VIRGINIA DIVISION OF MINERAL RESOURCES OPEN-FILE REPORT 91-1

PRELIMINARY GEOLOGIC SECTION ACROSS THE BURIED PART OF THE TAYLORSVILLE BASIN, ESSEX AND CAROLINE COUNTIES, VIRGINIA

Robert C. Milici, Kenneth C. Bayer, Phillip A. Pappano, John K. Costain,
Cahit Coruh, and Jack E. Nolde

COMMONWEALTH OF VIRGINIA
DEPARTMENT OF MINES, MINERALS AND ENERGY
DIVISION OF MINERAL RESOURCES
CHARLOTTESVILLE, VIRGINIA

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Prepared in cooperation with the
U.S. Minerals Management Service
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INTRODUCTION

The Taylorsville basin is an extensional basin of Triassic age that lies almost entirely beneath the coastal plain of northeastern Virginia and parts of adjacent Maryland (Figure 1). The southwestern end of the basin is exposed in Hanover and Caroline Counties several miles to the northeast of Richmond (Figure 2). From there, the basin extends northeastward into the subsurface beneath the Virginia coastal plain to the Potomac River and then into Maryland, as least as far as Chesapeake Bay (Wilkes and others, 1989). Judging from available well data, the Virginia part of the basin is about 120 miles long and 30 miles wide. The basin contains over 8,200 feet of sedimentary strata in northern Virginia, where it lies buried beneath 1500 to about 2000 feet of younger sediments. In places, these strata and the underlying igneous and metamorphic rocks are intruded by diabase dikes and sills of Jurassic age.

The Mesozoic basins of Virginia have been studied considerably since the middle of the last century (see Wilkes, 1988 for a detailed summary and bibliography of the Richmond basin). More recently, Weems (1980, 1981, 1986) and Goodwin and others (1985) have mapped and described the geology of the exposed part of the Taylorsville basin in detail. In addition, Cornet (1989) and Cornet and Olsen (1990) have described the Triassic flora and fauna of the Richmond and Taylorsville basins.

The west sides of the Richmond and Taylorsville basins are bounded by a major fault zone, called the Hylas zone by Weems (1974). In general, the zone is about a mile wide and

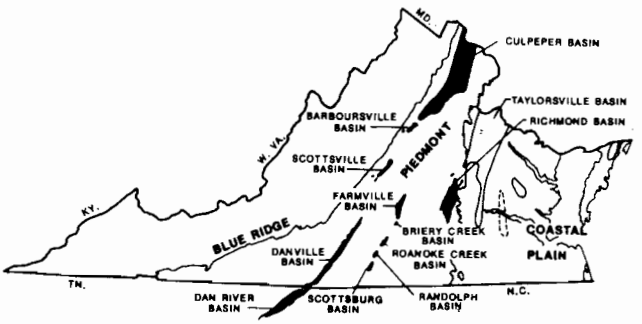

Figure 1. Mesozoic basins in Virginia.

consists of mylonite that resulted from the deformation of rocks ranging from felsic gneiss to amphibolite (Bobyarchick, 1976). The Hylas zone apparently was formed by thrusting during the Alleghanian orogeny at the end of the Paleozoic. During the Triassic, when the eastern margin of the North American continent was subjected to tensional forces, the zone was activated once again, but this time in a normal sense (Bobyarchick and Glover, 1979) so that extensional basins formed and began to receive sediment from uplifted highlands nearby.

The Hylas zone and other related deformed zones have been traced by Marr (oral communication, 1991) southward to the North Carolina line. To the north, deep reflectors beneath the section of the Taylorsville basin imaged on Vibroseis line 11A may represent the subsurface location of the Hylas zone (Plate 1). Accordingly, it is hypothesized herein that this zone of deformation extends along the west-

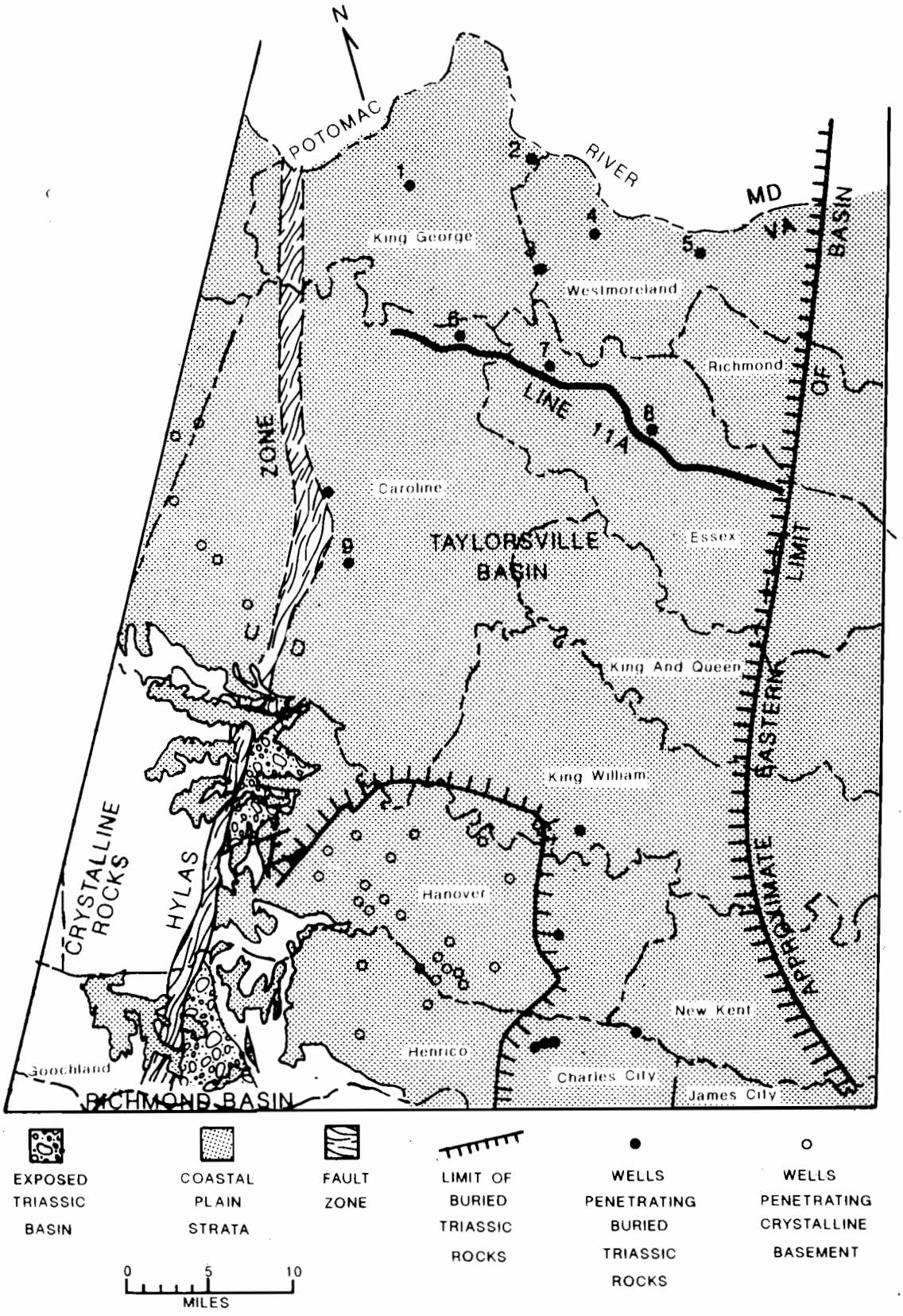

Figure 2. Location of the Taylorsville basin in northern Virginia. The west end of line 11A illustrated on Plate 1 is approximately 1 mile west of the Butler No. 1 core hole.

ern boundary of the Taylorsville basin from its exposures in the Virginia Piedmont in Caroline and Hanover Counties northeastward beneath the coastal plain. Its inferred location beneath coastal plain strata is shown on Figure 2.

The Taylorsville basin is currently an area of interest for oil and gas exploration. Texaco, in conjunction with Exxon, drilled 6 core holes in 1986 to obtain samples for study (Table 1). In 1989, Texaco drilled the W. B. Wilkins et ux No. 1 oil and gas test in Westmoreland County, Virginia to a depth of 10,135 feet. Although the hole did not contain commercial quantities of hydrocarbons, the results have encouraged Texaco to seek permits both in Maryland and in Virginia to drill additional deep tests.

A section across the buried part of the Taylorsville basin is imaged by the non-exclusive, proprietary Teledyne line 11A (Plate 1), which was purchased by the Division of Mineral Resources with funds made available under contract by the U. S. Minerals Management Service. At present, the Vibroseis data are being reprocessed at the Regional Geophysics Laboratory, Virginia Polytechnic Institute and State University, Blacksburg, Virginia. The purpose of this paper is to present a preliminary interpretation of the unreprocessed Vibroseis data and to identify some of the problems that may be resolved by reprocessing the field tapes.

STRATIGRAPHY

EXPOSED PART OF THE BASIN

The exposed part of the Taylorsville basin underlies about 50 square miles in Hanover and Caroline Counties, Virginia, several miles to the northwest of Richmond (Weems, 1980). Weems (1980, 1981, 1986) named the Triassic strata of the Taylorsville basin the Doswell Formation. He divided the Doswell into three members, in ascending order the Stagg Creek, Falling Creek, and Newfound Members. All told, the exposed part of the Doswell Formation is about 5000 feet thick and is composed almost entirely of siliciclastics, with minor amounts of coal and limestone.

Fossils studied by Cornet (1977) and Cornet and Olsen (1990) indicate that the age of the Doswell Formation is entirely Carnian (Triassic). Cornet and Olsen (1990) have revised Weems' stratigraphy based on their detailed studies of plant fossils. They conclude that, where the Stagg Creek Member of Weems (1980, 1981, 1986) was deposited upon the Petersburg Granite, the granite is not basement, but instead is a fault block that was emplaced subsequent to the formation of the basin. At the type section, plant fossils indicate that the Stagg Creek Member overlies, rather than underlies, the Falling Creek Member.

In order to coincide with the published Ashland and Hanover Academy quadrangle maps (Weems, 1981, 1986), the descriptions presented herein are in the order presented by Weems. The work of Cornet and Olsen (1990), however, strongly suggests that the stratigraphic nomenclature of the Taylorsville basin is in need of revision.

The Stagg Creek Member consists of about 800 feet of sandstone and conglomerate. Both of these lithologies contain pieces of the underlying Petersburg Granite. In one place, Weems (1986) observed an unconformable contact between the Stagg Creek and the Petersburg; elsewhere the contact is faulted and is mylonitic. Furthermore, Weems (1986) observed that the clasts in the Stagg Creek generally are not very angular; because of this he concluded that the sediment was transported into the basin by a well established drainage system and that significant fault scarps did not exist then.

The Falling Creek Member consists of about 1200 feet of sandstones, siltstones, shales, and a few coal beds and thin limestones. The siltstones and shales commonly are gray to black and have yielded fossils of pelecypods, crustaceans, fish, and reptiles (Weems, 1980, 1981, 1986; Goodwin and others, 1985). Sandstone beds tend to be fine to medium grained and flaggy. Both the upper and lower contacts of this middle member are marked by the more massively bedded sandstones of the overlying and underlying members. Weems (1986) concluded that the Falling Creek Member represented deposition in marsh and lake environments.

Goodwin and others (1985) note that the coal beds in the Falling Creek probably occur near the middle and at the top of the member. Although the coals have been mined on a small scale, there is little evidence to suggest that they have any economic potential. Goodwin and others (1985) suggest that the Falling Creek Member has some potential as a hydrocarbon source bed and, thus, the member has attracted the attention of petroleum exploration geologists in recent years.

The uppermost unit of the Doswell Formation is the Newfound Member. The Newfound Member is about 3000 feet thick and consists of a conglomerate/sandstone facies at the base overlain by a siltstone/sandstone facies. The conglomerate/sandstone facies consists of up to 1000 feet of massively bedded sandstone and conglomerate (Weems, 1986). In places, the sandstones contain petrified trunks and casts of *Araucarioxylon*. The upper part of the conglomerate/sandstone facies grades laterally into the lower part of the siltstone/sandstone facies (Weems, 1980; Goodwin and others, 1985), which may be as much as 2000 feet thick. The conglomerate/sandstone facies consists of fining-upward sequences that are interpreted to be the deposits of braided streams. The overlying facies is extensively bioturbated, probably by roots, and is interpreted by Goodwin and others (1985) to have accumulated on vegetated flood plains or under aquatic vegetation. Cobble and boulder conglomerates occur in a few places along the northwest border of the basin; their size and angularity attests to their formation by erosion of a steeply inclined fault scarp nearby.

Table 1: Locations and data for deep core holes and oil and gas tests in the northern part of the Taylorsville basin, Virginia. Core hole location 6 was not drilled; D/A equals dry and abandoned; coordinates are the 10,000-foot state plane grid.

Map No.	OPERATOR	FARM	COUNTY/QUADRANGLE COORDINATES	DATE	SURFACE ELEV. (Ft)	T.D. (Ft)	COMMENT	GEOLOGIC TOPS (Ft)
9	Texaco	Campbell #1	Caroline/Penola 117,850N; 2,333,650E	5/14/86	99.4	5550	Core Hole #1	Late Triassic, 499
6	Texaco	Butler #1	Caroline/Port Royal 175,200N; 2,389,550E	5/15/86	43.7	5500	Core Hole #2	Late Triassic, 1065
7	Texaco	Payne #1	Essex/Loretto 156,750N; 2,413,350E	6/23/86	26.8	5500	Core Hole #3	Late Triassic, 1290
8	Texaco	Ellis #1	Essex/Champlain 127,150N; 2,437,250E	8/21/86	144.2	5500	Core Hole #4	Late Triassic, 1580
4	Texaco	Bowie-Fogg #1	Wstmd/Col. Beach S. 190,372N; 2,438,804E	8/21/86	62.2	5500	Core Hole #5	Late Triassic, 1740
5	Texaco	Roberts #1	Wstmd/Stratford Hall 175,784N; 2,469,844E	8/21/86	154.1	3533	Core Hole #7	Late Triassic, 1945
2	Texaco	W. B. Wilkins #1	Wstmd/Dahlgren 218,808N; 2,427,225E	8/13/89	29.2	10135	D/A	Late Triassic, 2050
3	USGS	Oak Grove Core	Wstmd/Rollins Fork 186,609N; 2,419,969E	5/30/76	180	1380		Potomac Group, 454
1	JSC Drlg	Thompson #1	King Geo./King Geo. 223,833N; 2,389,939E	8/30/68	152.7	3029	D/A	Late Triassic, 2210

BURIED PART OF THE BASIN

The buried part of the Taylorsville basin is known from the several core holes and oil and gas tests that have been drilled through the coastal plain strata into underlying Early Mesozoic beds and from Vibroseis lines that have been surveyed by the petroleum industry across the basin. In recent years, six diamond drill core holes and one oil and gas test have been drilled into the basin by Texaco USA (Table 1). At the time of this writing, however, most of the data from the oil and gas test remain confidential and only the wire-line logs of the Texaco core holes are available for study. Completion reports on file with the Division of Gas and Oil indicate that numerous oil/gas shows occurred in the Texaco Campbell No. 1 core hole between 1182.5 feet and 3947.5 feet. In addition, possible shows were reported in the Butler No. 1 at 5348.5 feet and 5454.2 feet and in the Payne No. 1 at 5125.3 feet and 5135.7 feet. Coal beds were not reported in any of the core holes. Samples for the upper part of the Texaco W. B. Wilkins et ux No. 1 well were released to the Division of Mineral Resources and a description of them is included in this report (Appendix).

JSC DRILLING CO., THOMPSON NO. 1

An oil and gas test, JSC Drilling Company, Thompson No. 1 (Table 1) was drilled in 1968 in King George County to a reported depth of 3050 feet. Cable tool drilling commenced in April, 1968 and continued until August, 1968, when the well was geophysically logged to a depth of 3029 feet. Gas was detected in the interval between 2950 and 2960 feet. The well was treated unsuccessfully with water and sand in mid-September and drilled deeper in October and November to a depth of 3250 feet, when the tools were lost in the hole. Fishing continued until December 20, 1968 and the well was plugged and abandoned. The lower part of the hole between 3029 and 3250 feet was not geophysically logged. A summary interpretation of the driller's geophysical log is shown in Table 2 and an illustration of the portion of the well in Triassic rocks and in the lower part of the Cretaceous is shown in Plate 2. It should be noted that, in contrast with the well completion report, a single sample from the interval 3297-3307 is in the Division of Mineral Resources repository along with the other samples from the well.

Excluding this bottom sample, the well penetrated rocks of Triassic age for about 1040 feet. The contact was recognized by the driller because of a significant increase in the hardness of the strata, which he identified as "metamorphic." In addition, the gamma and neutron logs indicate that a significant lithologic break occurs at 2210. The contact is not readily picked utilizing the cuttings, however, because lithologies of the Cretaceous Potomac Group are very similar to those of the underlying Triassic.

The lithologies illustrated in Plate 2 were obtained from descriptions of the well samples made be Frank H. Jacobeen, Jr., and one of us (R. C. Milici) and are not interpreted from the logs. In contrast, lithologies illustrated for the Texaco core holes on Plate 2 are interpreted entirely from the logs because the cores were not available to us for this study.

Table 2. Operator's interpretation of drillers and geophysical log of the JSC Drilling Company, E.T. and Shirley Thompson No. 1 well (slightly modified from file copy).

STRATIGRAPHIC UNIT	TOP (Depth in feet)	BOTTOM	THICKNESS (Feet)
TERTIARY			
Nanjemoy Fm.	0	285	285
Aquia Fm.	285	457	172
CRETACEOUS			
Monmouth Fm.	457	765	308
Matawan Fm.	765	922	157
Magothy Fm.	922	1460	538
Patapsco Fm.	1460	1830	370
Patuxent Fm.	1830	2210	380
EARLY MESOZOIC			
Triassic	2210	3250 TD	1040

Note: Interval 3029-3250 was not logged geophysically; lost tools in hole at 3250; fished until December 20, 1968, without success.

In general, the Triassic portion of the Thompson No. 1 well consists of interbedded sandstones or sands and grayish-red and greenish-gray siltstones and shales. The sandstones and sands are generally very light gray, fine to coarse grained and the grains are subangular to subrounded. Feldspar and mica are common constituents. These bodies generally range from 20 to 30 feet thick and in the lower part of the well they commonly are calcareous. The younger Triassic sands, siltstones, and shales generally are only slightly calcareous or are non-calcareous. In contrast with sands in the lower part of the well, the upper parts of the younger sand bodies commonly are coarse grained or are even conglomeratic. Gamma and neutron signatures indicate that the sands are multi-storied and are very likely interbedded with thin shales. Thin limestone beds occur in three intervals, 2592-2596, 2784-2788, and between 2828 and 2869 (Plate 2). Some of the red and green siltstones and shales also are calcareous in the lower part of the well.

Shapes of the log signatures indicate the some of the sands accumulated as upward-coarsening progradational, regressive deposits, whereas other sands appear to become finer and more shaly upward. The progradational sand bodies probably represent alluvial fan deposits or fan/delta deposits that built out into standing bodies of water. The upward-

fining sand bodies are interpreted to have accumulated as bars in fluvial or deltaic channels or to have been deposited in the transgressive, shallow waters of tectonically subsiding lakes. In general, the calcareous sands, siltstones, and shales encountered below 2550 feet in the Thompson No. 1 well are considered to be more distal, subaqueous deposits than the overlying Triassic strata.

In summary, the entire sequence of Triassic strata encountered in the Thompson No. 1 well, which represents only the upper 10 percent of the section within the Taylorsville basin, is interpreted to record the final episode of basin filling and a transition from deposition in a shallow lake to deposition on an adjacent deltaic or alluvial plain.

Basalt and diabase are common in the lower part of the well and occur generally in the interval below 3100 feet. These rocks are assumed to be of Jurassic age like the others that have been dated in the region (Sutter, 1988) and, thus, are intrusive into the surrounding sedimentary rocks. Similar basalt has been reported by Texaco to occur in the core holes that they drilled and, indeed, conspicuous reflectors on the seismic line may be related to basalt or diabase intrusions (Plate 1).

TEXACO CORE HOLES

Three suites of logs were run on each of the Texaco core holes: gamma ray, caliper, neutron porosity, and density porosity; gamma ray, caliper, and sonic; and gamma ray, self potential, and focused resistivity. For the purposes of this report the gamma ray, neutron porosity, and self potential logs are illustrated for the Butler No. 1, Payne No. 1, and Ellis No. 1 core holes on Plate 3. The gamma ray, caliper, neutron porosity, and sonic logs for the upper part of the Ellis No. 1 core hole are illustrated in Figure 3. Interval velocity plots and synthetic seismograms were prepared from the sonic logs by Strata Search, Inc. (now Lauren Geophysical Processing Services), Denver, Colorado, and are illustrated on Plates 4 to 9.

The Butler, Payne, and Ellis core holes are located along the seismic cross section (Figure 1). The wire-line logs of the core holes, together with their interval velocity plots (Plates 3 - 9), were used in interpreting the seismic record section. Each of the interval velocity plots for these core holes exhibits several spikes that are significantly greater than the velocities for the underlying and overlying rocks. Some of these spikes may be related to intrusive basalt or diabase dikes and sills. Others may be related to beds of dense sandstone, sedimentary breccia, or conglomerate (border conglomerate, fanglomerate).

In the Butler core hole (Plate 5), several relatively high interval velocity spikes occur between 1800 feet and 2800 feet deep. When compared with the signature of the self-potential log for the hole (Plate 3), this zone appears to consist of numerous coarsening-upward sequences that are sugges-

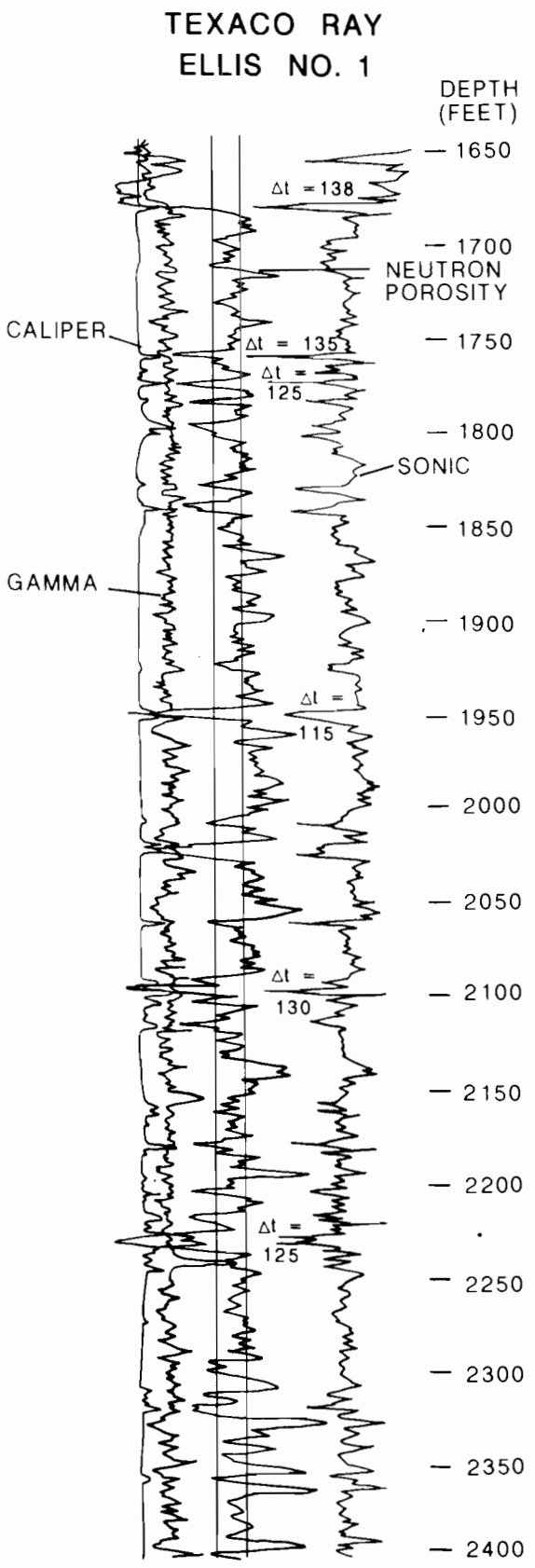

Figure 3. Texaco Ray Ellis No. 1 core hole: log evidence for coal beds in the upper part of the Triassic section.

tive of progradational deposits, such as alluvial fans.

In contrast, high interval velocity spikes at depths of about 3450, 4100, and 5100 feet very likely are related to diabase intrusives. Similar high interval velocity spikes occur in the Payne core hole (Plate 6) at depths of 4700, 4800, and 5400 feet, and in the Ellis core hole at a depth of 5200 feet (Plate 7). The latter appears to coincide with a strong reflector on the record section (Plate 1), which is tentatively interpreted as a diabase intrusion along or near the bottom of the basin.

Self-potential signatures of the Payne and Ellis core holes indicate that many of the sands fine upward and, thus, may have been deposited as point-bar sands in fluvial environments. In general, the upper part of the Triassic sections in the Payne and Ellis wells consist of numerous, relatively thin sands separated by shaly intervals. In the absence of information from the core, these zones are considered to reflect deposition on a low-relief alluvial plain or perhaps in the shallow waters of an adjacent lake, swamp, or marsh.

Although no coal was recovered from the six core holes by Texaco, transit times exhibited by several spikes on the sonic log for the Ray Ellis core hole are suggestive of coal. These spikes occur between 1650 and 2250 feet deep in the core hole (Figure 3). Transit times equal to or greater than 115 microseconds per foot occur in seven places in this interval. Each of these zones coincides with a conspicuous washout, as is indicated by the caliper log. It should be noted, however, that focused electric log readings coincident with the high transit time/washout zones are relatively low.

Gamma and neutron signatures from the Texaco core holes indicate that they contain numerous shale intervals that exhibit a relatively high radioactivity and low porosity (high hydrogen content). These intervals, also, are marked by washouts on the caliper log and exhibit relatively high transit times on the sonic logs, although these transit times are not as high as the transit times suggestive of coal beds. This evidence indicates that there is a significant amount of shale in the section that has a potential for serving as a source for hydrocarbons. Newspaper articles in the Richmond Times-Dispatch in 1991 quote Texaco spokesmen as stating the basin is more likely to produce gas than oil.

VIBROSEIS LINE 11A

Teledyne line 11A extends along U. S. Highway 17 from the town of Tappahannock, Essex County westward about 26 miles into Caroline County. About 22 miles of the line, extending westward from Tappahannock, were available for this report.

The top of the Taylorsville basin, the contact between Triassic basin fill and the overlying Cretaceous formations of the coastal plain (the postrift unconformity), is marked by a very conspicuous reflector. In general, the reflector is very gently inclined seaward, from a two-way travel time of 0.4 seconds on the western edge of the section to 0.6 seconds on the east. Similarly, the Cretaceous-Triassic contact was reported to be encountered in the Butler, Payne, and Ellis core holes at subsea elevations of -1021 feet, -1263 feet, and -1463 feet, respectively. Although the reflector is very nearly continuous, it is offset along its length by several small-displacement normal faults. This suggests that the extensional forces that formed the basin, while diminished, continued into the Cretaceous.

A conspicuous reflector appears to mark the base of the Taylorsville basin. Although it is broken in places by relatively small-scale extensional faults, this reflector is almost continuous across the eastern two-thirds of the basin. To the west, where the basin is deepest, other basal reflectors are discontinuous and appear to be offset significantly by extensional faults.

It is not certain, however, that the basal reflector beneath the eastern two-thirds of the basin marks the contact between Triassic sedimentary rocks and the underlying crystalline rocks of the Piedmont. Comparison with work done in other Mesozoic basins (Costain and Coruh, 1990) suggests, instead, that this basal reflector may be caused by the relatively high velocities of an intrusive diabase, and that the actual base of the basin may be deeper.

Because of their high contrast with surrounding data, certain reflectors within the interior of the basin also appear to represent intrusive dikes or sills rather than sedimentary formations. These areas are labled 1, 2, and 3 on Plate 1. A correct interpretation of the reflectors at locations 1 and 2 and of the subhorizontal reflectors between them is essential for a correct evaluation of the hydrocarbon potential of the basin. If, indeed, the inclined reflectors at locations 1 and 2 are of sedimentary origin rather than from basalt or diabase, they would appear to mark the limits of progradational sedimentary fill into the basin from the east and west. Providing they represent subhorizontal rock layers, the subhorizontal reflectors between locations 1 and 2 could represent relatively fine-grained lake, marsh, or swamp accumulations. Velocity analyses currently being conducted at the Regional Geophysics Laboratory, however, indicate that these subhorizontal data very likely are spurious multiples caused by the use of incorrect (too low) velocities in the original processing by Teledyne.

The steeply inclined reflectors at 3 appear to represent basalt or diabase dikes. Alternatively, they could represent some kind of enhanced diffractions; in places they appear to pass upward into domal reflectors and then downward into symmetrically inclined mirror images.

Deformed rocks of the Hylas zone appear to be represented by the conspicuous reflectors that extend downward and to the east from the apparent base of the basin along its western margin to about three and one-half seconds beneath the central part of the basin (Plate 1). If, indeed, Bobyarchick (1976) is correct and the basin is localized by a reactivated Paleozoic thrust fault, reprocessing of the deep data along the

thrust may be able to enhance subsidiary contractional features, such as inclined ramp zones and associated anticlines. Duplexes and splay thrusts, also, may be enhanced by reprocessing. Of particular importance for an accurate evaluation of the hydrocarbon potential of the basin is the location of the base of the Triassic sedimentary fill - whether or not it lies at or below the apparent basal reflector. This, too, may be determined by reprocessing the line.

TECTONIC DEVELOPMENT OF THE TAYLORSVILLE BASIN

Following Late Paleozoic collision of Africa with North America and the formation of the Appalachian Mountains, regional uplift early in the Mesozoic arched the sialic crust of the Atlantic continental margin. Africa separated from North America and the Atlantic Ocean began to form. In response to the extensional forces that opened the Atlantic Ocean, the crust along the Atlantic margin was stretched, thinned, and faulted so that many intermontane rift basins were formed from Florida to Nova Scotia. At present some of these basins are exposed in the Appalachian Piedmont; some lie buried beneath the Atlantic Coastal Plain; and others are buried beneath the younger strata of the Atlantic outer continental shelf. Exposed basins are filled mostly with fluvial and lacustrine deposits that were derived from nearby mountains (for a summary see Manspeizer and Cousminer, 1988).

As is indicated by the age of their fill, the basins began to form approximately 227 my ago, about in the middle of Carnian time (Late Triassic) (Manspeizer and Cousminer, 1988, their fig. 7). The period of crustal extension and basin formation (rifting) lasted for a relatively short period of time and ended early in the Jurassic. Deposits within the Mesozoic basins are commonly referred to as synrift deposits. In the Taylorsville basin, the 8,200-foot thick section of preserved synrift deposits apparently were deposited very quickly, in only two or three million years. Overlying strata, which accumulated as Africa "drifted" away from North America are commonly called postrift or drift deposits. They are separated from the synrift accumulations in the extensional basins by a major regional unconformity - the postrift unconformity. In the Taylorsville basin, the postrift unconformity marks the boundary between rocks of Carnian age below, and Aptian- and Albian- age rocks (Lower Cretaceous) above. Approximately 100 million years separates these strata (Jordan and Smith, 1988). During this time the rocks of the Taylorsville basin and adjacent Piedmont were eroded to the level now preserved beneath the postrift unconformity.

In general, many of the Mesozoic basins are faulted along their western margins and their hanging walls have moved relatively to the east, toward the opening Atlantic Ocean. The Hylas zone, an ancient Paleozoic thrust fault, exhibits late stage brittle deformation which has been interpreted to be Triassic (Bobyarchick and Glover, 1979). If the Taylorsville basin was formed by extension along the Hylas zone, the geometry of the basin would be controlled by the configuration of a low-angle thrust, rather than by that of a listric normal fault. The latter fault type apparently is associated with the formation of other extensional basins, such as the Early Mesozoic Georges Bank basin (Crespi, 1988).

A balanced cross section of the Taylorsville basin, based on data from drilling and seismic profiling, is shown in Figure 4. Several assumptions were made in drawing the section. These are: the location of the subcrop of the Hylas zone beneath the coastal plain is as proposed by Wilkes and others, 1989; the maximum depth of the basin is approximately that of the Wilkins et ux well (10,000 feet); and the basal reflector is, indeed, the bottom of the basin.

A very generalized hypothesis for the sequential development of the Taylorsville basin is illustrated in Figure 5. It is apparent from the cross sections that, as the basin opened from west to east, sediments were deposited concurrently on the hanging wall and on the foot wall of the fault system. Subsequently, these sediments would have been deformed in extension by eastward movement of the hanging wall as the basin continued to open. Synsedimentary faulting, thus, could have resulted in the development of a widespread zone of fracture porosity at the bottom of the western half of the

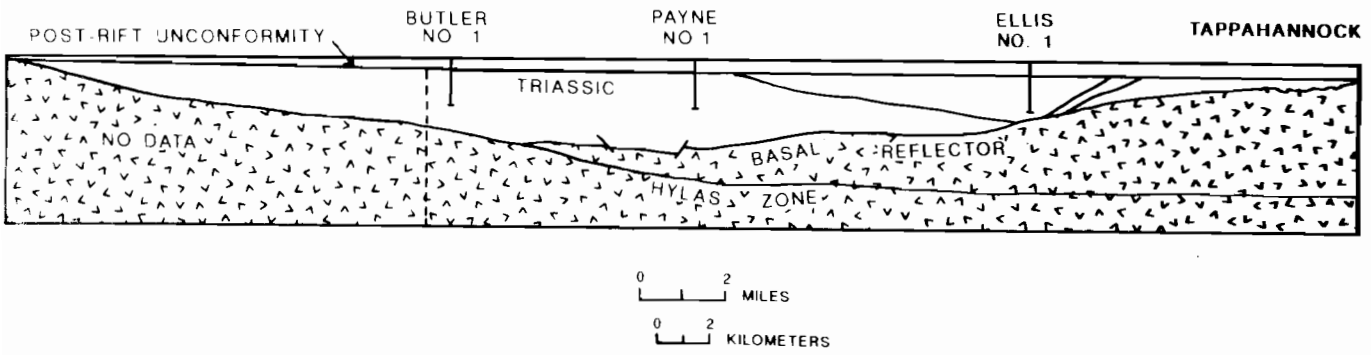

Figure 4. Balanced section across the Taylorsville basin along line 11A.

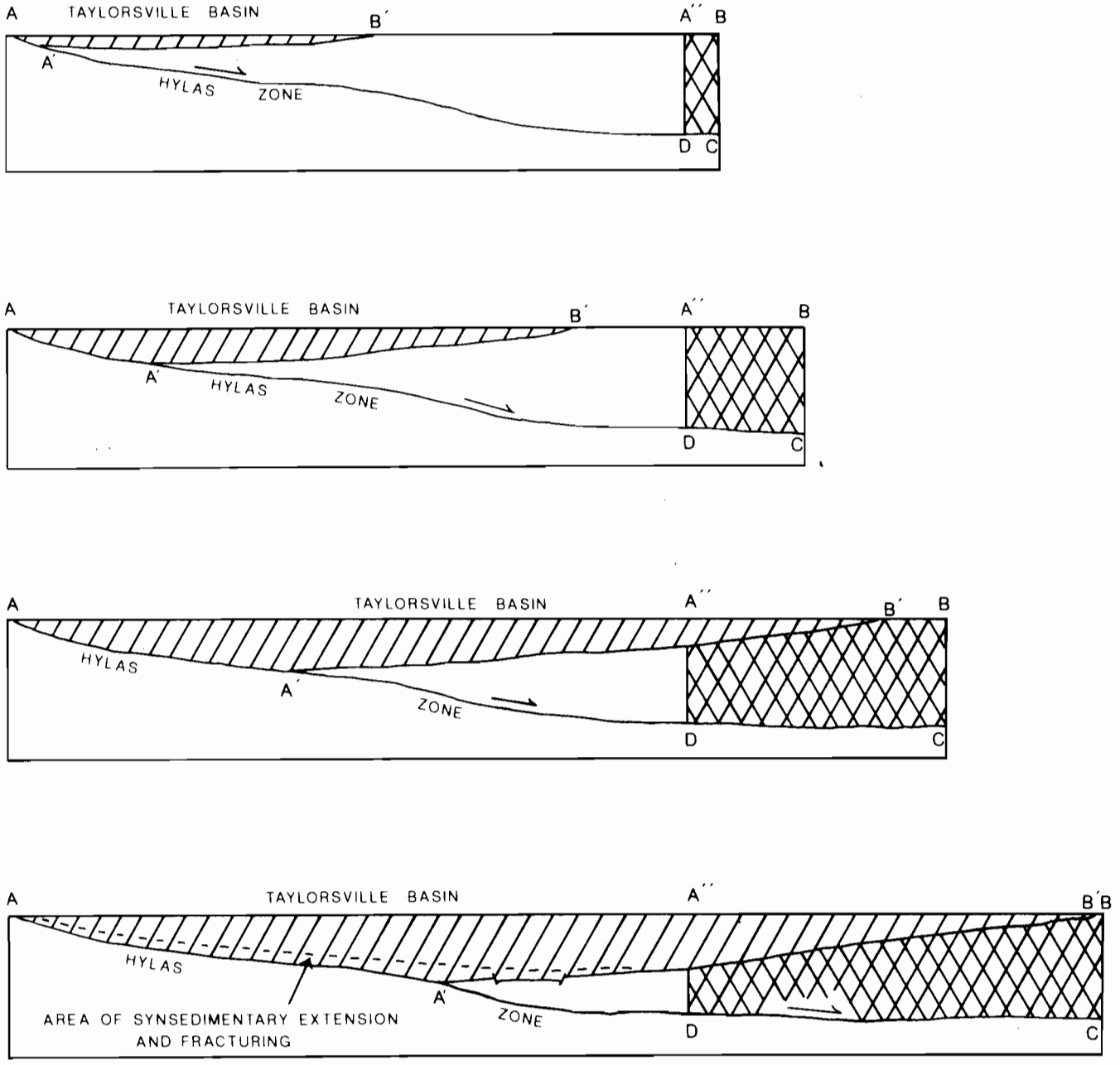

Figure 5. Sequential development of Taylorsville basin. Volume (area) of the displaced hanging wall, A'' B C D, is equal to the volume (area) of subsidence, A A' B. Line length A A'' equals A' B.

basin.

The major episode of extension and deposition in the Taylorsville basin apparently ceased by the end of the Carnian, as is indicated by paleontologic evidence, so that younger Triassic and Jurassic strata are not preserved. Relatively minor structural adjustments continued into the Late Cretaceous, however, as is indicated by the several small-displacement faults that cut across the Triassic-Cretaceous boundary (Plate 1).

HYDROCARBON GENERATION AND SOURCE ROCK POTENTIAL

Kerogen, the insoluble fossilized organic matter in sedimentary rocks that can be distilled into liquid and gaseous hydrocarbons, is of three common types, I, II, and III (Tissot and Welte, 1984). Type I is of lacustrine origin and is primarily a source of oil during catagenesis. Type II kerogen is of marine origin and can generate both oil and gas. Type III is derived from the woody remains of plants and is a common source of natural gas in suitably buried and heated sedimentary rock. There are several ways to estimate the thermal maturation and hydrocarbon potential of sedimentary strata, including vitrinite reflectance, Rock-Eval pyrolysis, time-temperature index modeling, and kinetic modeling (for examples, see Nuccio, 1990). The estimate herein utilizes data obtained from the color transformation of palynomorphs (Robbins and Weems, 1988; Cornet and Olsen, 1990), and time-temperature index (TTI) modeling.

In general, palynomorphs range in color from various shades of yellow to dark brown; the darker the color, the greater the thermal alteration of the sample. In order to provide an arbitrary Thermal Alteration Index (TAI) scale, colors are keyed to the Phillips, 1984 pollen/spore color standard. In the Taylorsville basin, TAI's commonly range from 2 to 4; medium-yellow colors are equivalent to a TAI of 2, whereas very dark brown is a 4 (Robbins and Weems, 1988). Because of the local effects of intrusive igneous rocks, however, alteration colors may range widely in short distances; alternatively, in strata which contain more than one color of palynomorph, the darker-colored palynomorphs may have been reworked from older strata so that they do not reflect accurately the depth of burial of the strata which contains them.

As used by Robbins and Weems (1988, their Table 3), strata which are in the oil window contain palynomorphs which range in color from a TAI of 2+ to a TAI of 3+ (E. I. Robbins, U. S. Geological Survey, oral communication, 1991). Almost all of the palynomorphs studied by Robbins and Weems (1988) fall into this range. Using color differences, Cornet and Olsen (1990) separated *in situ* palynoflorules from reworked ones in samples which they obtained from a well in the Richmond basin. The palynoflorules they studied were from the youngest Triassic formation in the basin (Carnian) and ranged in TAI values from 1 to 1+ for *in situ* fossils, to 2+ or 3- for fossils reworked from older beds.

In addition to the data from thermal alteration indices, time-temperature index modeling was used in this study to estimate the thermal maturity and time of petroleum generation for the buried part of the Taylorsville basin. The computer program, LOPATIN.ASC (Elphrick and Reed, 1989), was used to compute the TTI's for the model (Figure 6). Age and thickness data used in the program are shown in Table 3.

Table 3. Input data for calculation of Time-Temperature Index Values, Taylorsville basin, Virginia.

AGE	SYSTEM	THICKNESS		GEOTHERMAL GRADIENT
(Ma)		(feet)	(meters)	(Deg./Km)
0-60	Cenozoic	460	140	29
66-144	Cretaceous	1345	410	29
144-225	Hiatus	0	0	
225-227	Triassic (Carnian)	8200	2500	40

In addition to the data in Table 3, the computer program for calculation of TTI values requires an estimate of the paleogeothermal gradient during the life of the basin. The present day geothermal gradient of the Taylorsville basin area, calculated from the bottom-hole temperatures of a few wells, is about 29 degrees C per km. Lambiase and others (1980) compiled geothermal gradient data for sixty-five holes in the Atlantic Coastal Plain. Approximately 90 percent of the values for these holes are between 25 and 45 degrees C/km.

During early Mesozoic time, when the crust was being extended, faulted, and intruded by mafic magma, the paleogeothermal gradient must have been much higher. Pratt and others (1988), in their study of the Hartford and Newark basins, concluded that there was an episode of anomalously high heat flow when the Mesozoic sediment fill was intruded by basaltic magma during the Early Jurassic. Tillman and Barnes (1983) suggested a geothermal gradient of 40 degrees C/km for the central and northern Appalachian basin during late Paleozoic or early Mesozoic time; we have used that figure as a conservative estimate for the paleogeothermal gradient of the Taylorsville basin region at the onset of sedimentation.

TTI calculations indicate that the Taylorsville basin entered the oil window approximately 195 Ma at a temperature of about 100 degrees C (Fig. 6. Table 4). At present, the lower third of the basin remains within the oil window and in the realm of peak oil generation. It is apparent that much of the kerogen in the basin is type III, although there may be some type I kerogen associated with lake deposits. For type

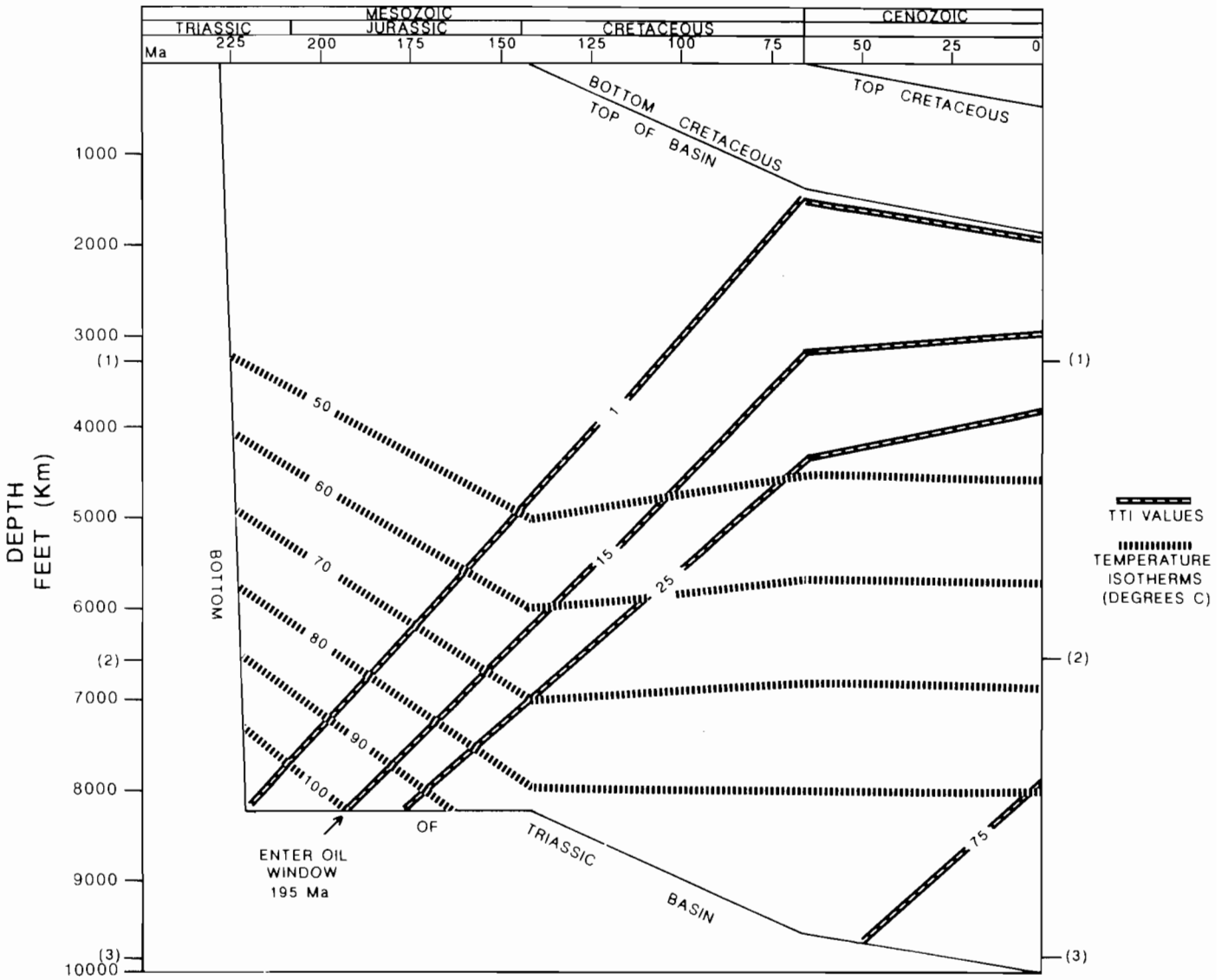

Figure 6. Time-temperature model for the buried part of the Taylorsville basin, Virginia.

III source rocks, however, gas is more likely to be generated in quantity than oil; significant gas generation begins at a TTI of 25 (Nuccio, 1990).

CONCLUSIONS

The Taylorsville basin is a elongate, deep Early Mesozoic basin that occurs below coastal plain strata in northeastern Virginia and adjacent Maryland. During the Early Triassic (Carnian), the basin was filled with sedimentary deposits that accumulated in alluvial fan, fluvial, deltaic, marsh, swamp, and lacustrine depositional environments. Source beds containing type III kerogen, and possibly type I kerogen, have entered the oil window at depth within the basin. The basin contains abundant coarse-grained reservoirs that should have intergranular porosity augmented by fractures. It is

Table 4. Temperature and TTI values calculated by LOPATIN.ASC program for the Taylorsville basin, Virginia.

TIME (Ma)	DEPTH (Meters)	TEMPERATURE (Degrees C)	TTI
Bottom of basin			
227	0	10	0.0
225	2498	110	0.2
144	2498	82	43.0
66	2908	94	67.0
0	3048	98	104.0
Top of basin			
144	0	10	0.1
66	410	22	0.3
0	550	26	0.5
Top of Cretaceous			
66	0	10	0.0
0	140	14	0.1

possible that the basin will yield significant, commercial quantities of natural gas and, perhaps, small amounts of oil. Reprocessing of the Vibroseis data is currently in progress. Additional drilling of strategically placed shallow drill-holes would significantly enhance our ability to evaluate the hydrocarbon potential of the Taylorsville basin.

ACKNOWLEDGEMENTS

Bruce Cornet, Lamont-Doherty Geological Observatory, provided us with unpublished correlation diagrams which he had made for several of the Texaco core holes. Our interpretations, however, do not entirely agree with his. The manuscript was reviewed by Nick H. Evans, Virginia Division of Mineral Resources.

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APPENDIX: WELL-SAMPLE DESCRIPTIONS

JSC Drilling Co., Thompson No. 1
King George Co., VA; VDMR Repository
Number W-2252

Interval	UNWASHED SAMPLES
0-15	Sand, glauconitic, olive gray, very-fine grained, argillaceous; with common mica.
15-25	Sand, glauconitic, olive gray, very-fine grained, argillaceous; with common mica.
	WASHED SAMPLES
25-35	Sand, very glauconitic, very-fine to fine grained, light gray and greenish black, subangular to well rounded; generally composed of transparent quartz grains, some translucent; with abundant very- coarse shell fragments (pelecypods) and rare mica.
35-45	Sand, very glauconitic, very-fine to fine grained, light gray and greenish black, subangular to well rounded; quartz grains are generally transparent or translucent; with several well-rounded, small quartz pebbles, abundant very-coarse shell fragments, a shark's tooth, and rare mica.
45-55	Sand, glauconitic, very-fine to fine grained, light gray and greenish black, subangular to well rounded; with abundant small, well-rounded quartz pebbles; quartz grains are translucent to transparent; with abundant very-coarse shell fragments, rare mica, and a few large pieces of clay.
55-65	Sand, very glauconitic, very-fine to fine grained, light gray and greenish black, subangular to well rounded, and abundant small well-rounded quartz pebbles; quartz grains are translucent to transparent; with abundant very-coarse shell fragments, rare mica, and a few large pieces of light-olive-gray clay.
65-75	Glauconite sand, very-fine to fine grained, greenish black and light gray, and abundant very-fine- to fine-grained, subangular to well-rounded quartz grains, and common small, well-

	rounded quartz pebbles; quartz grains are translucent to transparent; with abundant very-coarse shell fragments and a few light-olive-gray clay fragments.
75-85	Sand, very glauconitic, very-fine to fine grained, light gray and greenish black, subangular to well rounded, and a few small, well- rounded quartz pebbles; quartz grains are translucent to transparent; with abundant very-coarse shell fragments and a few large pieces of clay.
85-95	Sand, very glauconitic, very-fine to fine grained, light gray and greenish black, subangular to well rounded, and a few small, well- rounded quartz pebbles; quartz grains are translucent to transparent; with abundant very-coarse shell fragments, a very-dusky-red, cork-screw shaped object, and a few pieces of clay.
95-100	Sand, very glauconitic, very-fine to fine grained, light gray and greenish black, subangular to well rounded, with a few small, well-rounded quartz pebbles; quartz grains are translucent to transparent; with abundant very-coarse shell fragments, rare mica, and a few pieces of clay.
100-200	MISSING
200-210	Silt, argillaceous, dark greenish gray; with abundant very-light- gray, fine-grained, subangular quartz sand, common greenish-black glauconite, and common very-light-gray shell fragments.
210-220	Silt, argillaceous, greenish gray; with abundant very-fine- grained, greenish-black glauconite, and common shell fragments.
220-230	Clay, pale red; with some light-olive-gray, glauconitic siltstone.
230-238	Clay, pale red; with abundant light-olive-gray, glauconitic siltstone.
238-246	Clay, light-olive gray, silty; with abundant very-fine-grained glauconite, and common shell fragments.
246-255	Clay, light-olive gray, silty, glauconitic, some pale red; with common shell fragments.
255-275	MISSING
275-280	Silt, argillaceous, olive gray, glauconitic; with abundant shell fragments and very-fine-grained mica.
280-285	Silt, argillaceous, olive gray, glauconitic; with abundant shell fragments and common very-fine-grained mica.
285-290	Silt, argillaceous, olive gray, glauconitic; with abundant shell fragments, common fine-grained mica.
290-300	Silt, argillaceous, olive gray, glauconitic; with abundant shell fragments.
300-310	Greensand, medium grained, argillaceous, calcareous, very fossiliferous; with fine- to medium-grained sand (Jacobeen's log).
310-320	Greensand, argillaceous, fossiliferous; with fine- to medium- grained sand and some quartz gravel (Jacobeen's log).
320-330	Silt, argillaceous, olive gray, glauconitic; with abundant shell fragments.
330-340	Clay, yellowish gray, silty, is matrix to abundant very-fine- to coarse-grained sand and very-fine- to fine-grained glauconite; with several smooth grayish-black to brownish-black pebbles.
340-345	Silt, argillaceous, yellowish gray, is matrix to abundant very fine- to coarse-grained sand and common glauconite.
345-355	Clay, yellowish gray, is matrix to abundant very-fine- to very-coarse-grained sand and common glauconite.
355-358	Clay, yellowish gray, is matrix to common very-fine- to medium-grained sand and common glauconite.
358-370	Clay, yellowish gray to pale yellowish brown, is matrix to common very-fine- to medium-grained sand.
370-380	Clay, yellowish gray, is matrix to very-fine- to very-coarse-grained sand; with rare very-fine-grained mica.
380-390	Sand, fine-to coarse-grained, very-light to light gray, subangular to subrounded, some translucent; with abundant white feldspar and common glauconite; some sand is stained grayish orange.

UNWASHED SAMPLES

390-400 Clay, variegated yellowish gray to moderate reddish brown, is a matrix for scattered grains of very-fine- to fine-grained, subangular to rounded quartz sand, grit, and small pebble; disintegrates very readily in water; with common grains of silt-sized gray rock fragments and rare white feldspar.

400-410 Clay, grayish orange to yellowish orange, is a matrix to very-fine- to fine-grained, subangular to subrounded quartz and rare white feldspar sand; with silt-sized grains of gray rock fragments, some well-rounded quartz grit, and rare mica.

410-420 Clay, grayish orange to yellowish orange, is a matrix to very-fine- to fine-grained, subangular to subrounded quartz and rare white feldspar sand; with silt-sized grains of gray rock fragments.

420-430 Clay, yellowish gray to pale yellowish brown, grayish orange, yellowish orange, is a matrix to very-fine-grained, subangular to subrounded quartz and white feldspar sand; with rare silt-sized grains of gray rock fragments.

430-440 Clay, yellowish gray to pale yellowish brown, some oxidized grayish red, is matrix to very-fine-grained quartz sand and silt; with rare mica.

440-450 Clay, pale yellowish brown to light brown, is matrix to very-fine- to fine-grained quartz and white feldspar sand; with several small rounded translucent quartz pebbles and rare mica, and with several metallic spherules (microtectites ?) that were determined by Bill Glass, University of Delaware, to be contamination).

450-460 Clay, grayish orange, pale yellowish brown, light gray, is matrix to very-fine- to fine-grained quartz and white feldspar sand and some quartz grit; with rare grayish-red siltstone.

460-470 Clay, pale yellowish brown, light gray, yellowish orange, is a matrix to very-fine- to fine-grained quartz sand; with rare very-fine grained, white feldspar and silt-sized rock fragments.

470-480 Clay, pale yellowish brown, light gray, yellowish orange, is a matrix to very-fine- to fine-grained quartz sand; with rare very-fine-grained white feldspar.

480-490 MISSING

490-500 Clay, pale yellowish brown, light gray, yellowish orange, is a matrix to very-fine-grained quartz sand; with rare very-fine-grained white feldspar, and rare rounded, very-small pebbles of siderite.

500-510 Clay, light gray, grayish orange, yellowish orange, pale yellowish brown, is a matrix to very-fine-grained quartz sand; with rare very-fine-grained white feldspar, and rare rounded, small pebbles of siderite.

510-520 Clay, pale yellowish brown, yellowish orange; with several chips of very-light-gray, slightly glauconitic siltstone.

520-530 Clay, light-olive gray, is a matrix to very-fine-grained quartz sand and silt.

530-540 Clay, pale yellowish brown to reddish brown; with very-fine- to fine-grained sandstone and some light-gray siltstone.

WASHED SAMPLE

540-550 Sand, light gray, fine to coarse grained, and a few fragments of very-fine-grained, subangular to subrounded sandstone; with rare white feldspar; quartz is generally translucent; unwashed samples 542-550 also contain pieces of greenish-gray to reddish-brown shale.

UNWASHED SAMPLES

545-555 Clay, pale yellowish brown, moderate yellowish brown, very-pale orange, silty.

550-560 Clay, light-olive gray, very silty; with rare very-fine- to coarse-grained, subangular sand and small pebble.

560-570 Clay, light-olive gray; with common very-fine- to coarse-grained, subangular sand, common white feldspar, and rare pink garnet.

570-580 Clay, light gray to light-olive gray; with common very-fine- to coarse-

	grained, subangular sand, common white feldspar, and rare pink garnet.
580-600	Sand, light gray, fine to coarse grained, subangular; with abundant white feldspar.
600-615	Sand, very argillaceous, light-olive gray, fine to medium grained, subangular; with abundant white feldspar.
615-630	Clay, light gray, pale yellowish brown, moderate yellowish brown, very silty and sandy; with rare grains of fine- to medium-grained sand, common grains of a black mineral, and common white feldspar.
630-645	Clay, very silty and sandy, light gray, pale yellowish brown, moderate yellowish brown; with rare grains of medium- to very-coarse-grained sand and small pebble, a rare dark-colored mineral, and rare white feldspar grains.
645-655	MISSING
655-670	Sand, medium to coarse grained, subangular to subrounded; with common white feldspar and rare garnet (?).
670-685	Sand, medium to coarse grained; with common grains of very-coarse-grained, subangular to subrounded sand to fine pebble, common white feldspar, and rare garnet (?).
685-700	Clay, pale reddish brown, is matrix to medium- to coarse-grained, subangular sand and small pebble.
700-707	Clay, silty, light gray, pale reddish brown, is matrix to medium- to coarse-grained, subangular sand and fine pebble; with rare black, coarse- to very-coarse-grained, hard chert and common white feldspar.
707-715	Clay, silty, grayish red, is matrix to relatively small amounts of fine- to medium-grained, subangular sand; with rare fine-grained quartz pebble.
715-725	Clay, silty, grayish red, some pale red, is matrix to small amounts of fine- to medium-grained, subangular sand; with rare small quartz pebble.
725-735	Clay, silty, yellowish gray, some stained grayish red; contains small amounts of very-fine- to fine-grained sand.
735-750	Clay, pale reddish brown to yellowish gray, is matrix to fine- to medium-grained, subangular sand; with rare small quartz pebble and common white feldspar.
750-765	Clay, silty, pale reddish brown to light-olive gray; contains relatively small amounts of fine- to medium-grained, subangular sand and rare white feldspar.
765-780	Sand, medium- to very-coarse-grained, to fine pebble, subangular to subrounded; with common white feldspar and rare garnet (?).
780-800	Sand, fine- to medium-grained, subangular to subrounded; with common white feldspar and garnet (?).
800-815	Clay, light-olive gray to yellowish gray, is matrix to fine- to coarse-grained, subangular to subrounded quartz sand; with some quartz grit and rare white feldspar.
815-825	Clay, moderate yellowish brown, light gray.
825-840	Sand, fine- to coarse-grained, subangular, in matrix of grayish orange clay, some stained grayish red; with common white feldspar.
840-860	Clay, pale reddish brown, grayish orange, very-pale orange, is matrix to medium- to coarse-grained subangular sandstone.
860-880	Clay, pale reddish brown, some light gray.
880-890	Clay, pale reddish brown, some grayish yellow; with common grains of fine- to coarse-grained, subangular sand and rare white feldspar.
890-900	Clay, pale reddish brown, some grayish yellow; with rare grains of fine- to coarse-grained, subangular sand.
900-920	Sand, very-fine to coarse grained, angular to subangular, is in yellowish-gray, silty clay matrix; white feldspar common.
920-940	Sand, very-fine to coarse grained, angular to subangular, is in yellowish-gray, silty clay matrix; white feldspar common; with a few fragments of

coarse, uncolored, clear glass or quartz.

940-960 Clay, light brown, is matrix to fine- to very-coarse-grained, subangular to subrounded sand; with common white feldspar.

960-975 Sand, medium to very-coarse grained to pebble, subangular to subrounded in moderate-yellowish-brown clay matrix; with common white feldspar and rare rose quartz (garnet ?).

975-985 Sand, medium to very-coarse grained, light to medium-light gray, subangular to subrounded; with abundant white feldspar and common shell fragments.

985-992 Clay, pale reddish brown, contains some fine- to coarse-grained subangular sand; with rare white feldspar and quartz pebble.

992-996 Sand, argillaceous, fine to medium grained, pale reddish brown; with common white feldspar.

996-1000 Clay, yellowish gray to pale reddish brown, silty; with scattered grains of fine- to medium-grained, subangular sand; with rare white feldspar.

WASHED SAMPLES

1000-1010 Sand, fine to very-coarse grained, light to medium-light gray, subangular to subrounded; with common white feldspar and rare glauconite.

1010-1020 Sand, fine to very-coarse grained, light to medium-light gray, subangular to subrounded; with common white feldspar, rare glauconite, and a fragment of bone (?); plant (?).

1020-1030 Sand, fine to coarse grained, light to medium-light gray, subangular to subrounded; with common white feldspar and rare glauconite.

1030-1040 Clay, silty, pale reddish brown to grayish red; with streaks of yellowish-gray clay and silt and rare grains of medium- to coarse-grained sand.

1040-1050 Clay, grayish red, olive gray, pale yel lowish brown.

1050-1060 Clay, grayish red, olive gray, pale yellowish brown; with abundant very-fine-grained, light-gray sand and rare grains of medium- to very-coarse-grained sand.

1060-1070 Clay, pale yellowish brown, pale brown; with common very-fine- to medium-grained sand and common very-fine-grained flakes of mica.

1060-1075 Sand, fine to very-coarse grained, and quartz pebbles, very-light to light gray, some stained grayish orange, subangular to subrounded, in pale-yellowish-brown clay matrix; with rare white feldspar and rose quartz (garnet ?).

1070-1085 Silt, very argillaceous, yellowish gray; with common grains of fine-to medium-grained, light-gray sand.

1085-1100 Silt, very argillaceous, yellowish gray to grayish red; with rare very-fine to medium-grained sand.

WASHED AND UNWASHED SAMPLES

1100-1110 Sand, medium to very-coarse grained, and pebbles, angular to subangular, translucent to opaque, in matrix of light-olive-gray clay; with rare white feldspar.

1110-1120 Sand, fine- to medium-grained, very-light to light gray, subangular to subrounded; with common white feldspar.

1120-1130 Sand, fine to very-coarse grained, very-light to light gray, some stained grayish orange, subangular to subrounded, slightly argillaceous.

1130-1140 Sand, fine to very-coarse grained, very-light to light gray, subangular to subrounded; with common white feldspar (washed sample missing).

1140-1160 Sand, coarse grained to pebble, very-light to light gray, some stained grayish orange, pale yellowish orange, some translucent; with rare grains of rose quartz (?) and garnet (?).

1160-1170 Sand, medium to coarse grained with some small pebbles, very-light to light gray, stained grayish orange, subangular to subrounded; with common white feldspar.

UNWASHED SAMPLES

1170-1185 Clay, medium gray, slightly silty; with

	abundant coarse to very-coarse-grained sand and small pebble.
1185-1200	Clay, grayish red to light brown; with common grains of very-fine to very-coarse-grained sand, and one black spheroid picked off of surface of clay and bottled.
	WASHED AND UNWASHED SAMPLES
1200-1210	Siltstone, grayish red, argillaceous; and sandstone, fine to coarse grained, very-light to light gray, some reddish orange and translucent, subangular to angular; with common white feldspar and rare garnet (?).
1210-1220	Clay, pale reddish brown, pale red, grayish orange; with common very-fine- to coarse-grained, very-light- to light-gray sand, some stained reddish orange, and hematitic, grayish-red to dusky-red siltstone.
	UNWASHED SAMPLES
1220-1230	Clay, pale reddish brown, light gray, is matrix to abundant fine- to very-coarse-grained, very-light- to light-gray, subangular to subrounded sand and pebble; with common grayish-red to dusky red-siltstone.
1230-1240	Clay, pale red, grayish orange, light-greenish gray; contains fine- to coarse-grained fragments of dusky-red and grayish-red siltstone and medium-gray phyllite.
1240-1248	Clay, pale to moderate-reddish brown, with irregular lenses of light-greenish-gray silt, is matrix to coarse-grained sand and small pebbles composed of dusky-red silt.
	WASHED AND UNWASHED
1248-1255	Sand, fine to very-coarse grained, very-light gray, subangular to subrounded, some frosted, some translucent; with rare white feldspar and dark-colored grains.
1255-1265	Sand, fine to very-coarse grained to fine pebbles, very-light gray, subangular to subrounded, some frosted, some translucent; with rare white feldspar and garnet (?).
1265-1275	Sand, fine to very-coarse grained to pebbles, very-light gray, subangular to subrounded, some translucent; with rare white feldspar and garnet(?).
	UNWASHED SAMPLES
1275-1285	Clay, grayish red, grayish orange, light-greenish gray, silty, is matrix to fine- to very-coarse-grained, very-light- to light-gray, subangular to subrounded sand, some stained grayish red or grayish orange; with rare white feldspar.
1285-1300	Silt, argillaceous, light gray, slightly micaceous; with rare clasts of fine- to very-coarse-grained sand.
1300-1310	Sand, very-light to light gray, fine to coarse grained, angular to subrounded; with rare white feldspar.
1310-1318	Sand, silty and argillaceous, very-light to light gray, fine to very-coarse grained, subangular to subrounded; with rare white feldspar.
1318-1321	MISSING
1321-1328	Sand, very-fine to coarse grained, very-light to light gray, stained pale reddish brown, angular to subangular, some translucent; with rare white feldspar, fragments of light-greenish-gray and grayish-red siltstone, and rare pyrite.
1328-1335	Silt, light gray, argillaceous; and fine- to coarse-grained subangular to subrounded sand and fine pebble; with rare grains of light-greenish-gray and grayish-red siltstone.
1335-1342	Sand, fine to medium grained, very-light to light gray, subangular; with common light-greenish-gray and grayish-red, small pebbles of siltstone, and common white feldspar.
1342-1348	Sand, fine to coarse grained, subangular, frosted, feldspathic; and pink to white clay (Jacobeen's log).
1348-1355	Sand, very-fine to fine grained, some medium grained, very-light to light gray, some stained grayish orange, subangular; with rare white feldspar, rare light-greenish-gray and grayish-red pieces of siltstone, and rare very-fine-grained mica.

1355-1360	Sand, very-fine to fine grained, very-light to light gray, subangular; with rare pebbles, rare white feldspar, fine-grained mica, pyrite, and rare greenish-gray, grayish-red siltstone.
1360-1364	Sand, very-fine to medium grained, very-light to light gray, subangular to subrounded, slightly calcareous; with rare white feldspar, fine-grained mica, pyrite, and common greenish-gray and grayish-red siltstone.
1364-1370	Sand, very-fine to fine grained, some medium to coarse grained, very-light to light gray, subangular to subrounded; with rare fine-grained mica and rare gray to grayish-red siltstone.
1370-1376	Sand, very-fine to fine grained, some medium to coarse grained, very-light to light gray, subangular to subrounded; with common gray and grayish-red siltstone.
1376-1386	Sand, very-fine to coarse grained, yellowish gray, subangular to subrounded; with common grayish-red and gray siltstone.
1386-1393	Sand, very-fine to very-coarse grained, very-light to light gray, subangular to subrounded; with common gray and grayish-red siltstone, rare pyrite, and rare white feldspar.
	WASHED AND UNWASHED SAMPLE
1393-1400	Sand, very-fine to fine grained, some medium to coarse grained, very-light to light gray, subangular, silty, calcareous; with common light-greenish-gray to grayish-red siltstone, common fine-grained mica, and rare pyrite.
1400-1406	Sand, very-fine to fine grained, very-light to light gray, some medium to coarse grained, subangular, silty, calcareous; with common fine-grained mica and rare garnet (?).
1406-1410	Sand, very-fine grained, pale yellowish brown, silty, calcareous; with common fine-grained mica.
1410-1417	Sand, fine- to coarse grained, pale yellowish brown, subangular to subrounded, silty, calcareous; with some greenish-gray and grayish-red siltstone and some fine-grained mica.
1417-1427	Sand, fine to coarse grained, light-olive gray, subangular to subrounded, calcareous; with some greenish-gray, grayish-red, and gray siltstone and some fine-grained mica.
1427-1432	Sand, fine to coarse grained, yellowish gray, subangular to subrounded, calcareous; with some greenish-gray, grayish-red, and gray siltstone.
1432-1436	Sand, fine to coarse grained, yellowish gray, subangular to subrounded, calcareous; with common greenish-gray, grayish-red and gray siltstone.
1436-1440	Sand, fine to coarse grained, yellowish gray, subangular to subrounded, calcareous; with common greenish-gray, grayish-red, and gray siltstone.
1440-1445	Sand, very-fine to coarse grained, yellowish gray, subangular to subrounded, calcareous; with common greenish-gray, grayish-red, and gray siltstone.
1445-1452	Sand, very-fine to fine grained, some medium to coarse grained, yellowish gray, silty, calcareous; with some greenish-gray, grayish-red, and gray siltstone.
1452-1458	Sand, fine to coarse grained, some very-coarse grained, yellowish gray, subangular to subrounded, calcareous; with common greenish-gray and grayish-red siltstone.
1458-1465	Sand, fine to coarse grained, yellowish gray, subangular to subrounded, calcareous; with abundant grayish-red siltstone, some greenish-gray siltstone, and some mica.
1465-1472	Sand, fine to medium grained, yellowish gray to pale yellowish brown, subangular to subrounded, calcareous; with abundant grayish-red and greenish-gray siltstone.
1472-1482	Limonite, grayish brown.
1482-1490	Sand, fine grained, well sorted, yellowish gray, subangular to subrounded; with abundant grayish-brown limonite and some grayish-red siltstone.
1490-1508	Siltstone, grayish red; and grayish brown, calcareous limonite.

1508-1515	Siltstone, grayish red, some greenish gray and gray; with some grayish-brown limonite.
1515-1522	Sand, fine to medium grained, yellowish gray, subangular to subrounded; with some grayish-red and greenish-gray siltstone.
1522-1533	Sand, medium to very-coarse grained, angular to subrounded, calcareous; with common grayish-red and greenish-gray siltstone and some calcareous pieces.
1533-1545	Sand, fine to medium grained, some coarse grained, yellowish gray, subangular to subrounded, slightly calcareous; with some grayish-red and greenish-gray siltstone and some calcareous pieces.
1545-1555	Siltstone, grayish red, rare greenish gray; with some fine- to medium-grained sandstone.
1555-1565	Siltstone, grayish red, rare greenish gray; rare sandstone.
1565-1575	Siltstone, grayish red, common greenish gray; with some slightly calcareous, gray siltstone with bladed minerals.
1575-1580	Siltstone, grayish red, common greenish gray; with some slightly calcareous, gray siltstone, and fine-grained, subangular, indurated, light-gray sandstone, some with garnet(?).
1580-1590	Sandstone, fine to medium grained, some coarse grained, light gray, subangular; with abundant grayish-red siltstone, some gray and greenish gray.
1590-1602	Sand, medium to coarse grained, some pebble, very-light gray, some grayish orange pink, some translucent, subangular to subrounded (broken by drill bit), and very-fine-grained, subangular, light-gray, calcareous sandstone; with abundant grayish-red siltstone, and rare light-greenish-gray siltstone.
1602-1613	Sand, coarse grained to pebble, very-light gray, subangular, some translucent, and very-fine- to coarse-grained, very-light-gray, subangular, feldspathic sandstone; with abundant grayish-red siltstone, common medium-gray siltstone, and rare grayish-red shale.
1613-1621	Sandstone, fine to coarse grained, very-light gray, subangular to subrounded, arkosic, calcareous, and grayish-red to light-greenish-gray siltstone; with common grayish-red shale.
1621-1630	Siltstone and shale, grayish red, light greenish gray, and very- very-fine- to fine-grained, light-gray, subangular to subrounded, calcareous, feldspathic sandstone; with some quartz grit.
1630-1640	Sandstone, very-fine to fine grained, very-light gray, subangular to subrounded, feldspathic, calcareous, and abundant grayish-red siltstone and shale; with common light-gray siltstone and rare quartz grit.
1640-1651	Siltstone and shale, grayish red, light-greenish gray, medium- light gray, and fine- to coarse-grained, very-light-gray, subangular, feldspathic sandstone; with some grit.
1651-1660	Sandstone, very-fine to fine grained, very-light gray, subangular, feldspathic, slightly calcareous; with some quartz grit and grayish-red siltstone.
1660-1673	Sandstone, very-fine to fine grained, very-light gray, subangular, feldspathic, and slightly calcareous medium-gray siltstone; with some grayish-red siltstone.
1673-1685	Sandstone, very-fine to fine grained, very light gray, subangular, feldspathic, and grayish-red siltstone and shale; with common light-greenish gray siltstone and rare clear, crystalline calcite.
1685-1693	Siltstone and shale, grayish red, some light-greenish gray.
1693-1700	Siltstone and shale, grayish red, some greenish gray, light gray.
1700-1705	Sandstone, very-fine grained, very-light gray, subangular, feldspathic, slightly calcareous, and grayish-red siltstone and shale; with some medium-light-gray siltstone.
1705-1715	Sand and sandstone, very-fine grained, very-light gray, subangular to subrounded, and grayish-red siltstone and shale; with common light-greenish-gray and medium-light-gray siltstone.

1715-1723	Sand, very-fine to fine grained, very-light gray, subangular to subrounded; with common grayish-red and light-greenish-gray siltstone and shale.
1723-1730	MISSING
1730-1731	Sand, very-fine to fine grained, very-light gray to yellowish brown, iron stained, subangular to subrounded; with grayish-red and medium-light-gray siltstone and shale.
1731-1734	Siltstone and shale, grayish red, light greenish gray, and fine- to coarse-grained, very-light-gray, subangular to subrounded, feldspathic sandstone and quartz grit.
1734-1736	MISSING
1736-1743	Siltstone and shale, grayish red, light-greenish gray, and very-fine- to fine-grained, very-light-gray, subangular to subrounded, feldspathic sandstone.
1743-1750	Siltstone and shale, grayish red, light-greenish gray; and very-fine- to fine-grained, very-light-gray, subangular to subrounded, feldspathic sandstone; with some quartz grit and pebbles and rare translucent quartz grains.
	WASHED SAMPLES
1750-1790	MISSING
1790-1799	Sand, medium to coarse grained, very light gray, subangular to subrounded; with common white feldspar, common grayish-red shale and siltstone, and rare light-greenish-gray shale.
1799-1807	MISSING
1807-1815	Sand, medium to coarse grained, very-light gray, subangular to subrounded; with rare white feldspar, common grayish-red siltstone and shale, and rare light-greenish-gray shale.
1815-1826	Sand, up to gravel, slightly calcareous; with gray chert fragments (Jacobeen's log).
1826-1830	Sand, medium to very-coarse grained, very-light gray, subangular to subrounded, some quartz grains translucent; with very fine- to fine-grained, subangular to subrounded feldspathic sandstone, common grayish-red siltstone and shale, rare gray siltstone, and rare pyrite.
1830-1881	Shale, red brown, sandy in part, hema tite, pyrite, slickensides (Jacobeen's log).
1881-1890	Shale, red brown; some green shale; with white siltstone and fine-grained, clayey, slightly calcareous sandstone (Jacobeen's log).
1890-1895	A.A. - increase in siltstone and sandstone (Jacobeen's log).
1895-1897	MISSING
1897-1903	Shale, dark brown, red brown, and gray, silty, slightly calcareous (Jacobeen's log).
1903-1909	Gravel and pebbles, white (Jacobeen's log).
1909-1912	Quartzite - conglomerate, some white clay (Jacobeen's log).
1912-1917	Sand, medium to very-coarse grained, very-light gray, subangular to sub rounded, some quartz grains translucent; with abundant medium- to medium-dark-gray shale and common brownish-gray siltstone.
1917-1930	Sand, medium to very-coarse grained; some gray, green, waxy shale, with pyrite (Jacobeen's log).
1930-1931	Sand, fine to medium grained (Jacobeen's log).
1931-1935	Sand, fine to very-coarse grained; with common gray shale (Jacobeen's log).
1935-1942	Sand, fine to coarse grained, white, subangular, slightly calcareous; and light-gray to gray, medium-brown, waxy shale (Jacobeen's log).
1942-1956	Sand, medium to very-coarse grained, white, some shale A.A.; with pyrite (Jacobeen's log).
1956-1966	Sand, fine to very-coarse grained, very-light gray, subangular to subrounded, some quartz grains translucent; with common grayish-red, reddish-brown, and gray siltstone and shale, and rare pyrite.

1966-1976	Shale, red brown, silty in part (Jacobeen's log).
1976-1985	Sandstone, very-fine to medium grained, very calcareous; with common red, brown, and gray shale fragments (Jacobeen's log).
1985-1995	Sand, fine to coarse grained, white; with red, brown, and some gray, silty shale; hematite. (Jacobeen's log).
1995-2004	Siltstone and fine-grained, light-gray, micaceous sandstone (Jacobeen's log).
2004-2018	Sandstone, very-fine to very-coarse grained, white, subangular, very calcareous (Jacobeen's log).
2018-2026	Conglomerate, quartz pebbles and quartzite, white (Jacobeen's log).
2026-2030	Siltstone and shale, medium-light to medium gray, grayish red, and very-fine-grained, feldspathic, calcareous, micaceous sandstone.
2030-2045	Sand, fine to very-coarse grained, very-light gray, angular to subrounded; with common grayish-red and light-greenish-gray shale and siltstone, common white feldspar, and rare pyrite.
2045-2055	Sandstone, very-fine grained, light gray, micaceous, feldspathic, calcareous; medium-gray calcareous siltstone; and light-greenish-gray and grayish-red shale and siltstone.
2055-2065	Sandstone, very-fine to coarse grained, light gray, subangular to subrounded, feldspathic, calcareous; with common medium-gray, micaceous siltstone, and rare grayish-red and light-greenish-gray siltstone and shale.
2065-2075	Siltstone and shale, grayish red, light-greenish gray; with fine-grained mica and rare sandstone, as above.
2075-2085	Siltstone and shale, grayish red, light-greenish gray; with fine-grained mica and rare sandstone, as above.
2085-2095	Siltstone, grayish red; with fine-grained mica, light-greenish-gray shale, and very-light-gray, very-fine-grained, feldspathic, micaceous sandstone.
2095-2107	Sandstone, fine grained, calcareous, dirty; with red-brown and gray-green, waxy shale (Jacobeen's log).
2107-2120	Sandstone, medium grained, calcareous, tight; with some shale A.A., and included shale fragments (Jacobeen's log).
2120-2130	Sandstone, fine to very-coarse grained, calcareous; with red, brown, light-gray, and light-grayish-green shale (Jacobeen's log).
2130-2144	Shale, red brown, very silty and micaceous, and coarse- to very-coarse-grained, white sand (Jacobeen's log).
2144-2160	Siltstone and sand, light gray, poorly sorted, calcareous, micaceous (Jacobeen's log).
2160-2172	Sandstone, medium grained, white, slightly calcareous (Jacobeen's log).
2172-2184	MISSING
2184-2194	Sand, fine to medium grained, very-light gray, subangular to subrounded; with common white feldspar, common grayish-red siltstone, and rare light-greenish-gray shale.
2194-2204	Sand, fine to coarse grained, very-light gray, subangular to subrounded; with common white and grayish-orange feldspar, common grayish-red siltstone, and medium-light-gray, micaceous siltstone.
2204-2213	Sand, fine to coarse grained, very-light gray, subangular to subrounded; with common white feldspar, very-fine- to fine-grained, arkosic sandstone, medium-gray micaceous, calcareous siltstone, and grayish-red siltstone and shale.
2213-2216	Sand, fine to coarse grained, very-light gray, some grayish orange, subangular to subrounded; with common white feldspar and rare greenish-gray shale.
2216-2222	Sand, fine to coarse grained, very-light gray, some grayish orange, subangular to subrounded; with common white feldspar and grayish-red and greenish-gray siltstone.
2222-2229	Sandstone, fine to coarse grained, white, some pink; with some feldspar (Jacobeen's log).

2229-2235	Sandstone, fine to very-coarse grained, white, micaceous, calcareous; with gray shale fragments (Jacobeen's log).
2235-2246	Sandstone, very-fine to coarse grained, white, clayey, calcareous (Jacobeen's log).
2246-2251	Silt, light gray, and fine-grained, clayey, calcareous, white sand (Jacobeen's log).
2251-2259	Sandstone, very-fine to fine grained, very-light gray, arkosic; medium- to coarse-grained, very-light gray, some grayish-orange, subangular to sub-rounded, slightly calcareous sand; with common grayish-red and medium-gray siltstone and shale.
2259-2265	Siltstone, grayish red, greenish gray, light gray, very slightly calcareous; with fine-grained mica and rare sand-stone, as above.
2265-2272	Siltstone, grayish red, greenish gray, pale brown, and very-fine-grained, micaceous, slightly calcareous, pale brown sandstone.
2272-2279	Sandstone, very-fine grained, pale brown, micaceous; with common gray-ish-red and light-greenish-gray shale.
2272-2284	Siltstone, grayish red and medium gray; with very-fine-grained, very-light-gray, feldspathic and slightly micaceous sandstone.
2279-2285	Sandstone, very-fine grained, pale brown, micaceous; with common greenish-gray shale and rare grayish-red shale.
2285-2298	Shale, red brown, and medium- to very-coarse-grained, subangular, white sand; with some pink feldspar (Jacobeen's log).
2298-2306	Sand, medium to very-coarse grained, white, subangular (Jacobeen's log).
2306-2317	A.A., more very-coarse grained (Jacobeen's log).
2317-2327	A.A., very-coarse grained (Jacobeen's log).
2327-2335	Sand, coarse to very-coarse grained, very-light gray, some grayish orange, angular, some quartz grains translu-cent; with common greenish-gray and grayish-red shale and rare epidote.
2335-2345	Siltstone, grayish red to brownish gray; with common greenish-gray shale.
2345-2354	Sandstone, fine to coarse grained, very-light gray, subangular to subrounded; with common white to grayish-orange feldspar and common grayish-red and greenish-gray siltstone and shale.
2354-2358	Sandstone, medium to coarse grained, white, and red-brown and medium-gray shale (Jacobeen's log).
2358-2363	Sandstone, medium to very-coarse grained, white, slightly calcareous; some shale (Jacobeen's log).
2363-2366	A.A., mostly medium grained (Jacobeen's log).
2366-2372	A.A., medium to very-coarse grained, white, clayey, slightly calcareous (Jacobeen's log).
2372-2377	A.A.; with red-brown shale (Jacobeen's log).
2377-2386	Siltstone and shale, grayish red and greenish gray.
2386-2392	Siltstone and shale, grayish red and greenish gray.
2392-2403	A.A., with streaks of white, pink, and brown very-fine-to fine-grained sand-stone (Jacobeen's log).
2403-2406	Shale, grayish red, rare greenish gray.
2406-2411	Shale, grayish red, common greenish gray.
2411-2414	Shale, grayish red, common greenish gray; with common fine- to coarse-grained, very-light-gray sand.
2414-2420	Shale and siltstone, grayish red, and abundant medium- to coarse-grained quartz sand and pebble, some translu-cent; with common white feldspar and common greenish-gray and gray shale.
2420-2435	Sandstone, medium to very-coarse grained, white, angular to subangular; with feldspar and with dark-red-brown shale (Jacobeen's log).
2435-2445	Sand, very-coarse grained quartz con-glomerate; with dark-red-brown shale

	(Jacobeen's log).
2445-2451	Sand, medium to coarse grained, white, calcareous; with common dark-red-brown shale (Jacobeen's log).
2451-2457	Sand, very-light gray, fine to medium grained, subangular to subrounded, calcareous; with abundant grayish-red siltstone, common white feldspar, and rare mica.
2457-2467	Sand, fine to medium grained, calcareous; with feldspar and dark-red-brown shale (Jacobeen's log).
2467-2480	Shale, dark red brown, hard, sericitic (Jacobeen's log).
2480-2487	Siltstone and shale, grayish red, rare greenish gray.
2487-2490	Siltstone and shale, grayish red, rare greenish gray.
2490-2526	Shale, dark red brown, hard, sericitic (Jacobeen's log).
2526-2529	A.A.; with very-fine- to fine-grained, white, clayey sandstone and shale fragments (Jacobeen's log).
2529-2533	A.A.; with sand up to medium grained (Jacobeen's log).
2533-2536	Sand, very-fine to medium grained, white and pink, slightly calcareous, clayey (Jacobeen's log).
2536-2546	Shale, dark red brown, sericitic (Jacobeen's log).
2546-2552	Shale, A.A.; with very-fine- to fine-grained, slightly calcareous, clayey white sandstone (Jacobeen's log).
2552-2564	Sand, fine to medium grained, some coarse grained, white, subangular, calcareous (Jacobeen's log).
2564-2568	Siltstone and shale, grayish red, rare greenish gray; with common very-fine grained, very-light-gray, slightly micaceous sandstone.
2568-2574	Sand, medium to very-coarse grained, very-light gray, subangular to subrounded; with common white feldspar and grayish-red or greenish-gray siltstone and shale.
2574-2579	Sand, fine to very-coarse grained, white, subangular to subrounded, frosted, slightly calcareous, clayey; with feldspar (Jacobeen's log).
2579-2589	A.A., mostly fine to medium grained, white, very clayey; with some red-brown shale (Jacobeen's log).
2589-2592	Sandstone, very-fine grained, light gray, calcareous, feldspathic; with grayish-red and medium-gray siltstone and shale.
2592-2596	Limestone, finely crystalline, white, sandy; with medium-gray shale (Jacobeen's log).
2596-2601	Sand, very-fine to fine grained, white, slightly calcareous; with some red-brown and gray shale (Jacobeen's log).
2601-2605	Sand, very-light gray, stained yellowish brown, very-fine to fine grained, slightly calcareous; with rare white feldspar and grayish-red and medium-gray siltstone and shale.
2605-2611	Shale, red, iron stained (Jacobeen's log).
2611-2621	Sand, very-fine to fine grained, white, slightly calcareous; with some red-brown and gray shale (Jacobeen's log).
2621-2628	Shale, red brown (Jacobeen's log).
2628-2641	A.A.; with white to pink calcareous, clayey siltstone (Jacobeen's log).
2641-2646	A.A.; with more red-brown, micaceous shale (Jacobeen's log).
2646-2697	Shale, dark red brown, smooth, sericitic in part (Jacobeen's log).
2697-2700	A.A.; with some pink, calcareous siltstone (Jacobeen's log).
2700-2708	Shale, red brown (Jacobeen's log).
2708-2710	Siltstone, light brown; and very-fine-grained, slightly calcareous sand (Jacobeen's log).
2710-2716	A.A.; with red-brown shale (Jacobeen's log).
2716-2729	Shale, dark red brown (Jacobeen's log).
2729-2736	A.A.; with white to tan, calcareous silt (Jacobeen's log).

2736-2738	Sand, medium to coarse grained, white, slightly calcareous (Jacobeen's log).
2738-2748	Sand, A.A., fine to medium grained (Jacobeen's log).
2748-2757	A.A.; with red brown shale, slickensides (Jacobeen's log).
2757-2759	Sand, fine to medium grained, white, slightly calcareous; with red-brown shale (Jacobeen's log).
2759-2769	Sand, fine to medium grained, slightly calcareous (Jacobeen's log).
2769-2784	A.A.; with red-brown and green shale (Jacobeen's log).
2784-2788	A.A.; with thin red-brown, argillaceous limestone (Jacobeen's log).
2788-2795	Shale, red brown (Jacobeen's log).
2795-2801	Siltstone and sand, white, fine grained, clayey, calcareous (Jacobeen's log).
2801-2812	Sand, very-fine to fine grained, very-light gray, subangular to subrounded; with common white feldspar, rare mica, common grayish-red siltstone and shale, and rare greenish-gray and gray siltstone and shale.
2812-2820	Sand, fine to medium grained, white, very calcareous and clayey (Jacobeen's log).
2820-2825	Silt and sand, white to tan, fine grained; with red-brown shale (Jacobeen's log).
2825-2828	Sand, very-fine to fine grained, tan, clayey, calcareous, micaceous; with red-brown and green-gray shale (Jacobeen's log).
2828-2835	Shale, red brown; with thin red-brown limestone (Jacobeen's log).
2835-2846	A.A.; and very-fine to medium grained, white, slightly calcareous sand; with some green-gray, plastic shale (Jacobeen's log).
2846-2850	Sand, A.A.; with more shale (Jacobeen's log).
2850-2863	Shale, red brown, silty and micaceous; with green-gray ad gray plastic shale and some limestone (Jacobeen's log).
2863-2866	A.A., mostly red brown (Jacobeen's log).
2866-2869	Shale, red brown; with common limestone (broken pebbles ?) (Jacobeen's log).
2869-2875	Sandstone, fine to medium grained, white, calcareous; with red-brown shale (Jacobeen's log).
2875-2880	Sand, fine to very-coarse grained, very-light gray, subangular to subrounded, slightly calcareous, some quartz grains are translucent; with common white feldspar, common grayish-red siltstone, and rare medium-gray siltstone.
2880-2890	Sand, medium to coarse grained, very-light gray, subangular to subrounded, slightly calcareous, some quartz grains translucent; with common white feldspar and common grayish-red and medium-gray siltstone.
2890-2900	Sand, medium to coarse grained, very-light gray, subangular to subrounded, slightly calcareous, some quartz grains translucent; with rare white feldspar, rare translucent, pink garnet, abundant grayish-red siltstone, and common medium-gray siltstone.
2900-2903	Siltstone and shale, grayish red, some medium gray; and fine- to medium-grained, very-light-gray sandstone, as above.
2903-2913	Sandstone, mostly medium grained, white, subangular, slightly calcareous (Jacobeen's log).
2913-2925	Shale, red brown and gray, gray siltstone, and some fine-grained sandstone (Jacobeen's log).
2925-2934	Siltstone and sandstone, very-fine to fine grained, tan, very calcareous (Jacobeen's log).
2934-2937	Shale, red brown and gray; gray siltstone, and some fine-grained sandstone (Jacobeen's log).
2937-2965	Sand, fine grained, tan to white, calcareous; with shale, as above (Jacobeen's log).
2965-2966	Siltstone and shale, grayish red, rare greenish gray.

2966-2969	Shale, red brown (Jacobeen's log).
2969-2975	Shale, grayish red, rare greenish gray.
2975-2981	Shale, grayish red, rare greenish gray.
2981-2988	Shale, red brown (Jacobeen's log).
2988-3003	A.A.; with white, fine- to coarse-grained, calcareous sand (Jacobeen's log).
3003-3030	Shale, red brown (Jacobeen's log).
3030-3037	Siltstone, grayish red, and very-fine-grained, brownish-gray, silty sandstone.
	UNWASHED SAMPLES
3037-3044	Siltstone, grayish red; and very-fine-grained, brownish-gray, silty sandstone.
3044-3054	Siltstone, grayish red, micaceous.
3054-3062	Siltstone, grayish red, micaceous.
3062-3070	MISSING
3070-3078	Siltstone, grayish red.
3078-3085	Siltstone, grayish red, micaceous.
3085-3088	Siltstone, grayish red.
3088-3093	Siltstone, grayish red and light gray, micaceous.
3093-3098	Siltstone and shale, grayish red, and medium-dark-gray basalt; thin section 2.
3098-3100	Siltstone and shale, grayish red, and medium-dark-gray basalt.
3100-3107	Siltstone, grayish red, micaceous; fine grained, very-light-gray, slightly calcareous, feldspathic sandstone; medium-gray siltstone; and medium-dark-gray basalt; with rare pyrite.
3107-3115	Siltstone, grayish red, some medium gray; with common fine-grained, very-light-gray sandstone, as above.
3115-3122	Siltstone, grayish red, medium gray; with common fine-grained, very-light-gray sandstone, as above.
3122-3127	Siltstone, grayish red; very-fine- to fine-grained, very-light-gray, calcareous, feldspathic sandstone; with common gray siltstone and rare mica.
3127-3135	Shale and siltstone, grayish red, medium gray; very-fine- to fine-grained, very-light-gray, calcareous, feldspathic sandstone; and common medium-gray basalt (?).
3135-3140	Diabase, medium-dark to dark gray, contains green epidote; with common grayish-red siltstone, and very-fine-grained, very-light- gray-sandstone; thin section 1.
3140-3147	Diabase, medium-dark to dark gray, contains green epidote.
3147-3153	Sand, very-fine grained, very-light gray, calcareous, feldspathic; with grayish-red and medium-gray siltstone and rare epidote and diabase; several pieces of sandstone contain translucent green grains that look like epidote.
3153-3156	Sandstone, very-fine grained, very-light gray, feldspathic, some grains coarse; with abundant medium-gray shale and rare grayish-red shale.
3156-3172	Sandstone, very-fine grained, very-light gray, feldspathic; with abundant medium-gray and grayish-red shale and siltstone and rare mica.
3172-3185	Sand, very-fine grained, very-light gray, feldspathic, and medium-dark-gray epidote diabase; with common grayish-red and medium-gray siltstone.
3185-3197	Diabase, medium-dark gray, contains green epidote; with several pieces of grayish-red shale.
3197-3207	Quartzite and basalt (Jacobeen's log).
3207-3212	Sand, medium- to very-coarse grained, very-light gray, some grit, angular, feldspathic, and medium-dark-gray basalt; with rare grayish-red and medium-gray shale and rare very-fine-grained, very-light-gray sandstone.
3212-3220	Sand, fine to very-coarse grained, very-light gray, subangular to subrounded, feldspathic; medium-gray siltstone; medium-dark-gray epidote-bearing diabase.
3220-3230	Sand, medium to very-coarse grained, very-light gray, angular, some translucent, quartz grains; with common

	medium gray and grayish-red siltstone, and medium-dark-gray basalt.
3230-3231	MISSING
3231-3241	Siltstone, grayish red; and abundant medium-dark-gray basalt; with common sand, as above.
3241-3246	Siltstone, grayish red; with rare medium-dark-gray basalt.
3246-3248	Siltstone, grayish red; with common medium-dark-gray basalt and common medium- to very-coarse-grained, very-light-gray, feldspathic sand.
3248-3251	Siltstone, grayish red; with common medium-gray siltstone, rare basalt, and rare sand as above.
3251-3297	MISSING
3297-3300	Sand, very-light gray, fine to very-coarse grained, angular to subangular, feldspathic; medium-dark-gray basalt; and grayish-red siltstone.

Logged by Frank H. Jacobeen, Jr., 1968, and Robert C. Milici, 1991. The missing intervals indicate that two different sample sets were used.

Texaco Wilkens et ux #1 well
Westmoreland County, Virginia (samples unwashed)

Interval	
130-160	Silt to fine-grained sand, light-olive gray, calcareous, glauconitic, slightly micaceous; with some clear to translucent, rounded to angular, glossy quartz grains and a few shell fragments.
160-190	Silt to fine-grained sand, light-olive gray, slightly calcareous, glauconitic, slightly micaceous; with some clear to translucent, rounded to angular, glossy quartz grains.
190-220	Silt to fine-grained sand, light-olive gray, very slightly calcareous, glauconitic, slightly micaceous; with some clear to translucent, rounded to angular glossy quartz grains.
220-250	Silt to fine-grained sand, light-olive gray, some yellowish gray, moderately calcareous, slightly micaceous; with some clear to translucent, rounded to angular glossy quartz grains and some shell fragments.
250-280	Sand, very-fine- to fine-grained quartz and glauconite in approximately equal amounts, very slightly calcareous, rounded; quartz is transluent to transparent; with minor amounts of gypsum.
280-310	Silt to very-fine-grained sand, light-olive gray, glauconitic, slightly micaceous; with some clear to translucent quartz grains and abundant fossil fragments (mostly broken shelly megafossils) up to 0.5 cm long.
310-340	Silt to very-fine-grained sand, light-olive gray, glauconitic, slightly micaceous; with abundant fossil fragments (mostly broken shelly megafossils) up to 0.5 cm long.
340-370	Silt to very-fine-grained sand, light-olive gray, galuconitic, slightly micaceous; with fossil fragments (mostly broken shelly megafossils) up to 0.5 cm long.
370-400	Silt to very-fine-grained sand, light-olive gray, glauconitic, slightly micaceous; with a few fossil fragments up to 0.5 cm long and a few pieces of moderate-yellowish-green clay.
400-430	Silt to very-fine-grained sand, light-ol-

	ive gray, glauconitic, slightly micaceous; with a few invertebrate fossil fragments up to 0.5 cm long.
430-460	Silt to very-fine-grained sand, light-olive gray, glauconitic; with a few translucent, coarse quartz grains, a few invertebrate fossil fragments, and a few pieces of partly carbonized wood.
460-490	Silt, light-olive gray to light-olive brown; with a few translucent coarse quartz grains and a few invertebrate fossil fragments.
490-520	Silt, light-olive gray to light-olive brown; with a few translucent coarse quartz grains and a few invertebrate fossil fragments.
520-550	Silt, light-olive gray to light-olive brown, some stained dark reddish brown, slightly glauconitic, slightly calcareous.
550-580	Silt, light-olive gray to light-olive brown, some stained dark reddish brown, slightly glauconitic; with a few invertebrate fossil fragments.
580-610	Silt, light-olive gray to light-olive brown, slightly glauconitic; with abundant translucent to clear, coarse quartz grains and a few invertebrate fossil fragments.
610-640	Silt, light-olive gray to light-olive brown, glauconitic; with a few translucent coarse quartz grains and a few invertebrate fossil fragments.
640-670	Clay to silt, light-olive gray to light-olive brown; with common translucent, coarse quartz grains and a few pieces glauconitic.
670-700	Clay to silt, light-olive gray to light-olive brown, some stained dark reddish brown, slightly glauconitic; with perfectly round clear globule determined to be plastic contamination by Bill Glass, University of Delaware; washed sample is almost entirely fine- to medium-grained, angular sand; with small amounts of feldspar, garnet, mica, and a piece of gray phyllite.
700-730	Silt to very-fine-grained sand, pale yellowish brown, some pieces reddish brown; with a few pieces of black bitumen-like material that breaks with conchoidal fracture; washed sample contains a small amount of mica and white feldspar.
730-760	Sand, very-fine grained, silty, very-light gray, generally stained pale-yellowish brown, light brown, or yellowish orange, slightly micaceous; with a few coarse grains of light-gray, translucent, angular sand, common very small grains of a dark mineral, and a gray, metallic-looking piece.
760-790	Clay, pale brown; with a little very-fine-grained, very-light-gray sand.
790-820	Clay, pale brown; with a little very-fine-grained, very-light-gray sand.
820-850	Clay, pale yellowish brown; with abundant very-fine- to coarse-grained, subangular sand and some grayish-black lignite fragments.
850-880	Clay, pale yellowish brown; with abundant very-fine- to very-coarse-grained sand.
880-910	Sand, very-light-gray, very-coarse-grained, translucent; and pale-yellowish-brown clay.
910-940	Clay, pale yellowish brown; with abundant fine- to coarse-grained, light-gray, translucent, angular to subangular quartz sand and grit.
940-970	Clay, pale yellowish brown; with abundant fine- to very-coarse-grained, light-gray to pale-red, translucent, angular to subangular quartz sand and grit.
970-1000	Clay, pale yellowish brown; with abundant fine- to very-coarse-grained, light-gray to yellowish-gray and pale-red, translucent, angular to subangular quartz sand and grit; "rose" quartz (garnet ?) pebble in sample is very well rounded.
1000-1030	Clay, pale yellowish brown; with abundant fine- to very-coarse-grained, light-gray, translucent, angular to subangular, quartz, sand and grit.
1030-1060	Clay, pale yellowish brown; with abundant fine- to very-coarse-grained, light-gray to yellowish-gray, translucent, angular to subangular quartz sand, grit, and pebble, an invertebrate fossil fragment, and a few pieces of coalified wood.
1060-1090	Clay, pale yellowish brown; with common fine- to very-coarse-grained, light-gray to yellowish-gray and pale-red, trans-

	lucent, angular to rounded, quartz sand and grit, and some fragments of coalified wood.
1090-1120	Clay, grayish red; with a few grains of fine- to very-coarse-grained, light-gray, translucent quartz sand.
1120-1150	Clay, grayish red; with a few grains of fine- to very-coarse-grained, light-gray, translucent quartz sand.
1150-1180	Clay, grayish red; with a few grains of fine- to very-coarse-grained, light-gray, translucent quartz sand.
1180-1210	Clay, grayish red; with a few grains of fine- to very-coarse-grained, light-gray, translucent quartz sand and grit.
1210-1240	Clay, pale brown; with common fine-to very-coarse-grained, light-gray, translucent quartz sand and grit, some white feldspar, and a spherical globule as in 670-700.
1240-1270	Clay, light-olive gray, some stained pale brown; with abundant fine- to very-coarse-grained, light-gray, translucent quartz and white feldspar sand and grit.
1270-1300	Clay, light-olive gray; with abundant fine-to very-coarse-grained, angular to subangular, light-gray to moderate-yellow, translucent quartz and white feldspar sand.
1300-1330	Clay, pale brown; with common very-fine- to very-coarse-grained, angular to subangular, light-gray, translucent quartz and white feldspar sand.
1330-1360	Clay, pale yellowish brown; with common fine- to very-coarse-grained, angular to subangular, light-gray quartz and white feldspar sand; some pieces of very-fine-grained sandstone are glauconitic.
1360-1390	Clay, light-olive gray, some stained pale brown; with abundant fine- to very-coarse-grained, light-gray, translucent, sub-rounded to angular quartz sand and grit, common white feldspar, and several pieces of lignite.
1390-1420	Clay, light-olive gray to pale yellowish brown; with abundant fine- to very-coarse-grained, light-gray to moderate-yellow, translucent, sub-angular to angular quartz sand, some white feldspar and pale-olive siltstone, and a few pieces of lignite.
1420-1450	Clay, grayish red to light-olive gray; with common fine- to very-coarse-grained, light-gray, translucent, subangular to angular quartz sand; with some pale olive-siltstone, some black lignite that breaks with a conchoidal fracture, and some very-fine-grained feldspar.
1450-1480	Clay, pale brown to light-olive gray; with abundant fine- to very-coarse-grained, light-gray, translucent, subangular to subrounded quartz sand, some lignite, and a few pieces of pale-olive siltstone.
1480-1510	Clay, pale brown to light-olive gray; with abundant fine- to very-coarse-grained, light-gray, translucent, subangular to subrounded quartz sand, some white feldspar, and rare lignite.
1510-1540	Clay, pale brown to light-olive gray; with abundant fine- to very-coarse-grained, light-gray, translucent, subangular to subrounded quartz sand, some lignite, and a few pieces of pale-olive siltstone and white feldspar.
1540-1570	Clay, pale brown to light-olive gray; with abundant fine- to very-coarse-grained, light-gray, some moderate-orange pink, translucent, subangular to subrounded quartz sand, and some white feldspar.
1570-1600	Clay, pale brown to light-olive gray; with abundant fine- to very-coarse-grained, light-gray, translucent, subangular to subrounded quartz sand, and some white feldspar.
1600-1630	Grit to pebble, light-gray, translucent quartz and some white feldspar, subangular to subrounded; with pale-brown to light-olive-gray clay.
1630-1660	Sand, light-gray quartz and some white feldspar, coarse grained, subangular; coated with pale-brown clay.
1660-1690	Sand, light-gray quartz, coarse grained to grit, translucent, subangular to subrounded; with some greenish-gray, glauconitic siltstone that contains a soft, white mineral (gypsum), some white feldspar, and abundant pale-brown to light-olive-gray clay.
1690-1720	Clay, pale brown to light-olive gray; with

	abundant light-gray, translucent, coarse- to very-coarse-grained, subangular to subrounded quartz sand and grit, some light-olive gray siltstone to very-fine-grained sandstone, some lignite, and some white feldspar.
1720-1750	Clay, pale yellowish brown; with abundant light-gray, translucent, coarse- to very-coarse-grained, subangular to subrounded quartz sand and grit, some light-olive-gray siltstone to very-fine-grained sandstone, some white feldspar, and a piece of lignite.
1750-1780	Clay, pale brown; with abundant light-olive-gray siltstone to very-fine-grained sandstone, some mica, some coarse- to very-coarse-grained, subangular to subrounded, translucent quartz sand and grit, and some white feldspar.
1780-1810	Clay, pale brown; with abundant light-olive-gray siltstone to very-fine-grained sandstone, some mica, coarse- to very-coarse-grained, subangular to subrounded, light-gray to grayish-orange-pink, translucent quartz sand and grit, and some white feldspar.
1810-1840	Clay, pale brown; with common light-olive-gray siltstone to very-fine-grained sandstone, some mica, common coarse- to very-coarse-grained, subangular to subrounded, light-gray to grayish-orange-pink, translucent quartz sand, grit, and pebble, and some white feldspar.
1840-1870	Clay, pale brown; with common light-olive-gray siltstone to very-fine-grained sandstone, some mica, and some coarse- to very-coarse-grained, subangular to subrounded, translucent, quartz sand and grit.
1870-1900	Siltstone to very-fine-grained sandstone, light-olive gray; with some mica and a little very-coarse-grained, subangular, translucent quartz sand; coated with pale-brown clay.
1900-1930	Siltstone, to very-fine-grained sandstone, light-olive gray, some medium gray; with some mica and a little very-coarse-grained, subangular to subrounded, translucent quartz sand; coated with pale-brown clay.
1930-1960	Siltstone, light-olive gray; with some mica; coated with pale-brown clay.
1960-1990	Siltstone, light-olive gray; with some mica; coated with pale-brown clay.
1990-2020	Siltstone, light-olive gray; with some mica; coated with pale-brown clay.
2020-2050	Siltstone, light-olive gray, to medium gray; coated with pale-brown clay.
	WASHED SAMPLES:
2050-2080	Siltstone, grayish red, light-olive gray, medium-light to medium gray and very-fine- to medium-grained, feldspathic, sandstone; with rose quartz, garnet, mica, a piece of dark-gray slate, and some light-gray, grayish-orange to moderate-red, translucent, subangular to subrounded quartz grit.
2080-2110	Siltstone, grayish red, medium-light to medium gray, light-olive gray and very-fine- to medium-grained, medium-light-gray, feldspathic sandstone; with rose quartz, garnet, mica, and some light-gray, translucent, subangular to subrounded quartz grit.
2110-2140	Sandstone, very-fine to medium grained, medium-light gray, feldspathic; with light-gray to light-brown, translucent quartz grit, grayish-red, light- to medium-gray siltstone, a piece of dark-gray slate, and a piece of gray, glauconitic siltstone.
2140-2170	Siltstone, grayish-red, medium-light to medium gray, light-olive gray and very-fine- to medium-grained, medium-light-gray, feldspathic sandstone; with some light-gray translucent quartz grit.
2170-2200	Siltstone, grayish-red, medium-light to medium gray, light-olive gray and very-fine- to medium-grained, medium-light-gray, feldspathic sandstone; with some pieces of very-coarse-grained, subrounded, gray rock fragments in a fine-grained sandstone matrix, and some light-gray to light-brown translucent quartz grit.
2200-2230	Siltstone, grayish red, medium-light to medium gray, light-olive gray; with very-fine- to medium-grained, medium-light-gray, feldspathic sandstone, some light-gray translucent quartz grit, and some pieces of very-coarse-grained, subrounded, gray rock fragments in a fine-grained sandstone matrix.

2230-2260	Siltstone, grayish red, medium-light to medium gray, light-olive gray; with very-fine- to medium-grained, medium-light-gray, feldspathic sandstone, some pieces of very-coarse-grained, subrounded, gray rock fragments in a fine-grained sandstone matrix, and some light-gray to light-brown, translucent quartz grit.
2260-2290	Siltstone, grayish red, medium-light to medium gray, light-olive gray; with very-fine- to medium-grained, medium-light-gray, feldspathic sandstone, some light-gray to light-brown, translucent quartz grit, a piece of very-light-gray, glauconitic limestone, and some lignite.
2290-2320	Siltstone, grayish red, medium-light to medium gray, light-olive gray; with very-fine- to medium-grained, medium-light-gray, fledspathic sandstone, some light-gray to light-brown, translucent quartz grit, and some lignite.
2320-2350	Siltstone, grayish red, medium-light to medium gray, light-olive gray; with very-fine- to medium-grained, medium-light-gray, feldspathic, micaceous sandstone, and some coarse-grained, light-gray to light-brown, translucent quartz sand.
2350-2380	Sandstone, fine to medium grained, medium-light gray, feldspathic, micaceous, subangular to subrounded; with grayish-red, medium-light- to medium-gray, light-olive-gray siltstone, some coarse-grained, light-gray to light-brown, translucent quartz sand, and some lignite.
2380-2410	Sandstone, fine to medium grained, medium-light gray, feldspathic, in part micaceous, subangular to subrounded; with grayish-red, medium-light- to medium-gray, light-olive-gray siltstone and some coarse-grained, light-gray to light-brown, translucent quartz sand.
2410-2440	Siltstone, grayish red, medium-light to medium gray, light-olive gray; with very-fine- to medium-grained, medium-light-gray, feldspathic, micaceous sandstone, a little moderate-yellowish-brown siltstone, and coarse-grained, light-gray to light-brown, translucent quartz sand.
2440-2470	Siltstone, grayish red, medium-light to medium gray, light-olive gray; with very-fine- to medium-grained, medium-light-gray, feldspathic, micaceous sandstone, a little moderate-yellowish-brown siltstone, and coarse-grained, light-gray to light-brown, translucent quartz sand.
2470-2500	Siltstone, grayish red, medium-light to medium gray, light-olive gray; with very-fine- to medium-grained, medium-light-gray, feldspathic, micaceous sandstone, a little moderate-yellowish-brown siltstone, coarse-grained, light-gray to light-brown, translucent quartz sand, and some lignite.
2500-2530	Siltstone, grayish red, medium-light to medium gray, light-olive gray; with very-fine- to medium-grained, medium-light-gray, feldspathic, micaceous sandstone, a little coarse-grained, light-gray, translucent quartz sand, rare lignite, and a piece of glauconitic sandstone.
2530-2550	Siltstone, grayish red, medium-light to medium gray, light-olive gray; with very-fine- to medium-grained, medium-light-gray, feldspathic, micaceous sandstone, a little coarse-grained, light-gray, translucent quartz sand, and rare lignite.
2550-Circulation	Siltstone, grayish red, medium-light to medium gray, light-olive gray; with very-fine- to medium-grained, medium-light-gray, feldspathic, micaceous sandstone, a little coarse-grained, light-gray to light-brown, translucent quartz sand, and rare lignite.

Logged by Robert C. Milici, 1991.