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GEOLOGY OF DEVILS DEN STATE PARK

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INTRODUCTION

Devils Den State Park is located in southern Washington County, Arkansas near the northwestern boundary of the Boston Mountain Province (in parts of sections 23, 24, 25, 26, 35, and 36, Township 13 North, Range 31 West). The park is on Arkansas Highway 170, about 18 miles southwest of West Fork and 15 miles northwest of Winslow. Both of these towns are on U. S. Highway 71.

For a better understanding of the sequence of geologic events in the park area, it was necessary to study sections 22 and 27 in the western part of the park. Similarly, since sections 35 and 36 added little information of geologic interest, they were deleted from this investigation. As a result, the discussed area includes sections 22, 23, 24, 25, 26, and 27, and these sections will be referred to as the park area.

The region was mapped during the late winter and early spring of 1953 by plane table surveying, from air photographs, and by compass traverse.

PHYSIOGRAPHY

The area has a relief of more than 800 feet, and the mountains have elevations in excess of 1,800 feet. These mountains are erosional remnants in the Boston Mountain Plateau, which has been dissected deeply in this area by two streams--Lee Creek to the east and Ellis Branch to the west (Figure 1). The stream pattern is generally dendritic, but Lee Creek is conspicuously abraided in sections 24 and 25 where it courses through the Bloyd shale. The streams cut through the Brentwood and Pitkin limestones in other parts of the park area. The streams join in the north central part of section 34 at an elevation of about 980 feet above mean sea level.

The region represents late youth in the erosion cycle. This is evidenced by the flat-topped mountains which are the remnants of the original plateau and also by the stage of development of the drainage system.

STRATIGRAPHY

The surface rocks are Upper Mississippian and Lower Pennsylvanian in age; they are well exposed at many points, especially along the streams. However, in places, there has been an extensive amount of slumping of the Atoka sandstone on the underlying Atoka and Bloyd shales, and several critical points of investigation have been covered.

Mississippian System. The Mississippian system in the Devils Den area is represented by the Pitkin formation which is in the Chester series (all age determinations are from Croneis, 1930). The formation crops out along Lee Creek from below the dam in section 26 southwestward into section 35 (Figure 1) and forms the surface rock over much of the east central part of section 26. Along Ellis Branch it is well exposed in the creek bed and in its valley in the south central part of section 27.

Pitkin Limestone Formation. The Pitkin formation is a light-colored, gray or blue-gray limestone which is often dense and is sometimes massive. The normal thickness of exposed limestone is a little more than 30 feet. The formation is composed of several limestone beds of different textures which range from fine-grained, sublithographic in lower parts to medium and coarse grained near the upper portions. Most of the beds show a rough crinoidal weathering in outcrops where the formation is a scarp former. There is local development of oolitic limestone in the lower and middle portions of the formation. Near the top of the Pitkin formation is a well-defined zone of nodular, crossbedded, fine-grained calcareous siltstone. At a place about 300 yards downstream from the dam in section 26, there is an exposure of blue and tan shale below the limestone. This exposure is about eight feet thick and contains small lenses of sublithographic limestone and a few concretions. It is lithologically different from the brown or black Fayetteville shale which ordinarily underlies the Pitkin formation nonconformably (contact relations are also from Croneis, 1930); therefore, the shale has been referred to the Pitkin formation.

On weathered surfaces the Pitkin formation is usually a very light gray color. Lichens and mosses often grow on the exposed face of the rock. Where streams have cut across the formation the rock has a smooth surface and a pale blue color. Numerous potholes have been developed by stream abrasion and solution. The weathering of the nodular zone in the upper part of the formation can be observed in the lichen-covered, crumbly ledges in the southeastern part of section 27.

One cave has been developed in the Pitkin by the solution of the limestone by ground water. The cave, Farmers Cave, is 25 yards northwest of the county road bridge over Ellis Branch in the south part of Section 27.

The formation is generally fossiliferous, but collecting is difficult because of the hardness of the rock at most exposures. The bryozoan, Archimedes, is fairly abundant. There are many assemblages of gregarious horn corals. Brachiopods, coiled cephalopods, and bryozoans can be seen in section or relief in many of the stream exposures.

The Pitkin formation is overlain unconformably by the Hale formation.

Hale Formation. The Hale formation is the oldest of the Pennsylvanian rocks in Northwest Arkansas. It is the basal formation of the Morrow group, which is Pottsville in age. The formation outcrops along the valley walls of Lee Creek and Ellis Branch in sections 26 and 27. The average thickness of the formation is about 140 feet. A large shale interval comprises the lower part of the formation in the park area, and true thicknesses are difficult to measure because long, gentle, covered slopes have developed on this basal shale. The lower shale is a light brown or tan color and includes some fissle beds. There is development of small clay concretions throughout the lower Hale, but no fossil nuclei have been found. The middle portion of the Hale formation is made up of thin-bedded shales and fine-grained sandstones. The percentage of shale decreases upward in the formation, and the upper middle part is largely fine-grained, thin-bedded, calcareous sandstone which has been cross-bedded and ripple-marked extensively. The ripple marks are particularly evident at exposures near Ellis Branch in the central part of section 27. The trend of the ripple marks is about N80E; the ripples are primarily of the current type and the trends indicate currents moving from a northerly direction.

The upper part usually consists of a very dense, massive, fine-grained, calcareous sandstone which ranges from 15 to 20 feet in thickness. Frequently the contact between this sandstone and the overlying Brentwood is difficult to locate since the lower Brentwood is rather arenaceous and the two beds have similar weathering characteristics.

The formation is fossiliferous throughout, particularly in the upper portions, but the fauna is poorly preserved and good specimens rarely are found. Brachiopod and Bryozoan remnants are forms which are found commonly in this area.

The Hale formation is conformably overlain by the Bloyd formation which is the uppermost formation of the Morrow group.

Bloyd Formation. The Bloyd formation in the Devils Den area is characterized by extreme lateral and vertical variations in thickness and lithology of the various component members. The formation consists of the Brentwood limestone member at the base, the Bloyd shale, the Baldwin Coal, and the Kessler limestone member. The Bloyd shale occurs between the Brentwood and Kessler members and contains the Baldwin Coal; the Bloyd shale also occurs above the Kessler member. The Bloyd formation is overlain with angular unconformity by the Atoka formation, which is also Pottsville in age.

Brentwood Limestone Member. At points where the contact can be seen, the Brentwood member rests conformably upon the massive upper Hale sandstone. The limestone outcrops along Lee Creek in section 26 and along the stream bed and valley walls of Lee Creek in the northern part of section 24. In the northern part of section 27 the limestone can be followed in the stream bed nearly to section 15 (Figure 1).

The Brentwood limestone varies in thickness from about 50 to more than 100 feet, including the shale intervals between the several limestone beds. In sec-

AREAL GEOLOGICAL MAP

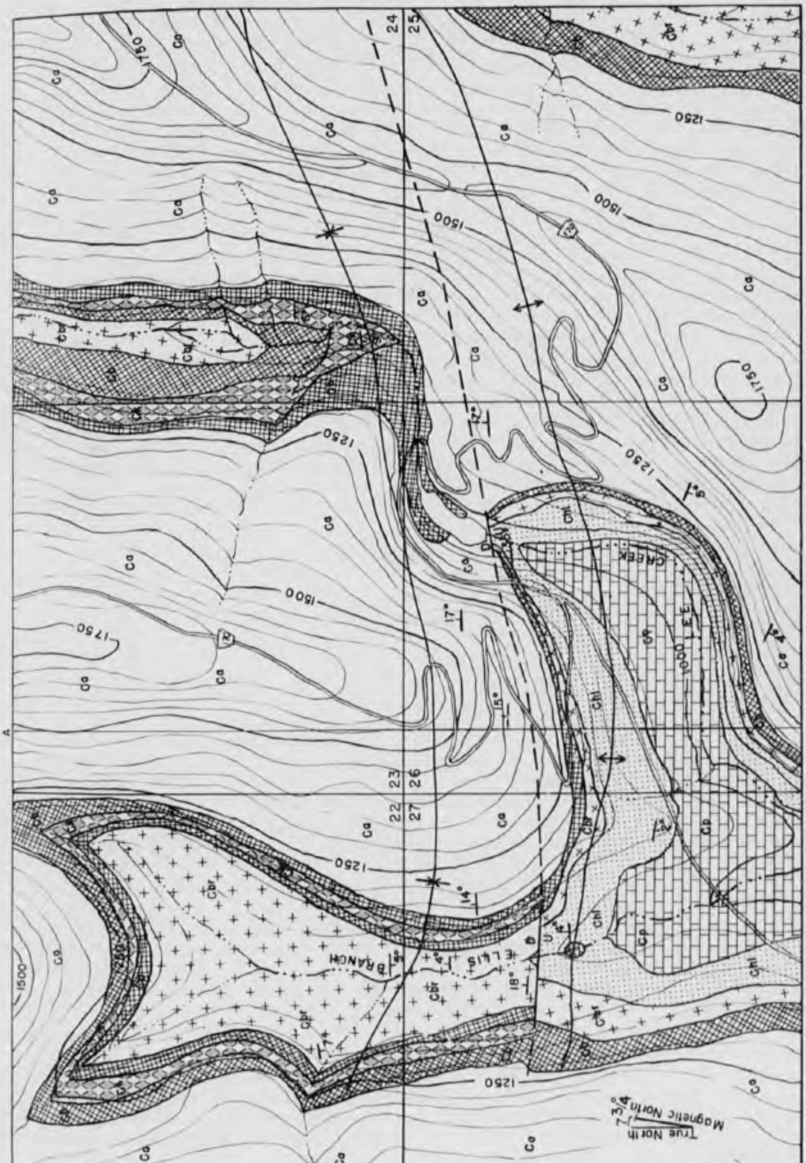

Figure 1. Sections 22, 23, 24, 25, 26, and 27, T 13 N, R 31 W, Washington County, Arkansas. Contour interval, 50 feet. Datum is mean sea level.

tion 26 and in the southern part of section 27 the entire Brentwood sequence is not present because the upper Brentwood limestone and remainder of the Bloyd formation were removed by pre-Atoka erosion, following faulting which elevated the southern portion of the Devils Den area. North of the trace of the axis of the fault, in the southern parts of sections 22 and 24, and in the northern part of section 27, the entire Bloyd formation is present.

The member is made up of several limestone beds which are generally blue-gray to light gray in color and range from sub-lithographic to coarsely crystalline types. There is some local development of oolitic limestone near the lower middle parts of the sequence. The thickness of the individual beds varies considerably, and they appear to interfinger with one another; there is also some lateral gradation of limestone to shale. The shales within the member are generally blue to tan, fissle, sparsely fossiliferous lenses. They range in thickness from one inch to about 15 feet. The shales are lithologically similar to the Bloyd shale lying between the Brentwood and Kessler members.

There is one fairly persistent massive limestone layer, about 15 feet thick, at the base of the member. The lower beds are sometimes arenaceous, and there is a local development of conglomeratic limestone at several different levels. There has been much replacement and filling of fossils in the beds by calcite.

In this area some of the weathered Brentwood limestone appears similar to the Pitkin limestone, but the lichens and mosses do not grow as abundantly on the surface of the Brentwood limestone; it also does not have the mottled-dark appearance of the weathered Pitkin formation. The yellow calcite crystals and sandy material in the Brentwood member give many exposures a yellow-brown appearance which is not common in the Pitkin; the Brentwood commonly weathers to rounded blocks, whereas the Pitkin often breaks in angular masses. The Brentwood fossils are so abundant and characteristic that they serve to identify doubtful exposures.

The member is very fossiliferous throughout the area of outcrop. The index blastoid, *Pentremites*, usually can be seen in section on stream-cut exposures. Plates of *Eupachycrinus* and *Hydreionocrinus*, calices of *Delocrinus*, and well-preserved specimens of many brachiopod species can be found in the park area. There is a locality near the center of section 24 on Lee Creek where a bioherm-like mass of very weathered, crumbly, crinoidal limestone contains many different species of Brentwood fossils and, in particular, yields excellent specimens of *Gastrioceras*, a coiled cephalopod. Collecting in the area is good because Brentwood often weathers to easily broken masses.

Bloyd Shale Member. The Bloyd shale, a varying lithologic unit lying between the Brentwood limestone and the Kessler limestone members of the Bloyd formation, also occurs above the Kessler member. The thickness of the shale varies considerably, but the average distance between the two limestones is about 60 feet. An arbitrary figure has been set on the thickness of the upper Bloyd above the Kessler; the dividing line between the Bloyd shale and the basal Atoka shale has been set at a point halfway between the Kessler and the lower sandstone scarp of the Atoka formation. The resulting thickness of the upper Bloyd shale is about 40 feet.

The shale ranges from tan to blue and brown to black in color. It occurs as medium-bedded, compact masses in places. In other localities it is notably fissle. There is an excellent exposure of the fissle type within the upper Bloyd interval on Lee Creek in the southwest corner of section 24 north of the abandoned spillway. The fissility is so great in the shale at this point that it has a greasy feel. Several joint systems in the shale are evident.

Baldwin Coal Lentil. In the Bloyd shale interval between the two limestones is a persistent coal seam, the Baldwin Coal, which outcrops around the valley walls and in the creeks in sections 22 and 24. The coal is approximately eight inches thick at most exposures. The coal can be traced by the "bloom" which appears through the covering shales and by the old workings which have been made by farmers.

No fossil flora were found in the roof shale in the park area, but an extensive search was not made. The underclay shows fossil roots.

The best exposures of the coal are found up a western tributary of Ellis Branch in section 22 on the northern side of the tributary wall at an elevation of about 1,150 feet.

Kessler Limestone Member. The Kessler limestone member is the most variable of the stratigraphic units in the park area. It occurs as several beds of varying thicknesses and of widely diverse lithologies. The entire member ranges in thickness from about 20 to 80 feet in sections 22, 23, and 24. Some of the Kessler is a dark, fossiliferous, coarse-grained limestone which weathers to a chocolate brown color. Other types are found which are lithologically identical with common Brentwood limestone. This Kessler limestone is medium to coarse-grained, dense, fossiliferous, and light blue-gray in color. Sand fragments and yellow calcite crystals give the common Brentwood a weathered appearance. These limestones normally are found in the upper portion of the Kessler interval. As is common in the Brentwood member, the various component beds are separated by shale intervals, which, however, are generally more arenaceous than those of the Brentwood sequence.

Conglomeratic beds are seen throughout the Kessler member, some occurring in the limestone beds and others in beds which are calcareous siltstones. These siltstones are very dense, dark gray in color, and weather to a dark brown. They have a flagstone-like appearance and are almost invariably conglomeratic. There are several lenses of this material--one at or near the top of the Kessler member and another at the bottom. However, both lenses have not been found in the same vertical section. On Lee Creek, in the southeastern part of section 24, the siltstone conglomerate outcrops near the stream bed. Here it is the basal Kessler. On Ellis Branch, in section 22, an identical siltstone occurs at the top of a very thick Kessler section.

In the extreme northwest corner of section 24 there is a sandstone bed about five feet thick within the Kessler interval. This bed is argillaceous and easily weathered, and contains a most prolific assemblage of productid brachiopods of many different species.

The Kessler member is generally fossiliferous, containing numerous small horn corals, species of *Michelinia*, and many species of brachiopods. Good collections can be made in the northwestern part of section 24.

Atoka Formation. The Atoka formation overlies the Bloyd formation with angular unconformity. It has the largest areal distribution and the greatest vertical extent of any of the formations in the park area. The lower part of the Atoka formation is a black shale that is lithologically similar to the upper Bloyd shale. An arbitrary contact line has been drawn between the two shales. There is a persistent bed of calcareous, massive sandstone near the base of the formation, which is a prominent scarp former and can be traced on air photographs. Above the lower massive Atoka sandstone is a series of alternating thin bedded sandstones and shales. The shales are variable in terms of color, ranging from light blue to black. Near the middle of the formation is another prominent sandstone which is very dense, fine-grained, and quartzitic. This bed often shows a pink color on fresh surfaces. Above this sandstone are more series of sandstones and shales.

There are several notable original sedimentary structures in the formation. Ironstone concretions in the sandstones are common at nearly all levels in the Atoka formation. They weather to concentric rectangular structures when viewed in section. They are useful in identifying slump blocks of the formation. In addition to these unique concretions one can find exposures of sandstones which show branching, feather-like outlines parallel to the bedding surfaces. These have a small relief and a random orientation. Possibly, they are swash marks of a specialized kind.

There has been much extensive slumping of the lower Atoka sandstone on the lower Atoka and upper Bloyd shales. Some of the slump blocks are large, and the crevices between the block and wall are well-known tourist attractions--featuring such picturesque names as "Devils Ice Box." The lower Atoka sandstone occasionally shows honeycomb weathering in the vicinity of waterfalls.

The total thickness of the formation exceeds 800 feet. The best accessible exposures can be seen in the northeastern corner of section 25 where park trails have been constructed between the large slump blocks and the rock in place.

A few fossils can be found in the Atoka formation, but collecting is usually limited to casts of spirifiroid and productid brachiopods in sandstone.

STRUCTURAL GEOLOGY

Diastrophic movements in the area have resulted in the formation of three major structural elements--a syncline, fault, and anticline. The existence of the structure is indicated by dips in the various formations, abutting of different strata against each other, truncation of lower bedding surfaces by beds which are stratigraphically higher and by the absence of beds which should be present. Interpretation of the structural geology has been difficult because of the overlapping of the three main elements.

The fault was mapped in 1903 and the other structures were discussed but not figured (Purdue, 1907).

The syncline extends from the southwestern quarter of section 24 to the southwest, passing out of the area in the northwestern part of section 27. The trace of the axis of the syncline is slightly curved, as shown by dip relationships (Figure 1). The structure is asymmetrical--the dips south of the trace of the axis are greater than those to the north. The dips on the south limb range from four degrees in the Pitkin limestone in section 27 to 17 degrees in the Hale formation in section 26. The dips on the northern limb vary from seven degrees in the Brentwood limestone in section 22 to nine degrees in the Kessler limestone in section 24. On the northern limb of the syncline, in section 24, the tilted beds become nearly horizontal near the north section line. The structure has been observed in a valley to the east of section 24, indicating that the structure is elongated in a general east-west direction. The relationship of the syncline to the other structural elements can be seen in the structure section (Figure 2).

The southern limb of the syncline has been faulted--the upthrown side is to the north, and the downthrown side is to the south. In the north-central part of section 27 the fault can be seen in the creek bed and valley, where the middle Hale formation, a thin-bedded, calcareous, ripple-marked sandstone abuts against the massive, calcareous upper Hale sandstone. The stratigraphic displacement is about 60 feet. Faulting is exposed in Lee Creek below the dam in section 26. Here there are several faults, roughly parallel, trending in a general northeast-southwest direction. There is a confused stratigraphic relationship here because of pre-faulting tilting of the strata and fault drag. However, exposures show the middle Hale sandstone abutting against the upper Hale sandstone. Instead of the middle Hale being south of the trace of the fault--as the other locality was found to be--it is north of the trace.

The fault or zone of faulting extends to the valley east of section 25 where the upper Bloyd shale has been downfaulted against the middle Brentwood limestone.

Dip relationships due to drag tend to obscure the precise relationship of the fault to the folding which occurred.

The faulting occurred before the deposition of the Atoka formation. On the upthrown side of the fault the upper Brentwood limestone and the remainder of the Bloyd formation were removed by erosion before the deposition of the Atoka formation.

There is a pronounced anticlinal structure which is very asymmetrical. In fact, it was referred to by Purdue (1907) as a monocline. It trends parallel to the fault and syncline, passing out of the park area to the east, continuing for some distance. The anticline is best shown in the lower resistant sandstones of the Atoka formation. The beds of the Atoka dip northward at an angle of 18 to 19 degrees in the northern part of section 25 and the southern part of section 23. However, the beds south of the trace of the axis of the fault dip south or southeast at about four degrees. The dips are pronounced in the Brentwood limestone in sections 22 and 27 and in the Hale formation in section 27. The prevailing dip on the north limb of the structure in these beds is about 17 degrees. Within the Atoka formation the dips die out upward in indication that the arching occurred during the deposition of the lower sands.

HISTORICAL GEOLOGY

The history of the deposition of the various formations and the diastrophic agencies acting upon the deposited beds in the Devils Den area is somewhat complex. The following hypotheses are not intended to represent a final, authoritative interpretation of the environmental conditions existing during the geologic past within the region.

The Pitkin formation was deposited in a warm sea which contained much carbonate matter as indicated by the character of the faunal assemblage (horn corals, crinoids) and the limestones which comprise the formation. At one time, or several times, during the deposition of the Pitkin formation the water of the sea was shallow and agitated as is shown by the occurrence of oolitic limestones. The seas withdrew from the region at the end of the Mississippian period, and there was a short period of erosion or non-deposition. In a few locations the bedding planes of the Pitkin formation seem to be truncated by the shales of the Hale formation.

At the beginning of the Pennsylvanian period the Hale formation was deposited in a shallow sea which, at first, lacked carbonate material. The bottom shales were derived from muds which apparently came from a northern source. Throughout Hale time the seas were encroaching as is indicated by the increase in clasticity upward in the formation. The thin-bedded, ripple-marked middle Hale sandstone is indicative of shallow waters in which moderately strong currents moved constantly from a northerly direction. An alternate reason for the increase in the clasticity of the Hale sediments is that a land area was rising to the north as time progressed.

There was an encroaching, fluctuating sea during the deposition of the Brentwood member of the Bloyd formation. The shallowness is shown by the oolitic limestones and local, small-scale cross-bedding. During the deposition of the shale, forming muds of the Bloyd interval, the seas were somewhat less favorable to animal life and at least one time the sea withdrew entirely and coal was deposited under swamp conditions.

The Kessler interval represents a re-initiation of conditions favorable to prolific growth of animal life and favorable to deposition of fossiliferous-fragmental limestones. Following the carbonate Kessler sea there was some deepening of the water and the upper Bloyd shale was deposited.

During the deposition of the Bloyd formation there was a series of downwarps re-initiated along the same parallel lines. Possibly, this was due to block faulting in the basement rock contemporaneous with sedimentation (Payne, 1953). Between the time of deposition of the Bloyd formation and the Atoka formation, faulting cut through the members of the Bloyd formation and a period of strong erosion followed, removing the middle and upper Bloyd formation on the upthrown side of the fault. The Atoka seas then encroached and there was apparently recurrent movement along the same fault lines. This threw the Atoka formation into steeply dipping beds along the margin of the original syncline.

The recurrent faulting ceased during the deposition of the quartzitic sandstones during Atoka time and the uppermost beds of the formation show only the normal regional dip to the south.

ECONOMIC GEOLOGY

There is little of economic value in the park area. At one time, the coal was utilized by farmers for fuel, but this is not done today. The vast amount of limestone and sandstone in the area could be used as building material, but there is no nearby market. The limestones are too impure for use as commercial limes.

The scenery produced by the combination of geologic phenomena, topography, and plant life have economic use in that they are tourist attractions.

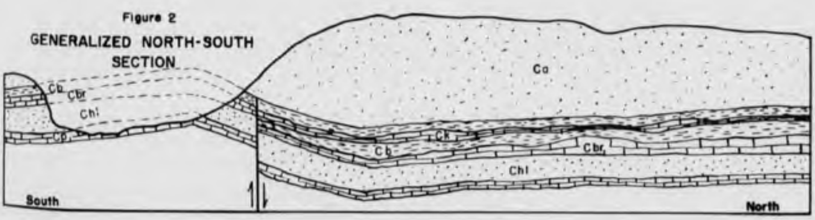

Figure 2
GENERALIZED NORTH-SOUTH SECTION

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