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CONSERVATION AND DEVELOPMENT COMMISSION
VIRGINIA GEOLOGICAL SURVEY
Wilbur A. Nelson, *State Geologist*

BULLETIN 27

OIL AND GAS POSSIBILITIES

AT

EARLY GROVE

SCOTT COUNTY, VIRGINIA

By Charles Butts

Prepared In Co-operation with the United States Geological Survey

University, Virginia
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STATE CONSERVATION AND DEVELOPMENT COMMISSION.

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LETTER OF TRANSMITTAL

COMMONWEALTH OF VIRGINIA
Virginia Geological Survey
University of Virginia

Charlottesville, Va., April 11, 1927.

To the State Conservation and Development Commission:

Gentlemen:

I have the honor to transmit and to recommend for publication as Bulletin 27 of the Virginia Geological Survey Series of reports a manuscript and illustrations of a report on *Oil and Gas Possibilities at Early Grove, Scott County, Virginia,* by Charles Butts.

The general purpose of this bulletin is to show that there is a possibility of finding gas or oil near Early Grove, Scott County, Virginia, and likewise to give a detailed section of the Mississippian rocks in which are found the salt and gypsum deposits several miles north of this point at Saltville, Virginia. This is the first publication of a detailed geological section of these beds, giving their fossils and correlating them with formations in other parts of the eastern United States.

This is one of a series of reports which will be prepared by Mr. Butts in connection with the detailed mapping of the stratigraphy of the Valley of southwestern Virginia which he is engaged in at the present time, under a cooperative agreement between the State and Federal surveys.

Respectfully submitted,
WILBUR A. NELSON,
State Geologist.

Approved for publication:

State Conservation and Development Commission
By E. O. Fippin, *Executive Secretary.*
Richmond, Virginia, April 14, 1927.

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OIL AND GAS POSSIBILITIES AT EARLY GROVE, SCOTT COUNTY, VA.

By Charles Butts.

INTRODUCTION.

This paper is designed to bring to the attention of oil operators structural and stratigraphic conditions bearing upon the possibility of oil and gas accumulation at Early Grove, Scott County, Va. Early Grove is in the Bristol quadrangle, nine miles northwest of Bristol, Va.-Tenn., just west of the Scott county line. Its location is shown on the topographic map of the Bristol quadrangle published by the United States Geological Survey. The general geology is mapped and described in the Bristol Folio, No. 59, of the Geological Survey.

The sketch map, fig. 1, accompanying this paper is based on the areal geology map of the folio named but several divisions of the Mississippian rocks not discriminated in the folio are also shown. These are based upon the writer's own observations made in 1926, in a reconnaissance survey of the valley of Virginia, for a new geologic map of the State.

The existence of an anticline, the axis of which is about one-quarter of a mile north of Early Grove, is plainly apparent on the main Bristol-Gate City road. From the axis the strata dip 10-15 degrees southeast toward the boundary fault along which various older formations, Cambrian to Devonian, are thrust over the upper Mississippian sandstones and shales of the Pennington formation, as shown on the geologic maps of the Bristol folio. Northwestward from the axis the rocks dip northwest at an undetermined degree to the axis of a syncline which is not more than a mile northwest of Early Grove. The presence and effect of this structure is indicated on the folio map by the southeastern indentation in this locality of the Newman limestone of the folio beyond the general line of the boundary between the Newman limestone and Pennington shale. This indentation is expressed by the disposition of the Newman-Pennington boundary in the vicinity. Probably this boundary west of Early Grove is located on the folio map too far north as its position is at variance with the observed dips. Its more probable position is indicated by the broken line.

The existence of the anticline is also plainly shown by the outcrops of the Fido sandstone, which is described beyond. This sandstone outcrops along the slope north of Cove Creek from Fido, northeastward, as shown on the sketch map, fig. 1, and dips below the surface near that

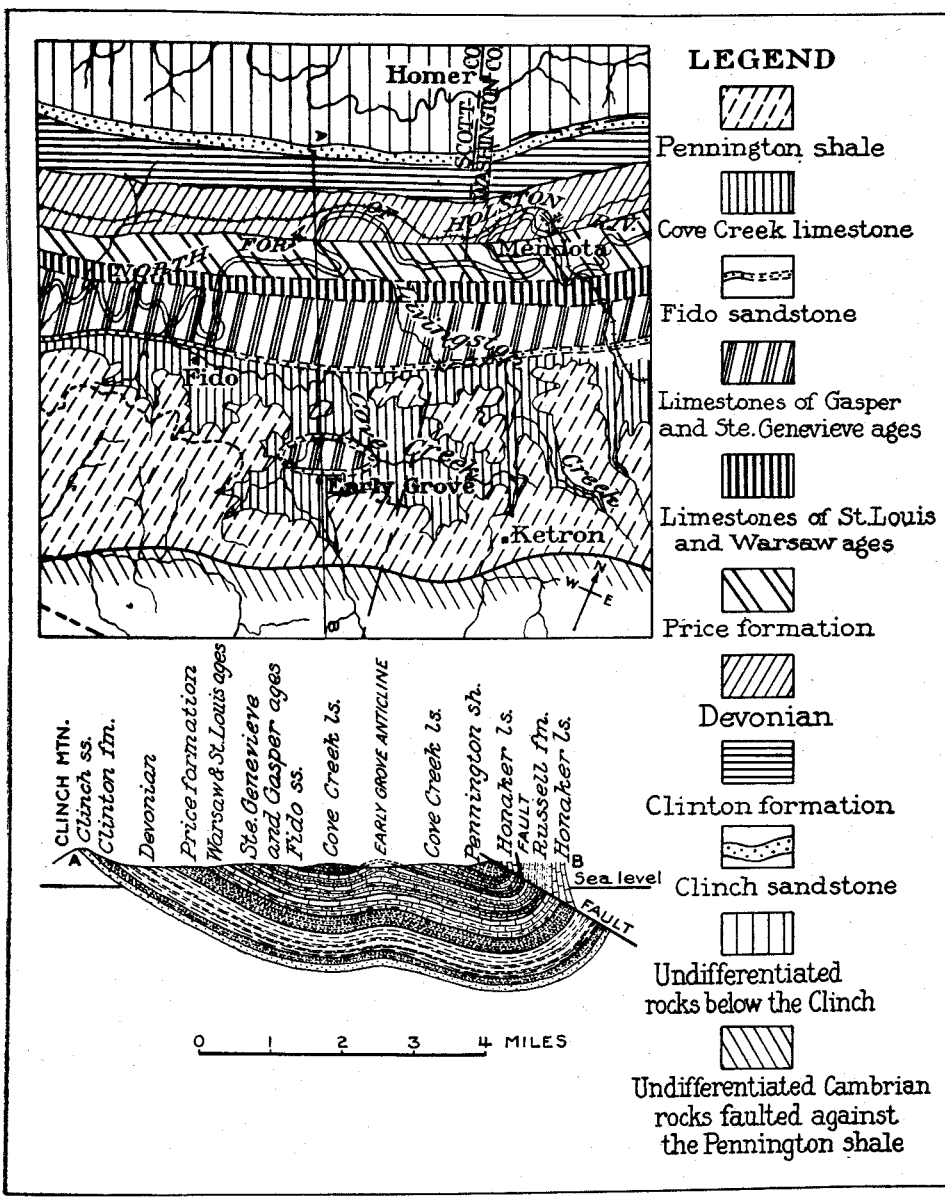

Fig. 1. Geologic map and profile section showing structure of area in vicinity of Early Grove, 9 miles northwest of Bristol, Virginia-Tennessee in the Bristol quadrangle. Based on the geologic map of the Bristol folio. The dashed line southwest of Early Grove represents the more probable position of the boundary between the Pennington and Cove Creek limestone.

line, higher beds, dipping southeastward, being exposed just southeast of the intersection of the Bristol road with the Cove Creek road.

The Fido sandstone emerging from the syncline to the north, crops out also about a half mile north of Early Grove, and bending over the Early Grove arch dips southeast beneath the surface near Early Grove and at the forks of the road about one-quarter of a mile southeast of that place. The Fido sandstone is mapped near the roads, but accurate mapping which would outline the extent of the Early Grove arch could not be done for lack of time, so the approximate outcrop of the sandstone is indicated by broken lines. The profile section accompanying the map, fig. 1, graphically illustrates the preceding description of the structure. It indicates a closure on the line of section of about 1,000 feet, which may be somewhat excessive because the section is drawn on the basis of 15 degrees dip and this may be a little too great. It is not, however, less than 10 degrees.

The rocks of this locality which might carry oil and which would have to be penetrated in drilling are shown in the following descriptive section and in the columnar section, fig. 2. This section was studied and measured just northwest of Greendale along the State highway from Abingdon, Washington County, to Lebanon, Russell County. The section above the Price formation is exposed along the road where it follows Greendale Creek between Holston River and Greendale. The exposure is nearly continuous and the dip is nearly constantly 30 degrees to the southeast. The part of the section below the limestone of Warsaw age extends one and one-quarter miles along the State road northwestward toward Little Moccasin Gap. The exposures here are not so continuous as southeast of the river, but the Devonian part of the section is nearly all exposed either in the road cuts or in a parallel ravine 500 feet west of the road. Although the Price formation is not fully exposed along this road, its general character is well known from exposures at many other localities, in the region. As this Greendale-Holston section is across the same belt of outcrop 19 miles northeast of Early Grove, it is substantially the same as the section at that place. The examination of the section was sufficiently detailed both as to lithology and fossils to warrant the following provisional subdivisions and correlations of the Devonian and Mississippian rocks in the belt of outcrop extending along the southeastern flank of Clinch Mountain from Saltville to the Virginia-Tennessee State line.

GEOLOGIC SECTION.

Section of Mississippian and Devonian formations along State road from Greendale to one and one-half miles north of Holston River in the Bristol Quadrangle, Washington County, Virginia.

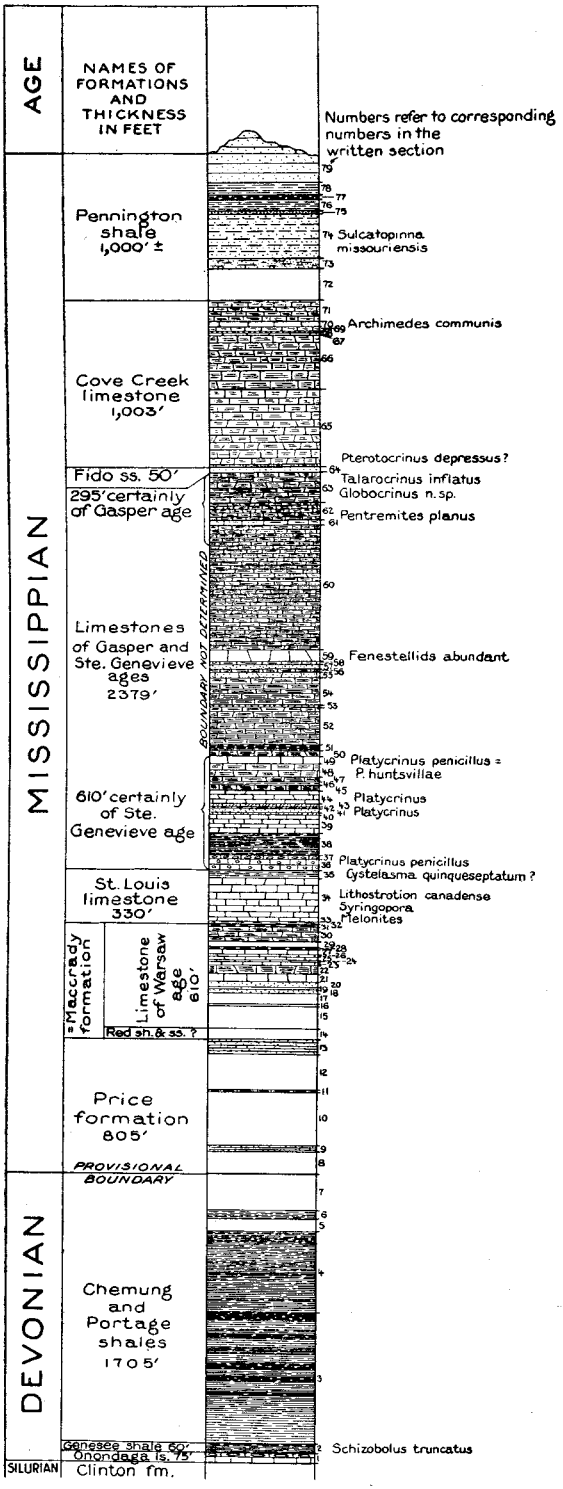

Fig. 2. Columnar section showing the sequence, character, and thickness of geologic formations at Early Grove, Virginia.

MISSISSIPPIAN FORMATIONS.

Pennington shale (top not reached in this section nor preserved anywhere in region):

		FEET	
79.	Sandstone, bluish, fine-grained, weathers to shale.	165	
78.	Shale	80	
77.	Shale, red	20	
76.	Shale	60	
75.	Sandstone, red	10	
74.	Sandstone, with calcareous and fossiliferous layers. *Diaphragmus elegans, Chonetes chesterensis, Pugnoides* sp?, probably undescribed. *Sulcatopinna missouriensis*	250	
73.	Sandstone, shaly, reddish	50	
72.	Not exposed. Probably shale	230	
	Total Pennington shale		865

Cove Creek limestone:

71.	Limestone, argillaceous, weathering to shale	115	
70.	Limestone, crinoidal, cross-bedded, *Archimedes communis*	20	
69.	Limestone, argillaceous	20	
68.	Sandstone, red	10	
67.	Limestone, fragmental. *Zaphrentis, Pentremites, Pterotocrinus* plates, Bryozoa	8	
66.	Limestone, thick-bedded, argillaceous	330	
65.	Limestone, thick-bedded, bluish, compact, slightly to highly argillaceous, the purer layers white on exposed and weathered surfaces making conspicuous displays on Cove Creek and generally along its outcrop. At bottom 5-10 feet highly fossiliferous with abundant *Pterotocrinus* plates, probably *P. depressus*. Also *Pentremites* and Bryozoa	500	
	Total Cove Creek limestone		1003

Fido sandstone:

64.	Sandstone, thick-bedded, coarse, rather soft, reddish or brownish	50	
	Total Fido sandstone		50

Limestones of Gasper and Ste. Genevieve ages (boundary not determined):

63. Limestone, thick-bedded somewhat argillaceous,

		FEET
	highly fossiliferous, *Pentremites planus, P. welleri, Globocrinus* n. sp., *Talarocrinus inflatus*..	180
62.	Limestone, more or less argillaceous, lower part, crinoidal, *Pentremites planus*	115
	(Nos. 62 and 63 certainly of Gasper age.)	
61.	Limestone, thick-bedded, ferruginous, reddish, highly crinoidal	30
60.	Limestone, largely highly argillaceous, weathers to shale, some layers crowded with fenestellid Bryozoa	700
59.	Limestone, thick-bedded, gnarly, ferruginous, red, sandy. A mass of curled fenestillid Bryozoa fronds	60
58.	Limestone, argillaceous, shaly.....	10
57.	Sandstone, soft-brown, stained red on joint faces, looks like hematite.....	30
56.	Limestone, shaly	15
55.	Limestone, sandy with coarse crinoidal layers...	30
54.	Limestone, thick-bedded, argillaceous, shaly.....	165
53.	Sandstone, bluish, fine-grained, calcareous.....	2
52.	Limestone, argillaceous, probably weathers to shale like No. 60.....	280
51.	Shale, weathered argillaceous limestone.....	50
50.	Limestone, thick-bedded argillaceous.....	50
49.	Limestone, coarse crinoidal, *Platycrinus penicillus (huntsvillae)*	30
48.	Limestone, thick-bedded argillaceous.....	82
47.	Limestone, shaly	30
46.	Shale	15
45.	Limestone, thick-bedded, breaks down into shaly debris	30
44.	Limestone, medium thick-bedded, rather coarse, with quartz grains, *Platycrinus penicillus* bases in bottom	80
43.	Limestone, coarse, crinoidal, cross-bedded, *Hydrieonocrinus* spines	15
42.	Limestone, argillaceous, shaly.....	5
41.	Sandstone, evenly bedded, soft, reddish.....	30
40.	Limestone, sandy, *Platycrinus penicillus* bases....	5
39.	Limestone, medium coarse crystalline, (fragmental crinoidal), bluish gray.....	110
38.	Shale, probably weathered argillaceous limestone.	150
37.	Limestone, full of platy chert nodules arranged in layers 1 inch thick.....	15

		FEET	
36.	Limestone, thick-bedded, coarsely crystalline, with nodules of black chert, *Platycrinus penicillus* bases and spiny stem plates abundant. *Cystelasma.* Small *Productus* apparently related to *P. parvus*	65	
	(Nos. 36 to 49 certainly of Ste. Genevieve age.)		
	Total limestones of Gasper and Ste. Genevieve ages		2379
	St. Louis limestone:		
35.	Shale	50	
34.	Limestone, very dark to black, thick-bedded medium coarse crystalline. *Syringopora* common. *Melonites* plates and *Archeocidaris* spines. Spiny stem plates similar to those of *Platycrinus penicillus* rare, observed only 65 feet above bottom, *Productus* and *Orthotetes*	264	
33.	Limestone, argillaceous, shaly	16	
	Total St. Louis limestone		330
	Limestone of Warsaw age:[1]		
32.	Shale, dark, soft	14	
31.	Shale, black	1	
30.	Limestone, argillaceous, shaly	100	
29.	Not exposed, depression in surface, probably black shale	30	
28.	Shale, black, fossils, *Tetracamera,* probably new species	10	
27.	Limestone, argillaceous, compact. Probably weathers to shale	20	
26.	Limestone, shaly	15	
25.	Limestone, compact, argillaceous, thick-bedded	20	
24.	Limestone, laminated	5	
23.	Limestone, compact, rather thick-bedded	30	
22.	Limestone, shaly, fossiliferous	50	
21.	Limestone, coarsely crystalline, bluish	50	
20.	Sandstone	25	
19.	Limestone, argillaceous	5	
18.	Sandstone, coarse-grained, cross-bedded, weathered and leached calcareous sandstone	20	
17.	Not exposed	60	

1. Nos. 14 to 32, inclusive, are believed to be the same as the Maccrady formation of Stose at Maccrady, near Saltville.

		FEET	
16.	Limestone, argillaceous	10	
	Total of beds of known Warsaw age	465	
15.	Not exposed, river bed, probably of Warsaw age	145	
	Total of beds of known and probable Warsaw age		610

Not exposed in river bed:

14.	Shale and sandstone, partly red, basal part of Maccrady formation of Stose, in here if present in this section	60	60

([redacted])

Price formation:

13.	Sandstone exposed in south bluff of river ½ mi. west of Holston River bridge about	80	
	The top of this sandstone is supposed to be about the same as the sandstone reported at the bottom of the north pier of the river bridge. Warsaw fossils were found not more than 100 feet above the top of the sandstone at the top of the bluff.		
12.	Not exposed	230	
11.	Shale and thin sandstone	15	
10.	Not exposed	315	
9.	Sandstone	30	
8.	Not exposed	135	
	Total Price formation		805
	The boundary between the Price formation and the Devonian in this section and in this region generally, has not been precisely determined. In folios of the U. S. Geological Survey covering this region, the upper Devonian rocks have been grouped with the early Mississippian into the Grainger shale.		

DEVONIAN FORMATIONS

Portage and Chemung shales:

7.	Not exposed; sandstone and shale with Devonian fossils ½ mi. S. of Zenobia probably in this interval	215	
6.	Shale	30	
5.	Not exposed, probably shale	60	
4.	Shale, soft pinkish to yellowish as weathered, probably a predominantly green clay shale in the fresh conditions	500	

	FEET	
3. Shale	900	
The upper several hundred feet of this mass is composed of stiff green siliceous shale with thick layers of densely black fissile shale. This part of the section is exposed in a ravine 500 feet west of the State highway beginning about ½ mile north of Holston Postoffice.		
Genesee shale:		
2. Shale, black, fissile, *Schizobolus truncatus,* about	60	
Unconformity (Marcellus, Hamilton, and Tully absent).		
Onondaga limestone:		
1. Limestone cherty, *Orthotetes pandora, Chonetes acutiradiata, Chonetes (Eodevonaria) arcuata, Anoplia nucleata. Spirifer duodenaria, Amphigenia curta? Anoplotheca acutiplicata? Platystoma lineata, Bollia ungula,*[1] *Bythocypris favulosa,*[1] *Octonaria stigmata.*[1] Called Hancock limestone in the Bristol folio.....	75	
Total Devonian.....		1840
Total Mississippian and Devonian.....		7942

SILURIAN ROCKS.

Clinton formation:

Shale and sandstone.

DESCRIPTIONS OF FORMATIONS.

The following brief descriptions will supplement the preceding section.

DEVONIAN FORMATIONS.

ONONDAGA LIMESTONE.

The rocks identified as Onondaga limestone consist of sandstone at top, 5 feet thick, underlain, as far as exposed, by solid chert and cherty limestone about 70 feet thick. Conditions did not permit accurate measurement. This section is exposed in a ravine north of the road to Rillford and ½ mile east of the main road through Little Moccasin Gap. From this place, species of fossils listed in No. 1 of the detailed

1. Same forms as identified by Kindle as these species. Kindle, E. M., U. S. Geol. Survey Bull. 508, 1912.

section p. 9 were collected. The fossils listed and others both from this locality and from the same horizon elsewhere are Onondaga species only and, as collections were made from beds as low as 15 feet above the bottom, it is believed that the full thickness of the limestone described under this head is of Onondaga age.

UNCONFORMITY.

As the black shale overlying the Onondaga limestone is of Genesee age there is here a break in the stratigraphic succession due to the absence of beds of Marcellus, Hamilton, and Tully ages, aggregating perhaps a maximum thickness 1,500 to 2,000 feet in Pennsylvania and New York. In the vicinity of Hilton Station, 24 miles southwest of the section here described, the Genesee is in practical contact with the Clinton formation, only a few feet of sandstone intervening that may be of Lower Devonian age. In the vicinity of Hayter Gap about 8 miles along the same outcrop northeast of the section, apparently the Hamilton and Marcellus, as indicated by such fossils as *Leiorhynchus limitare* and *Tornoceras uniangulare,* are both represented.

GENESEE SHALE.

The Genesee is a black fissile shale, seemingly about 60 to 75 feet thick, overlying the Onondaga limestone. This shale is assigned to the Genesee both on account of its lithologic character and on account of its fossils, particularly on account of the common occurrence of *Schizoblus truncatus,* which is regarded as an index fossil of the Genesee. Associated with *Schizoblus* in a collection obtained on the slope of Clinch Mountain about ½ mile northwest of Hilton are abundant specimens of *Styliolina fissurella* and occasional conodonts of the genus *Hindeodella.*

PORTAGE AND CHEMUNG SHALES.

The following description applies to the section along the State road north of Holston. Immediately overlying the black shale of the Genesee near the road north of Holston there is exposed a small thickness of green shale. Immediately succeeding this green shale there is about 300 feet not exposed but almost certainly green shale and probably also including layers of black shale such as is present still higher in the section. This 300 feet is the lower part of No. 3 of the sections. Above the unexposed part there is 600 feet partly exposed, in a ravine 500 feet west of the road in the space from one-half to about three-fourths of a mile north of Holston. This is the upper part of No. 3. It is composed of alternating beds of fissile black shale, and stiff green siliceous shale. The green siliceous shale is typical of the Portage shale throughout its extent from southwestern Virginia to central Pennsylvania. Above the alternating black and green shale is a fully exposed thickness

of about 500 feet of shale, No. 4 of the sections, which weathers to a soft pale pinkish yellow condition. In the fresh condition this is probably a green clay shale. It is persistent along Poor Valley southwest to Big Moccasin Gap and is commonly exposed in highway and railroad cuts. There is still about 300 feet up to the assumed boundary between the Devonian and the Mississippian. This is mostly unexposed, but shows about 30 feet of green shale in the lower part. No fossils have been found in this mass of shale in Poor Valley above the Genesee except at the top as described below. Its Upper Devonian age is however known from its lithologic character, stratigraphic position, and relations to fossiliferous formations above and below it.

As just intimated, the location of the boundary between the Devonian and Mississippian in the section north of Holston has not been determined. In the road one-half mile south of Zenobia, which is 7 miles along the Devonian outcrop southwest of Holston, there are green shale and sandstone with fossils regarded as Upper Devonian in age that crop out on the northwest flank of Pine Mountain the crest of which is occupied by the outcrop of beds of early Mississippian age as described below. The fossils found by the writer near Zenobia and Alum wells are a large species of *Camarotoechia* of the *C. sappho* type but identified by Joel Swartz [1] as *C. orbicularis*. Swartz also reports *Productella histricula, Spirifer disjunctus* and *Leiorhyncus* cf. *L. mesacostale* at this locality so there seems to be grounds for the provisional location of the Devonian-Mississippian boundary as high at least as the horizon of these fossils and the boundary is located in the section north of Holston at what is judged to be the approximate position of the fossil bearing sandstone.

MISSISSIPPIAN FORMATIONS.

PRICE FORMATION.

The Price formation, next overlying the Devonian in southwest Virginia, is but little exposed in the section near Holston except the upper 80 feet or so, composed of rather thick-bedded sandstone, which is exposed in the south bluff of the river just south of Holston. The formation is well exposed in other places, however, as in the gap through Pine Mountain at Hilton occupied by the Bristol-Gate City road, in a road cut about three-fourths mile southeast of Big Moccasin Gap, and along the Carolina, Clinchfield, and Ohio Railroad through the gap of Cowan Creek 6 miles west southwest of Gate City in the Estillville quadrangle. As exposed in these places the formation is composed of shale and sandstone. The upper one-half or thereabouts of the formation is predominantly sandy and there is at the top a persistent bed of sandstone 50 to 80 feet thick (No. 13 of the detailed section) with locally at

1. Swartz, Joel H. Age of the Big Stone Gap shale of Southwestern Va. Am. Jour. Sci. 5th Ser., Vol. 12, No. 72, pp. 522-531 Dec. 1926.

least a thin layer of quartz pebble conglomerate at bottom. Any of these sandstones or sandy beds would function as reservoirs for oil or gas. The lower half of the formation is predominantly green clay shale which includes relatively thin beds of sandstone.

As delimited in the State road section just north of Holston, assuming a constant southeast dip of 30 degrees, the Price formation is 805 feet thick. In the Cowan Branch section 6 miles west—southwest of Gate City where the formation is largely exposed, and where conditions for measurement are exceptionally good, the thickness is about 950 feet.

Fossils as listed below have been collected from the Price formation at various localities in the southwestern counties of the State, but exhaustive collecting has not been done and the list is probably only a partial representative of the total fauna.

Taonurus caudigalli, Fenestella compressa, F. herrickana, F. cf. *F. tenax, Cystodictya lineata, C. ziggag, Rhipidomella diminutiva?, Orthotetes crenistria, Chonetes shumardanus, C.* sp. 1, *C.* sp. 2, *Productus fernglenensis, P. samsoni?, P. shumardianus, Pustula* sp?, *Leiorhynchus* sp?, *Spirifer biplicatus* Herrick not Hall, *S.* cf. *S. marionensis* Herrick Bull. Denison Univ., vol. 3, Plate 6, figs. 2-5, *Syringothyris* sp? common, *Pseudosyrinx gigas, Reticularia pseudolineata, Ambocoelia* sp? *Spiriferina depressa, S. octoplicata?, S. subelleptica? S.* sp? cf. Weller. Mon. Pl., 35 figs. 39-40, *Athyris lamellosa, Cliothyridina* sp?, *Leda* sp?, *Conocardium pulchella, Aviculopecten* sp?, *Cypricardinia scitula, Schizodus chemugensis?, Allorisma consanguinatum, Bellerophon cyrtolites* Hall. Not a *Bellerophon* but probably a *cyrtolites, B. (Euphemus) galericulatus* Winchell, *Loxonema* sp?.

Most of the fossils of the above list are common species of the New Providence formation of eastern Kentucky, Middle Tennessee and of the equivalent Cuyahoga and Logan formations of Ohio. The *Taonurus* is especially significant, as it is the most abundant fossil of the New Providence formation along the western escarpment of the Cumberland plateau, just east of the Blue Grass region of central Kentucky, where this fossil is present in nearly every sandy layer of the New Providence throughout its full thickness of about 600 feet. Hence the Price formation is correlated with the New Providence and with the Cuyahoga and Logan.

RED BEDS.

Lower Part of Maccrady Formation.

At Saltville and northward the Price formation is overlain by about 60 feet of red and green shale and red and green sandstone composing the basal part of the Maccrady formation of Stose,[1] named from the

1. Stose, George W., Geology of the salt and gypsum deposits of Southwestern Virginia, U. S. Geol. Survey Bull. 530, pp. 232-255, 1913.

town of Maccrady, near Saltville. This part of the Maccrady has not been recognized at Holston nor southwestward along the belt of Mississippian rocks southeast of Clinch Mountain, possibly because its outcrop is not exposed. If present in the section where crossed by the State highway northwest of Greendale it lies beneath the bed of Holston River. No fossils have been found in these reddish clastic beds in this belt but at Sunbright, Scott County, at the south end of Powell Mountain, red beds 30 feet thick immediately beneath the St. Louis limestone with *Lithostrotion proliferum* are abundantly fossiliferous having yielded a number of the New Providence species listed on p. 12, including *Taonurus caudigalli.* This apparently establishes the New Providence age of the red beds. It follows that they are separated from the limestone of Warsaw age by an unconformity due to the absence of any representative of the Keokuk limestone of the typical Mississippian section.

LIMESTONE OF WARSAW AGE.

Upper Part of Maccrady Formation.

The rocks included under this head consist mostly of argillaceous limestone, which weathers to shale or shelly calcareous rock. There are a few layers of purer limestone and two beds of sandstone, Nos. 18 and 20 of the sections. At the top is a thin bed of black shale and 50 to 95 feet lower another bed 10 feet thick. These are beds 28 and 31 of the sections. On Smith Creek, five miles west of Greendale, and about one-half mile west of Craig's Mill, both beds are fairly well exposed, separated by about 50 feet of shaly limestone. The upper bed on Smith Creek is about 10 feet thick and is reported to be petroliferous.

The thickness of the limestone is 465 feet, and that of the unexposed beds (No. 15 of the section) which are probably of the same age, 145 feet, making a total of 610 feet.

This limestone is abundantly fossiliferous but only a little collecting has been done. The following species have been identified:

Michelinia sp?, *Anisotrypa tuberculata, Fenestella serratula, Fenestralia sancti-ludovici, Hemitrypa proutana?, Polypora biseriata, P. varsoviensis, Rhombopora* sp?, *Cystodictya lineata, Productus altonensis, P. ovatus?, P.* n. sp. large coarse-ribbed strongly spinose, *Camarotoechia mutata, C.* sp?, *Tetracamera* n. sp., *Spirifer bifurcatus, S. keokuk?, Spiriferina* aff? *S. salemensis, Athyris* sp., *Aviculopecten* 3 or more sp., *Allorisma* sp?.

The above listed fossils constitute a good Warsaw fauna, all the specifically identified forms occurring in the Warsaw elsewhere, and some, like *Anisotrypa tuberculata, Fenestralia sancti-ludovici, Hemitrypa proutana,* and *Productus altonensis,* being apparently confined to the

Warsaw, while *Spirifer bifurcatus* is not recorded from older formations although it occurs in the succeeding St. Louis limestone. Ulrich in personal communcation expresses the belief that *Polypora biseriata* and *P. varsoviensis* are also nearly or quite limited to the Warsaw, although appearing in lists of Keokuk fossils as determined by some geologists. According to the writer's own observations *Spirifer keokuk* is also most common and abundant in the Warsaw of central Kentucky and Tennessee, if not indeed confined to that formation.

The red shale and sandstone immediately overlying the Price formation above described and the limestone of Warsaw age constitute the Maccrady formation of Stose [1] at its type locality (Maccrady) 2 miles northeast of Saltville. However, the Maccrady of the Big Stone Gap region of Wise County [2] and elsewhere in southwest Virginia corresponds only to the basal red part, and it is doubtful if the 800 feet of red shale of Pulaski and Montgomery counties originally named by Campbell [3] the "Pulaski shale," and for which he [4] later adopted Stose's name Maccrady because Pulaski was preoccupied, includes any representative of the limestone of Warsaw age, as does the typical Maccrady. For reasons already stated, p. 13, the present writer believes that the red beds, being of New Providence age, and the overlying limestone of Warsaw age should not be included together in the same formation, and that if the name Maccrady is to be retained its application should be restricted to the red beds at base.

ST. LOUIS LIMESTONE

Overlying the Warsaw limestone is 330 feet of mostly dark to black, thick-bedded rather coarsely crystalline limestone carrying the corals *Lithostrotion canadense* and *L. proliferum* in a few places, and everywhere a species of *Syringopora* which is also associated with the *Lithostrotion* where that fossil occurs. Another fossil is *Melonites,* which does not seem to be recorded from post-St. Louis formations. *Lithostrotion canadense* was found about one-fourth mile northeast of Ravens Nest and 4½ miles northeast of Mendota in the Bristol quadrangle and in the small patch of limestone in the triangular area erroneously mapped as Grainger shale in the Estillville quadrangle 2 miles southeast of Gate City. A single coralite of *L. proliferum* was found in Allison Gap at Saltville. There can be no doubt as to the St. Louis age of this limestone.

LIMESTONES AND OTHER ROCK FORMATIONS OF STE. GENEVIEVE AND GASPER AGES.

These two are treated together because no satisfactory horizon at which to locate a boundary between them has as yet been de-

1. Stose, G. W., loc. cit.
2. Stose, G. W., Va. Geol. Surv. Bull. 24, 1925.
3. Campbell, M. R., Geol. Atlas U. S., Pocahontas folio No. 26, 1896.
4. Ibid. Va. Geol. Surv. Bull. 25, Valley coal fields of Va., p. 28, 1925.

termined in this region, although a boundary could doubtless be established by adequate investigation. At the bottom are over 600 feet of limestone and shale carrying the index fossil of the Ste. Genevieve, *Platycrinus penicillus (huntsvillae)* both the spiny stem plates and the tricarinate bases, which are fairly plentiful in the purer limestone layers. At top are 300 feet or so of limestone carrying *Talarocrinus* and other guide fossils of the Gasper limestone, so that the Ste. Genevieve and Gasper ages of the whole mass are definitely proven.

At the bottom is 65 feet, of thick-bedded, coarsely crystalline or fragmental drab limestone overlain by 15 feet of very cherty limestone with black chert arranged in parallel layers of flat nodules 1 inch thick. These are beds Nos. 36 and 37 of the sections. These beds are followed above by nearly 500 feet of shale, probably weathered argillaceous limestone, argillaceous limestone, coarse crinoidal limestone, including a bed of coarse sandstone, No. 41, 30 feet thick, 350 feet above the bottom. The top bed of this certainly Ste. Genevieve part of the combined formations is a coarse crinoidal limestone, 30 feet thick, No. 49 of the sections. Above this layer for a thickness of 1500 feet the beds are predominantly argillaceous limestone which weathers to a shaly condition through solution of the lime. There is one thick bed of fossiliferous limestone, No. 59 of the sections, and just below it a bed of soft brown sandstone 30 feet thick, No. 57 of the sections. At the top of the mass is 180 feet of less argillaceous fossilferous limestone, its fossils including several distinctively Gasper species.

Besides *Platycrinus penicullus (huntsvillae),* remains of which are fairly common throughout the lower 600-700 feet at least of these limestones of Ste. Genevieve and Gasper ages, there have been collected in the lowest bed (No. 36 of the sections) *Cystelasma,* probably *C. quinqueseptatum* and a small productus similar to *P. parvus.* At the same horizon in other localities *Productus inflatus* occurs abundantly in oolitic limestone. The *Platycrinus* and *Cystelasma* are sufficient evidence of the Ste. Genevieve age of the including beds. The oolitic limestone is another character by which the Ste. Genevieve throughout Kentucky, Tennessee, and Illinois can be distinguished from the St. Louis limestone, which is nowhere oolitic. At the top of the limestones of Ste. Genevieve and Gasper ages bed No. 63 of the sections has yielded *Pentremites planus, Talarocrinus inflatus, T. ovatus,* and *Globocrinus* n. sp., with 16 arms, instead of 18, as in *G. unionensis,* the type of the genus. Otherwise the Virginia species agrees with the type. On the Bristol-Gate City road at the bend by the church and big sink holes 1 mile southeast of the Holston River bridge and 2 miles southeast of Hilton, is a good exposure of this upper Gasper horizon just beneath the Fido sandstone the same as in the State road, as shown in the sections 63 and 64. At the above described exposure southeast of Hilton

the following named fossils were collected: *Zaphrentis spinulosa?* *Pentremites planus, P. pyriformis, P. welleri* or *P. lyoni, Talarocrinus inflatus, T. sexolbatus, Globocrinus* n. sp. as described above, *Zeacrinus,* cf. *Z. manniformis, Meekopora?, Lyropora* sp.?, *Glyptopora* sp.?, *Productus inflatus?, Spirifer pallaensis?, Spiriferina spinosa, Reticularia setigera, Composita trinuclea,* and *Cliothyridina sublamellosa.*

The species of *Pentremites* and of *Talarocrinus* named are not known to occur anywhere below the Gasper limestone, and may be taken as adequate evidence of the Gasper age of the upper several hundred feet of the 2379 feet here correlated with the Ste. Genevieve and Gasper limestones.

FIDO SANDSTONE *(new name).*

The Fido sandstone is a coarse, friable, brown to reddish sandstone about 50 feet thick. It is known to extend from a point 5 miles west-southwest of Gate City to the road between Lindell and Holston River in the Abingdon quadrangle, and probably extends nearly the entire length of the Mississippian trough southeast of Clinch Mountain. It is exposed at several places along the State road from the curve 1 mile southeast of Holston River bridge to the vicinity of Fido, from which locality it is named. It is also well exposed where crossed by the road on opposite sides of the anticlinal axis at Early Grove. The horizon of the Fido sandstone may be that of the Cypress sandstone or that of the Hardinsburg sandstone of the Mississippi Valley region, but for reasons stated under the next head it is believed most probable that the Fido corresponds to the Hardinsburg rather than the Cypress sandstone.

COVE CREEK LIMESTONE *(new name).*

The Cove Creek limestone is here named from Cove Creek, 5 miles southwest of Mendota, in the Bristol quadrangle. The formation is excellently exposed along the creek and conspicuous from the Bristol-Gate City road. It is also fully exposed along the road northwest of Greendale beginning 3200 feet northwest of the village and continuing 2100 feet northwest to the outcrop of the Fido sandstone. The Cove Creek is predominantly argillaceous limestone like the limestones of Warsaw, Ste. Genevieve, and Gasper ages below it. The lower 500 feet (No. 65 of the sections) has a considerable proportion of fairly pure limestone conspicuously exhibited along Cove Creek and elsewhere on its outcrop. Some coarse-grained crinoidal limestone occurs, as beds Nos. 67 and 70, and one bed of red sandstone was noted, bed No. 68. Much of the argillaceous limestone weathers to shale through leaching of the limey matter.

The Cove Creek is generally unfossiliferous, but a few beds are an exception. At the bottom in the section northwest of Greendale, in

immediate contact with the Fido sandstone, is about 5 feet of impure sandy and argillaceous limestone crowded with the wing plates of *Pterotocrinus,* apparently *P. depressus.* Higher in the formation, in beds 67 and 70, *Archimedes communis* and unidentifiable fragments of other fossils occur. This meager fossil evidence points to the Glen Dean age of the Cove Creek limestone, and as the Glen Dean lies next above the Hardinsburg sandstone it is thought that the Fido sandstone represents the Hardinsburg. The Cove Creek is also probably about equivalent to the Bangor limestone of Alabama and the Fido sandstone to the Hartselle sandstone next beneath the Bangor.

The formations from the limestone of Warsaw age to the Cove Creek limestone, both inclusive, correspond to the Newman limestone of the Bristol and Estillville folios.

PENNINGTON SHALE.

Above the Cove Creek limestone is 1000 feet of clastic rocks, mainly shale and sandstone, some of which is calcareous. This mass corresponds in position to the Pennington shale, which crops out along the Cumberland escarpment of Cumberland Mountain from Bluefield, West Virginia, to Cumberland Gap, Tennessee, and was named by Campbell from Pennington Gap in Lee County. Some beds of the Pennington are highly fossiliferous, although only a few species have been found. The specifically identified forms are *Chonetes chesterensis, Diaphragmus elegans, Dielasma arkansana, Spirifer leidyi, Eumetria verneuiliana* and *Sulcatopinna missouriensis.* In a collection ½ mile northwest of Greendale *Pugnoides,* probably a new species, is common. There are also unidentified species of *Orthotetes, Composita, Sphenotus, Aviculopecten,* and *Myalina.* The most significant form for correlation is *Sulcatopinna missouriensis,* which occurs in every collection from 5 miles southwest of Gate City to the road northwest of Greendale. In southern Illinois and western Kentucky this species is characteristic of the Menard and Clore limestones of the upper part of the Chester group, being much more common in the Menard. This fossil, together with the stratigraphic position of the Pennington, justifies its provisional correlation with that part of the Chester group of Mississippi Valley including and overlying the Menard limestone and possibly going down as far as the base of the Tar Springs sandstone.

CONDITIONS AFFECTING THE OCCURRENCE OF OIL AND GAS.

In this connection it may be noted that the region is underlain by a large body of black shale of Devonian age which, while not now petroliferous, was, judging from its similarity to the black shale probably of the same age in Kentucky, originally petroliferous. The black shale at the top of the limestone of Warsaw age (Nos. 28, 29, and 31

of the sections) is reported to be now petroliferous at least locally. All the other Mississippian formations that underlie the Early Grove region carry highly fossiliferous beds from which oil and gas could have been derived. The great synclinal belt flanking Clinch Mountain on the southeast side was subjected to high pressure in the formation of the syncline, sufficient doubtless to have caused distillation of oil from the fossiliferous limestones and sandstones and from the carbonaceous black shales. At the same time the pressure and compression were relieved by the great boundary fault on the southeast so that there was no great crushing and fracturing of the rocks affording avenues for escape of the oil nor a great rise in temperature of the rocks which would tend to vaporization and easy escape of oil in the gaseous form. However, the fixed carbon of the coal in Powell Mountain 18 miles northwest of Early Grove, which is the nearest coal to that place is above 63 per cent, pure coal basis, and so somewhat above the 60 per cent that is regarded by David White [1] as the maximum carbon content of the coal of the Appalachian coal field compatible with the occurrence of oil in that region. This must be accepted as an unfavorable condition bearing on the possibility of oil at Early Grove or elsewhere in southwest Virginia. The chance is better for gas.

The anticlinal structure at Early Grove seemingly could have trapped any oil that might have been generated in its vicinity and prevented it from escaping along the bedding and it might have been held in the rocks until the present time. There are several beds of coarse sandstone in the section below Early Grove that seemingly are of high porosity and so would serve extremely well as reservoirs for oil or gas. Beds 13, 18, 20, 41, 55 and 57 are examples. Probably some of the coarse crinoidal limestone beds would be good reservoirs also. The lowest of these beds, No. 13, would be penetrated by a well about 3500 feet deep at Early Grove.

It is not to be concluded from this discussion that the writer believes there is more than a faint chance for oil in paying quantities in this region nor that drilling is recommended; but it is the purpose of this paper to call attention to the fact that the chance is better here than anywhere else in southwest Virginia, and that if anyone is determined to drill in that region, as some are, this location is suggested as the most promising.

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1. White, David, Some relations in origin between coal and oil. Journ. Wash. Acad. Sci., Vol. 5, No. 6, p. 210, 1915.