typical sequence, the following happens: (1) A small lake exists with mosses, sedges, and other water-loving plants growing around its margins. (2) The rim of vegetation gradually extends farther and farther into the lake until eventually the lake is totally covered with vegetation. At that stage most of the vegetation is floating on the water. (3) As many years go by, vegetation grows, dies, and accumulates in the water. The accumulation of dead but undecayed vegetation finally fills the depression and the peat bog is no longer floating. (4) As more and more vegetation accumulates and is compressed, the surface of the bog is capable of supporting larger

Map of Promised Land State Park Showing Sites of Geologic Interest



forms of vegetation, and some peat bogs become forested. Sites 16 and 17 are good examples of peat bogs.

We should note some additional processes which continue to change the landscape even though the rate of change is so slow that we cannot see it happening. After the ice melted from the area, the larger rock ledges were probably free of loose rock because of the erosive action of the ice which we discussed before. Also, most of the rock surfaces should have been covered with striations (Figure 5). Yet if we look at the ledges we see an abundance of loose rock and no striations on the bedrock. This is due to the natural processes of weathering that have been working on these rocks ever since the ice melted. These processes are so slow that we cannot see most of the changes within our normal lifetime, but they are effective. During the fall, winter, and spring when the temperature reaches the freezing point, water in very small partings in the rock freezes, expands, and places pressure on the rock. After countless repetitions of this process, the rock will split and break loose. Future freezes and thaws will begin to move it away from its original position on the ledge (Figure 7). Rocks that have been broken loose from a ledge, as well as those strewn about by the glacier, are moved imperceptibly down any slope by a process called *creep.*

Many of the rocks lying on the surface in the park have been broken into smaller pieces by the splitting action of freezing water. In a few cases we can also see examples of the splitting action of tree roots (Figure 8), which exert pressure by growth of the root. And what about the striations? Over long periods of time even the hard rocks present in the park gradually break up into individual grains by a process called *granular disintegration.* As this happens, the striations, which are only surface scratches, become obscure and then disappear. If we were to remove some of the dirt and vegetation and expose a fresh surface of rock that has not been exposed to weathering, we would probably find the striations still there.

Figure 7. Blocks moving downslope by creep at site 10.

Figure 8. Tree root splitting rock at site 5.

Now that we know something about why the blocks and slabs of rock are strewn about the surface of the park, let us consider how the rock originated.

Ancient Rivers

About 385 million years ago, during the latter part of the Devonian Period, all of the eastern United States was vastly different than it is today; it was covered by the Appalachian Sea, a great seaway which occupied an elongate depression called the

Appalachian basin (Figure 9). On the southeast edge of the sea, in the approximate position of today's Atlantic coastline, was a large mountain range which geologists call the Acadian Mountains. These mountains are believed to have resulted from pressure generated by the "collision" of the North American and African continental plates, which were in much different positions at that time (Figure 9).

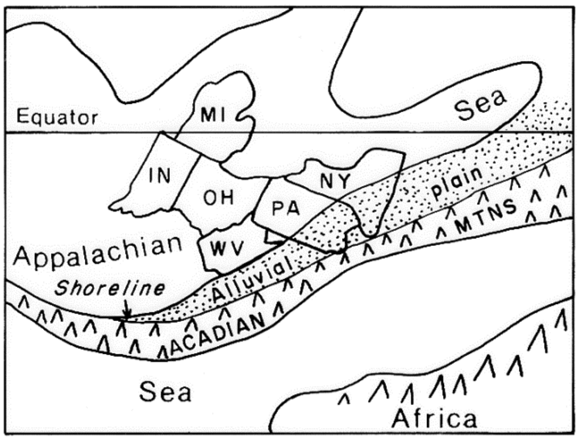


Figure 9. Geography of part of the world about 370 million years ago.

During the 20 million years between 385 and 365 million years ago, the Acadian Mountains grew in elevation and became increasingly subjected to the processes of erosion. Many streams flowed out of the mountains and carried eroded sediment to the Appalachian Sea. The sediment was deposited both on the sea bottom and at the shoreline much in the same manner that sediment carried by the Mississippi River has been deposited in the Gulf of Mexico. As more and more material was eroded from the mountains, transported to the Appalachian Sea, and deposited, the shoreline was extended gradually northwestward as an alluvial plain developed between the Acadian Mountains and the Appalachian Sea. Much of the sediment carried by streams flowing across this plain was deposited along the riverbeds and never reached the sea. The rocks (part of the Catskill Formation) that occur in Promised Land State Park were once those sediments deposited on that ancient alluvial plain. What are the features of the rocks that tell us this?

The answers to our questions are preserved in the rocks at sites 3, 7, 8, 13, and 15, as well as at many other rock ledges in the park. Examination of these rocks reveals several things: (1) the rocks are composed mainly of grains of sand which have been cemented together into solid rock called *sandstone;* (2) some layers (beds) of rock contain an abundance of gravel-sized material (pebbles) which has been cemented together into rock called *conglomerate;* and (3) the angled curved partings (crossbeds), which occur between the horizontal partings (bedding planes), are tilted in many different directions (Figure 3).

Careful study of the crossbeds shows that they have a definite pattern which is repeated over and over. That pattern is a series of small troughs (Figure 10), and the sedimentary structure it represents is called *trough crossbedding.* If we compare the sediment grain size (sand and gravel) and the trough crossbedding of the rocks in the park to

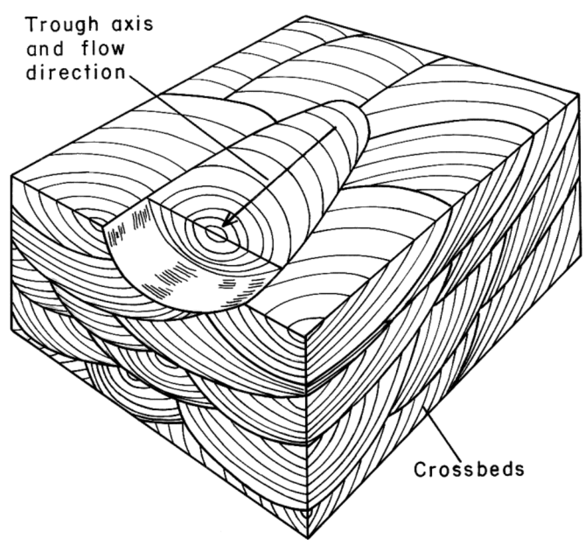


Figure 10. Schematic representation of trough crossbedding.

alluvial sediments being deposited today, we find that these features are most common in braided rivers (Figure 11). Because we assume that braided rivers deposited sand and gravel and formed trough crossbeds 365 million years ago in the same way that they do now (the present is the key to the past), we conclude that the rocks in the park represent the cemented deposits of ancient braided rivers. We can then use information about modern braided rivers to help us gain more information about the ancient braided rivers. For example, each trough has an axis (Figure 10) which parallels the direction of water flow at the time of deposition, and the direction in which the crossbeds dip indicates actual flow direction. An excellent example of the top of a trough occurs at site 4, and one can easily determine the direction of water flow when that pebbly rock was deposited.

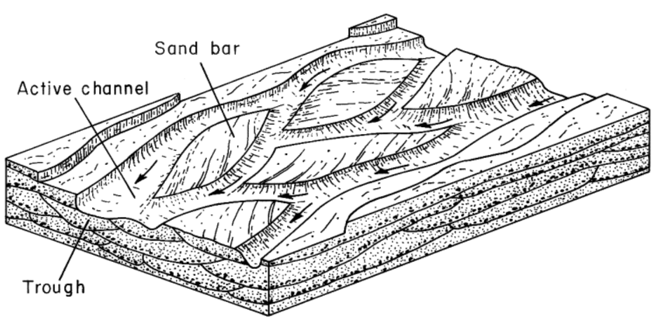


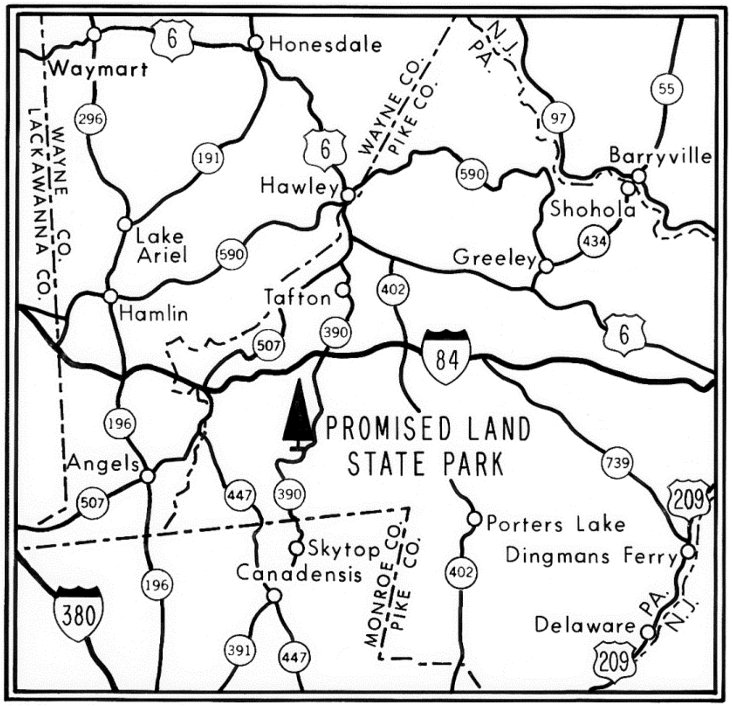
Figure 11. Idealized representation of a braided stream.

We know from evidence in rocks of comparable age located elsewhere in Pennsylvania and New York that the alluvial plain was semiarid, was subject to seasonal rainfall, and supported a variety of land plants as well as a variety of burrowing and surface-living creatures. Impressions (fossils) of some of the land plants may be found at site 15.

Other Things, Too

As you might suspect, a lot happened to the park area and all of the eastern United States during the time between the sediment deposition 365 million years ago and the ice age 21,000 years ago. During that time much more sediment was deposited on top of what we see in the park today. This sediment was cemented into rock. An even stronger "collision" of the North American and African continental plates about 270 million years ago compressed the Appalachian basin, and the rocks in the basin became the Appalachian Mountains. Erosion has worked continuously since that time to produce the landscape we see today. The North American and African continental plates have slowly drifted apart to reach their present positions. All of this information is derived from careful study and interpretation of many rocks in many places. Have fun doing some of your own interpretation. Visit some of the sites indicated on the map and see the features from which interpretations are made.

—W. D. Sevon and T. M. Berg, Geologists
Pennsylvania Geological Survey
1984



LOCATION MAP

Promised Land State Park
100 Lower Lake Road
Greentown, PA 18426
Phone: 570–676–3428

Modified to page-size format in 2012.
Series updated in 2016.

PREPARED BY

Department of Conservation and Natural Resources
Bureau of Topographic and Geologic Survey