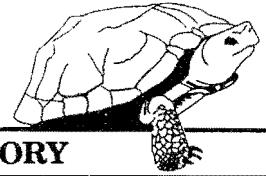


Cacapon



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Geology of the Cacapon River Basin

by Eberhard Werner, Morgantown, WV

Let's begin by looking at a map. Any map will do as long as it shows the streams.

A drainage map of West Virginia, for example, reveals regional differences. In the center of the state, streams do not form any particular pattern — they simply wander about in the general direction of the nearest larger stream. In our part of eastern West Virginia, though, the larger streams run parallel. Only a few short segments of the mainstems flow in a direction other than northeast-southwest. If you follow the Cacapon (figure 1), you will see that it proceeds for long distances in a northeasterly direction, occasionally joggling sharply right or left.

To understand what has caused this curious drainage pattern we need to explore the rocks underlying the surface.

Structure

The field of geology concerned with the arrangement of rocks is known as structural geology. The geological structures relevant here are folds and fractures.

Folds — You may have noticed that rock layers in the basin are either flat or bent. Keep in mind that most folds are too large to be seen in their entirety; you only see a small part. Folds come in two basic types: anticlines, where rock layers are folded upward at the center and slope down away from the center; and synclines, which are like anticlines turned upside-down (figure 2).

Folding comes about when forces within the earth compress a piece of the earth's crust (See "Cacapon Natural History", p. 9 this issue.). If the forces are ap-

plied slowly the rock layers will bend (up to a point).

As you can see in cross-section (figure 2), the surface of the earth may not mirror the folding of the rocks. There are instances where a ridge coincides with an anticline and a valley with a syncline, but the reverse also occurs. It all depends on the resistance of the various layers to erosion, and how active the erosional process has been. We will discuss this further in a bit.

Fractures — Sometimes forces in the earth are applied fast enough or the bending is so extensive that the rocks break. Look carefully at an outcrop and you will see some breaks. Most of these are simple fractures with no significant movement of one piece with respect to the other; these are called fractures or joints.

Where there has been significant movement along the break, it is called a fault. What movement is deemed significant depends on many factors. Sometimes it must be far enough to show up on a map, sometimes just being able to see that the layers no longer line up is enough. Basically it depends on who is looking and why.

The major structures of the Cacapon River basin are shown in figure 3. At this scale only the largest folds show up. Smaller folds and faults can be seen on more detailed maps (e.g., Tilton and others 1927, Dean and others 1985).

Kinds of Rocks

Geologists divide rocks into three basic types: igneous — those formed from molten material either on the surface or within the earth, metamorphic — those altered

INSIDE

6

Letters
to the
Editor

7

Cacapon
T-Shirts
for sale!



8

Lab
News

9

Cacapon
Natural
History

Lab needs:

canoe trailer

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from previously existing rocks by heat and/or pressure but without actually melting them, and sedimentary - those formed from tiny pieces of various kinds of materials laid down in water.

With minor exceptions, the only type of rock that occurs in the Cacapon River basin is sedimentary. Sedimentary rock usually forms in the ocean near shore, or where rivers slow down so they no longer carry the load. As materials pile up on the bottom of the water body, their own weight compresses the bottom layers. Minerals from water in the pores come out of solution and cement the grains together, and the result is rock.

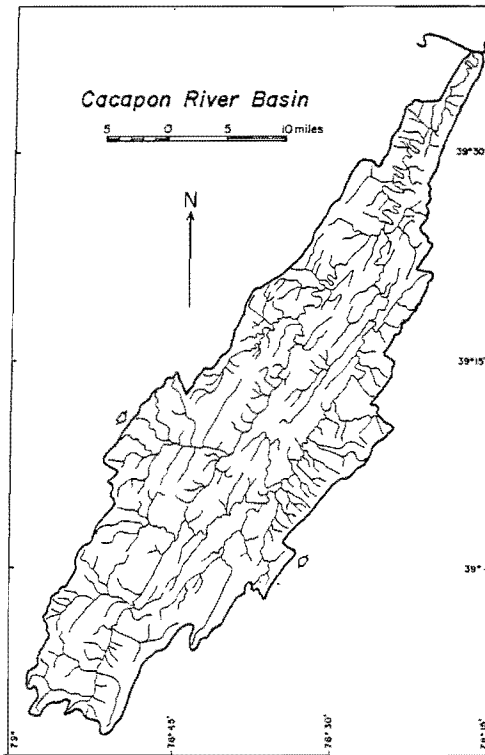


Figure 1. Stream network of the Cacapon River basin as shown on the U.S. Geol. Surv. 1:250,000 scale maps. The two small arrows show the location of the cross-section in figure 2.

Sedimentary rocks can be classified by the materials making them up; and most people recognize their names: shale, siltstone, sandstone, and limestone. Although that classification looks simple, there are complications. Shale, siltstone, and sandstone are named for the size, not composition, of the particles making them up. One can find sandstone made of calcite, quartz, or hematite. Although no one would normally call a rock made entirely of sand-sized grains of calcite or hematite a sandstone, most geologists would call them limestone or rock hematite. If it is a mixture

of these and quartz, the normal name is sandstone. Sandstone is mostly quartz, but it contains other minerals as well. For example, calcite ("lime") and hematite ("iron") commonly cement the grains together. The same idea applies to shale and siltstone.

Limestone is different from other sedimentary rocks in that it is built of material taken out of oceanic water by plants and animals that build their shells or skeletons out of calcite (and other related minerals). These skeletal remains are the grains which form limestone. Most calcite grains are deposited near where they were created by organisms, unlike sandstones whose grains have been carried long distances by rivers and ocean currents.

Rock Layers

In the Cacapon River basin, different kinds of rocks are found at various depths. Rocks of the vertical column can be assigned to different *formations*. The name applied to a formation is the place where it was first described. For example, the Helderberg Group is named for the Helderberg escarpment of east-central West Virginia. Identification of layers is based on characteristics of the rocks themselves and fossils within, or more recently on ages determined by the rock's level of radioactivity. Most of the Cacapon River basin's rocks, listed below by increasing age, are detailed by Cardwell and Erwin (1968) and by Hobba (1985):

I. Mississippian Rocks (formed 360 - 320 million years ago)

- Pocono Group (570 feet thick) - gray or tan, massive, fairly hard sandstones topping ridges in the western part of the Cacapon River basin.

II. Devonian Rocks (formed 408 - 360 million years ago)

- Hampshire Formation (2000' thick) - mostly shales and fine-grained sandstones, with some coarser grained, massive sandstone beds; mostly red or brown; generally on hillsides in the western half of the basin.

- Chemung Group (2500 - 3000' thick) - alternating sandstone and shale beds, with each bed only a few inches thick; mostly yellowish brown in color; very fossiliferous in some places; mostly on hillsides in the basin.

- Brallier Formation (1300-2170' thick) - mostly greenish-gray, very thin bedded shales and siltstones, other-

wise fairly nondescript; weathers readily and tends to slump into masses of shale chips.

- Harrell Shale (125-300' thick) - dark brown or gray to black, thinly laminated shale; with a few fossils.
- Mahantango Formation (300-1000' thick)-mostly brown sandy shales with a few thin beds of sandstones and limy sandstones; may be very fossiliferous.
- Marcellus and Needmore shales (500-900' thick)-dark brown or black shales with little variety, splitting easily into thin flakes; one or two limestone beds about 20 feet thick toward the base of the formation.
- Oriskany sandstone (100-500' thick)-white to brown sandstone, locally limestone or sandy limestone; cementation varies from very strong to almost none; silica or calcite; chert layers are sometimes found at the top and bottom of the formation, although either or both may be absent.
- Helderberg Group (300-600' thick)-light colored, usually gray limestone; upper portion is thin bedded, with cherty layers at the top and shaly layers below; lower part is massively bedded pure limestone; some of the lower part may be Silurian.

III. Silurian Rocks (formed 438-408 million years ago)

- Tonoloway formation (200-400' thick)-gray, sometimes very dark, thin-bedded limestones or dolomites; often containing appreciable amounts of silica.
- Wills Creek and McKenzie formations (400-800' thick)-limy shales or shaly limestones for the most part; most of the rock is actually gray but is almost always stained red from weathered material washing onto it; the two formations are sometimes separated by the Williamsport sandstone which may be up to 100 feet thick.
- Tuscarora Sandstone (50-300' thick)-mostly thick-bedded light gray sandstone, very resistant to weathering; tops the highest ridges in the eastern portion of the basin.

IV. Ordovician Rocks (formed 505-438 million years ago)

- Juniata and Oswego formations (600-1200' thick)-mostly red or gray, thick bedded sandstones; not as resistant to weathering as the Tuscarora, but still quite resistant.
- Martinsburg formation (1500-2300' thick)-mostly shale, usually sandy near the top; contains lenses of limestone

"With minor exceptions, the only type of rock that occurs in the Cacapon River basin is sedimentary."

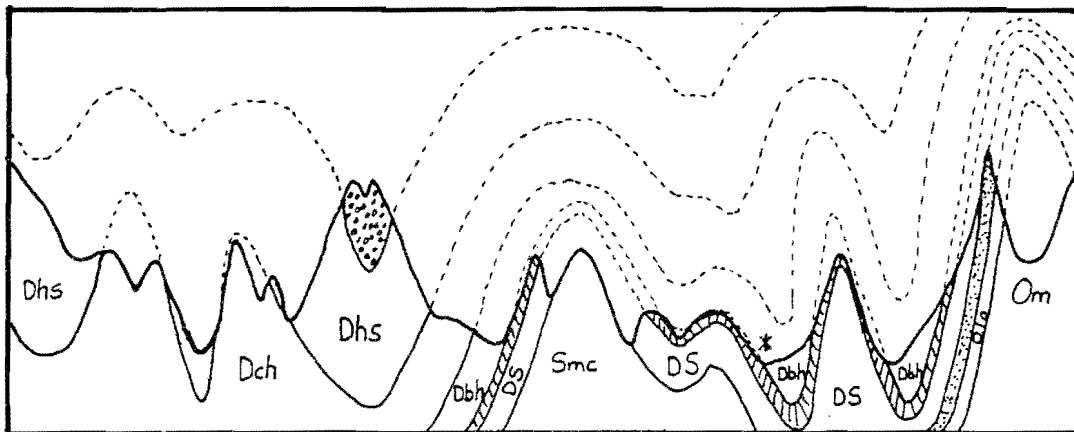


Figure 2. A general cross-section of the Cacapon River basin (See figure 1 for location.). The vertical scale has been exaggerated to clearly show the folds. The heavy line indicates the land's surface; lighter solid lines are boundaries between rock layers; dashed lines indicate where rock boundaries may have been in the past before erosion removed rocks. The patterns on the rock layers are for rocks which are most resistant to erosion: small dots indicate the Tuscarora formation; lines, the Oriskany sandstone; and small circles, the Pocono Group. Letter abbreviations are used for the remainder. Some of the units given separately in the text are grouped together here: Om - Martinsburg, Oja - Juniata and Oswego, DS - Helderberg and all the Silurian rocks above the Tuscarora combined (except Smc - McKenzie, shown near the center of the figure), Dbh - Brallier and Harrell (and Mahantango, Marcellus, and Needmore), Dch - Chemung Group, and Dhs - Hampshire Group.

"The most resistant rock, Tuscarora sandstone, forms the highest and steepest ridges."

here and there, but not commonly in the Cacapon River basin; underlies valleys in the very eastern part of the basin.

This entire series of rocks, from Mississippian through Ordovician, can be divided into two natural groups. Rocks older than Oriskany sandstone, shown as the tail side of the hachured dash lines (figure 3), are structurally more competent and therefore occur in large folds. In contrast, younger rocks, on the flat side of the hachure dashes, flow more easily and form small, gentle folds.

Stream Patterns

Our world has been classified in many ways, depending on the interests of the classifier. Geomorphologists (people who study the characteristics and changes of the earth's surface) have placed the Cacapon River basin within the Ridge and Valley province of the Appalachians. This province, which features long parallel ridges and valleys, is sandwiched between the Appalachian Plateau (e.g., Morgantown) to the west and the Great Valley (locally called the Shenandoah Valley) to the east.

Let us return now to the connection between the landscape's topography and the underlying rocks. Rocks that resist weathering will remain while softer, more chemically reactive ones will disintegrate. Therefore, you would expect ridges to be made of resistant rocks and valleys to host weak ones.

Applying this idea to the Cacapon River basin, the resistant rocks are sandstones, usually fairly pure ones, and the weak rocks are shales and limestones. The impure (shaly or limy) sandstones are in-between.

Looking at the cross-section (figure 2), you can see how this works out. The most resistant rock, Tuscarora sandstone, forms the highest and steepest ridges. The sandstones and conglomerates (pebbles cemented together) of the Pocono group are next-most resistant, and also underlie high and steep ridges. The McKenzie is not especially resistant, but where the Williamsport sandstone is present on top, it may hold up a ridge, such as Pine Ridge, near the middle of the cross-section. Oriskany sandstone is also a ridge-former because it soaks up water, precluding flow over the surface and the washing away of particles. There are also sandstones in the Chemung Group

which hold up some of the gentler, lower ridges in the western part of the basin.

Shales underlie the valleys: the Martinsburg, Brallier, and Harrell shales in the eastern part of our cross-section, and the Hampshire in the west. The middle of the cross-section valleys are also underlain by limestones of the Helderberg and Tonoloway Groups.

Rock type is not the only factor influencing where streams have eroded material to form valleys. Fragmented rock is more easily weathered than fresh, massive beds. A zone of broken rock forms an easy path for a river to cut through a ridge. Because folds extending northeast-southwest form narrow stripes of the various rock types running in the same direction, streams are mostly aligned in that direction. Where streams venture across the grain, there is likely to have been a fracture. Thus, it is both the rock types and fracture zones that control the regional patterns of streams.

As I stated at the outset, in areas west of the Ridge and Valley province, streams wander seemingly randomly, forming a pattern known as dendritic (as in the branches of a tree). In the Cacapon River basin, however, intensely folded rocks cause a dif-

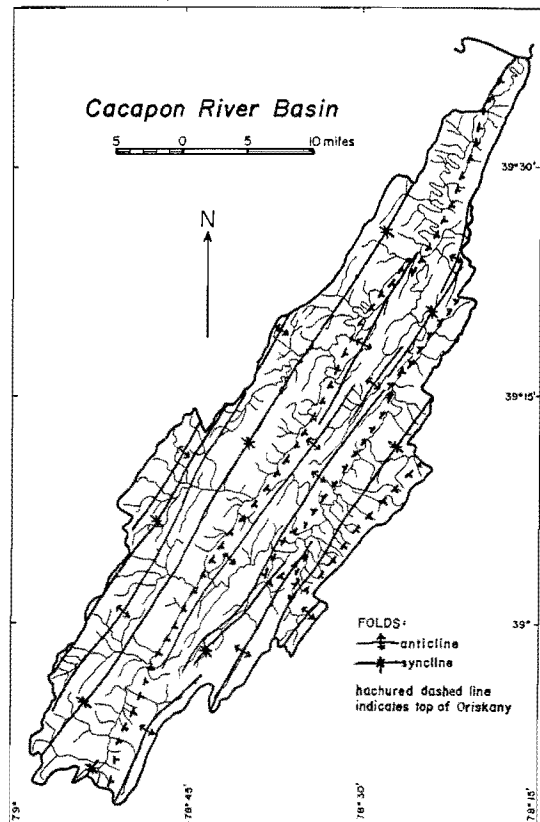


Figure 3. Major structures and top of Oriskany overlaid on the drainage network of the Cacapon River basin. More smaller folds and some faults also exist but are not large enough to show on this map.

ferent pattern, called trellised drainage (like the trellis supporting a rose bush). Tributaries flow directly down hillsides to meet large master streams at right angles, which in turn flow along the weak rocks in the parallel folds.

As mentioned previously, these weak strata have been exposed by erosion at the center of synclines, on the flanks of folds, or at the centers of anticlines. Where there is a valley at the center of an anticline or a ridge at the center of a syncline, the term "inversion of relief" is applied, emphasizing the fact that the land's surface does not mirror the rock folds beneath.

Solution features

When sandstones and shales break down, they form particles which are carried off by water. Limestone, on the other hand, can weather without leaving particles - its breakdown products go into solution. You know this solution as water hardness, which is simply calcium and magnesium dissolved in water. Because this material is dissolved, it does not require fast currents to carry it off. Where flowing water touches limestone underground, caves and channels form.

Features associated with solutional weathering are called karst. Even though karst topography is not common in the Cacapon River basin, it does not mean the process is absent here. The most obvious feature of karst landscape is the sinkhole.

Although Davies (1958) reports only ten caves in the basin, and none more than a few hundred feet long, there is considerable potential for cave discoveries in the area, especially in the Helderberg and Tonoloway groups. In some places in the basin, when water wells are being drilled through Oriskany sandstone, the drill bit drops suddenly, indicating an open space.

One unusual aspect of solutional landscape in the Cacapon River basin are the sinks of Lost River at McCauley. Water seeping through limestone has dissolved an underground channel that often carries the entire flow of Lost River. Although underground water flow in karst regions is normal, the average flow of 90 cubic feet per second (Hobba 1985, p. 15) through a single inlet and outlet in an area with few karst features is uncommon.

Landslides

Recent research has revealed that huge landslides have occurred in the last ten or

twenty thousand years. Along the east side of Lost River, about a half mile north of the town of Lost River, rests one of these giant prehistoric landslides (Southworth 1987, 1988). It appears that the Lost River undercut the hillslope. This removed support from the Oriskany sandstone, which was not securely attached to the rocks below because of solution at the top of the Helderberg limestone. The steepness of the hillside did the rest and approximately 100,000,000 cubic feet of Oriskany sandstone slipped off the mountain into the valley. Most of the slide's debris is still there today.

Conclusion

This has been a general geology of the Cacapon River basin. References below go into more detail. The Cacapon River basin has received less study than other areas of Appalachia probably because there are few economically attractive mineral resources.

Less commercial potential, though, does not make for a less interesting area. Many aspects of the Cacapon River basin interest geologists, and some of these features are just now being investigated. Meanwhile, the Cacapon River basin remains an area where many interesting rocks are seen and fascinating geologic features can be appreciated.

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"Water seeping through limestone dissolved an underground channel that often carries the entire flow of Lost River."

Cacapon Natural History

To complement Eb Werner's basin perspective (page 1), we thought you might enjoy this broader Appalachian view.

Appalachian Origins

by George Constantz

Earth was born 4.6 billion years ago as a hot ball of condensed atoms. It began cooling immediately and with time its outer crust began to harden. As the crust cooled and shrank, it broke into sections called crustal plates, which began shifting about the earth's surface 2.5 billion years ago. Currently, seven large and about thirty medium-sized and small plates slide about the earth's surface at speeds of up to 5 inches per year.

About 600 million years ago, when multicellular animals arose, two plates of controversial identity drifted towards each other and collided. While the plates were grinding against one another, three distinct episodes of mountain-building uplifted the Appalachians. In succession, the Taconic, Acadian, and Alleghenian orogenies (episodes of mountain building) each produced folding, faulting, and metamorphism. Each wave of uplifting was followed by nearly complete erosional flattening of the mountains.

The third orogeny, the Alleghenian, which occurred during the Triassic Period (245-208 million years ago), thrust the Appalachian Mountains 4 - 6 miles above sea level. Our round hills are the eroded remnants of this third orogeny.

By the end of the Alleghenian orogeny, the east coast curvature of the United States was hooked onto the Atlantic coast bulge of Africa, and Canada was jammed against Europe, with Greenland wedged in between. Thus, as the Mesozoic Era began (245 million years ago), all of the major landmasses were united as one supercontinent, Pangaea.

By the end of the Triassic (208 million years ago), Pangaea began to break slowly apart so that by the end of the Jurassic Period (208-144 million years ago) slight gaps opened between the continents.

Today, the seaward portion of the Appalachians includes blocks of terrain from what became Africa. These foreign rocks were apparently welded onto what became North America during the collision that produced the Appalachians. Today, foreign blocks occur on the east side of the Brevard Zone, which is a long fault, or suture line, caused by the collision of these two continents. The zone trends northeast-southwest, running through Brevard, North Carolina, and connecting Atlanta, Asheville, and Roanoke. Discontinuous extensions of the Brevard Zone even reach Staten Island, making part of the Big Apple a piece of the Old World.

Since the Carboniferous Period (360 - 286 million years ago), when reptiles arose, the plate of eastern North America has been tectonically quiet and drifting west-southwest at one inch per year.

The Appalachian revolution lasted about 300 million years, and ended about 300 million years ago. Ever since our mountains have been steadily eroding. Altogether, Appalachia has been uplifted from the oceans for almost 600 million years, making the Cacapon River basin part of one of the oldest terrestrial environments on earth. By comparison, today's great mountain ranges, like the Andes, Himalayas, and Alps, are merely 50 million-year-old children.

This article was adapted from George's forthcoming book, *The Evolutionary Play in Appalachia* (Mountain Press, Missoula, MT).

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