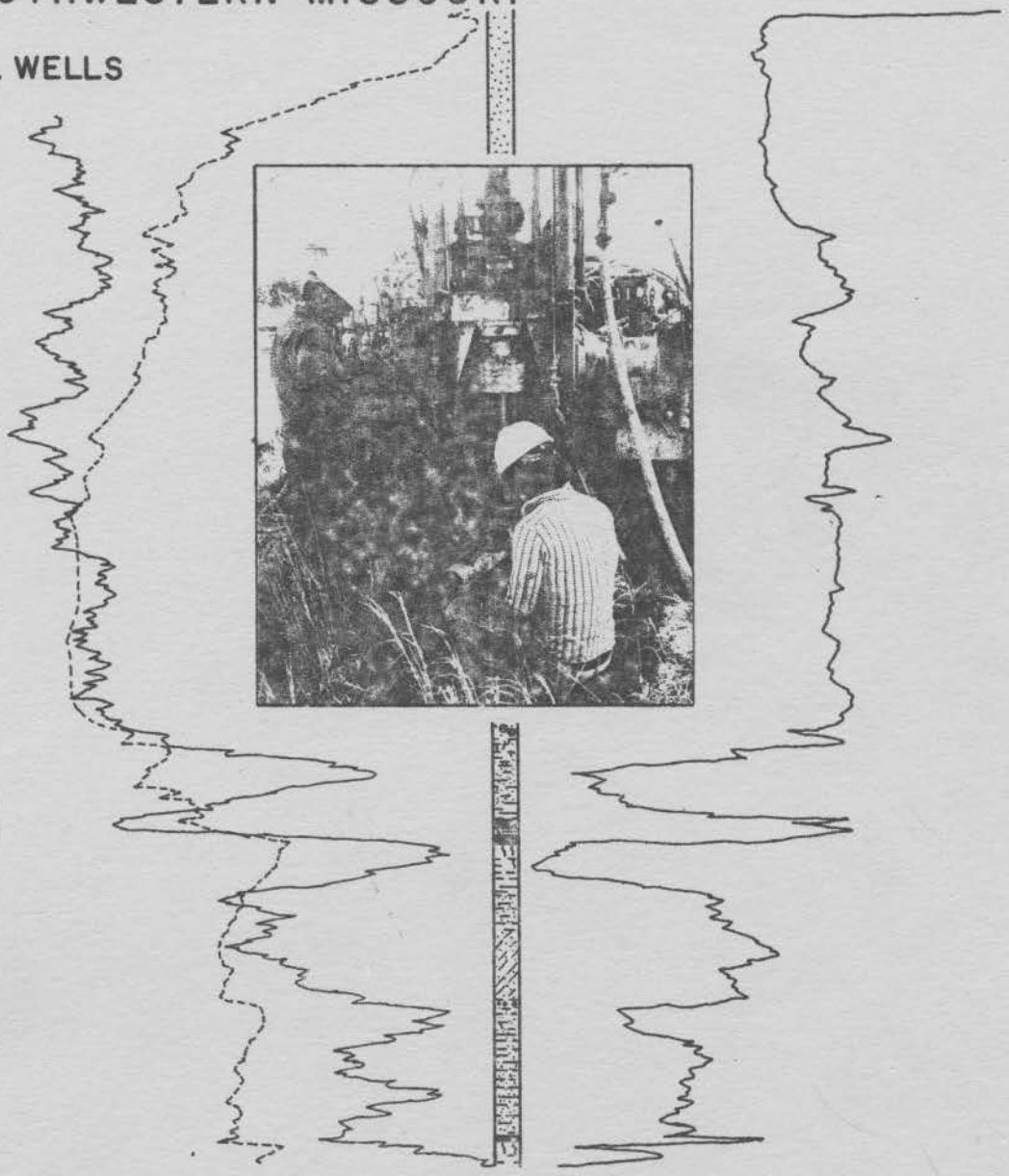
INVENTORY OF STRIPPABLE

# TAR SANDS

IN SOUTHWESTERN MISSOURI

JACK S. WELLS



PREPARED BY DIVISION OF GEOLOGY AND LAND SURVEY
MISSOURI DEPARTMENT OF NATURAL RESOURCES

# INVENTORY OF STRIPPABLE TAR SANDS IN WESTERN MISSOURI

By Jack S. Wells

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## ABSTRACT

*Estimates of the amount of heavy oil in place in parts of western Missouri, eastern Kansas, and northeastern Oklahoma have ranged from a few million barrels to 75 billion barrels. This report is the result of a grant utilizing U.S. Geological Survey funds under Grant No. 14-08-0001-G0266 for Missouri's part of the initial phase of a comprehensive tri-state coordinated study detailing the extent and characteristics of the heavy oil deposits. This project was conducted in three stages: 1. compilation of existing data; 2. geologic mapping; and 3. drilling of test holes along county and township road rights-of-way.*

*Estimates of the oil in place for the study area are revised downward from an earlier figure of over one billion barrels to 287 million barrels. Oil-bearing deposits occur generally within two broad, northwest-trending bands. Columnized sections, and cross sections portraying correlation of the rock units present are included, as well as core and sample descriptions of the test holes drilled. Graphic logs of the Self Potential-Resistivity-Gamma Ray of these tests are included in Appendix A.*

# INTRODUCTION

In parts of western Missouri, eastern Kansas, and northeastern Oklahoma, sandstones of the Middle Pennsylvanian (Desmoinesian) Cherokee Group are impregnated with highly viscous "heavy" oil. These deposits, commonly referred to as "tar sands" or "asphaltic" sandstones, occur from the surface or near-surface to depths in excess of 500 feet. In Missouri, these tar sands are present in an area of over 600 square miles, and represent a potential resource that conceivably could be exploited by surface mining techniques.

Estimates of the amount of oil in place in the tri-state area have ranged from a few million barrels to 75 billion barrels. The latter is more than the known reserves of crude oil in the contiguous United States, and has been generally regarded as a very optimistic figure. The fact that these estimates were made on the basis of fragmentary surface and subsurface data has shown the need for more detailed information about the extent and characteristics of these deposits.

There has been increasing concern on the part of the State Geological Survey personnel in Missouri as well as in Kansas and Oklahoma that too little information was available for objective assessment of the potential for heavy oil recovery from these formations, and that there was an essential need for resource evaluation, followed, if needed, by reserve studies.

Meetings of the State Geologists of Kansas, Missouri, and Oklahoma, and U.S. Geological Survey personnel in 1973 and 1974 led to a draft proposal for undertaking a coordinated study of the surface and shallow subsurface occurrences of heavy oil and tar sands in the adjoining areas of the three states. Early information from the Oil and Gas Branch of the U.S. Geological Survey indicated that funding would be available to assist in supporting a program to improve estimates of the location, size, and quality of these potential energy resources. Budgets in line with the indicated funding were submitted to the USGS by the three states.

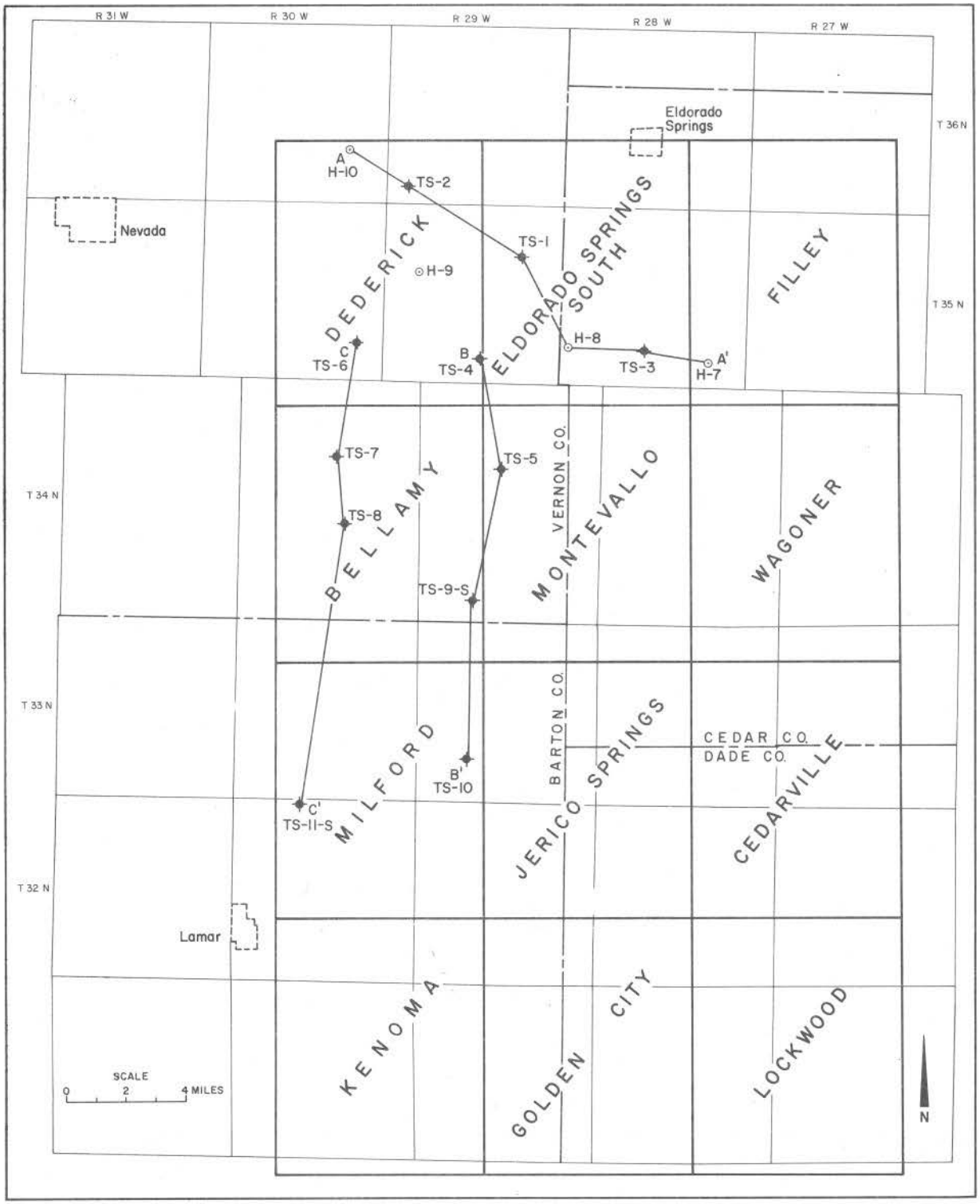


**Figure 1. Index showing quadrangles mapped by Haley, area of study, and location of cross sections.**

It was subsequently determined that only a fraction of these funds would be made available to the three State Geological Surveys. As a result of a conference it was decided that Missouri would be in the best position to make effective use of the funds available. By mutual agreement, Kansas and Oklahoma recommended to the USGS that these funds be allocated to Missouri.

This report is the result of work accomplished under the initial phase of the overall program utilizing USGS funding in the amount of $25,000 under Grant No. 14-08-0001-G0266.

## LOCATION

The area of study under this grant covers parts of the four western Missouri counties of Vernon, Barton, Dade, and Cedar, described generally as that area west and north of the Pennsylvanian-Mississippi contact, and south of U.S. Highway 54. The western limit approximates the west edge of the Milford, Bellamy, Dederick, and Kenoma $7\frac{1}{2}$-minute quadrangle maps (fig. 1).

For the geologic mapping phase, twelve $7\frac{1}{2}$-minute quadrangles were used as base maps with an estimated nine full quadrangles being mapped (eight full quads and parts of four others in the eastern portion).

## GENERAL PROJECT OUTLINE

This program was conducted generally in three phases: 1) compilation of surface and subsurface data; 2) geologic mapping; and 3) drilling for acquisition of data in areas for which subsurface data were lacking.

To initiate this program all existing non-proprietary subsurface data were compiled, both for the area of the study, and the westward adjacent areas of Vernon and Barton Counties so that structural trends of sand deposition might be more clearly defined.

An attempt to acquire data obtained by the Shell Oil Company from their evaluation of western Missouri tar sands resulted in release to the Survey of approximately 100 well logs for use in this program. Unfortunately there were apparently no data available for the area included in this study.

The geologic mapping phase was conducted by Mr. Boyd Haley, U.S. Geological Survey, Little Rock, Arkansas, utilizing both areal photography and field reconnaissance methods. Geologists from the Missouri and Kansas Surveys met in the field with Mr. Haley during this mapping program to help with the

local stratigraphy and to insure that stratigraphic correlation of Missouri and Kansas units would be achieved during planned future extensions of this program.

The drilling of eleven holes was carried out late in the grant program by a core-drilling rig mounted on an all-terrain-vehicle under a contract with the Layne-Western Drilling Company of Kansas City, Missouri, awarded on the basis of competitive bidding. There were nine NX and NQ (wireline) core holes and two "slim hole" rotary holes drilled, resulting in 1,476.9 feet (450 m) of section drilled and sampled.

Gamma-Ray, Self-Potential and Resistivity logs were obtained from all of the test holes. The logging was done by the drilling contractor under a subcontract with Roberts Geophysical Services of Council Bluffs, Iowa. The logs were run using a Well Reconnaissance Inc. Model 8036, with single-point resistivity, which is of the differential type discrimination. The resultant logs are of the "primitive" or uncalibrated type as compared to multi-point well logs commonly run by the oil industry.

## ACKNOWLEDGMENTS

The author acknowledges the generosity and cooperation of the U.S. Geological Survey in making funds available under Grant No. 14-08-0001-G0266 for this project. Appreciation is expressed to the State Highway Commission and the various township highway boards that gave permission to drill along state and township road right-of-ways.

Mr. Larson Heath, project leader, Petroleum Production Research, Research and Development Administration, Bartlesville, Oklahoma arranged for the core analyses at the Bartlesville Energy Research Center facilities.

DNR staff geologist Charles Robertson helped throughout the field mapping program phase and contributed ideas on the stratigraphic succession encountered during the drilling phase. Other DNR staff members who read the manuscript and suggested improvements are: Kenneth H. Anderson, Larry D. Fellows, and Thomas L. Thompson. Jerry Vineyard, Barbara Harris, and Arthur Hebrank performed editing services. George Miller, Randy Rinehart, Sue Dunn, and Bill Ross drafted the illustrations and Golda Roberts typeset the copy. Brenda Talty, part-time employee and undergraduate geology student of UMR, helped in the compilation of subsurface data in the overall area of interest.

Finally I would like to acknowledge the help of Dr. Richard J. Gentile, Professor of Geology, UMKC, who sat on most of the wells that were drilled and described all of the cores that were taken during this project. The cross sections were constructed by Dr. Gentile and many of his ideas on stratigraphy and environments of deposition are incorporated in this report.

## WORK ACCOMPLISHED

### COMPILATION

In the initial stage of this program, subsurface data from the files of the Missouri Survey were evaluated, correlated, and plotted on a base map of 1:125,000 scale ($\frac{1}{2}$ inch = 1 mile) for an area extending from Township 39 North in Bates County, south to the southern edge of Barton County. The western boundary is the Kansas-Missouri border and the area of interest extends eastward past the drop line of the Pennsylvanian in Cedar and Dade Counties.

Approximately 350 well logs were evaluated and the results plotted, however only about 100 well logs were available for the specific area encompassed in this study. It was hoped that maps based on these data would show depositional and structural trends of the sandstone bodies, thus aiding in the selection of drilling sites. Unfortunately, data in the eastern part of the region, including the study area, were insufficient to identify or clearly define trends. The preliminary maps, therefore, are not included in this report but are available for inspection in the offices of the Missouri Geological Survey in Rolla.

### GEOLOGIC MAPPING

Boyd R. Haley of the U.S. Geological Survey mapped the rocks in the 12-quadrangle area as shown in figure 1. His objective was to define and delineate the geographic limits of the sandstones that serve as the reservoir rock for the heavy oil. His map units in ascending order are as follows: 1) the Mississippian-age rocks or, in the areas where they are missing, the Ordovician-age rocks; 2) an interval, generally less than 70 feet thick, of shale and siltstone with one or two coal beds, and in several places a basal bed of sandstone; and 3) a zone, as much as 100 feet thick, which is predominantly sandstone that comprises the reservoir rock. Within the second zone Mr. Haley attempted to distinguish the

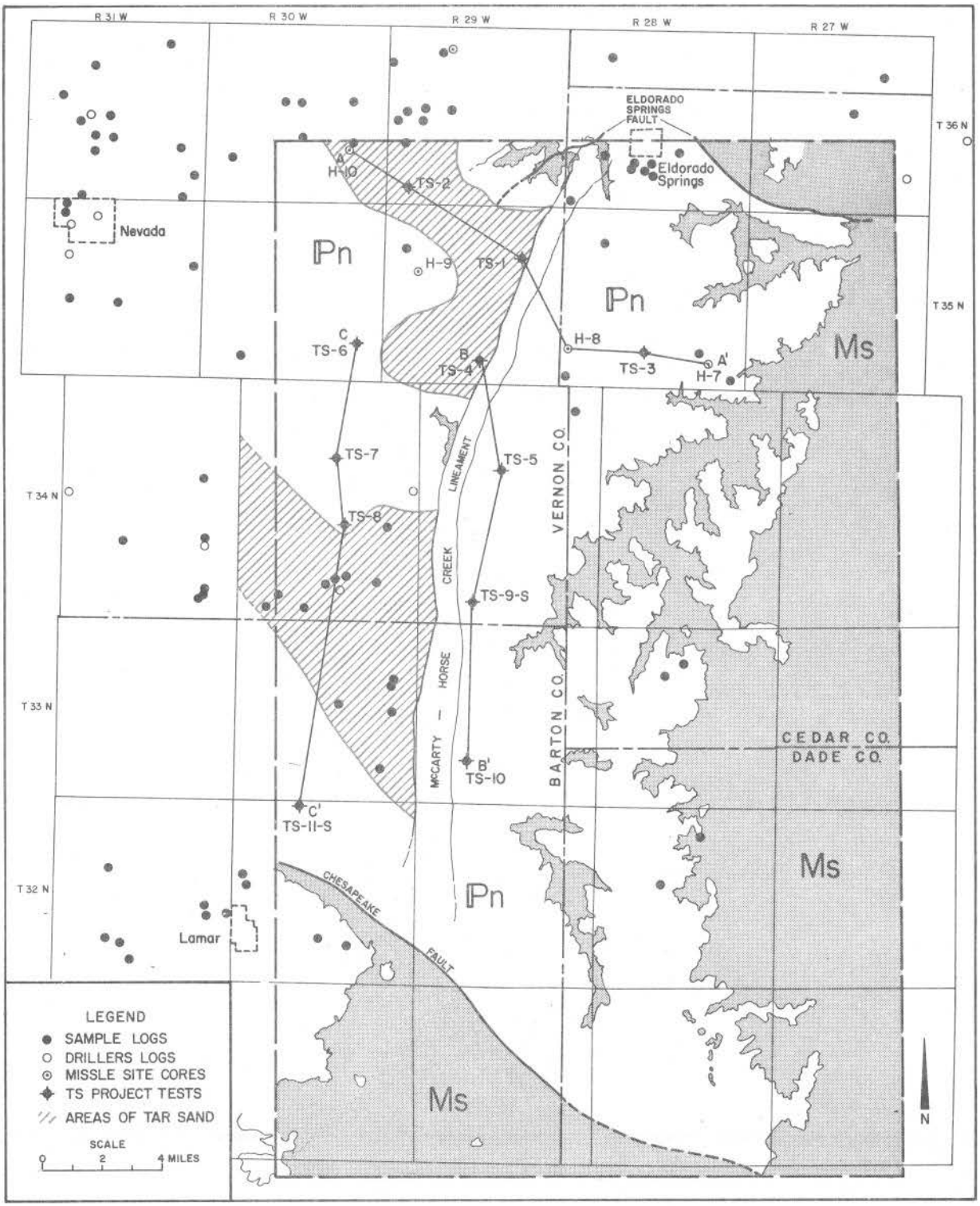


Figure 2. This map of the study area shows geology and surface features as mapped by Haley and location of lines of cross sections and location of tar sands as plotted by Wells. Locations and types of drill holes indicated in the legend are shown for the general area.

Riverton Formation from the Warner and the Rowe-Drywood Formations.

Before mapping, Mr. Haley was provided with published references, and toured the area with Missouri Survey personnel to review various sections that had been either measured or otherwise previously identified. One of the key sections crops out approximately 4 miles south of Lamar, Missouri in the southern portion of the study area and is identified by Searight (1955, fig. 6, p. 5) as Bluejacket sandstone over a "typical" exposure of the underlying Rowe and Drywood coals. Other described sections within the area were similarly used for references and correlation during the course of mapping.

Because of some continuing problems with correlation of surface exposures as mapped, with subsurface data acquired in the course of drilling, the geologic maps of Haley will not be published until further work can be scheduled, and the problems resolved.

It appears to the author that the contact line representing the base of the sand unit identified as Bluejacket on the maps is consistent and accurate, but he questions the identification of the sand as Bluejacket. Based on data available at this time it appears that this contact may well be the Warner-Riverton boundary. This interpretation would result in the outcrop section south of Lamar (previously referred to) being Warner sandstone rather than Bluejacket, and the underlying coals being in the Riverton instead of the Rowe and Drywood as presently identified.

Tectonic features mapped by Mr. Haley include the extension of the northwest-trending Chesapeake fault from southwestern Dade County into Barton County. Two parallel north-trending lineaments were mapped which extend from the El Dorado Springs fault system near the town of El Dorado Springs in the north, to near the Chesapeake fault in the southern part of the map area. On the base map, figure 2, this is referred to as the McCarty-Horse Creek lineament. At first this lineament was thought to be a fault, but the current interpretation favors it being some sort of structural flexure such as a monocline.

## DRILLING

Test drilling sites were selected primarily on the basis of the absence of existing data, so that the geographic extent of tar sands could be determined. A few sites were selected so that existing core data (missile-site cores) could be utilized in the construction of cross sections. Topographically high areas were selected so that a maximum of section could be sampled. Areas were ruled out in which an estimated minimum of 50 feet of section would not be present. The result was a modified grid pattern, the drilling on which would

hopefully achieve our basic need for stratigraphic control as well as test for heavy oil occurrences.

Actual drilling started on June 21, 1976 and was completed July 14, 1976. Nine core holes and two rotary "slim holes" were drilled into or nearly to the top of the Mississippian. A total of 1,476.8 feet of section was sampled, of this amount about half (695 ft.) was sandstone of the Bluejacket and Warner Formations. Gross sand thickness encountered varied from 20 feet in test hole 9, to 95 feet in test hole 8, with an overall average of 63 feet of sand per hole.

## GEOLOGY

The study area of southeastern Vernon and northeastern Barton Counties lies along the southern edge of the Forest City basin and the northern margin of the Cherokee platform. Regionally, the Pennsylvanian strata dip west to northwest at 10 to 20 feet per mile; however, local structures may modify the general attitude of the beds.

Major structural features in the study area include the El Dorado Springs fault (fig. ), which is considered to be part of the Bolivar-Mansfield fault system of southwest Missouri (McCracken, 1971, p. 14). This fault system was a factor in determining the northern boundary of the study area, as very few shows of heavy oil have been recorded northeast of the fault, even though it appears that sand deposits within the Krebs subgroup are particularly well developed in that area.

Another major structural feature is the Chesapeake fault (fig. 2) which effectively served as the southern boundary of the study area, as rocks on the south side of this northwest-trending fault are Mississippian in age.

On the basis of geologic mapping by Mr. Boyd Haley, a north-trending structural lineament was defined and is herein referred to as the McCarty-Horse Creek lineament. A westward-facing topographic scarp is prominent along much of the lineament. Beds along this lineament dip sharply westward over a relatively short distance and then regain the gentle westward regional dip defining a structure which is interpreted on the cross section as a monocline. It is possible that future studies may indicate faulting along part or all of this feature.

A composite, generalized stratigraphic section of the exposed Pennsylvanian rock units present within the study area is shown in figure 3. This column represents the strata encountered during drilling; it should not be considered representative for the whole of Vernon and Barton Counties. Correlation problems between subsurface and surface data arose during the course of this investigation that make the column nomenclature disagree with recognized Missouri Survey nomenclature.

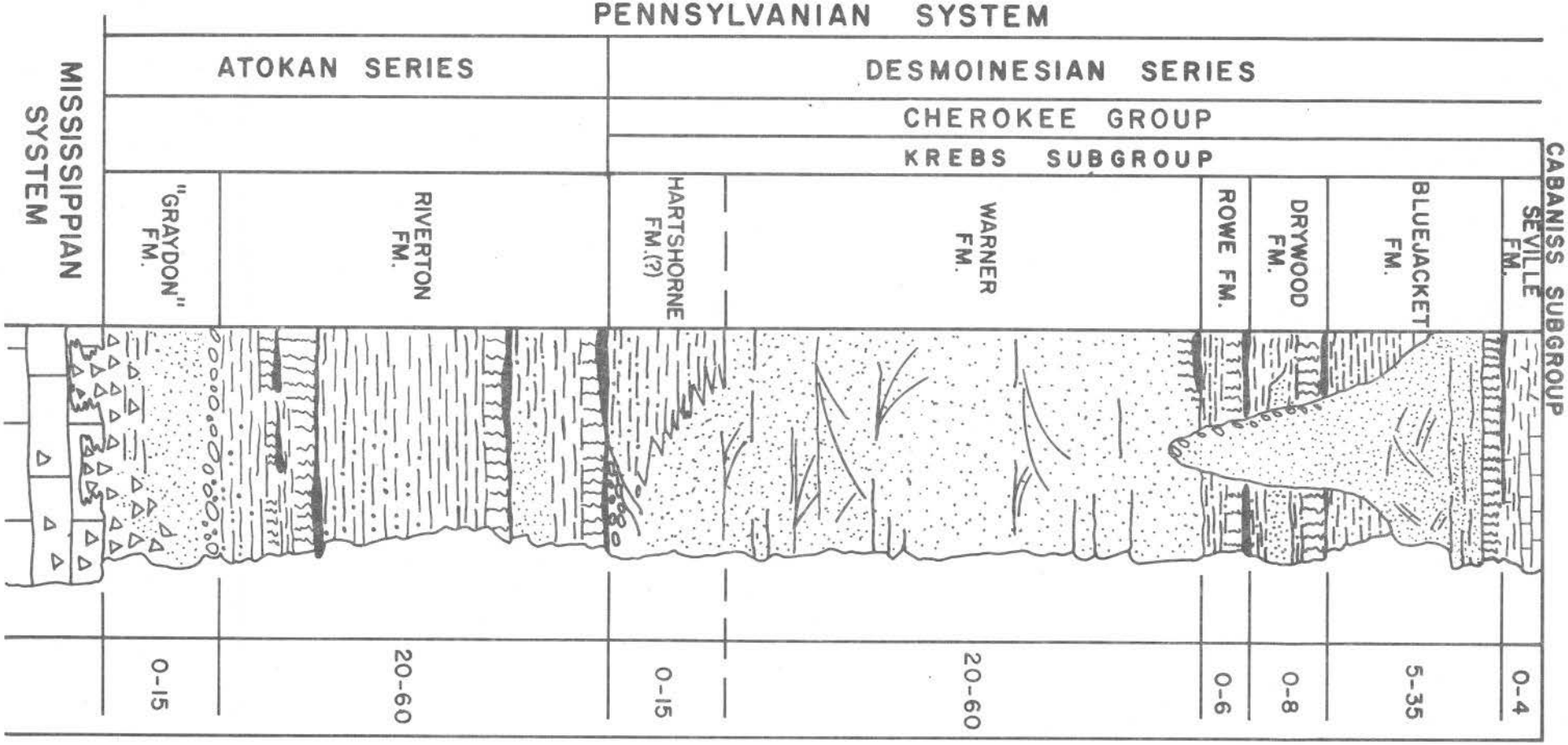


Figure 3. Generalized composite stratigraphic section of Pennsylvanian rock units encountered within the study area.

The following descriptions of and comments pertaining to the Pennsylvanian formations encountered are brief and limited to conditions as observed within the study area. For additional information, the reader is referred to Richard J. Gentile's 1976 report on the geology of Bates County, and The Pennsylvanian System, Supplement 2 to Volume 40, The Stratigraphic Succession in Missouri, by Thomas L. Thompson and Wallace B. Howe (in progress).

## "GRAYDON" FORMATION

Although the term "Graydon" is not formally recognized by the Missouri Survey at this time, strata fitting the description of the "Graydon" Formation as described by Winslow, 1894, p. 422-424, have been recognized in the study area and have therefore been so assigned in this report.

The strata between the Riverton shales and the Mississippian limestones consist of several feet of chert breccia with a matrix of varying amounts of clay and sandstone. In one of the test holes (No. 1) a breccia composed of a poorly sorted quartz sandstone matrix containing chert fragments up to .2 foot diameter was encountered overlying approximately 15 feet of medium-grained clean quartz sandstone with contorted laminae of green clay. This in turn graded downward into another chert breccia with a dark gray to black clay matrix. Generally the "Graydon" grades downsection into "beds" of chert over .3 foot thick that are interpreted as residual chert with the once-interbedded limestone dissolved away. In sections of this type the Mississippian-Pennsylvanian contact was placed arbitrarily where the chert comprised most of the sample, and appeared to be bedded or existed as large horizontally-aligned blocks.

## RIVERTON FORMATION

Rocks assigned to the Riverton Formation were encountered consistently during the drilling program, and ranged from 30 to 50 feet in thickness, averaging 40 feet thick. Surface exposures identified as Riverton have been recognized, but, they are very limited in areal extent. Mr. Haley mapped exposures at only two isolated locations and these averaged less than 20 feet in thickness. One of the exposures occurs along a portion of Cedar Creek in Secs. 10 and 15, T. 35 N., R. 27 W. (Filley quad); the other occurrence, also on the Filley quad, is in Sec. 5 along the north side of Alder Creek.

In this area the Riverton consists of dark gray to black shale that is hard, brittle and "slickensided". In subsurface sections sandy zones may occur in beds identified as Riverton. Thin (4- to 6-foot) beds of relatively clean sandstone occur locally within this interval and are thought to have contributed to

the misidentification of some surface exposures of Riverton as Warner in earlier mapping.

One of the major discoveries made during the drilling program was the fairly persistent occurrence of three thin coal beds in the Riverton Formation. These coal beds were generally thicker and were more persistent in occurrence than coals found in the Rowe and Drywood Formations. The thickest coal bed was 1.2 feet thick, although 1.8 feet of coal in two beds separated by 1 foot of shale was penetrated at a depth of 103.8 feet in test hole 8.

The disconformity at the top of the Riverton marking the contact between the Atokan and Desmoinesian Series is not well defined. When present it is probably represented and marked by the base of distributary channel sandstones of the Warner Formation. In many cases however, the contact with the overlying Warner appears to be conformable, and deposition is interpreted as having been within an interdistributary or delta-front environment. In this situation, the contact is represented by a gradational sequence, several feet thick, of alternating laminae of light gray sandstone and dark gray shale. This interval may represent the Hartshorn*.

In either case, the time lapse between the close of deposition of the Riverton and the beginning of Warner deposition appears to be insignificant.

## WARNER FORMATION

The Warner Formation is basically a sandstone with minor amounts of shale underlain by a thin clay. When in the channel mode of deposition a chert conglomerate at the base of the unit may also be present. A thin coal (Warner) is occasionally present at the top of the sandstone. Thickness of the sandstone ranges from 20 to 65 feet in this area, averaging 50 feet.

The predominantly quartz sand is fine to medium-coarse, and is generally coarser, more rounded and mineralogically more mature than the overlying Bluejacket sandstone. It is commonly cross-stratified and more massive than the Bluejacket; however, this criterion cannot be relied upon to differentiate between the two sands. (Drilling has shown cross-bedded channel-type deposits to be more common in the Bluejacket than previously thought.) The sandstone of the Warner is locally impregnated with hydrocarbons and is considered one of the

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** Beds of sandstone and shale that lie between the Warner Formation and the Riverton have been tentatively assigned to the Hartshorn(?) Formation by Howe and Searight (1961). In cross section A-A this interval may be respresented in test hole No. 1 and in the missile site test No. H-7. Other test holes in which this interval may be represented are numbers 8 and 11.*

two major horizons from which commercial quantities of heavy oil may be exploited in the future.

The upper boundary of the Warner is difficult to determine in much of the study area because the overlying Rowe and Drywood Formations may be absent, cut out by channels now filled with Bluejacket sands. As a result, in several of the test holes an upper boundary cannot be established with any degree of certainty. In many instances a disconformity at the base of the Bluejacket, marked by a thin conglomerate of rounded and eliptical particles of claystone, coal fragments and shale, represents an eroded upper surface of the Warner.

## ROWE-DRYWOOD FORMATIONS

The Rowe Formation, from the base upward consists of gray shale, sandy shale, siltstone, an underclay and, at the top, the Rowe coal. Thicknesses range from 0 to 6 feet in this area. The Rowe coal bed is thin (less than 8 inches) where present in small, local depositional "basins".

The Drywood Formation attains an observed thickness of 5 to 12 feet in test holes 2, 3, 5, 10 and 11, and consists of gray shale, sandy shales, siltstones, and an underclay with an overlying coal, the Drywood. This sequence is indistinguishable from the underlying Rowe and unless both sequences were present no attempt was made to separate the Rowe-Drywood. As a result the two formations were identified as a single unit on the geologic maps as well as on most logs of the test drilling.

Throughout much of the study area, channel cutting during Bluejacket time virtually eliminated the Rowe-Drywood Formations.

## BLUEJACKET FORMATION

The Bluejacket Formation is represented by a thick sandstone unit that varies from thin-bedded fine sandstone or shaly siltstone, to medium-bedded to massive, cross-bedded, medium-grained sandstone. The "sands" may grade from siltstone to shale within relatively short distances. Thicknesses range from 5 to 35 feet, varying as a result of erosion (if exposed at the surface) and because of the channel-fills extending downward into the underlying formations.

The Bluejacket Formation is one of the two major reservoir rocks for the accumulation of heavy oil in Vernon and Barton Counties. Shows of "tar" occur seemingly at random, in amounts ranging from a "trace" to "heavily saturated".

## SEVILLE FORMATION

The Seville Formation is basically a thin, patchy, marine limestone but may contain a few feet of calcareous and fossiliferous shale below and above the limestone. Typically the limestone is pinkish-gray or rusty-red in outcrop, to gray or black, finely crystalline and fossiliferous (brachiopodal), and ranges from a few inches to less than 4 feet in thickness.

## EXTENT OF TAR SANDS

Core-drilling demonstrated the variability of occurrence of tar sands or shows of oil; some wells did not encounter shows even though they were located within an area where oil was more or less expected. One of the notable wells in this category was test hole 8 northwest of the town of Bellamy, where the Phillips Petroleum Company conducted a pilot in situ recovery project between 1955 and 1958. Sand development in this well was excellent with approximately 100 feet encountered in one continuous interval. Traces of gilsonite and "dead oil" were encountered in the lower 50 feet of the sand. One interpretation suggests that oil had been present at one time, but has since been flushed.

Fair shows of oil, later calculated on the basis of core analysis to indicate a minimum resource of 300 bbl/acre ft., were encountered in test holes 1, 4 and 7, which cut a total of 52 feet of petroliferous sand.

A much larger percentage of sandstone contained dead oil as a disseminated, dark, "tarry" residue and as gilsonite(?) or disseminated black shiny particles. Occurrences of this nature, amounting to a total of 66 feet, were encountered in test holes 2, 6, 7, 8, 9 and 10.

Oil and "tar" occurrences were present in both the Bluejacket and Warner Formations. If stratigraphic or structural controls for the oil occurrences exist, they are not apparent. There were more occurrences within the Warner; however, this unit is thicker and more widespread in occurrence than the Bluejacket which would naturally result in an apparent preference for the Warner. Additional, deeper drilling in western Vernon and Barton Counties may resolve some of the unanswered questions about the occurrence and apparently erratic nature of these heavy oil deposits.

The U.S. Bureau of Mines analyzed five samples that were selected as being representative of what is casually classified in the field as a "fair" show; that is, something better than "poor" but not as rich as the "good", dark brown, oil saturated sands as exposed at the Silica Rock Products Quarry immediately southeast of Bellamy, Missouri.

The results of the analyses of these five samples are as follows:

| Sample No. | Depth (ft.) | Oil (saturation, %) | Porosity (%) | Permeability (md.) |
|---|---|---|---|---|
| 1 | 13 | 20.7 | 25.6 | 736 |
| 2 | 15.5 | 21.5 | 21.9 | 286 |
| 3 | 17.5 | 21.4 | 22.3 | 252 |
| 4 | 19.0 | 20.7 | 23.1 | 137 |
| 5 | 21.0 | 27.1 | 20.0 | 245 |

Original estimates of the amount of oil in place for a portion of western Missouri were made by Wells in 1974 (unpubl. map) based on scattered subsurface data and the few known outcrops. More than one billion bbls. of oil were estimated to be present within the study area. This figure assumed an average of 20 feet of saturated sand and 400 bbls. of oil per acre foot.

Based on data acquired during the course of this investigation, the estimated resource base has been revised sharply downward to 287 million bbls. The average thickness of saturated sand remained at 20 feet. The estimated 400 bbls. of oil per acre foot of sand was reduced to 350 bbl/acre ft. The major change was a reduction in the number of acres that may be underlain by saturated sands. This is now estimated to be approximately 41,000 acres in two broad northwest-trending bands as shown on figure 2.

Although a slight show of oil was recorded in hole 9-S, no other subsurface occurrence was noted east of the McCarty-Horse Creek lineament. It appears that this structure may have been a factor limiting the occurrence of these deposits eastward. However, as well control is sparse in the area, more drilling would be needed to validate this general statement. No occurrences of tar sands were plotted on the map (fig. 2 ) east of this lineament.

Depths to the top of the tar sands within the map area range from 5 to 10 feet (just under surface soil and clay) to a maximum of 70 feet. A majority of the oil shows occur between 25 and 45 feet, making this area attractive for the possible recovery of oil through stripping or mining techniques.

## CROSS SECTIONS

Plates 1 and 2 show three cross sections that were constructed using

drillhole data acquired under this contract, along with core descriptions of some test holes drilled by the U.S. Corps of Engineers for U.S. Air Force missile sites. Plate 1 is a generally east-west cross section and Plate 2 consists of two north-south cross sections. The locations of cross sections AA', BB' and CC' are shown on figure 2.

In general the two most persistent units present in the area are the Riverton and Warner Formations. Based on the correlations shown on the cross sections, it is interpreted that the Riverton and Warner Formations did not pinch out by reason of onlap near the present area of outcrop, but extended eastward over a much broader area than previously believed. This correlation also reinforces the argument of the author that the base of the sandstone unit mapped by Haley and thought to be Bluejacket is in reality the base of the Warner Formation.

The structure shown in cross section AA' between test holes 1 and H-8 is portrayed as a monocline although it was mapped as a possible fault during surface mapping by Haley. It is possible that this feature may be a fault along all or part of its length deeper in the subsurface.

Other notable features include channel-fills of Bluejacket sand into the Warner, cutting out the Rowe and Drywood Formations. Some of the correlations relative to this part of the section are somewhat tentative, being based on the presence of clay pebbles, transported coal fragments, etc., that would indicate the bottoms of distributary channels.

## SUMMARY AND CONCLUSIONS

Within the study area, occurrences of tar sands were mapped in two broad northwest-trending bands having an areal extent of approximately 41,000 acres, and containing a calculated 287 million barrels of oil. No attempt was made to estimate how much of the resource base might be considered reserves, as there are too many factors outside the scope of this study that must be considered to arrive at a figure of this nature.

Based on the results of drilling, it appears that the Bluejacket and Warner sands are part of a paleodeltaic distributary system. Channel deposits, and what are interpreted as overflow deposits characterize both formations, but especially the Bluejacket. Within the study area, the Warner Formation is the thicker of the two and is more extensively developed; the Bluejacket is somewhat thinner (partially a result of recent erosion where exposed at the surface) except where it is preserved as channel deposits extending down into the underlying strata.

More occurrences of heavy oil were observed in the Warner than in the Bluejacket; however, this relationship may simply reflect the fact that the Warner is thicker and has a greater areal extent. The study revealed no apparent controls, structure or stratigraphic, for the heavy oil occurrences. It is emphasized however, that the amount of drilling completed for this project was insufficient to provide a basis for any valid conclusions pertaining to the manner of accumulation or entrapment.

Oil is not uniformly distributed throughout the 41,000 acres described in this report as oil-bearing; some areas may be practically barren. Conversely, other areas lying outside of the oil-bearing region may contain oil. The resource base estimate of 287 million barrels of oil assumes that the values assigned such anomalous areas balance or cancel each other. Because of the erratic distribution of sands as well as the oil within the sands, a much more closely spaced drilling pattern would be required for calculation of a precise resource base.

In addition to the resource evaluations derived through this investigation, another major result was the realization that several horizons in the "outcrop" section may have been misidentified by previous investigators. It is anticipated that the continuing program of ERDA-funded drilling will result in a series of reports dealing with identification of outcropping stratigraphic units and correlation with those units present in the subsurface of Missouri, Kansas and Oklahoma.

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# APPENDIX A

Core descriptions, lithologic logs, and Spontaneous Potential-Restivity and Natural Gamma curves of the 11 tests drilled are presented in this section of the report. "Standard" symbols were used in drafting the lithologic columns. If the reader is not familiar with these symbols, he is referred to the written core description which follows each graphic log.

Cores were described by Dr. Richard Gentile, and strip logs prepared by the author from those descriptions. Sample logs for tests 9-S and 11-S were prepared by the author following microscopic examination of ditch samples. Sample descriptions were typed from notes taken by Richard Gentile based on field examination of these cuttings. Correlations on the written logs are those of Richard Gentile; the author agrees very closely with most of these.

MISSOURI DEPARTMENT OF NATURAL RESOURCES
DIVISION OF GEOLOGY AND LAND SURVEY
USGS – TS NO. 1
LOC: 15' FSL & 2640' FEL, SEC. 11, T. 35 N., R. 29 W., VERNON CO.
SURF. ELEV. 845 FT. TOTAL DEPTH 119.6 FT. (36.5 M.)

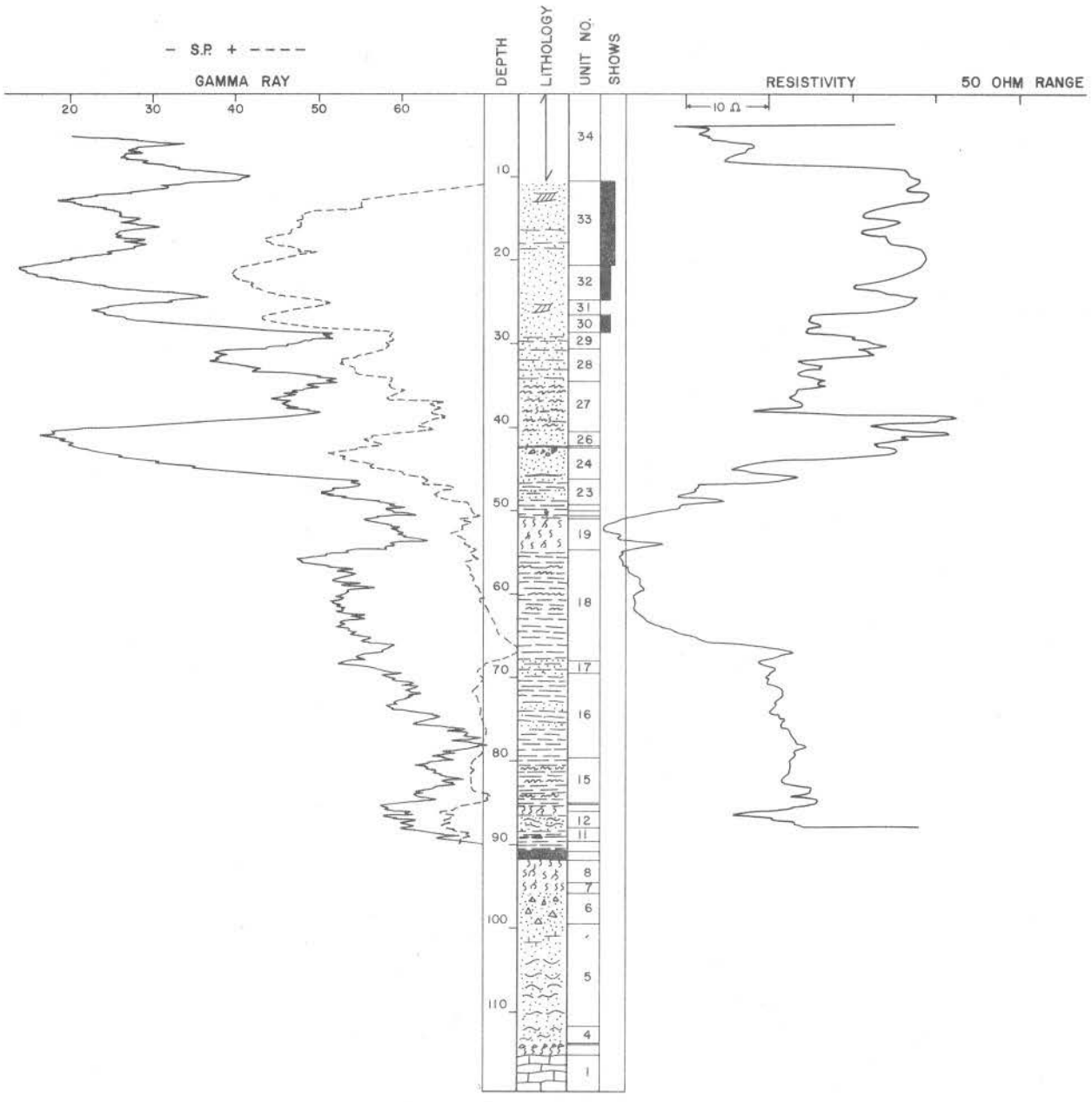


Figure 4. Composite log of USGS No. 1.

USGS-TS - No. 1
NQ Core, logged by Richard J. Gentile, 6-12-76
Location: 15' FSL & 2,640' FEL, Sec. 11, T. 35N., R. 29W., Vernon County

Cored in drainage ditch on N side of gravel road. 80 ft. east of center of T road to north and 50 ft. east of corner fence post. Coast and Geodetic Survey Bench Mark no. H262 (1963) is 22 ft. east of corner fence post. 5 miles SW Eldorado Springs.

Elevation: 845' Total Depth: 119.6' (36.45 m)

| DEPTH | | UNIT | DESCRIPTION |
|---|---|---|---|
| 0.0 | 10.6 | 34 | no core; soil and weathered rock |
| 10.6 | 20.6 | 33 | ss., fine grained, quartzose, micaceous, approx. 5% of section in bottom 5 ft. is interbedded shale laminae; asphalt or heavy oil stained, oil coats grains, no bleeding observed |
| 20.6 | 24.7 | 32 | ss., fine grained, dk. gray with some lt. gray speckled areas. micaceous, asphaltic |
| 24.7 | 26.4 | 31 | ss., fine grained, dk. gray with lt. gray ss. lenses, cross stratified |
| 26.4 | 28.6 | 30 | ss., same as from 20.6 to 24.7, thin streaks, asphalt stained |
| 28.6 | 30.6 | 29 | ss., interbedded with clayey, fine ss. or silt |
| 30.6 | 34.6 | 28 | ss., lt. gray, ripple marked, cross-bedded, interbedded with dk. gray silty shale |
| 34.6 | 40.6 | 27 | siltstone, clayey with lt. gray ss., laminae |
| 40.6 | 42.2 | 26 | ss., lt. gray (1/8-1/4 mm. grain size) |
| 42.2 | 42.3 | 25 | coal, bright |
| 42.3 | 46.1 | 24 | ss., lt. gray, med. grained (1/8-1/4 mm), few thin shale laminae; angular clasts of clay or coal in top few inches; thin laminae of coal at bottom; nodule of pyrite to .05 ft. dia. at 44.6 |
| 46.1 | 49.2 | 23 | shale dk. gray (wet) and lt. gray fine to med. sandstone, ripple marked, interbedded |

| | | | |
|---|---|---|---|
| 49.2 | 50.0 | 22 | shale, black, (wet) |
| 50.0 | 50.6 | 21 | lost core |
| 50.6 | 50.8 | 20 | shale, black, broken fragments in drilling |
| 50.8 | 54.8 | 19 | clay, lt. gray, fossilized roots at top, difficult to drill, broken; possibility of coal lost at this interval instead of from 50.0 to 50.6 |
| 54.8 | 68.1 | 18 | shale, black (wet); .2 ft. zone of sand sized siderite concretions at 55.6; few lt. gray silt laminae; inclusions of pyrite .02 to .01 ft. dia. |
| 68.1 | 69.6 | 17 | shale, dk. gray to black, about 10% of unit interbedded laminae of fine lt. gray ss. |
| 69.6 | 79.6 | 16 | shale, dk. gray to black; pyrite inclusions, plant remains (bits of leaves, etc.) few interbedded laminae of lt. gray, quartzose ss. |
| 79.6 | 85.0 | 15 | shale, dk gray to black, few thin laminae of lt. gray silt |
| 85.0 | 85.05 | 14 | clay, slightly calc., nodular |
| 85.05 | 86.0 | 13 | clay, lt. to med. gray, fossil root and leaf remains |
| 86.0 | 88.2 | 12 | shale, dk. gray, thin contorted lt. gray ss. lenses; linear burrows filled with calc. clay |
| 88.2 | 89.6 | 11 | shale, black; a .1 ft. coal lens near center with nodules and thin laminae of pyrite, plant remains near bottom |
| 89.6 | 90.8 | 10 | shale, black |
| 90.8 | 91.9 | 9 | coal, inclusions of pyrite to .05 in. dia. and thin pyrite lenses to .02 in. thick |
| 91.9 | 94.6 | 8 | clay, top .25 ft. is dk. gray, lt. gray at bottom; fossil roots |
| 94.6 | 95.9 | 7 | clay, dk. gray, slickensided |
| 95.9 | 99.6 | 6 | breccia, poorly sorted (to 1 mm dia.) quartzose ss. matrix; chert fragments to .2 ft. thick |

| | | | |
|---|---|---|---|
| 99.6 | 111.8 | 5 | ss., med. grained, lt. gray, clean, quartzose; contorted laminae of green clay comprising about 15% of unit; top 4 ft. calcareous; small pyrite nodules. |
| 111.8 | 113.8 | 4 | ss., quartzose, contorted dk. gray clay laminae, pyrite |
| 113.8 | 114.0 | 3 | breccia, dk. gray clay matrix; particles of chert to .2 ft. dia. |
| 114.0 | 115.2 | 2 | clay, green, abundant pyrite nodules to .05 ft. dia. at bottom |
| 115.2 | 119.6 | 1 | ls., lt. gray, coarsely crystalline, stylolites; green clay along stylolite surfaces; few chert nodules, some pyrite |

Formational Summary

| | |
|---|---|
| 0 - 10.6 | no core |
| 10.6 - 28.6 | Bluejacket Formation |
| 28.6 - 49.2 | Warner Formation |
| 49.2 - 95.9 | Riverton Formation |
| 95.9 - 115.2 | "Graydon" |
| 115.2 - 119.6 | Burlington Limestone |

Note: The coal at 42.2 ft. may be the Rowe but the absence of an underclay and disturbed nature of the underlying unit indicate woody material that was transported and incorporated into ss. at the base of a channel fill.

asphalt or heavy oil stained - 10.6-24.7, 26.4-28.6 ft.

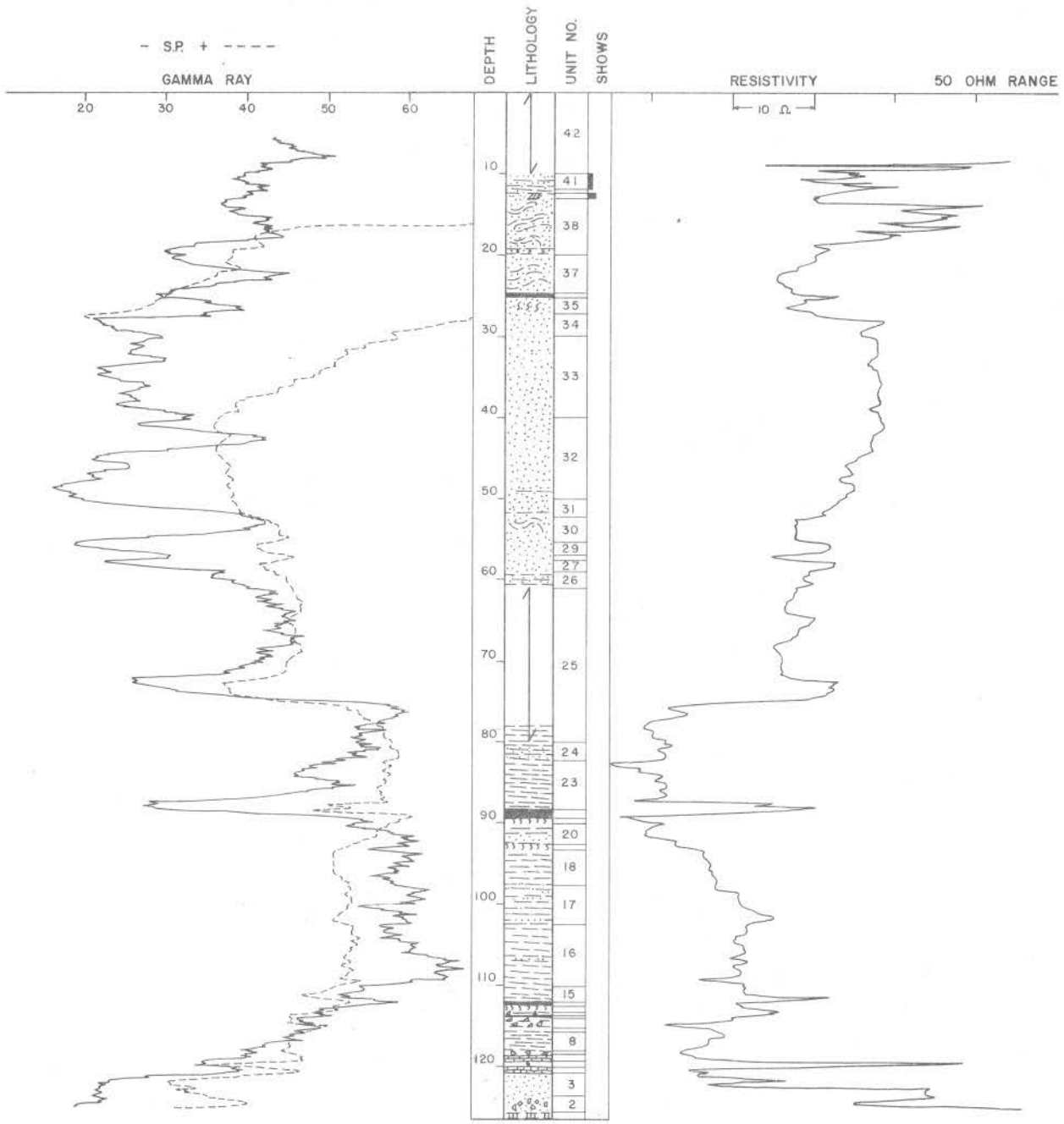


Figure 5. Composite log of USGS No. 2.

USGS-TS - No. 2
NQ Core, logged by Richard J. Gentile, 6/22-23/76
Location: 2,600'FNL & 1,320' FEL, Sec. 31, T. 36N., R. 29W., Vernon County

Approx. 2 miles west-southwest of Dederick. North side of dirt road at right angle bend to south.

Elevation: 820' Total Depth: 126.0' (38.4m)

| DEPTH | | UNIT | DESCRIPTION |
|---|---|---|---|
| 0.0 | 10.0 | 42 | no core - cuttings of weathered brown ss. |
| 10.0 | 12.0 | 41 | ss., a shale interbedded, few zones of dk. gray asphaltic stained ss. |
| 12.0 | 12.3 | 40 | shale, dk. gray |
| 12.3 | 12.5 | 39 | ss., dk. gray, cross-bedded, asphaltic stained |
| 12.5 | 20.0 | 38 | ss., lt. gray and shale dk. gray in intercalated laminae, contorted, bits of carbonized wood, leaves, etc.; bottom few inches a gray clay |
| 20.0 | 24.7 | 37 | ss., lt. gray and shale dk. gray in contorted intercalated laminae |
| 24.7 | 25.1 | 36 | coal, bright |
| 25.1 | 27.3 | 35 | ss., fine-grained, carbonized roots; lenses & nodules of pyrite |
| 27.3 | 30.0 | 34 | ss., fine-grained, specks of carbonized wood, etc. |
| 30.0 | 40.0 | 33 | ss., dk. gray, fine-grained, micaceous, coalified plant remains in small pieces |
| 40.0 | 50.0 | 32 | ss., dk. gray, fine-grained intercalated with lt. gray laminae of ss.; .1 ft. clay lens about .5 ft. from bottom |
| 50.0 | 52.2 | 31 | ss., med. to lt. gray, fine-grained; 2 thin, dk. gray shale lenses .5 ft. from bottom |
| 52.2 | 55.4 | 30 | ss., lt. gray and shale dk. gray, interlaminated, extensively contorted |

| | | | |
|---|---|---|---|
| 55.4 | 57.0 | 29 | ss., med. gray, fine-grained |
| 57.5 | 59.0 | 27 | ss., lt. to med. gray, fine-grained |
| 59.0 | 61.0 | 26 | ss., lt. gray (.1 ft. beds) and shale laminae interbedded, evenbedded |
| 61.0 | 80.0 | 25 | lost core except for 1 ft. section of clayey ss. which appears to be at top of column and 2 ft. section of black shale which probably represents bottom of column |
| 80.0 | 82.2 | 24 | shale, black, pyrite nodules, few ss. lenses |
| 82.2 | 88.2 | 23 | shale, black |
| 88.2 | 89.2 | 22 | coal, bright, pyrite |
| 89.2 | 90.0 | 21 | underclay, lt. gray |
| 90.0 | 92.6 | 20 | shale, med. gray to darker at bottom, few lt. gray ss. lenses & pods near bottom; some clay ironstone concretions |
| 92.6 | 93.2 | 19 | lost core, (possible coal) |
| 93.2 | 97.6 | 18 | clay-shale (poor fissility) med. gray; top few inches slickensided with fossil roots; silty at bottom |
| 97.6 | 102.5 | 17 | shale, dk. gray to black; about 20% of unit is intercalated with laminae and pods of lt. gray siltstone; evenbedded but some microfaulting |
| 102.5 | 110.0 | 16 | shale, dk. gray to black at bottom; 5% of unit is intercalated with lenses & pods of lt. gray ss.; bits of woody material along bedding planes |
| 110.0 | 112.0 | 15 | shale, dk. gray to black (wet) |
| 112.0 | 112.3 | 14 | coal, bright to dull fusain; pyritized wood |
| 112.3 | 113.2 | 13 | underclay; fossilized roots, slickensided; dk. gray mottled lt. gray |

| | | | |
|---|---|---|---|
| 113.2 | 113.3 | 12 | breccia, lt. gray chert fragments to .05 ft. dia.; dk. gray slickensided clay matrix, roots |
| 113.3 | 113.35 | 11 | coal, bright |
| 113.35 | 115.2 | 10 | breccia, chert fragments to .1 ft. dia., med. to lt. gray clay matrix |
| 115.2 | 115.4 | 9 | clay, lt. gray, pyrite inclusions to .05 ft. dia. |
| 115.4 | 118.0 | 8 | shale, lt. gray with .5 to 1 mm dia. soft white, non calc. concretions with soft white rind and hard interior, contorted laminae |
| 118.0 | 118.4 | 7 | clay, lt. gray, chert to .05 ft. dia. |
| 118.4 | 119.2 | 6 | ls., finely crystalline, solution cavities filled with green clay |
| 119.2 | 120.0 | 5 | lost core |
| 120.0 | 120.6 | 4 | ls., med. gray, finely crystalline |
| 120.6 | 123.4 | 3 | ss., quartzose, fine to med. grained, large inclusions of pyrite (Pennsylvanian age ss. filling solution cavity in Miss. ls.) |
| 123.4 | 125.5 | 2 | chert, lt. gray with blue-gray zones, interbedded with poorly sorted ss. (fine to coarse), chert fractures and is difficult to core; much pyrite |
| 125.5 | 126.0 | 1 | ls., lt. gray, finely crystalline with lenses of brownish gray chert |

Formational Summary

| | |
|---|---|
| 0.0 - 10.0 | no core |
| 10.0 - 12.0 | Bluejacket Formation |
| 12.0 - 75.0 | Warner-Rowe-Drywood Formations |
| 62.0 - 78.0 | core loss interval |
| 78.0 - 113.2 | Riverton Formation |
| 113.2 - 118.4 | "Graydon" |
| 118.4 - 126.0 | Mississippian |

Note: Lost interval from 62.0 to 78.0 represents lower part of Warner ss. and upper part of Riverton shale possibly also contained a coal and underclay.

Asphalt is confined to top 2 or 3 ft. of core

MISSOURI DEPARTMENT OF NATURAL RESOURCES
DIVISION OF GEOLOGY AND LAND SURVEY
USGS – TS NO. 3
LOC: 25' FSL & 1800' FEL, SEC. 28, T. 35 N., R. 28 W., CEDAR COUNTY
SURF. ELEV. 945 FT. TOTAL DEPTH 132 FT. (40.2 M.)

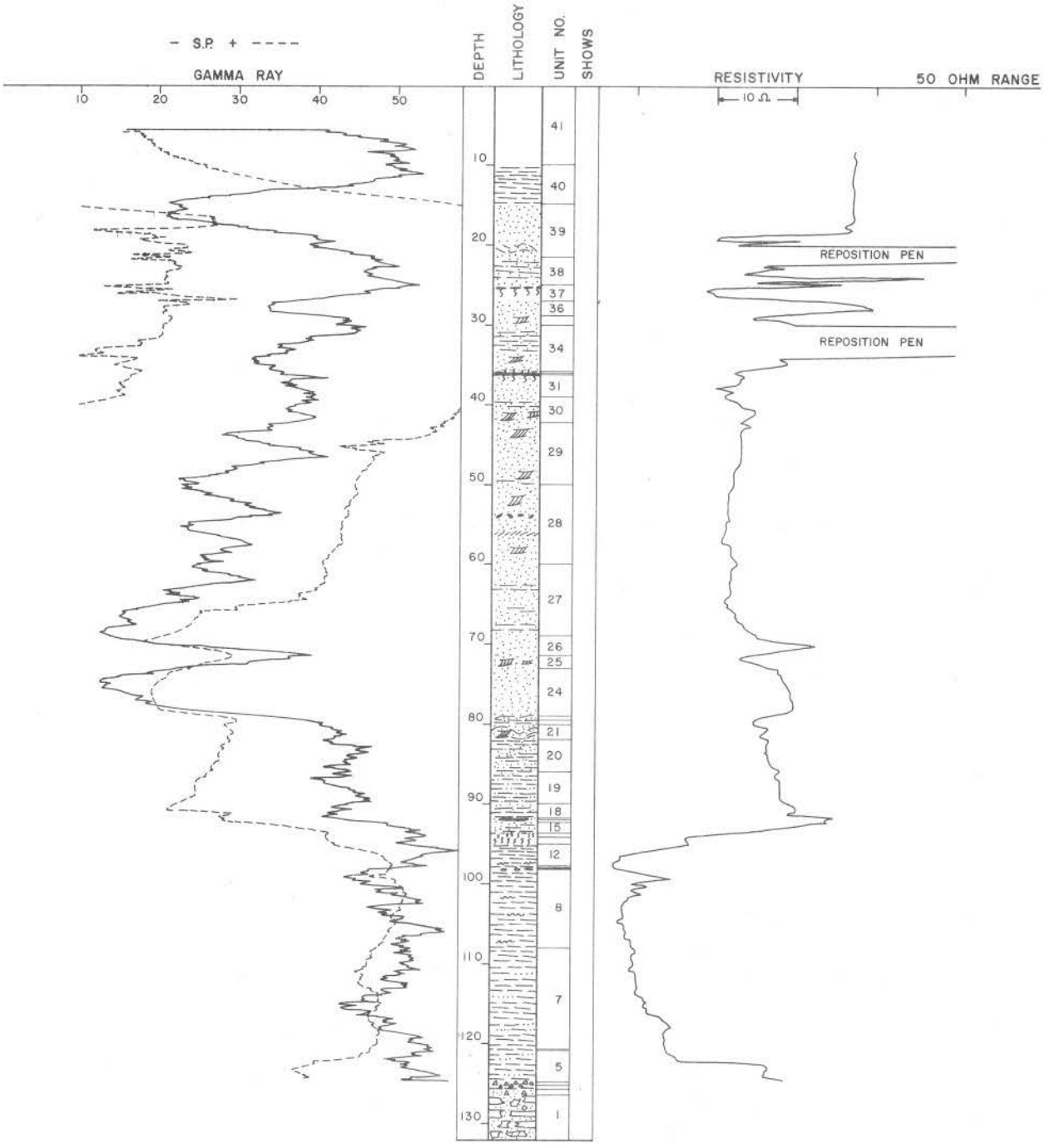


Figure 6. Composite log of USGS No. 3.

USGS-TS - No. 3
NQ Core, logged by Richard J. Gentile, 6/25-26/76
Location: 25' FSL & 1,800' FEL, Sec. 28, T. 35N., R. 28W., Cedar County

North side of State Hwy. 97, 18 ft. off of asphaltic pavement; 600 ft. east from Y in road of Hwy. 97 south and County road BB west. About 6 1/2 miles south of jct. Hwys. 54 and 32 at Eldorado Springs.

Elevation: 945' Total Depth: 132.0' (40.2m)

| DEPTH | | UNIT | DESCRIPTION |
|---|---|---|---|
| 0.0 | 10.0 | 41 | no core, soil and sandy red clay |
| 10.0 | 14.9 | 40 | no core; cuttings of gray shale too soft to core |
| 14.9 | 21.4 | 39 | ss., weathered brown, fine grained (1/8 mm) quartzose, few ironstone concretions and hollow casts to .1 ft. dia.; intercalated with wavy gray micaceous shale laminae in bottom |
| 21.4 | 25.0 | 38 | ss., med. gray clayey, laminated |
| 25.0 | 27.0 | 37 | clay, lt. gray, sandy, fossil root impressions in top, laminae of dk. shale at top may represent a coal horizon |
| 27.0 | 28.8 | 36 | ss., med. gray, micaceous, fine grained, specks of fossil plant material; appears homogeneous with few if any structures |
| 28.8 | 30.0 | 35 | ss., med. gray, salt and pepper appearance, intercalated with lt. gray ss. laminae; small scale cross-stratification |
| 30.0 | 35.8 | 34 | ss., med. to lt. gray, intercalated with dk. gray shale laminae; cross-bedded to homogeneous at bottom |
| 35.8 | 36.0 | 33 | clay, sandy, slickensided, interbedded laminae of coal |
| 36.0 | 36.2 | 32 | coal, pyritized plant bearing concretions to .05 ft. dia. |
| 36.2 | 39.0 | 31 | ss., fine grained, fossilized roots pyritized in places, clayey |
| 39.0 | 42.2 | 30 | ss., lt. gray, thin bedded, mica flakes along bedding planes, |

| | | | |
|---|---|---|---|
| 42.2 | 50.0 | 29 | ss., thick even beds to cross stratified; fine grained (1/8 mm dia.); few dk. gray shale laminae, micaceous; 2 or 3 distorted, discontinuous coal laminae 1 ft. from bottom represents transported wood |
| 50.0 | 60.0 | 28 | same as overlying unit but with .2 ft. zone of discontinuous randomly oriented coal pieces at 54.0 to 54.2 ft.; (a breccia with clasts of coal); .2 ft. zone of inclined dk. gray shale lenses from 56.2 to 56.4 ft. |
| 60.0 | 69.0 | 27 | ss., fine grained, quartzose, micaceous, thick bedded, lenses of dk. gray shale every several inches in section |
| 69.0 | 71.3 | 26 | ss., fine grained, cross-stratified; small irregular shaped light gray blotches cemented with $CaCO_3$ |
| 71.3 | 73.0 | 25 | ss., lt. gray, cross bedded, interbedded with med. gray shale |
| 73.0 | 79.0 | 24 | ss., fine grained, massive appearance |
| 79.0 | 79.6 | 23 | ss., with discontinuous randomly oriented coal laminae |
| 79.6 | 80.0 | 22 | shale, med. gray |
| 80.0 | 82.0 | 21 | ss., lt. gray, cross-bedded to convolute bedded; interbedded with med. gray shale |
| 82.0 | 86.0 | 20 | shale, very sandy, med. gray; few lt. gray convoluted fine grained ss. lenses |
| 86.0 | 90.0 | 19 | shale, med. gray, very sandy |
| 90.0 | 91.7 | 18 | ss., clayey, med. gray, fine to coarse grained |
| 91.7 | 91.9 | 17 | coal, lenticular, pyrite |
| 91.9 | 92.2 | 16 | ss., lt. gray, med. grained, interbedded with med. gray fine grained ss.; lenses of pyritized coal and plant fragments throughout interval; sharp contact with underlying unit |
| 92.2 | 93.7 | 15 | ss., lt. gray, ripple marked and dk. gray shale interlaminated in top half; grading into predominantly dk. shale at bottom |

| | | | |
|---|---|---|---|
| 97.3 | 94.1 | 14 | clay, lt. gray, fossil roots, sharp wavy contact with overlying unit (a scour surface) |
| 94.1 | 95.2 | 13 | clay, lt. gray |
| 95.2 | 97.7 | 12 | shale, med. gray at top to black at bottom; few lenses of lt. gray siltstone |
| 97.7 | 98.0 | 11 | shale, black |
| 98.0 | 98.15 | 10 | clay, concretionary, with cone-in cone structure, calcareous; high S.G. |
| 98.15 | 98.3 | 9 | shale, black, high S.G. |
| 98.3 | 108.0 | 8 | shale, black; 2 or 3 zones to .1 ft. thick of small siderite concretions in top half, a few thin lt. gray siltstone lenses, some pyrite |
| 108.0 | 120.7 | 7 | shale, black, a few thin lt. gray horizontal ss. laminae and pods; small nodules of pyrite; vertical joint filling of calcite at 115.0 ft. (The fracturing in angular fragments of this shale makes drilling difficult.) |
| 120.7 | 120.9 | 6 | shale, dk. gray with lt. gray patches; resembles a bioturbite |
| 120.9 | 124.8 | 5 | shale, dk. gray grading into black shale at bottom; horizontal lt. gray laminae and pods of fine grained ss. |
| 124.8 | 125.1 | 4 | breccia; chert fragments to .05 ft. dia. with dk. gray clay matrix |
| 125.1 | 125.6 | 3 | breccia, mostly large .2 ft. angular fragments of bluish-white chert with ss. matrix |
| 125.6 | 126.3 | 2 | ss., poorly sorted; rounded clear quartz grains and angular pieces of chert to coarse sand size; non calc. |
| 126.3 | 132.0 | 1 | breccia, chert beds to .5 ft. thick; solution pockets filled with poorly sorted ss. of fine to coarse size range, clayey, some pseudo oolites of clay to sand grain size; also pyrite concretions to sand grain size |

Formational Summary

| | |
|---|---|
| 0.0 - 10.0 | no core |
| 10.0 - 25.0 | Bluejacket Formation |
| 25.0 - 39.0 | Rowe-Drywood Formations |
| 39.0 - 93.7 | Warner Formation |
| 93.7 - 124.8 | Riverton Formation |
| 124.8 - 126.3 | "Graydon" |
| 126.3 - 132.0 | Mississippian |

Notes: Drywood coal horizon at 25 ft. Rowe coal at 36.0-36.2 ft. Interval 125.1-132 ft. represents chert rubble with ss. matrix underlain by bedded chert with ss. filling solution cavities probably where ls. was dissolved out. The top of the Mississippian is placed at 126.3 ft. or at top of the bedded chert.

No asphalt or heavy oil observed.

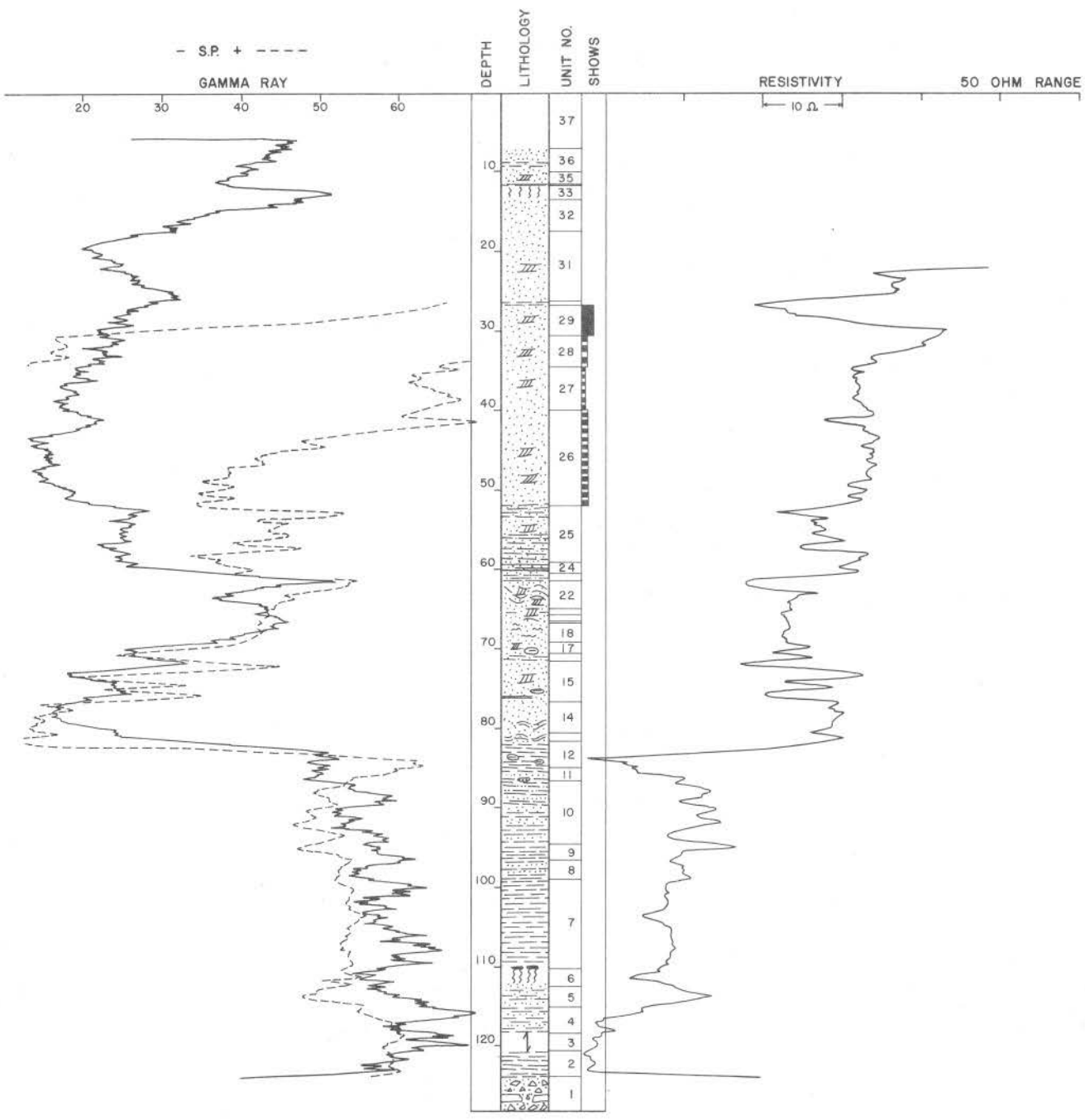


Figure 7. Composite log of USGS No. 4.

USGS-TS - No. 4
NQ Core, logged by Richard J. Gentile, 6/28-7/1/76
Location: 220' FNL & 1,170' FWL, Sec. 34, T. 35N., R. 29W., Vernon County

20 ft. west of N-S dirt road; 220 ft. south of right angle bend in road to south. 2 3/4 miles west of Virgil City.

Elevation: 925' Total Depth: 127.2' (38.8m)

| DEPTH | | UNIT | DESCRIPTION |
|---|---|---|---|
| 0.0 | 7.0 | 37 | no core, clay, sandy with granular ss. in bottom 1 ft. |
| 7.0 | 10.0 | 36 | ss., lt. gray with yellow-brown weathered zones, micaceous, ripple marked in bottom half, dk. gray sandy clay lenses |
| 10.0 | 11.7 | 35 | ss., fine grained cross-bedded, brown weathered zones |
| 11.7 | 11.8 | 34 | coal, 2 or 3 thin smuts with maroon clay partings |
| 11.8 | 13.4 | 33 | underclay, lt. gray, fossil roots, weathered brown zones |
| 13.4 | 17.3 | 32 | ss., lt. gray, fine grained, weathered brown zones; clay lenses to .1 ft. thick in bottom half |
| 17.3 | 26.2 | 31 | ss., brown, fine grained, cross-bedded, massive, laminae of dk. shale or coal smut at top, micaceous |
| 26.2 | 26.8 | 30 | ss., gray, grades downsection into brown sandy shale |
| 26.8 | 30.6 | 29 | ss., dk. gray to brown, asphaltic stained, fine grained, cross-bedded, micaceous |
| 30.6 | 34.6 | 28 | ss., same as overlying unit but asphaltic stained zones comprised about 1/2 of unit; unstained areas appear cemented with iron oxide |
| 34.6 | 40.0 | 27 | ss., same as overlying unit but slight asphaltic staining, zones cemented with hematite to .5 ft. thick; few nodules of pyrite weathering to hematite |

| | | | |
|---|---|---|---|
| 40.0 | 52.0 | 26 | ss., same as overlying unit but asphalt staining more pronounced but not as heavy as 26.8 to 30.6 ft. interval; few thin zones near top cemented with iron oxide |
| 52.0 | 59.0 | 25 | ss., gray, very little asphalt stain; pieces of carbonaceous plant material; fine grained, lt. gray cross bedded ss. laminae every few inches; soft shale laminae about every one foot interval |
| 59.0 | 60.2 | 24 | ss., med. grained, micaceous, 2 or 3 laminae of coal material in bottom .3 ft.; mica and bits of fusain along bedding plane |
| 60.2 | 61.5 | 23 | shale, sandy, med. gray |
| 61.5 | 65.0 | 22 | ss., lt. gray laminae and thin beds, cross bedded; intercalated with dk. gray wavy shale laminae and med. gray ss. beds to .1 ft. thick, med. grained, bits of carbon |
| | | | String of tools lost in hole, never recovered; new hole designated 4a drilled 5 ft. to south of abandoned hole; rock bitted to 60 ft. and no samples saved. |
| | | | Hole No. 4a |
| 65.0 | 65.7 | 21 | ss., lt. gray, fine grained, laminae and thin beds, cross stratified; interlaminated with dk. gray shale laminae and med. grained, dk. gray ss. beds to .2 ft. thick, bits of carbon |
| 65.7 | 66.6 | 20 | ss., dk. gray, (wet) clayey, massive with a few horizontal lt. gray ss. laminae and pods, micaceous |
| 66.6 | 66.7 | 19 | ss., med. gray, med. grained, flaser structure, interbedded with dk. gray sandy shale, contorted laminae |
| 66.7 | 69.1 | 18 | same as from 65.0 to 65.7; good flaser structure |
| 69.1 | 70.7 | 17 | ss., med. grained (1/4 mm) pred. round to angular quartz grains; bits of carbonaceous matter; cross bedded; bottom .4 ft. contains lenses and clasts of sandy shale |
| 70.7 | 71.7 | 16 | ss., laminae, lt. gray, fine grained, ripple marked, intercalated with dk. gray shale |

| | | | |
|---|---|---|---|
| 71.7 | 76.7 | 15 | ss., same as from 69.1 to 70.7 but friable; some inclined clayey ss. beds to .1 ft. thick; thin laminae of coal at 76.0 and 76.6 ft.; med. gray shale from 75.0 to 75.4 ft. |
| 76.7 | 80.7 | 14 | ss., med. grained, lt. gray, cross bedded; few thin contorted shale lenses in bottom half; friable in places |
| 80.7 | 81.7 | 13 | ss., similar to above unit but with intercalated dk. gray contorted shale laminae composing 30% of unit; fragments of coal in bottom .5 ft. |
| 81.7 | 85.0 | 12 | shale, black, sharp wavy contact with overlying lt. gray, med. grained ss.; .1 ft. clayey non calc. dk. gray finely crystalline ironstone lens or nodule at 82.6-82.7, 83.3-83.4, 84.4-84.5 and 84.9-85.1 ft. |
| 85.0 | 86.7 | 11 | shale, dk. gray, intercalated with thin laminae and pods of lt. gray ripple marked ss. |
| 86.7 | 94.7 | 10 | shale, black (wet) with approx. 40% of unit intercalated lt. gray, ripple marked laminae and lenses of fine grained ss. |
| 94.7 | 96.7 | 9 | shale, dk. gray to black, fractures into angular chips |
| 96.7 | 99.0 | 8 | shale, black, few thin laminae of lt. gray ss., laminae comprise about 20% of unit |
| 99.0 | 110.2 | 7 | shale, black, bits of fusain along bedding planes in lower part |
| 110.2 | 112.7 | 6 | clay, lt. gray, soft, sticky with exception of .1 ft. bands of hard, lt. gray slickensided clay at 112.4 and 112.6 ft. |
| 112.7 | 115.1 | 5 | ss., greenish gray, clayey, small concretions of siderite the size of oolites |
| 115.1 | 118.4 | 4 | shale, greenish gray, sandy lenses and streaks of dk. gray shale |
| 118.4 | 120.7 | 3 | lost core |
| 120.7 | 123.9 | 2 | shale, black, slickensided |

| | | | |
|---|---|---|---|
| 123.9 | 127.2 | 1 | breccia, waxy brown to white angular clasts to .3 ft. thick; bleached or weathered rinds around clasts; solution cavities filled with greenish gray, poorly sorted coarse ss., clayey; clasts of .2 ft. thick floating in ss. cavity fill; small siderite concretions |

Formational Summary

| | |
|---|---|
| 0.0 - 7.0 | no core |
| 7.0 - 81.7 | Warner-Rowe-Drywood-Bluejacket Formations |
| 81.7 - 123.9 | Riverton Formation |
| 123.9 - 127.2 | "Graydon" |

Note: Rowe and Drywood poorly developed or weathered unrecognizable. Top of Mississippian might be included in interval 123.9-127.2 as chert appears bedded. Estimated top of Mississippi Limestone at 130 ft.

Asphalt or heavy oil stained from 26.2 to 52.2 ft.

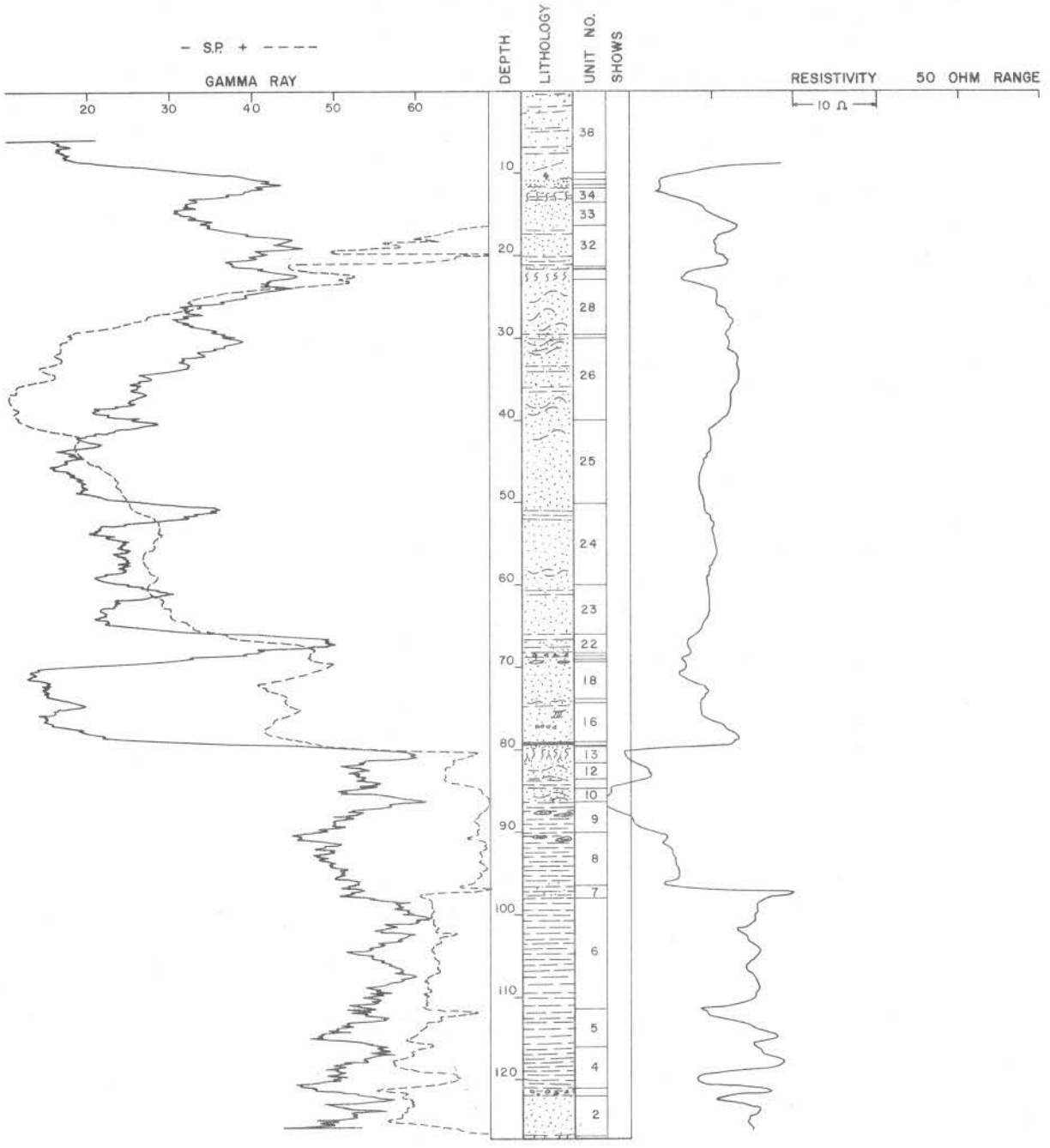


Figure 8. Composite log of USGS No. 5.

USGS-TS - No. 5
NQ Core, logged by Richard J. Gentile, 7/1-2/76
Location: 350' FSL & 1,340' FEL, Sec. 4, T. 34N., R. 29W., Vernon County

100 ft. to east of bend in county road NN. 3/4 mile south of Montevallo.

Elevation: 965' Total Depth: 127' (38.7 m)

| DEPTH | | UNIT | DESCRIPTION |
|---|---|---|---|
| 0.0 | 10.0 | 38 | sand, loose, lenses of brown clay |
| 10.0 | 10.8 | 37 | lost core |
| 10.8 | 11.5 | 36 | ss., weathered brown, fine grained, thin bedded |
| 11.5 | 11.55 | 35 | coal smut |
| 11.55 | 13.5 | 34 | clay, lt. gray, plant leaves, roots |
| 13.5 | 16.2 | 33 | ss., lt. gray, fine grained, micaceous; sideritic ss. zone at 16.0 to 16.2 ft. |
| 16.2 | 21.2 | 32 | ss., lt. gray, fine grained, laminae of dk. gray shale increasing to approx. 50% of unit at bottom |
| 21.2 | 21.4 | 31 | ss., lt. gray, 2 or 3 thin coal laminae |
| 21.4 | 21.45 | 30 | shale, black, carbonaceous |
| 21.45 | 23.0 | 29 | underclay, fossil roots |
| 23.0 | 29.6 | 28 | ss., lt. gray, fine grained, flaser structure; contorted laminae of dk. gray shale composing about 10% of unit; nodules of pyrite at 25.5 ft.; micro-scour surfaces |
| 29.6 | 30.0 | 27 | shale, dk. gray laminae, plants, intercalated wtih lt. gray ss. |
| 30.0 | 40.0 | 26 | ss., lt. gray, fine grained, quartzose, interbedded with dk. gray, irregular contorted to horizontal in places, carbonaceous material shale in bundles to .3 ft. thick in top 4 ft. and near bottom |

| | | | |
|---|---|---|---|
| 40.0 | 50.0 | 25 | ss., lt. gray, fine grained, dk. gray coaly shale laminae comprise about 5% of unit; appears cross bedded |
| 50.0 | 60.0 | 24 | ss., same as preceeding unit but 2 or 3.05 ft. thick clay lenses in top 2 ft.; wavy transported coal laminae about 1 ft. from bottom |
| 60.0 | 66.0 | 23 | ss., lt. gray, fine grained; dk. gray carbonaceous shale laminae in upper 2 ft. |
| 66.0 | 68.1 | 22 | shale, black (wet), few lt. gray fine grained contorted ss. laminae |
| 68.1 | 68.4 | 21 | breccia, clasts of brown silty shale, ironstone, dk. gray shale and coal; fine to med. grained lt. gray ss. matrix |
| 68.4 | 69.0 | 20 | shale, black; .2 ft. lt. gray ss. bed in bottom |
| 69.0 | 69.1 | 19 | clay ironstone, fine grained |
| 69.1 | 73.8 | 18 | ss., med. grained, friable, rounded to subrounded grains |
| 73.8 | 74.1 | 17 | ss., lt. gray, with lenses and discontinuous laminae of coal |
| 74.1 | 79.0 | 16 | ss., similar as from 69.1 to 73.8 but with .1 ft med. gray shale bed at top; cross bedded; breccia zone with brown clay clasts at 77.0 to 77.4 ft. |
| 79.0 | 79.2 | 15 | coal, bright |
| 79.2 | 79.3 | 14 | ss., similar to preceeding unit of ss. |
| 79.3 | 81.6 | 13 | underclay, lt. gray, fossil roots |
| 81.6 | 83.6 | 12 | ss., lt. gray and shale dk. gray in wavy interlaminations |
| 83.6 | 84.8 | 11 | clay, lt. gray |
| 84.8 | 86.1 | 10 | ss. and shale similar to 81.6 to 83.6 ft. |
| 86.1 | 90.0 | 9 | shale, black (wet); .1 ft. zone of clay ironstone near middle |
| 90.0 | 96.4 | 8 | shale, black (wet); clay ironstone zone at 90.3 to 90.5 ft. |
| 96.4 | 98.0 | 7 | shale, black, few dk. gray lenses of lt. gray ss., pyrite |

| | | | |
|---|---|---|---|
| 98.0 | 111.4 | 6 | shale, black (when wet) |
| 111.4 | 116.0 | 5 | clay-shale, lt. gray with ooid sized siderite concretions |
| 116.0 | 121.0 | 4 | shale, black |
| 121.0 | 122.0 | 3 | breccia, chert clasts to .3 ft. thick; waxy brown to white; ss. and black shale matrix with granular subrounded to angular chert clasts |
| 122.0 | 126.9 | 2 | ss., green with gray patches; pyrite nodules |
| 126.9 | 127.0 | 1 | ls., med. gray, coarsely crystalline, crinoid columnals |

Formational Summary

| | |
|---|---|
| 0.0 - 11.5 | Bluejacket Formation |
| 11.5 - 21.2 | Drywood Formation |
| 21.2 - 23.0 | Rowe Formation |
| 23.0 - 79.0 | Warner Formation |
| 79.0 - 121.0 | Riverton Formation |
| 121.0 - 126.9 | "Graydon" |
| 126.9 - 127.0 | Burlington Limestone |

Note: New type of drill bit used starting on this test obscures cross bedding and other structures.

No asphalt or heavy oil observed.

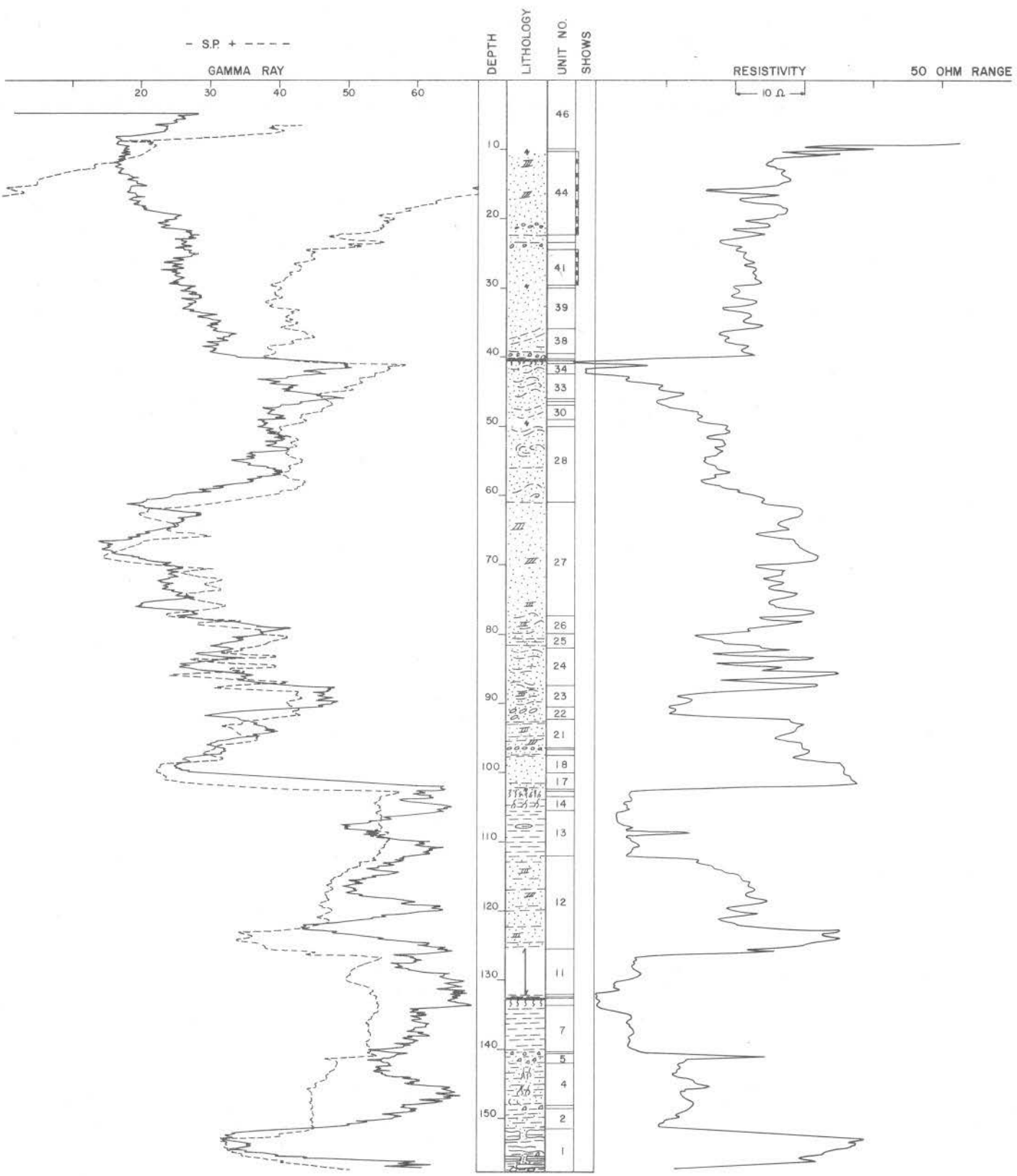


Figure 9. Composite log of USGS No. 6.

USGS-TS - No. 6
NQ Core, logged by Richard J. Gentile, 7/6-7/76
Location: 1,350' FSL & 10' FWL, Sec. 25, T. 35N., R. 30W., Vernon County

25 ft. north of quarter section corner; east side of N-S dirt road. 7 miles SW of Dederick.

Elevation: 895' Total Depth: 157.5 (48.0 m)

| DEPTH | | UNIT | DESCRIPTION |
|---|---|---|---|
| 0.0 | 10.0 | 46 | no core, soil and weathered clay and ss. |
| 10.0 | 10.3 | 45 | lost core |
| 10.3 | 22.4 | 44 | ss., weathered yellow and deep red zones; bottom half contains elongate holes .01 ft. long filled with a soft gummy residue resembling tar but comprises only about 1% of unit; cross bedded, micaceous<br><br>Conglomerate with clasts of brown clay ironstone or shale which dissolve out to form hollow casts structure; forms 2 or 3 zones about .1 ft. thick from 20.5 to 21.5 ft. |
| 22.4 | 23.4 | 43 | ss., fine grained, micaceous, thin laminae of dk. shale |
| 23.4 | 24.6 | 42 | ss., fine to med. grained with .1 ft. conglomerate clay ironstone at top |
| 24.6 | 29.7 | 41 | ss., fine grained, med. gray, appears slightly asphaltic; does not bleed; med. gray color results mostly from bits of carbonaceous woody material |
| 29.7 | 30.0 | 40 | lost core |
| 30.0 | 36.0 | 39 | ss., fine grained, med. gray, pieces of woody material but possibly some "dead" oil |
| 36.0 | 39.8 | 38 | ss., fine grained, med. dk. gray (N4 by GSA Rock Color Chart) small scale cross bedding, interbedded with lt. gray inclined laminae of ss. and dk. gray carbonized wood or shale |
| 39.8 | 40.3 | 37 | breccia, clasts of tan clay ironstone, pyrite, coal with lt. gray fine grained ss. matrix; three inclined coal layers to .02 ft. thick appears to be pieces of transported coalified wood |

| | | | |
|---|---|---|---|
| 40.3 | 40.6 | 36 | coal |
| 40.6 | 41.0 | 35 | underclay, lt. gray, fossilized roots; grades downsection into fine grained lt. gray ss. |
| 41.0 | 42.5 | 34 | ss., interbedded with dk. gray wavy shale; sand sized concretions of siderite |
| 42.5 | 46.0 | 33 | ss., lt. gray, fine grained, interbedded with laminae, lenses and pods of dk. gray shale with abundant siderite concretions |
| 46.0 | 46.5 | 32 | ss., lt. gray, thin laminae and beds of carbonized wood |
| 46.5 | 47.0 | 31 | ss., fine grained, massive |
| 47.0 | 49.0 | 30 | ss., lt. gray, contorted dk. gray shale laminae, flaser bedding |
| 49.0 | 50.0 | 29 | lost core |
| 50.0 | 61.0 | 28 | ss., lt. gray, fine grained, micaceous, ripple marks, regular to contorted laminations of dk. shale and carbonaceous woody material, scour surfaces overlain by convoluted shale laminae produced by gravity slumping or directional currents |
| 61.0 | 77.3 | 27 | ss., fine grained, dk. gray with particles of carbonaceous woody material; even to small scale cross bedding; irregular spots .01 ft. dia. cemented with $CaCO_3$ from 68.0 to 70.0 and 76.0 to 77.3 ft.; lighter gray ss. from 72 to 76.0 ft.; becomes fine to med. grained in bottom 1 ft. |
| 77.3 | 80.0 | 26 | ss., lt. gray beds to .1 ft. thick, small scale cross bedding; laminae of even to wavy and contorted shale; flute casts? |
| 80.0 | 82.0 | 25 | ss. with lenses of dk. gray shale |
| 82.0 | 87.5 | 24 | ss., lt. gray, massive in intervals 1 ft. thick, some irregular patches cemented with $CaCO_3$ interbedded with 1 ft. thick intervals of lt. gray ss. and dk. gray contorted shale laminae |
| 87.5 | 91.6 | 23 | ss., interbedded with med. gray shale; small scale cross bedding, uneven surfaces of scour resembling flute casts |
| 91.6 | 92.3 | 22 | congl. tabular shaped clasts of brown ironstone, pyrite and coal, rounded; imbricate structure; lt. gray fine grained ss matrix |

| | | | |
|---|---|---|---|
| 92.3 | 96.5 | 21 | ss., lt. gray, fine grained, micro-crossbedding, dk. gray carbonaceous shale lenses |
| 96.5 | 96.6 | 20 | congl. similar to 91.6 to 92.3 ft. interval |
| 96.6 | 97.7 | 19 | ss., lt. gray; two or three .1 ft. dk. gray shale beds |
| 97.7 | 100.0 | 18 | ss., massive, lt. gray |
| 100.0 | 102.2 | 17 | ss., lt. gray (N7 on GSA Rock Color Chart), fine grained; one or two laminae of dk. gray shale near bottom |
| 102.2 | 102.6 | 16 | lost core |
| 102.6 | 103.6 | 15 | underclay, slickensided, fossil roots |
| 103.6 | 105.6 | 14 | clay, med. gray with irregular discontinuous laminae of dk. gray shale and carbonaceous woody material, fossil roots |
| 105.6 | 112.0 | 13 | shale, black, wet, (GSA Color Chart N1) and grayish black (N2 GSA Color Chart); .1 ft. zone of brownish red clay ironstone at 107.5 ft. and .2 ft. zone at 118.2 ft. |
| 112.0 | 125.6 | 12 | shale, black and ss., (lt. gray, small scale foreset cross bedding, irregular discontinuous lenses and pods) in interbedded laminae .1 ft. thick; bits of fusain and mica on bedding planes |
| 125.6 | 132.0 | 11 | lost core |
| 132.0 | 132.2 | 10 | shale, black |
| 132.2 | 132.25 | 9 | coal |
| 132.25 | 133.75 | 8 | underclay, lt. gray, fossil roots, pyrite nodules, siderite concretions of oolite size |
| 133.75 | 140.4 | 7 | shale, black, lt. gray discontinuous lenses of lt. gray ss. comprise less than 5% of unit; pyrite |
| 140.4 | 140.8 | 6 | breccia, chert with angular clasts to .1 ft. dia., porous, spongy structure; chert "floats" in black shale (A lithified mud flow?) |
| 140.8 | 142.0 | 5 | clay, med. gray, sandy, angular chert clasts to .05 ft. dia., small siderite concretions |

| | | | |
|---|---|---|---|
| 142.0 | 148.0 | 4 | clay, lt. greenish gray, sandy, slickensided, irregular, vertical branching black root-like markings; few chert fragments to .05 ft. thick; small siderite concretions coarse sand sized (A horizon of paleosoil.) |
| 148.0 | 148.6 | 3 | breccia, chert comprises 10% of unit; lt. gray, massive to .1 ft. dia. |
| 148.6 | 151.5 | 2 | clay, fine sand, greenish gray mottled brick red; white chert fragments size of coarse sand and few clear, rounded coarse quartz sand grains; slickensided, siderite concretions sand size cavity filling or B horizon of paleosoil |
| 151.5 | 157.5 | 1 | chert, in beds to .5 ft. thick; cavities filled with lt. gray slickensided clay with chert fragments |

Formational Summary

| | |
|---|---|
| 0.0 - 10.0 | no core |
| 10.0 - 40.3 | Bluejacket Formation |
| 40.3 - 41.0 | Rowe Formation |
| 41.0 - 102.2 | Warner Formation |
| 102.2 - 140.4 | Riverton Formation |
| 140.4 - 151.5 | "Graydon" |
| 151.5 - 157.5 | Mississippian |

Note: Top of Mississippian weathered - possible paleosoil at 140.8-151.5 ft. Very little tar sands, small amounts tar in minute cavities and "dead" oil 10.3 to 36.0 ft.

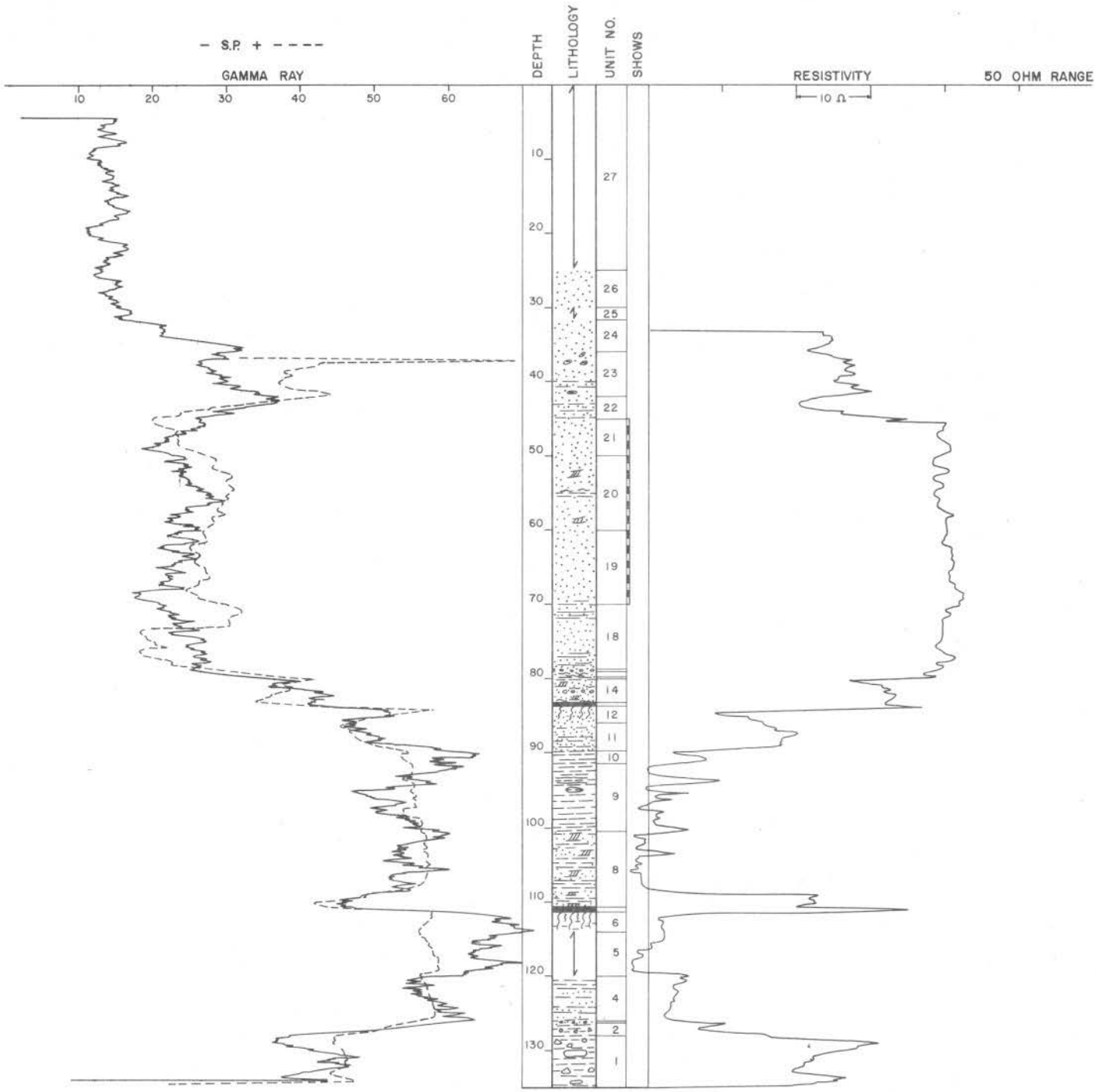


Figure 10. Composite log of USGS No. 7.

USGS-TS - No. 7
NQ Core, logged by Richard J. Gentile, 7/7-8/76
Location: 2,300' FSL & 10' FWL, Sec. 3, T. 34N., R. 30W., Vernon County
3 1/4 mi. NW of Bellamy. (Long Section)

Elevation: 920' Total Depth: 135.0 ft. (41.1 m)

| DEPTH | | UNIT | DESCRIPTION |
|---|---|---|---|
| 0.0 | 25.0 | 27 | soil, loose weathered sand, few clay lenses near bottom, too soft to core |
| 25.0 | 30.0 | 26 | ss., quartzose, loose weathered; core too poor to save |
| 30.0 | 31.7 | 25 | lost core, very loose sand |
| 31.7 | 36.0 | 24 | ss., friable, fine grained, quartzose, brown |
| 36.0 | 42.0 | 23 | ss., same as above but with soft clay clasts to .1 ft. dia. (conglomeratic); clay lenses and clasts in bottom half washed out |
| 42.0 | 45.0 | 22 | ss. and soft clay beds to .2 ft. thick; most of clay washed out |
| 45.0 | 50.0 | 21 | ss., fine grained, dk. gray specks of "dead" (gilsonite) oil |
| 50.0 | 60.0 | 20 | ss., fine grained, med. gray crossbedded; stained red from 57.0 to 58.0 ft.; laminae of carbonaceous woody material, "dead" oil, micaceous, grades downsection into lt. gray ss. |
| 60.0 | 70.0 | 19 | ss. med. gray fine grained, "dead" oil or gilsonite specks; thin laminae of coal at 69.0 and 70.0 appears formed from single pieces of transported wood; crossbedded, micaceous; becomes med. grained at bottom |
| 70.0 | 78.8 | 18 | ss., same as above but with irregular laminae of coal (pieces fusain) interbedded with ss. at 71.0 to 72.0, 76.0 to 76.5 and 77.0 to 78.0 ft. |
| 78.8 | 79.0 | 17 | congl. rounded clasts of clay ironstone, coal, nodules pyrite; med. grained quartzose ss. matrix |

| | | | |
|---|---|---|---|
| 79.0 | 79.9 | 16 | ss., lt. gray, even to contorted laminae of dk. gray shale, scour surface, flame structures |
| 79.9 | 80.0 | 15 | shale, med. gray |
| 80.0 | 83.1 | 14 | ss., fine grained, lt. gray, interbedded with dk. gray sandy shale and laminae of carbonaceous material consisting of bits of fusain; mostly even-bedded but some scour surfaces, small scale cross bedding, swirled pods; .02 ft. of conglomerate with clasts of pyritized wood to .01 ft. dia. at 82.0 ft. |
| 83.1 | 83.8 | 13 | coal, bright, cleats filled with a white noncalc. mineral, pieces of pyritized wood |
| 83.8 | 86.0 | 12 | underclay, fossilized roots, sandy below upper .3 ft. |
| 86.0 | 89.8 | 11 | ss., med. gray, clayey, few brown zones .1 ft. thick in bottom 2 ft. |
| 89.8 | 91.5 | 10 | clay, greenish gray; ooid sized siderite concretions; pea sized nodules of pyrite |
| 91.5 | 100.5 | 9 | shale, black; .1 ft. thick clay ironstone zones at 95.0, 95.6, 100.0 and 103.0 ft.; few pea sized pods of lt. gray ss. |
| 100.5 | 110.5 | 8 | shale, black and lt. gray ss., in thin beds to .01 ft. thick, forset cross bedding |
| 110.5 | 111.3 | 7 | coal, nodules of pyrite to .05 ft. dia. |
| 111.3 | 114.0 | 6 | underclay, lt. gray |
| 114.0 | 120.0 | 5 | lost core |
| 120.0 | 126.0 | 4 | shale, black, few thin discont. lenses of lt. gray ss. |
| 126.0 | 126.1 | 3 | breccia, granular sized angular chert clasts in black shale matrix; pyrite lenses |
| 126.1 | 128.0 | 2 | clay, greenish gray, sandy, few rounded chert clasts to .01 ft. dia., in top half, chert becomes more abundant downsection |

| | | | |
|---|---|---|---|
| 128.0 | 135.0 | 1 | conglomerate mostly rounded but some angular chert clasts to .3 ft. dia.; white, massive chert; greenish gray, slickensided matrix with rounded coarse quartz grains; intact framework in top 2 ft. but becomes a pebbly mudstone at bottom; some inclined, green clay laminae in bottom 3 ft. |

Formational Summary

| | |
|---|---|
| 0.0 - 81.3 | Warner-Rowe-Drywood-Bluejacket undifferentiated |
| 81.3 - 126.0 | Riverton Formation |
| 126.0 - 135.0 | "Graydon" |

Note: A few clay cuttings recovered at 25.0 ft. may represent Rowe-Drywood interval, but interval appears to be a filled in channel--probably Warner sandstone. However, both Warner and Bluejacket may be represented, in which case the conglomerate at 36 to 42 ft. may be base of Bluejacket.

Hole cased to 30.0 ft. when sand caved.

MISSOURI DEPARTMENT OF NATURAL RESOURCES
DIVISION OF GEOLOGY AND LAND SURVEY
USGS – TS NO. 8
LOC: 15' FSL & 2585 FWL, SEC. 15, T. 34 N., R. 30 W., VERNON CO.
SURF. ELEV. 970 FT. TOTAL DEPTH 160 FT. (48.8 M.)

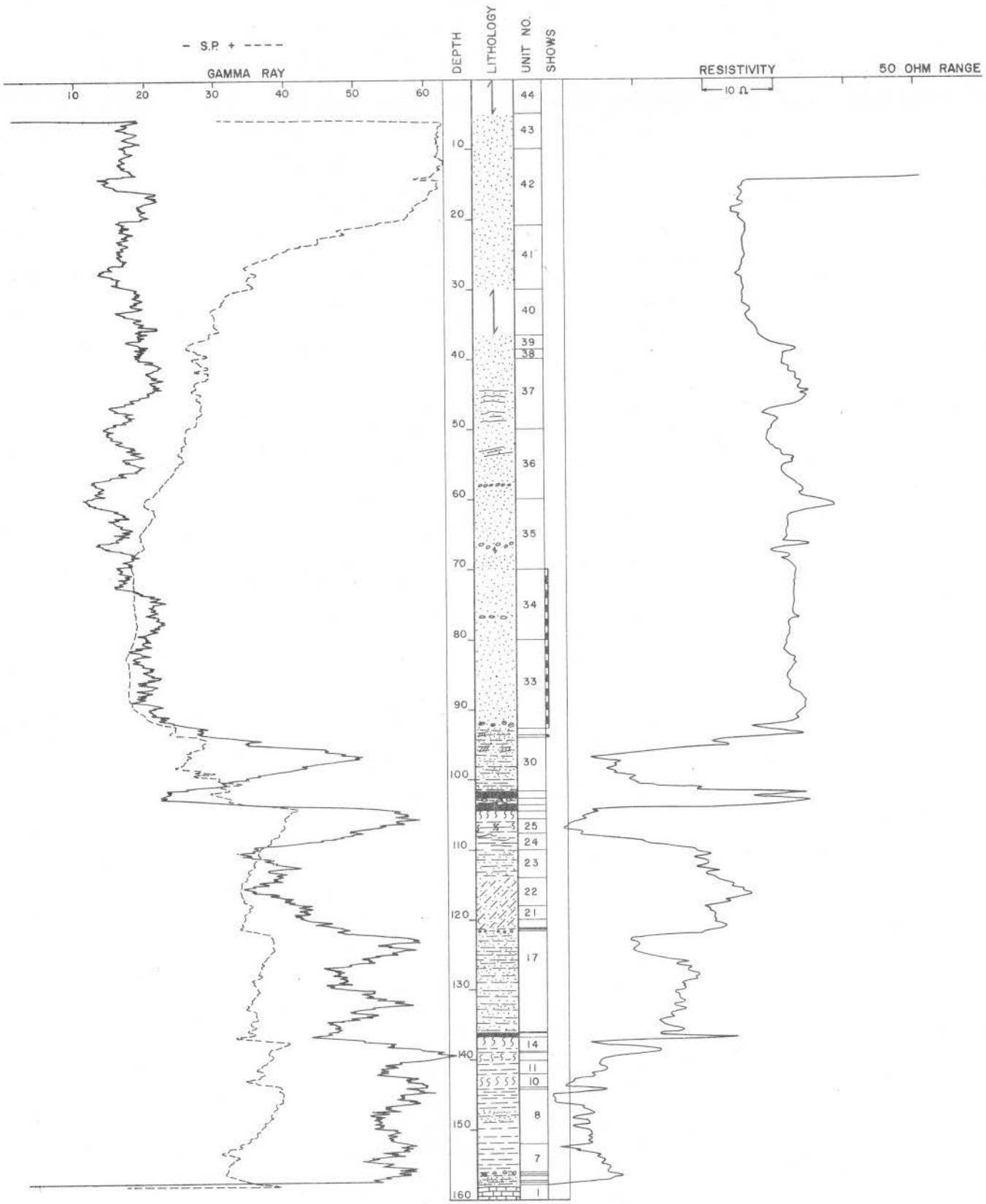


Figure 11. Composite log of USGS No. 8

USGS-TS - No. 8
NQ Core, logged by Richard J. Gentile, 7/9 & 12/76
Location: 15' FSL & 2,585' FWL, Sec. 15, T. 34N., R. 30W., Vernon County

North side of county road DD. 1 1/2 miles WNW of Bellamy.

Elevation: 970' Total Depth: 160 ft. (48.8 m)

| DEPTH | | UNIT | DESCRIPTION |
|---|---|---|---|
| 0.0 | 5.0 | 44 | soil and brown fine grained loose ss. (wash sample) |
| 5.0 | 10.0 | 43 | ss., brown, loose; wash sample |
| 10.0 | 21.0 | 42 | ss., but too soft to core, lost |
| 21.0 | 30.0 | 41 | ss., friable, lt. brown, quartzose; fine grained |
| 30.0 | 36.8 | 40 | lost core, loose sand |
| 36.8 | 38.8 | 39 | ss., friable, brown |
| 38.8 | 40.0 | 38 | ss., friable, med. gray, slightly asphaltic |
| 40.0 | 50.0 | 37 | ss., fine grained, lt. gray with red weathered zone from 44.0 to 47.0; thin irregular laminae of coal consisting of bits of fusain (charcoal) interbedded with ss. at 44.0 to 46.0 and 47.5 to 49.0 ft. |
| 50.0 | 60.0 | 36 | ss., lt. gray, fine grained, massive to cross bedded; discontinuous irregular laminae of coaly material at 53.0 to 54.0 ft.; conglomerate bed .1 ft. thick of pieces of fusain (mineral charcoal) at 58.0 ft. |
| 60. | 70.0 | 35 | ss., med. gray, fine grained, massive, conglomerate with clasts of coal and hard ss. matrix 65.5 ft. |
| 70.0 | 80.0 | 34 | ss., same as preceeding unit but with bits of dead oil or gilsonite; conglomerate of well rounded clay ironstone clasts .2 ft. dia. with ss. matrix at 76.6 to 76.9 ft. |

| | | | |
|---|---|---|---|
| 80.0 | 92.8 | 33 | ss., med. gray, fine grained, bits of gilsonite more abundant in bottom 2 ft. forms a "salt and pepper" texture; bottom 1 ft. contains clasts of shale to .05 ft. dia. Binocular microscope examination of sandstone at 90.0 ft.: predominantly quartz sand, angular to subrounded grains .15 to .25 mm dia.; approx. 10% a soft white mineral appears to be weathered feldspar; gilsonite in irregular, discontinuous, specks that fills in voids between quartz grains, gilsonite is black and glistening; soft, gummy, about .15 mm dia., gives brown streak, salt and pepper appearance of sandstone with gilsonite comprising about 15% of sample; dissolves in turpentine. |
| 92.8 | 93.6 | 32 | ss., lt. gray, small scale cross bedding and dk. gray shale alternating in thin beds and laminae |
| 93.6 | 94.0 | 31 | ss., med. gray, fine grained, specks of dead oil or gilsonite |
| 94.0 | 101.8 | 30 | shale, dk. gray with thin laminae and pods of lt. gray ss., foreset cross bedded ss. bed at 95.4 to 95.6 scour surfaces |
| 101.8 | 102.8 | 29 | coal, bright, pyrite nodules to .02 ft. dia., sharp contact with overlying unit |
| 102.8 | 103.7 | 28 | shale, dk. yellowish brown (10YR4/2 GSA Color Chart) top .2 ft. conglomeratic with clasts of fusain and pyrite; about 10 thin coal beds to .03 ft. thick interbedded in middle and bottom part |
| 103.7 | 104.5 | 27 | coal, bright, pyrite nodules and lenses |
| 104.5 | 105.7 | 26 | underclay silty, plant leaves |
| 105.7 | 107.7 | 25 | shale, med. gray, plant material |
| 107.7 | 110.0 | 24 | shale, silty, micaceous, patches of oolite sized siderite concretions; thin discontinuous laminae of coal or dk. shale |
| 110.0 | 114.0 | 23 | ss., lt. gray, fine grained, clayey, bottom 1 ft. interlaminated with dk. gray shale; siderite concretions in top 2 ft.; mica flakes on bedding planes |
| 114.0 | 118.0 | 22 | ss., lt. gray intercalated with inclined irregular laminae of dk. gray shale (inclination the result of deposition) |

| | | | |
|---|---|---|---|
| 118.0 | 120.0 | 21 | shale, med. gray, inclined irregular laminae of lt. gray ss.; small scale cross bedding, microfaulting, bits of fusain and mica between laminations |
| 120.0 | 121.2 | 20 | ss., similar to overlying unit but predom. ss. |
| 121.2 | 121.25 | 19 | black shale |
| 121.25 | 121.6 | 18 | congl. clasts of clay ironstone, lt. gray clay and dk. shale |
| 121.6 | 136.0 | 17 | shale dk. gray (N3) and lt. gray ss. (N7, wet), even bedded, lenses and pods; about 60% of unit is shale |
| 136.0 | 136.1 | 16 | shale, dk. gray |
| 136.1 | 136.7 | 15 | coal, lenses pyrite |
| 136.7 | 138.8 | 14 | underclay, gray, fossil roots |
| 138.8 | 139.0 | 13 | shale, black |
| 139.0 | 140.0 | 12 | underclay, slickensides, few roots impressions at top |
| 140.0 | 142.0 | 11 | clay, lt. gray, slickensided |
| 142.0 | 144.0 | 10 | clay, poor fissility, med. gray, black fossil root impressions |
| 144.0 | 144.2 | 9 | clay, sideritic |
| 144.2 | 152.0 | 8 | shale, black, 5% of unit from 148.0 to 152.0 ft. contains lt. gray discontinuous laminae and pods of ss.; pyrite nodules |
| 152.0 | 156.0 | 7 | shale, black, irregular shaped pyrite nodules to .05 ft. dia. |
| 156.0 | 156.3 | 6 | shale, black, conglomeratic, pieces of white chert to .02 ft. dia., angular to subrounded; chert composes about 5% of unit to form a conglomeratic mudstone; laminae of lt. gray ss. in bottom; about 10% of unit is nodules of pyrite to .03 ft. dia. |
| t | | | |
| 156.3 | 156.6 | 5 | ss., lt. gray, clayey, fine grained; a few coarse grained, rounded clear quartz grains; pyrite inclusions to .01 ft. dia. |
| 156.6 | 157.2 | 4 | clay, med. gray |

| | | | |
|---|---|---|---|
| 157.2 | 157.6 | 3 | ss., lt. gray, fine grained, clayey; pyrite |
| 157.6 | 157.9 | 2 | clay, lt. gray, noncalc., slickensided; pyrite nodules to .02 ft. dia.; small amount of coarse sand sized particles of chert and clear rounded quartz grains |
| 157.9 | 160.0 | 1 | ls., lt. gray, stylolites, coarsely crystalline; sharp contact with overlying unit (Burlington) |

Formational Summary

| | |
|---|---|
| 0.0 - 101.8 | Warner-Rowe-Drywood-Bluejacket Formations |
| 101.8 - 156.0 | Riverton Formation |
| 156.0 - 157.9 | "Graydon" |
| 157.9 - 160.0 | Burlington Limestone |

Note: The Rowe and Drywood Formations are poorly developed or may have been eroded away--Bluejacket sandstone may fill channel cut into Warner.

Small amount of gilsonite from 60.0 to 94.0 ft.

MISSOURI DEPARTMENT OF NATURAL RESOURCES
DIVISION OF GEOLOGY AND LAND SURVEY
USGS TS – NO. 9-S
LOC: 15' FNL & 900' FEL, SEC. 32, T. 34 N., R. 29 W., VERNON CO.
SURF. ELEV. 975 FT. TOTAL DEPTH 75 FT. (22.9 M.)

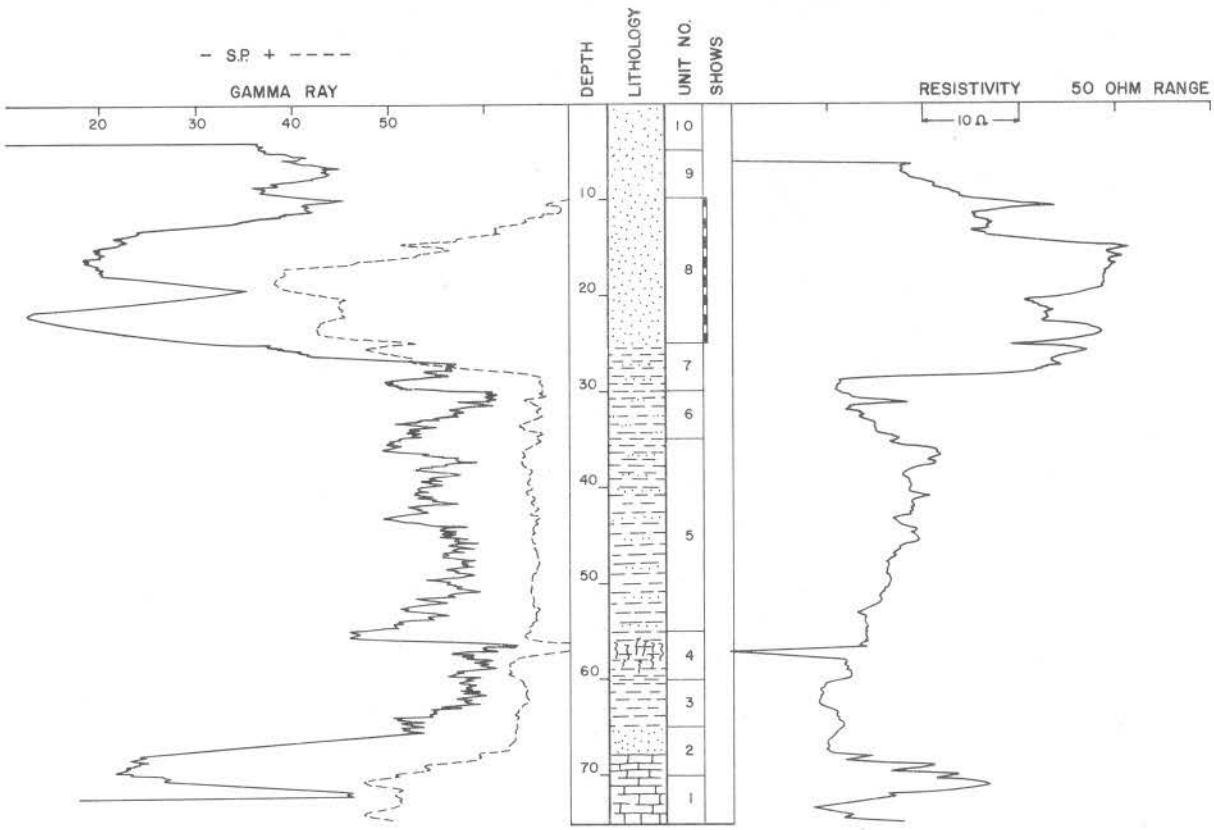


Figure 12. Composite log of USGS No. 9.

USGS-TS - No. 9-S
"Slim hole" cuttings, logged by Richard J. Gentile, 7/9/76
Location: 15' FNL & 900' FEL, Sec. 32, T. 34N., R. 29W., Vernon County

Test in drainage ditch south side of county road B; .85 mile east of jct. with county road N; 4 1/2 miles south-southeast of Montevalla.

Elevation: 975' Total Depth: 75' (22.9 m)

| DEPTH | | UNIT | DESCRIPTION |
|---|---|---|---|
| 0.0 | 5.0 | 10 | ss., fine grained, weathered brown, hematite concretions |
| 5.0 | 10.0 | 9 | ss., med. dk. bluish gray, fine grained, particles of woody material and gilsonite; thin bedded micaceous |
| 10.0 | 25.0 | 8 | ss., dk. gray, glistening black specks of gilsonite, micaceous, becomes med. gray in bottom 5 ft. |
| 25.0 | 30.0 | 7 | shale, dk. gray to black |
| 30.0 | 35.0 | 6 | shale, med. gray, silty |
| 35.0 | 55.0 | 5 | shale, dk. gray with thin lenses of ss. |
| 55.0 | 60.0 | 4 | clay, med. gray, slickensided, and soft, lt. gray clay (possible underclay) |
| 60.0 | 65.0 | 3 | shale, black |
| 65.0 | 70.0 | 2 | ss., quartzose and ls., lt. gray |
| 70.0 | 75.0 | 1 | ls., tan to lt. gray, fine to coarsely crystalline; green shale lenses, pyrite; very little chert (St. Louis ls.) |

Formational Summary

| | |
|---|---|
| 0.0 — 25.0 | Warner Formation |
| 25.0 — 65.0 | Riverton Formation |
| 65.0 — 67.5 | "Graydon" |
| 67.5 — 75.0 | Mississippian limestone (St. Louis ls. ?) |

Note: Small specks of "dead" oil from 5.0 to 25.0 ft. interval

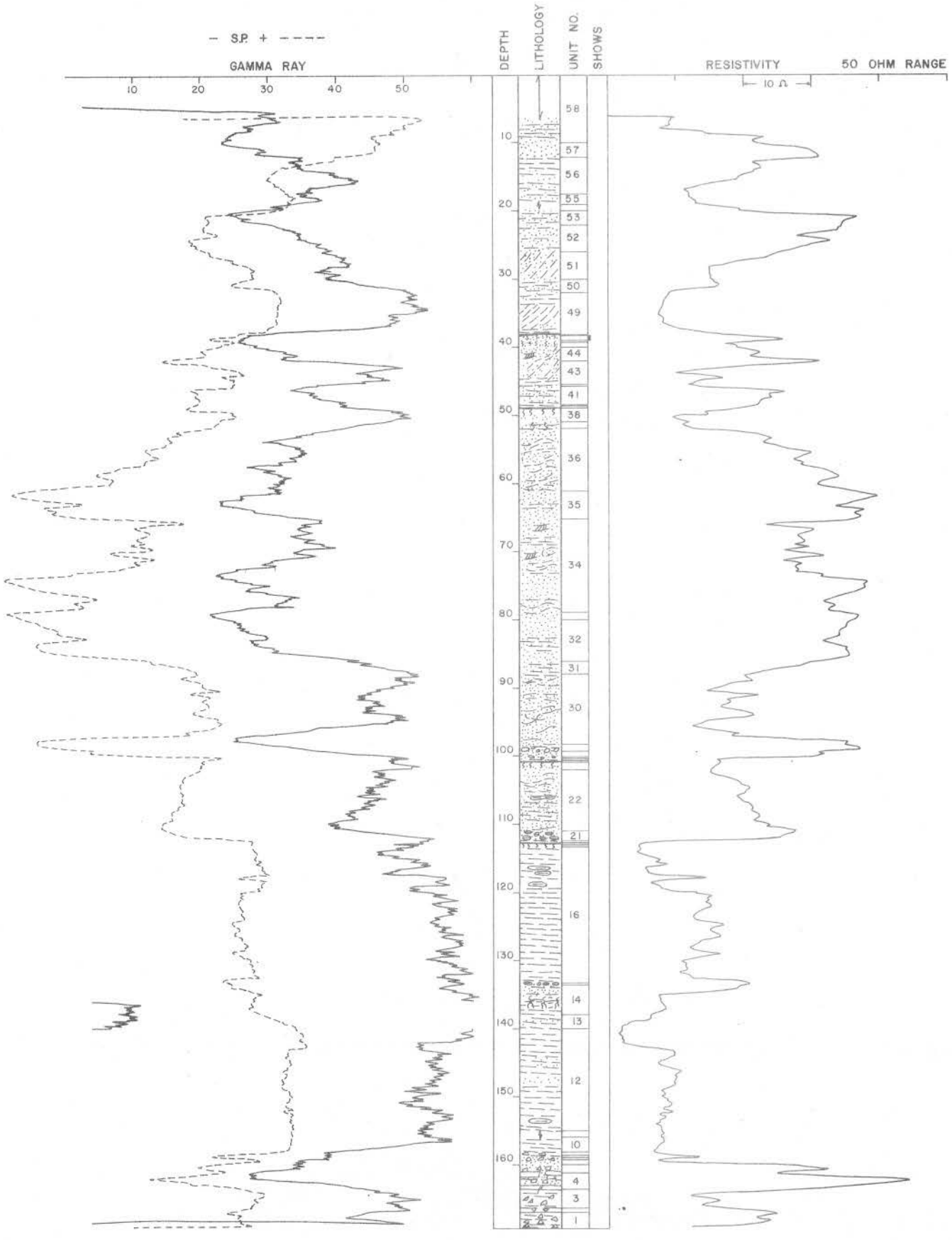


**Figure 13. Composite log of USGS No. 10.**

USGS-TS - No. 10
NQ Core, logged by Richard J. Gentile, 7-12-13/76
Location: 2,550' FNL & 1,320' FEL, Sec. 29, T. 33N., R. 29W., Barton County

North side of dirt road at right angle bend to south; 1 1/2 miles SE of Milford.

Elevation: 1,009' Total Depth: 169.5' (51.7 m)

| DEPTH | | UNIT | DESCRIPTION |
|---|---|---|---|
| 0.0 | 10.0 | 58 | soil, and loose brown ss., to thin bedded lt. gray ss. with clay partings at bottom |
| 10.0 | 12.2 | 57 | ss., lt. gray, fine grained |
| 12.2 | 17.6 | 56 | shale, weathered brown, few thin ss. beds |
| 17.6 | 19.1 | 55 | shale, dk. gray; ss. bed .1 ft. thick at 18.3 ft. |
| 19.1 | 20.0 | 54 | lost core |
| 20.0 | 22.1 | 53 | ss., brown, thin dk. gray interbedded shale laminae comprise about 10% of unit |
| 22.1 | 26.0 | 52 | ss., dk. gray, fine grained, clayey |
| 26.0 | 30.0 | 51 | shale, dk. gray, sandy with interbedded laminae and pods of lt. gray ss.; inclined bedding |
| 30.0 | 32.0 | 50 | shale, dk. gray with lt. gray ss. laminae and pods |
| 32.0 | 38.1 | 49 | shale, grayish black (N-2 GSA Color Chart) silty, inclined fissility at 35.0 to 36.0 ft. |
| 38.1 | 38.2 | 48 | coal, thin bedded |
| 38.2 | 39.0 | 47 | ss., clayey, root impressions, few .01 ft. elongate cavities filled with asphalt |
| 39.0 | 39.2 | 46 | underclay, poorly developed, root impressions |
| 39.2 | 40.0 | 45 | ss., clayey, fine grained, root impressions |

| | | | |
|---|---|---|---|
| 40.0 | 42.0 | 44 | ss., lt. gray, fine grained, cross-bedded; lt. gray inclined shale laminae |
| 42.0 | 45.6 | 43 | ss., lt. gray interbedded laminae of dk. gray shale grades downsection into predom. shale |
| 45.6 | 45.9 | 42 | ss., tan colored by abundant oolite sized siderite concretions |
| 45.9 | 48.9 | 41 | ss., lt. greenish gray, irregular, lenses, and med. gray shale in alternating laminae; siderite conc. |
| 48.9 | 48.95 | 40 | shale, black |
| 48.95 | 49.0 | 39 | coal, thin bedded, pyrite lenses |
| 49.0 | 51.0 | 38 | underclay, lt. gray, silty, root impressions, becomes med. gray at bottom |
| 51.0 | 52.0 | 37 | shale, sandy, lt. gray, root impressions; tan ss. pods to .05 ft. dia. |
| 52.0 | 61.2 | 36 | ss., lt. gray and dk. gray carbonaceous shale beds in alternating laminae; cross-bedding, scour surfaces, convolute bedding; bottom 2 ft. predom. med. gray ss. |
| 61.2 | 65.3 | 35 | ss., med. gray, fine grained, massive; .2 ft. dk. gray shale bed near middle |
| 65.3 | 79.0 | 34 | ss., fine grained, medium gray (N5) in beds to .2 ft. thick that alternate with laminae of lt. gray ss. (N8) and dk. gray shale (N3). The lt. gray ss. shows ripple marks; small scale foreset cross bedding, convolute bedding, scour contact with underlying shale; interval of massive ss. from 73.8 to 76.4 ft. |
| 79.0 | 80.0 | 33 | ss., med. gray, fine grained, massive |
| 80.0 | 86.1 | 32 | ss., lt. gray, fine grained, massive to cross bedded; 5% of unit is dk. gray interbedded shale laminae |
| 86.1 | 88.0 | 31 | ss., med. gray, interbedded with lt. gray cross bedded ss. and dk. shale same as from 65.3 to 79.0 ft. |

| | | | |
|---|---|---|---|
| 88.0 | 98.2 | 30 | shale, dk. gray, silty, and lt. gray contorted ss. lenses and concretions; very irregular bedding |
| 98.2 | 99.3 | 29 | conglomerate; clasts to .08 ft. dia. of rounded blades and spheres of clay ironstone, brown, tan and black ss., pyrite, coal with med. grained quartz ss. matrix; top .3 ft. is lt. gray ss. and dk. gray shale is alternating laminae |
| 99.3 | 100.1 | 28 | ss., fine grained, quartzose, massive |
| 100.1 | 100.2 | 27 | congl. same as from 98.2 to 99.3 ft. |
| 100.2 | 100.5 | 26 | ss., lt. gray, shale dk. gray and coal alternating in discontinuous laminae; inclined, distorted bedding |
| 100.5 | 100.6 | 25 | ss., lt. gray massive |
| 100.6 | 101.0 | 24 | coal, bright, laminations of pyrite; sharp contact with overlying ss. |
| 101.0 | 102.0 | 23 | underclay, sandy, fossil roots |
| 102.0 | 111.0 | 22 | shale, silty to sandy; inclined and distorted lt. gray ss. laminae; bits of woody material; discont. coal lenses at 107.7 to 108.7 ft.; .2 ft. siderite concretion zone at 107.0 ft. |
| 111.0 | 112.5 | 21 | conglomerate, predom. clasts and discontinuous lenses of coal; some clay ironstone; lt. gray ss. matrix; siderite concretions |
| 112.5 | 112.8 | 20 | shale, med. gray and lt. gray ss. |
| 112.8 | 112.9 | 19 | coal |
| 112.9 | 113.0 | 18 | congl. of coal clasts, same as from 110.0 to 112.5 ft. |
| 113.0 | 113.3 | 17 | underclay, slickensided, med. gray, fossil roots |
| 113.3 | 133.3 | 16 | shale, black, clay ironstone zone .1 ft. thick at 116.6, 117.1 and 119.0 ft.; less than 5% of unit is lt. gray discont. laminae and pods of ss. |

| | | | |
|---|---|---|---|
| 133.3 | 133.4 | 15 | conglomerate, clay ironstone clasts |
| 133.4 | 138.0 | 14 | shale, lt. gray, very sandy with siderite concretions in top half; bottom half is slickensided clay with root impressions |
| 138.0 | 140.0 | 13 | shale, med. gray |
| 140.0 | 155.0 | 12 | shale, black, brown claystone bed .2 ft. thick at 153.5 ft.; pyrite nodules; 5% of unit is interlaminations of lt. gray ss. |
| 155.0 | 156.0 | 11 | lost core |
| 156.0 | 158.2 | 10 | shale, black |
| 158.2 | 158.7 | 9 | breccia, angular white and tan chert fragments in black shale matrix top .1 ft. grading downsection into med. gray shale matrix |
| 158.7 | 158.8 | 8 | shale, black and med. gray interbedded; scour surface at bottom |
| 158.8 | 159.4 | 7 | breccia, angular chert fragments to .2 ft. dia. with pyrite halos; pyrite composes about 30% of unit; coarse ss. matrix |
| 159.4 | 160.0 | 6 | ss., fine grained, med. greenish gray with black blotches; greenish gray clay laminae; coarse, rounded, clear quartz grains |
| 160.0 | 161.2 | 5 | ss., med. grained with coarse grained angular chert fragments |
| 161.2 | 163.6 | 4 | chert, white, massive; .3 ft. zone of gray sandy clay with chert fragments at 162.4 to 163.0 ft. |
| 163.6 | 166.4 | 3 | clay, greenish black, approx. 10% of unit is chert fragments to .1 ft. dia. |
| 166.4 | 167.0 | 2 | chert, white |
| 167.0 | 169.5 | 1 | clay, greenish gray, slickensided, with angular chert fragments to .2 ft. dia. |

Formational Summary

| | |
|---|---|
| 0.0 - 38.1 | Bluejacket Formation |
| 38.1 - 52.0 | Rowe-Drywood Formations |
| 52.0 - 100.6 | Warner Formation |
| 100.6 - 158.2 | Riverton Formation |
| 158.2 - 169.5 | "Graydon" |

Note: Graydon may possibly be sink fill. Estimated top of Mississippian Limestone at 170 ft. No asphalt observed except minute amount from 38.2 to 39.0 ft.

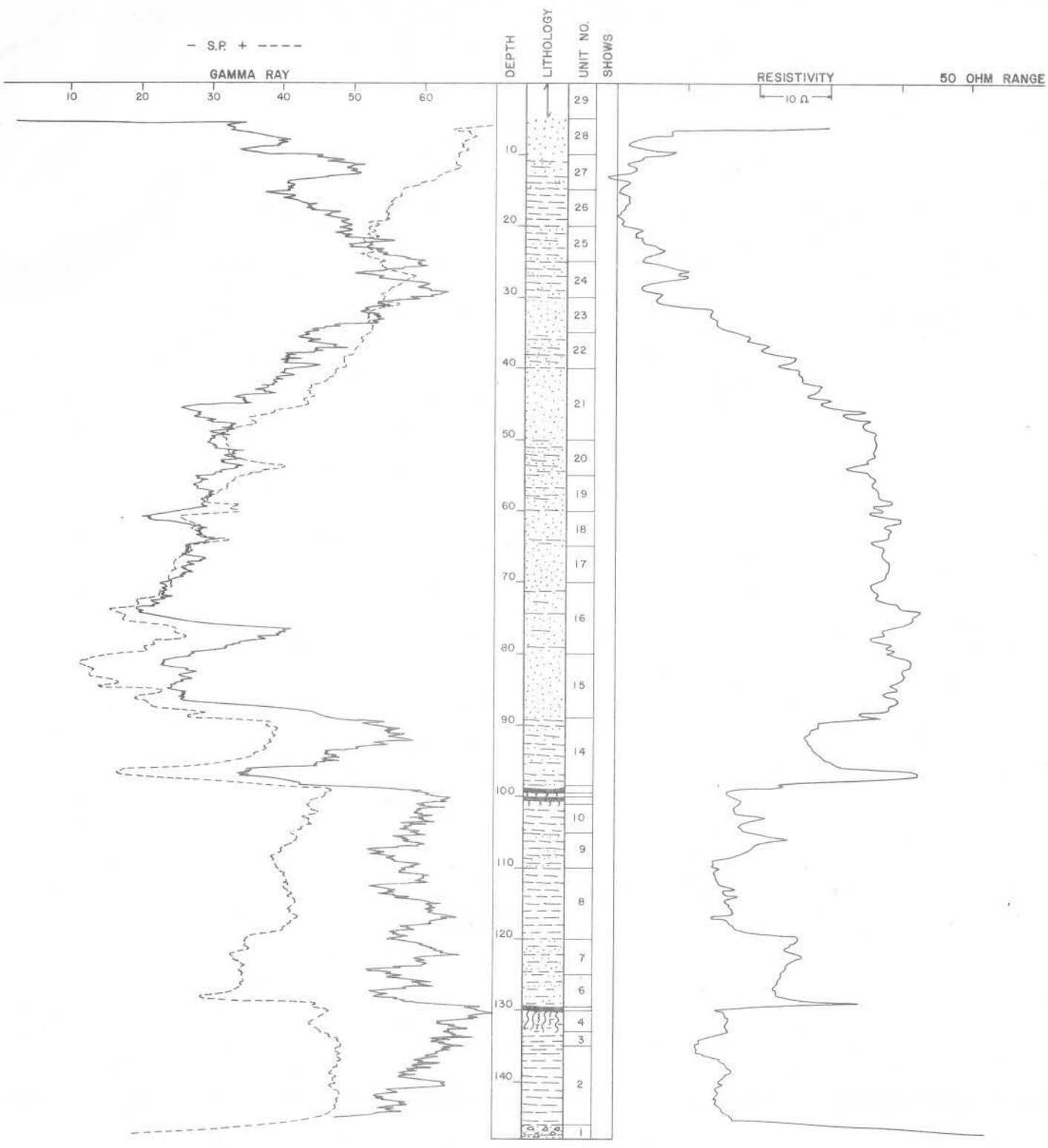


Figure 14. Composite log of USGS No. 11.

USGS-TS - No. 11-S
"Slim hole" cuttings, logged by Richard J. Gentile, 7/14/76
Location: 50' FNL & 100' FWL, Sec. 4, T. 32N., R. 30W., Barton County

Test in triangular-shaped area bounded by county road EE and E-W and N-S dirt roads; 5 miles SW of Milford.

Elevation: 975' Total Depth: 148' (45.1 m)

| DEPTH | | UNIT | DESCRIPTION |
|---|---|---|---|
| 0.0 | 5.0 | 29 | soil and sandy clay, brown ss. |
| 5.0 | 10.0 | 28 | ss., med. grained, brown to lt. gray, limonite nodules |
| 10.0 | 15.0 | 27 | clay, silty, brown, red clay zone about 12.0 ft. |
| 15.0 | 20.0 | 26 | shale, dk. gray |
| 20.0 | 25.0 | 25 | shale, black, sandy |
| 25.0 | 30.0 | 24 | shale, lt. gray, silty |
| 30.0 | 35.0 | 23 | ss., lt. gray, thin bedded |
| 35.0 | 40.0 | 22 | ss.; thin bedded, shaly, fine grained, bits of mica and carbonaceous material |
| 40.0 | 50.0 | 21 | ss., dk. gray, thin bedded, micaceous |
| 50.0 | 55.0 | 20 | ss., dk. gray, alternating with thin beds or laminae of lt. gray ss. and dk. gray shale |
| 55.0 | 60.0 | 19 | ss., same as overlying unit but very few dk. gray shale beds |
| 60.0 | 65.0 | 18 | ss., lt. gray, fine grained, thin bedded; small amount of dk. gray carbonaceous shale near bottom |
| 65.0 | 70.0 | 17 | ss., lt. gray, micaceous, fine grained |
| 70.0 | 80.0 | 16 | ss., lt. gray micaceous, some black pyritiferous shale |
| 80.0 | 89.0 | 15 | ss., lt. gray, fine grained, thin bedded |

| | | | |
|---|---|---|---|
| 89.0 | 98.5 | 14 | shale, dk. gray, fine sand to silt, micaceous |
| 98.5 | 99.5 | 13 | coal with some black shale |
| 99.5 | 100.0 | 12 | underclay, lt. gray |
| 100.0 | 101.0 | 11 | coal and underclay |
| 101.0 | 105.0 | 10 | shale, lt. gray top 1 ft. to black at bottom |
| 105.0 | 110.0 | 9 | shale, alternating lt. and dk. gray, silty, possible thin coal |
| 110.0 | 120.0 | 8 | shale, black |
| 120.0 | 125.0 | 7 | shale, lt. gray silty, thin ss. beds |
| 125.0 | 129.5 | 6 | shale, dk. gray, silty, micaceous, black at bottom |
| 129.5 | 130.0 | 5 | coal |
| 130.0 | 133.0 | 4 | underclay, lt. gray |
| 133.0 | 135.0 | 3 | clay, med. gray, slickensided |
| 135.0 | 146.0 | 2 | shale, black |
| 146.0 | 148.0 | 1 | chert, brown to white, black shale, ss. and chert at 147.0, chert and black shale to 148.0 ft. |

Formational Summary

| | |
|---|---|
| 0.0 - 10.0 | Bluejacket Formation |
| 10.0 - 30.0 | Rowe-Drywood Formations |
| 30.0 - 98.5 | Warner Formation |
| 98.5 - 146.0 | Riverton Formation |
| 146.0 - 148.0 | "Graydon" |

Note: No asphalt observed. Estimated top of Mississippian Limestone at 155 ft.

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