Vertical Electrical Resistivity And Structural Geometry of Faulted, Thermally Altered and Fractured Clastic Rock Sequences and Crystalline Rock Complexes of the North-Central Culpeper Basin, Virginia

By Charles E. Brown

U.S. GEOLOGICAL SURVEY

Open-File Report 96-141

U.S. DEPARTMENT OF THE INTERIOR

Bruce Babbitt, Secretary

U.S. GEOLOGICAL SURVEY

Gordon P. Eaton, Director

For additional information write to:

Office of Ground Water
U.S. Geological Survey
Water Resources Division
411 National Center
Reston, VA 22092

Copies of this report can be purchased from:

U.S. Geological Survey
Earth Science Information Center
Open-File Reports Section
Box 25286, Mail Stop 517
Denver Federal Center
Denver, Colorado 80225-0425

CONTENTS

ILLUSTRATIONS

CONVERSION FACTORS

Multiply	By	To obtain
meter (m)	39.37	inches
meter (m)	3.281	feet

VERTICAL ELECTRICAL RESISTIVITY AND STRUCTURAL GEOMETRY OF FAULTED, THERMALLY ALATERED AND FRACTURED CLASTIC ROCK SEQUENCES AND CRYSTALLINE ROCK COMPLEXES OF THE NORTH-CENTRAL CULPEPER BASIN, VIRGINIA

Charles E. Brown

ABSTRACT

Direct current-electrical resistivity soundings were completed using a Schlumberger field array at nine sites in the early Mesozoic Culpeper basin, Virginia to ascertain basinal-rock characteristics. The apparent resistivity of lower Mesozoic sedimentary rock sequence above pre-Mesozoic crystalline rock is highly variable. Thick sequences of shale and siltstone or of sandstone can be characterized on the basis of resistivity values, and generally the sequences are readily distinguishable from crystalline geoelectrically resistive rocks. Apparent resistivities of the sedimentary rocks above geoelectric basement range from 42 to about 700 ohm-meters for unaltered sedimentary rock and 825 ohm-meters for thermally altered rock. Geophysical well logs indicate that the sedimentary rocks with low resistivities (less than about 350 ohm-meters) have a higher clay content and consist of interbedded thin arkosic sandstones and thick sequences of siltstone and shale. Thick beds of arkosic sandstone have apparent resistivities ranging from 500 to 700 ohm-meters. Geoelectrically resistive rock, which generally has the highest apparent resistivity (generally more than 1,000 ohm-meters), and that includes Pre-Mesozoic rocks ("basement"), is metamorphic or igneous depending upon the location in the basin. Geoelectrically resistive rock includes Jurassic igneous rocks (thick extrusive basalt flows and intrusive diabase sheets) as well as pre-Mesozoic "basement" rock of metamorphic origin.

The distribution of diverse rocks with different electrical properties has made the interpretations of resistivity soundings extremely complex; however, geophysical models support the interpretation that different types of pre-Mesozoic "basement" rock are present beneath the lower Mesozoic sedimentary rocks in the basin. Geoelectric resistive rock comprised mainly of igneous rocks within the basin (or within the sedimentary succession) or metamorphic rocks beneath the basin generally have apparent electrical resistivities greater than 1,000 ohm-meters and are as high as 4,400 ohm-meters in some areas. However, apparent resistivities in local areas may be anomalously low (305 ohm-meters), because locally less-resistive pre-Mesozoic "basement" rocks with lower apparent resistivity are present or because of some other unidentified causes. Nevertheless, it is possible to determine the depth values even where "basement" resistivities are anomalously low on the basis of the contrast between resistivities in sedimentary rocks and those in crystalline rocks. The resistivity data were processed by an automatic iterative computer program; results from the computer analysis were constrained by the available geologic and borehole geophysical information. Depth to geoelectrically resistive rock calculated from the soundings and geophysical models ranges from 4,500 ft (1371 m) in the east-central part of the basin, to about 5,100 ft (1555 m) in the west-central part of the basin. This study provides a broad interpretation of the

diverse character and distribution of the Mesozoic sedimentary and igneous rock and of the pre-Mesozoic metamorphic rocks of the Culpeper basin.

INTRODUCTION

The Culpeper basin is a north-northeast-trending faulted trough at the inner margin of the Piedmont geologic province along the east front of the Blue Ridge geologic province in Virginia and Maryland (fig. 1). It is part of a belt of similar Newark rift-basin structures of early Mesozoic age in eastern North America exposed from South Carolina to Nova Scotia (fig. 2) (Bain, 1973; Ackermann and others, 1976; Bain and Bisdorf, 1977; Bain and Brown, 1981; Froelich and Olsen, 1984). The basin is about 20 km (12.4 miles) wide and extends for about 140 km (87 miles) north from the Rapidan River across the Potomac River and terminates near Frederick, Maryland (fig. 3).

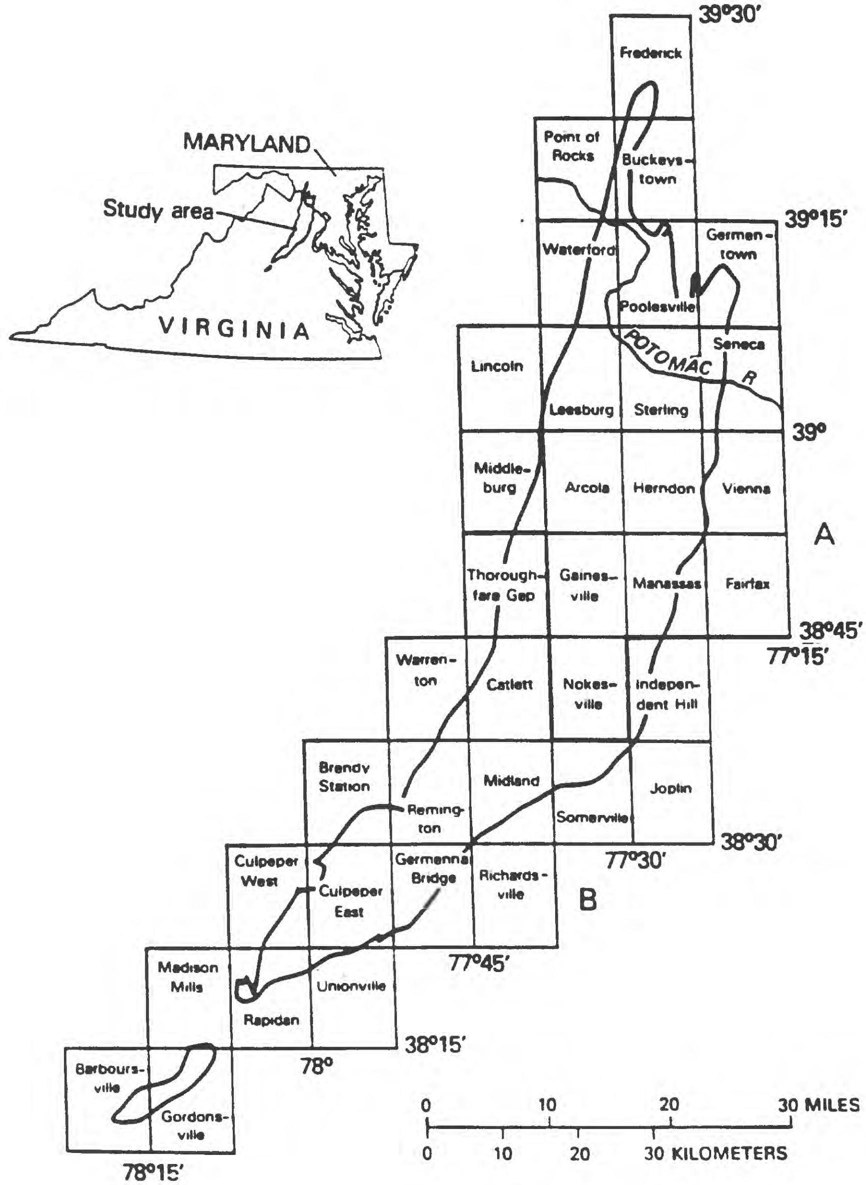
The inherent problems during this investigation are (1) distinguishing between mainly Triassic sedimentary rocks and the underlying pre-Triassic crystalline rocks, and (2) distinguishing sedimentary rocks and basalts from Jurassic diabase that intrudes the sedimentary rocks. Previous geophysical studies in this area include aeromagnetics (Johnson and Froelich, 1982), Bouguer gravity (Wise and Johnson, 1980) and seismic reflection (Virginia Division of Mineral Resources (1982) and Manspiezer and others, 1989), as well as electromagnetic, seismic refraction and electrical resistivity (Daniels, 1980). The effort to better understand the geology and hydrology in the Culpeper basin is ongoing and arduous because of associated geologic complexity in the basin.

Purpose and Scope

This report describes the results of a study intended to refine and extend knowledge of the subsurface geology in the Culpeper basin, Virginia, using direct-current electrical resistivity methods.

The study included electrical resistivity field surveying using a Schlumberger field array to collect raw data. Knowledge of the regional geology from previous studies (Lee, 1977, 1978, 1979, 1980; Lee and Froelich, 1989; Froelich and Leavy, 1982; Froelich and Gottfried, 1988; Tollo and others, 1988; Drake and Morgan, 1981; Drake and Lee, 1989; and Leavy and others, 1983) were supplemented by local drill hole data then incorporated with computer-processed data to produce the final interpretive models of the subsurface geology. Electrical resistivity field surveys were completed in 1978 by Phoenix Geophysics, Ltd., under contract to the U.S. Geological Survey (USGS). Daniels (1980) also provides a discussion of four of the electrical resistivity profiles completed in Fairfax County.

The reader is referred to a series of USGS 7- 1/2-minute topographic quadrangles on which each electrical resistivity site can be located. An index map showing the 7- 1/2-minute topographic quadrangles that cover the Culpeper basin and those containing the electrical soundings discussed in this report is shown in figure 1. Electrical sounding sites 4A to 4I are located in the quadrangles as shown on figure 3 and 4.



Geological maps and reports for these quadrangles are in: Area A, Lee (1978, 1979) and Eggleton (1975); and Area B, Lee (1980).

Figure 1. Location of quadrangle maps and reports that discussed the geology of the Culpeper basin area (From Lee and Froelich, 1989).

Figure 2. Map showing location of exposed Mesozoic basins of eastern North America (modified from Brown, 1987; Smoot and Robinson, Jr., 1988).

Geologic Setting of the Culpeper Basin, Virginia

The sedimentary rocks of the Culpeper basin are part of the Newark Supergroup and comprise a distinctive sequence of non-marine clastic strata (Culpeper Group) ranging in age from Late Triassic to Early Jurassic (Froelich and Olsen, 1984). The Triassic section is predominantly red beds, mainly fluvial arkosic sandstone and siltstone with a variety of lenticular conglomerates with minor amounts of shale. The Jurassic sequences also contain red beds but is characterized by a series of intercalated basalt flows and lacustrine gray and black shales.

The entire sequence dips regionally westward, with steeper dips (as much as 70 degrees west) in Jurassic strata along the major normal fault near the west margin of the basin. Triassic strata along the eastern margin of the basin dip gently westward away from the regional unconformity with the underlying Piedmont crystalline rocks, except where cut by minor normal faults. Regional dip generally increases progressively westward, except where interrupted by faults, intrusions, or folds. In many areas the Culpeper Group is intruded and locally metamorphosed by dikes, sills, and stocks of tholeitic diabase (Nutter, 1975; Lee, 1977, 1979, 1980; Lindholm, 1979; Leavy and others, 1983; Froelich and Gottfried, 1988) (See fig. 4).

Igneous rocks of the Culpeper basin include (1) two extensive systems of diabase sheets, (2) three systems of chemically distinct diabase dikes, and (3) three series of multiple basalt flows (Tollo and others, 1988). Froelich and Gottfried (1988) showed that the diabase intrudes both upper Triassic and lower Jurassic strata and that the sheets are bordered by extensive contact aureoles. A full description of the intrusive sheet and dike systems of the Culpeper basin is provided by Froelich and Gottfried (1988). Lee (1979, 1980) described a sequence of three flow series with at least 6 basalt flows intercalated with lower Jurassic strata in the west-central portion of the Culpeper basin (see also Tollo and others, 1988 who recognized at least 13 separate flows).

Pre-Mesozoic rocks that outcrop outside the basin have similar character to rocks beneath the basin. The variable character of the pre-Mesozoic metamorphic rock that crops out east of the study area in the Piedmont of Fairfax County is described by Drake and others (1979) and Drake and Morgan (1981). The Peters Creek Schist, as redefined by Drake and Morgan (1981), is the regionally most extensive pre-Mesozoic unit. It is mainly quartz-rich mica schist and phyllite, metagraywacke and mica gneiss locally containing fragments, blocks, and slabs of ultramafic and mafic rocks. The Peters Creek Schist east of the Culpeper basin is in a complex thrust relationship with the Piney Branch Complex, a tectonic melange of ophiolites consisting of serpentinite, soapstone, actinolite schist, and metagabbro intruded by dikes of plagiogranite (Drake and Morgan, 1981).

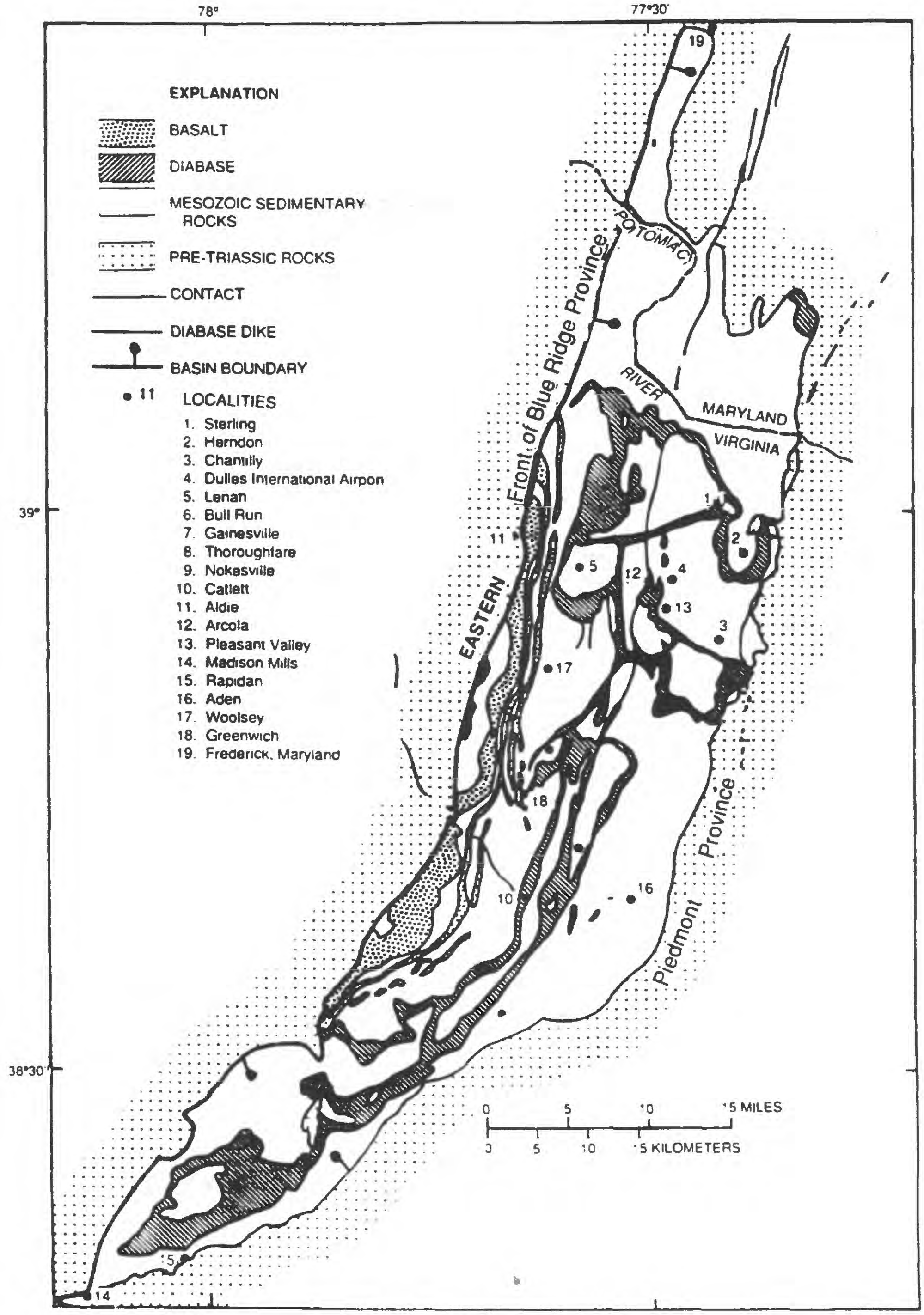


Figure 3. Generalized geologic map of Culpeper basin and vicinity (Modified from Smoot and Robinson, Jr., 1988).

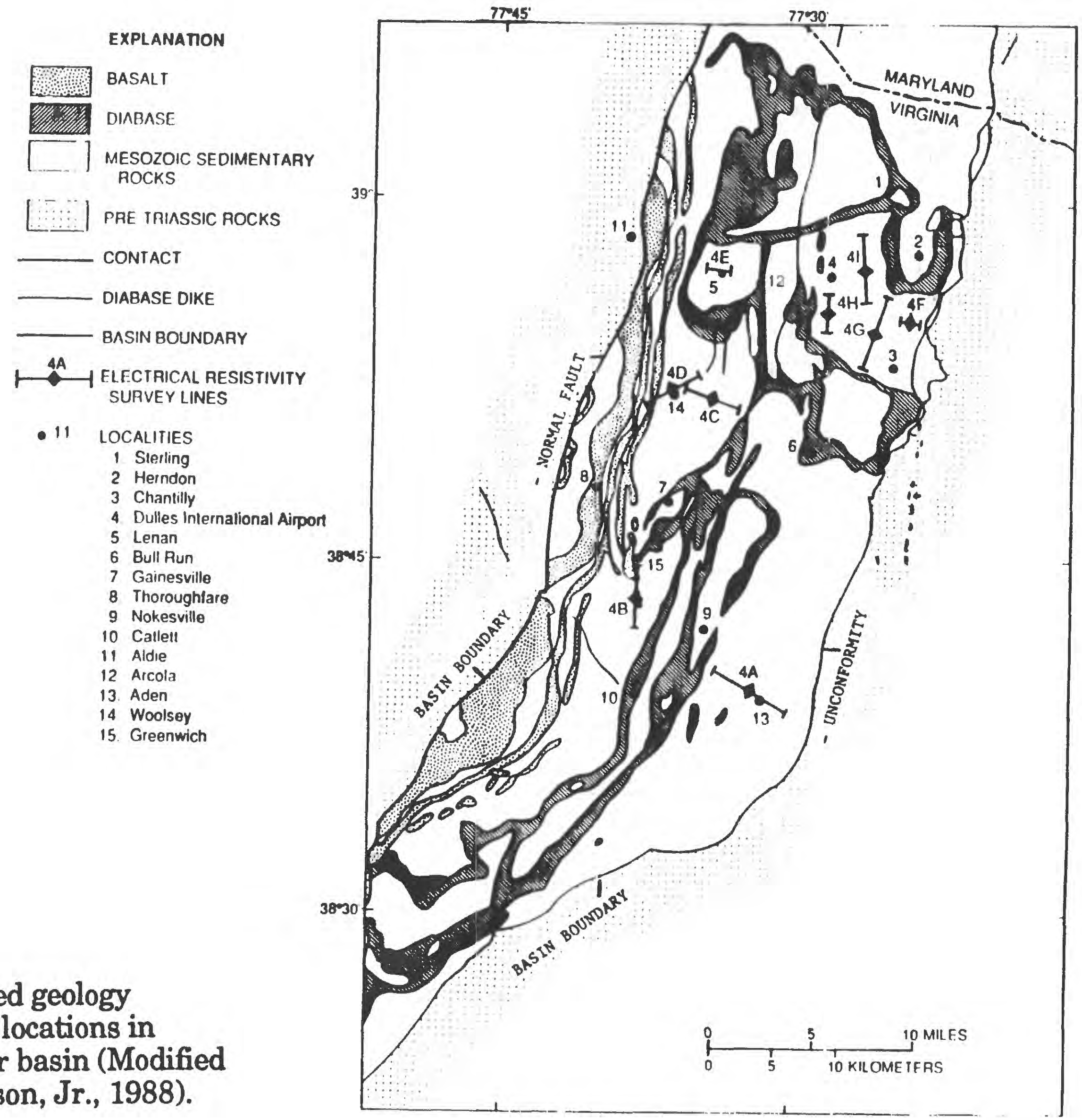


Figure 4. Map showing generalized geology and electrical sounding locations in North-Central Culpeper basin (Modified from Smoot and Robinson, Jr., 1988).

ACKNOWLEDGMENTS

The author thanks the late Albert Froelich, U.S. Geological Survey, for review and critical suggestions.

ELECTRICAL SOUNDING SURVEYS

The direct current-electrical resistivity method was used in the Culpeper basin to determine whether or not there was sufficient resistivity contrast to distinguish between the Mesozoic sedimentary rock layers, Mesozoic igneous intrusive and extrusive rocks, and pre-Mesozoic basement rock, to make the resistivity method an effective exploration tool.

Nine direct current-electrical soundings using a Schlumberger field array were completed in the north-central Culpeper basin (fig. 4). The Schlumberger method was chosen because it had proved effective for exploration of other deep basins (Ackermann and all, 1976). In this method, a pulsed direct current is introduced into the earth through two outer current electrodes (A and B), and the resulting potential is measured between two closer spaced inner electrodes (M and N) located at the center of the sounding. Measurements are made at increasing current electrode spacings, and the apparent resistivity, in ohm-meters (Ω-m) is calculated using a simple formula (see Zohdy and others, 1974). The electrical sounding curve is derived by plotting apparent resistivity versus half the distance between current electrodes (AB/2). The apparent resistivity and half spacing (AB/2) are input for the computer model.

The electrical sounding data were interpreted using several data analysis programs (Zohdy, 1973, 1974, 1989; Zohdy and Bisdorf, 1975, 1989). The individual smoothed sounding curves (apparent resistivity versus distance) were interpreted by inverting them into values of apparent resistivity versus depth using the data analysis program, which iteratively compares the observed field data with computed resistivities for various subsurface layer models. For each sounding, the program generated an interpretation which assigned specific resistivity values to depth intervals. Constraints may be incorporated in the program through which depths and resistivities of certain layers are specified. To obtain an acceptable layer model from the program, several constraints were applied on the basis of knowledge of the local geology and the resistivity of rock layers determined from geophysical logs. Additional adjustments to layer resistivities for some soundings were applied to shallower layers to minimize differences in lateral resistivities, thereby improving layer correlation between adjacent soundings for the final geologic interpretation.

VERTICAL ELECTRICAL RESISTIVITY

<u>Soundings in Culpeper Basin</u>
Sounding 4A - Nokesville Quadrangle

Sounding site 4A is located along Route 646 in the Nokesville 7- 1/2-minute quadrangle near the eastern margin of the basin. The survey line is 16,000 ft

(4,878 m) and is oriented in a northwest-southeast direction with the center of the survey located 3,000 ft (915 m) northwest of the town of Aden, Virginia (fig. 4). The geologic setting along this survey line comprises a gently tilted sequence of generally west-dipping siltstones and shales (less than a mile to the east) that overlie sandstone and basal Triassic conglomerate in contact with foliated Peters Creek Schist (Lee, 1979).

The depth model is presented showing the layer relationships in sounding 4A (fig. 5). Resistivity values for electrical sounding 4A range from about 75 to approximately 1,500 Ω-m. Below 4,800 ft (1,463 m) the resistivity contrast is abrupt and the underlying Peters Creek Schist has an apparent resistivity of 1,500 Ω-m.

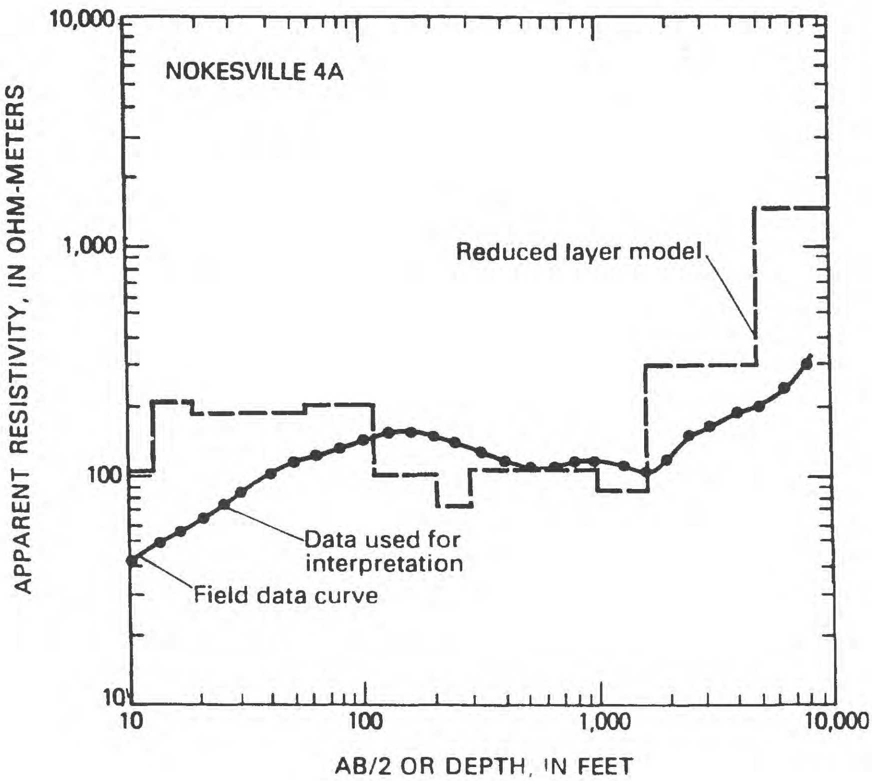


Figure 5. Graph showing geoelectrical model for sounding 4A, Nokesville, Va.

Furthermore, analysis of VPI-USGS-VDMR seismic reflection profile No. 1 in the same area indicates a faulted basement at about 0.3 sec., or less than 2,500 ft (762.2 m) in the east and descending to 0.7 sec (5,100 ft (1,554.9 m)) in the west, thus providing independent geophysical confirmation of depth to geoelectric basement (Costain and Froelich, 1989). The geologic analysis based on geophysical data and outcrop geology is that the Balls Bluff Siltstone extends from the surface down to about 1,600 ft (487.8 m), and is underlain by the Manassas Sandstone that includes the conglomerate of the Reston Member near the base from 1,600 to 4,800 ft (487.8 to 1,463.4 m). The Reston Member probably unconformably overlies the Peters Creek Schist.

Sounding 4B - Catlett Quadrangle

Sounding site 4B is located in the west-central part of the basin in the Catlett quadrangle, extending 8,000 ft. (2,439 m) north-northeast to south-southwest along State Road 604 south of Greenwich, Virginia (fig. 3 and fig. 4).

The geologic setting in this area is that of moderate to steeply west dipping siltstone that is cut and thermally metamorphosed by a diabase dike at the surface. As a result of the metamorphism, the sedimentary rocks are more indurated in this section, reflected by the higher resistivity of hornfels interpreted in the lower part of the section.

Sounding 4B has many thin layers above geoelectrically resistive rock which can be combined into four thicker layers (fig. 6).

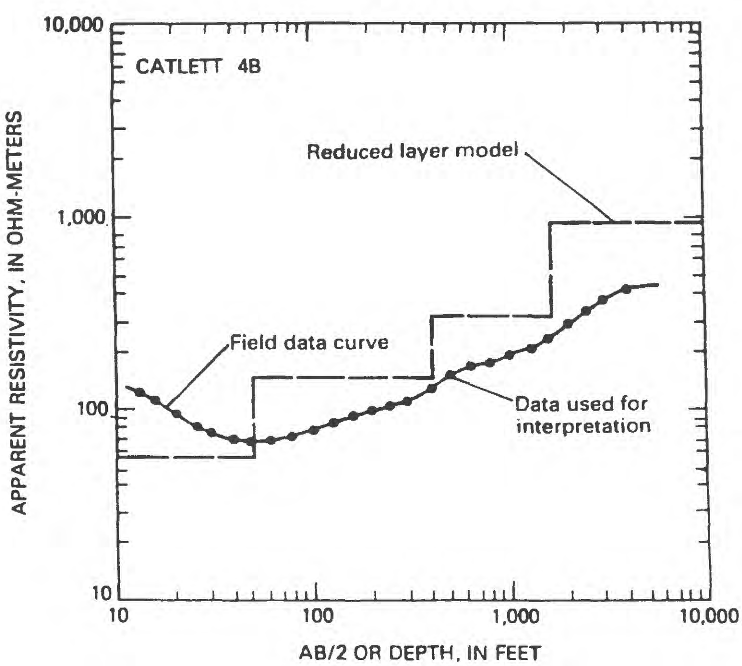


Figure 6. Graph showing geoelectrical model 4B, Catlett, VA.

Resistivity values of about 1,000 Ω-m occur below a depth of 2,360 ft (719.8 m). As this sounding is located near Jurassic diabase, igneous and metamorphosed rocks are likely to be present at a fairly shallow depth. Layers 1 and 2 are composed primarily of shale and siltstone of the Balls Bluff, whereas layers 3 and 4 could be slightly metamorphosed or could have a larger amount of sandstone and thus have higher resistivity. Layer 4 is interpreted to be composed predominantly of metamorphosed sedimentary rocks (hornfels) and the geoelectrically resistive rock below is probably diabase. The final geologic model developed for sounding 4B is that the Balls Bluff Siltstone overlies metamorphosed sedimentary rock above geoelectric resistive rock composed of diabase intrusive rock.

Sounding 4C - Catharpin, Gainesville Quadrangle

Sounding site 4C is located along State road 234 northwest of Manassas, Virginia near the town of Catharpin. The center of the sounding is 550 ft (169 m) west of the intersection of Route 234 with Route 701 west of Catharpin, Virginia. The survey line is oriented in a northwest-southwest direction and is 16,000 ft (4,878 m) in length (fig. 4).

The surface geology in the area indicates Jurassic diabase within one half mile of the electrical resistivity sounding site, with a west-dipping sheet underlying the site. Quartz pebble conglomerate and sandstone dip moderately to steeply westward at this site.

The geoelectric section is highly variable in terms of gross electrical resistivity layering (fig. 7). The basal unit averages 4,400 Ω-m below 5,100 ft (1,554.9 m). Analysis of the eastern end of VPI-USGS seismic reflection profile no. 2 at this approximate locality indicates a maximum depth of about 11,480 ft (3,500 m) to pre-Mesozoic crystalline rocks, thus it is clear that the geoelectrically resistive rock at this site is intrusive diabase, high in the stratigraphic section (Costain and Froelich, 1989; Virginia Polytechnic Institute and State University, 1982).

The final interpretive model consists of sandstones of the Catharpin Creek Formation with a quartz pebble conglomerate member to approximately 2,700 ft (823.2 m), underlain by thermally metamorphosed rocks and possibly thin diabase from 2,700 to 5,100 ft (823 to 1,555 m). The thermally metamorphosed rock apparently becomes progressively more indurated and altered to 5,100 ft (1,555 m) depth where the bottom layer is interpreted to be Jurassic diabase.

Sounding 4D - Woolsey Area, Arcola, Gainesville, and Thoroughfare Gap Quadrangle

Sounding site 4D is oriented northeast-southwest for 1,000 ft. (305 m) along State Road 601 in the Arcola and Gainesville 7- 1/2-minute quadrangles extending into the Thoroughfare Gap quadrangle. The center of the sounding is approximately 1,600 ft (487.8 m) northeast of the intersection of SR 601 with US Route 15 east of Woolsey (fig. 4).

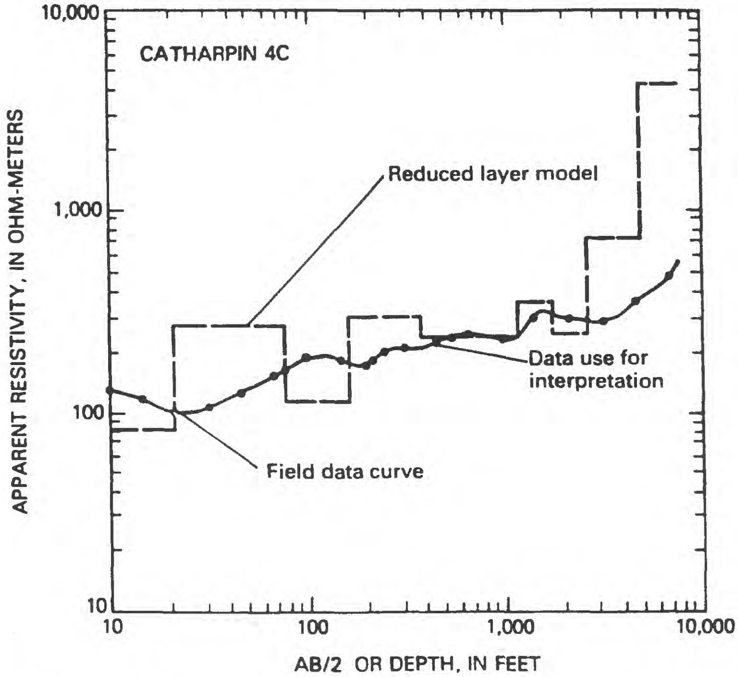


Figure 7. Graph showing geoelectrical model for sounding 4C, Cartharpin, VA.

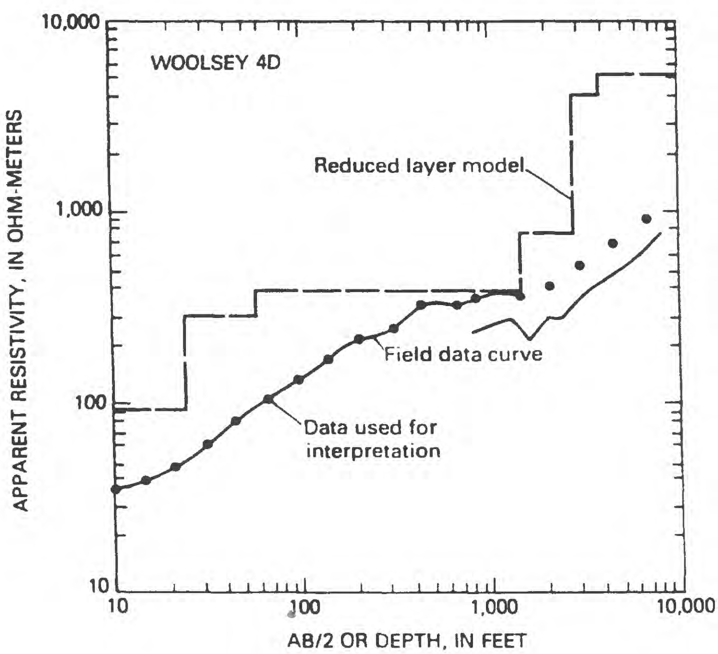


Figure 8. Graph showing geoelectrical model for sounding 4D, Woolsey, VA.

The geology at this site shows steeply west dipping layers of pebbly sandstone and conglomerate interbedded with basalt flows that strongly influence the responses from the electrical resistivity sounding.

Electrical sounding 4D (fig. 8) is interpreted to have four distinct layers above geoelectrically resistive rock. Geoelectric resistive rock at the bottom of the section has apparent resistivity estimated at 4,300 Ω-m.

Analysis of the central portion of VPI-USGS seismic reflection profile no. 2 at this approximate locality indicates a maximum depth to pre-Mesozoic crystalline rocks of about 10,000 ft (3,000 m), thus the geoelectrically resistive rock at this site is intrusive diabase high in the stratigraphic section (Costain and Froelich, 1989; Virginia Polytechnic Institute and State University, 1982).

Sounding 4E - Lenah, Arcola Quadrangle

Sounding site 4E is located along State Route 50 near Lenah, Virginia, in the Arcola 7- 1/2-minute quadrangle. The center of sounding 4E is located approximately 1,700 ft (518 m) west of the town of Lenah. It is oriented westerly for 2,600 ft (792 m) (fig. 4).

The geology in this area shows Jurassic diabase in proximity to the sounding site with steeply-dipping sedimentary rock and Jurassic diabase underlying the site. Jurassic diabase is interpreted at 348 ft (106 m) with an apparent resistivity of 3,651 Ω-m (fig. 9). A large thickness of sedimentary rock probably is present below the geoelectric resistive rock underlying the site, thus Jurassic diabase probably intrudes high in the sedimentary section. The site has underlying geology very similar to that at sounding site 4C that involves the Catharpin Creek Formation with quartz pebble conglomerate underlain by Jurassic diabase as the geoelectric resistive rock.

Sounding 4F - Fox Mill Area, Herndon Quadrangle

Sounding site 4F is located in the Fox Mill area about 2,000 ft (610 m) northwest of Lawyers Road. The length of the sounding spread is 2,000 ft (610 m) and is oriented southeasterly (fg. 4).

Sounding 4F (fig. 10) is located in an area where the Manassas Sandstone, is definitely known to be underlain by the Peters Creek Schist. A well at this sounding location penetrated about 500 ft (150 m) of interbedded sandstone and siltstone overlying 110 ft (30 m) of pebbly sandstone and conglomerate unconformably overlying foliated mica schist at 610 ft (86 m).

The Peters Creek Schist below 610 ft (186 m) has a resistivity value of about 150 Ω-m. The Manassas Sandstone overlies conglomerate of the Reston Member at about 500 ft (152 m). The basal conglomerate unconformably overlies Peters Creek Schist at 610 ft (186 m).

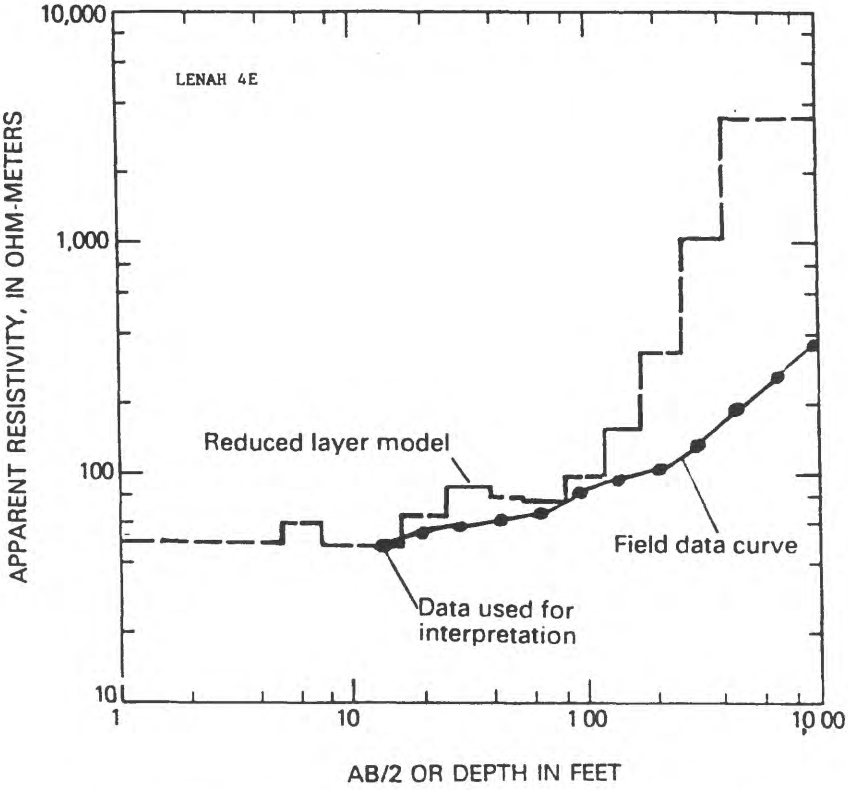


Figure 9. Graph showing geoelectrical model for sounding 4E, Lenah, VA.

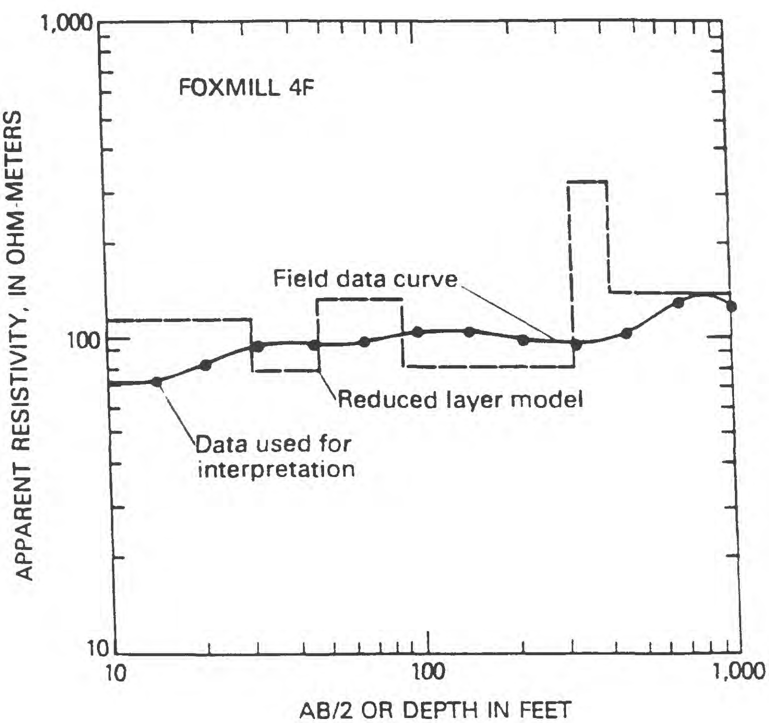


Figure 10. Graph showing geoelectrical model for sounding 4F, Foxmill area of Dulles Airport Corridor.

Sounding 4G - Chantilly Area, Herndon Quadrangle

Sounding site 4G is located along State Route 657, Centreville Road, in the Herndon quadrangle. It is a 13,000 ft (3,900 m) spread and is oriented northeasterly. The center of the sounding is shown on figure 4.

The geology of this area consists of southwest-dipping Balls Bluff Siltstone overlying the Manassas Sandstone. The depth to geoelectrically resistive rock-true pre-Triassic basement-is approximately 1,775 ft (541.2 m). The dips are moderate to gently westward at this location (see Leavy and others, 1983).

The sedimentary rock is similar to rock at sounding 4H that has low resistivity values that correlate with shales, siltstones, and sandstones. The Peters Creek Schist or unknown lithology with an anomalously low resistivity of about 305 Ω-m is interpreted to underlie the Triassic sedimentary rocks (fig. 11).

Sounding 4H - Willard Road, SW Dulles Airport Area, Herndon Quadrangle

Sounding site 4H is located southeast of Dulles International Airport on Willard Road north of Route 50 in Chantilly, Virginia. The center is approximately 0.6 miles (1.2 km) south of the intersection of the Loudoun-Fairfax County line with Willard Road. The survey line is an 11,000 ft (3,300 m) spread and is oriented northerly (fig. 4).

The geology of the area consists of gently dipping siltstone and sandstone with a basal conglomerate unconformably above the Peters Creek Schist. Sounding 4H shows many thin variably resistive layers that have been combined into 3 to 4 distinct layers above geoelectrically resistive rock (fig. 12).

The sedimentary rocks in this area represented by the first two layers, have low resistivity values which generally correlate with siltstone and shale of the Balls Bluff. The thick layer immediately above basement is possibly a very thick sandstone and conglomerate sequence of the Manassas. Geoelectric resistive rock with resistivity of about 975-1,000 Ω-m at this site is probably the Peters Creek Schist, but this sounding is not near a core hole or well drilled to basement or outcrop of the Peters Creek Schist.

Sounding 4I - Dulles Airport Area, Herndon Quadrangle

Sounding site 4I is located along the east runway of Dulles International Airport north of Chantilly, Virginia. The survey line is approximately 16,000 ft (4,878 m) long and is oriented northerly (fig. 4).

The geology of this area consists of gently west-dipping Balls Bluff Siltstone overlying Manassas Sandstone unconformably above probably the Peters Creek Schist, similar to the geologic setting of soundings 4G and 4H.

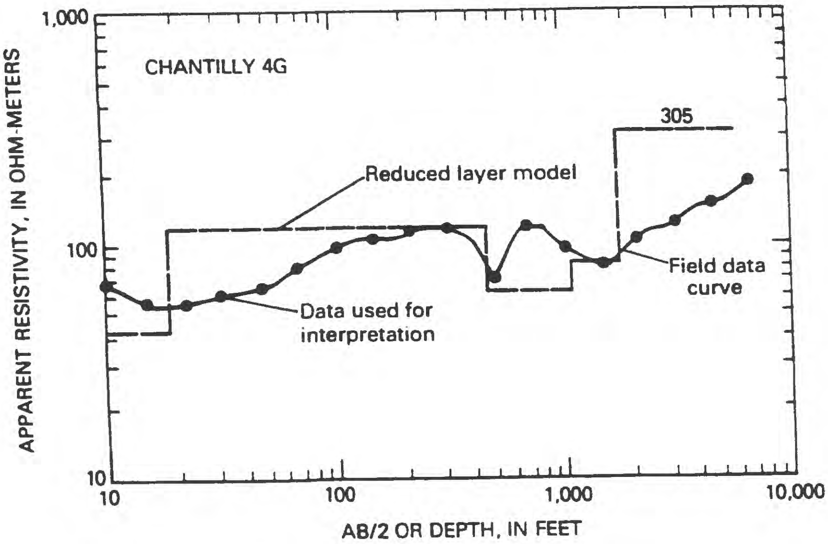


Figure 11. Graph showing geoelectrical model for sounding 4G, Chantilly, VA.

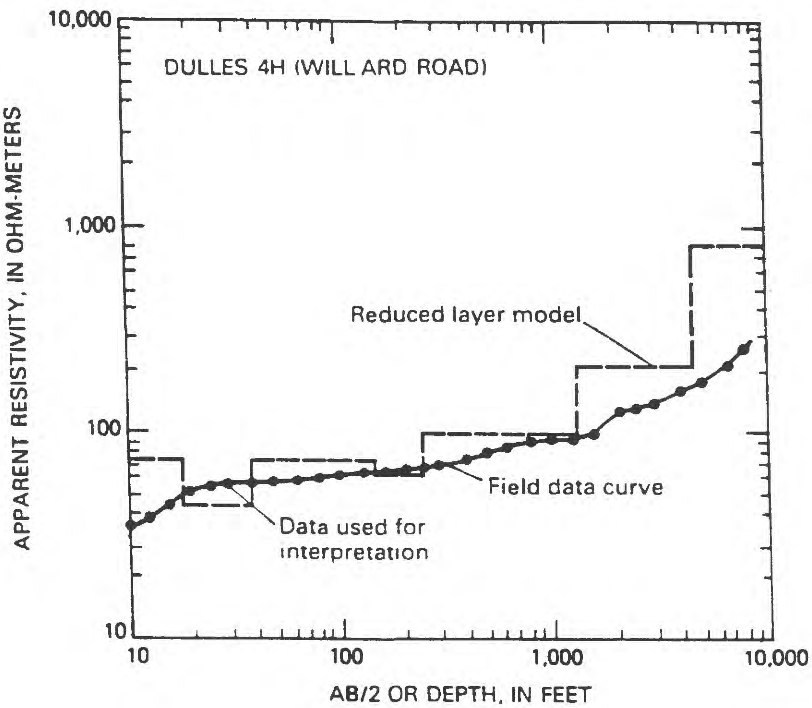


Figure 12. Graph showing geoelectrical model for sounding 4H, Willard Road area of Dulles Airport Corridor.

Sounding 4I (fig. 13) shows three distinct layers above geoelectrically resistive rock. The basal layer is interpreted as the Peters Creek Schist with a resistivity of 1,545 Ω-m at a depth of approximately 4,400 ft (1,341 m).

STRUCTURAL GEOMETRY

The geoelectric cross sections (fig. 14 and 15) indicate that the structural geometry of the Culpeper basin is similar to that of other Triassic-Jurassic basins, such as the Durham basin of North Carolina, where step-faulted basin margins, igneous intrusions, and local metamorphism of the sedimentary basin fill are characteristic of the geology (Ackerman and others, 1976; Bain and Brown, 1978). The geoelectric cross sections representing the sedimentary section above geoelectrically resistive rock show the interbedded nature of thick and very thin stratigraphic units. The apparent electrical resistivity for sedimentary rock units and geoelectrically resistive rock show striking contrasts on the cross sections. The cross sections indicate a wide variability in the physical properties of pre-Triassic metamorphic rock, and that there is not a unique value of apparent resistivity for the pre-Mesozoic basement rocks or igneous intrusive rock. The wide range in electrical resistivity is analogous to differences in physical properties. This variation is supported by the character of rocks examined in outcrops of the Peters Creek Schist and Piney Branch ultramafic igneous rocks outside the basin (on the east flank).

As noted, the eastern part of the Culpeper basin is underlain by gently west-dipping Manassas Sandstone unconformably overlying the Peters Creek Schist. The Balls Bluff Siltstone conformally overlies the Manassas Sandstone. The central and western part of the Culpeper basin are underlain by the Catharpin Creek Formation and basalt flows and sedimentary strata overlying hornfels and diabase, hence the geoelectric properties are influenced more by the metamorphism and intrusion of igneous rock. Because this study provides a summary of major geoelectrical units, the geoelectrical model may be used to obtain more knowledge on ground-water systems in the North-Central Culpeper basin.

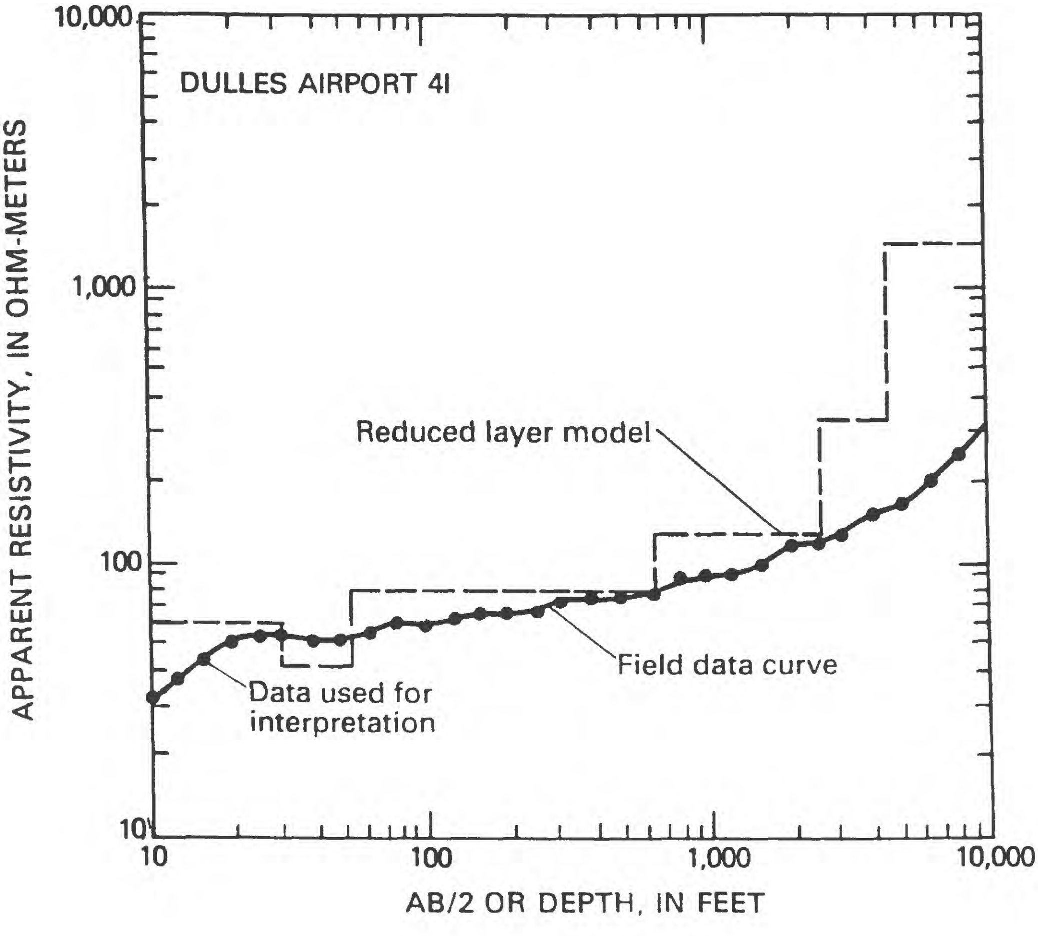


Figure 13. Graph showing geoelectrical model for sounding 4I, Dulles Airport, Chantilly, VA.

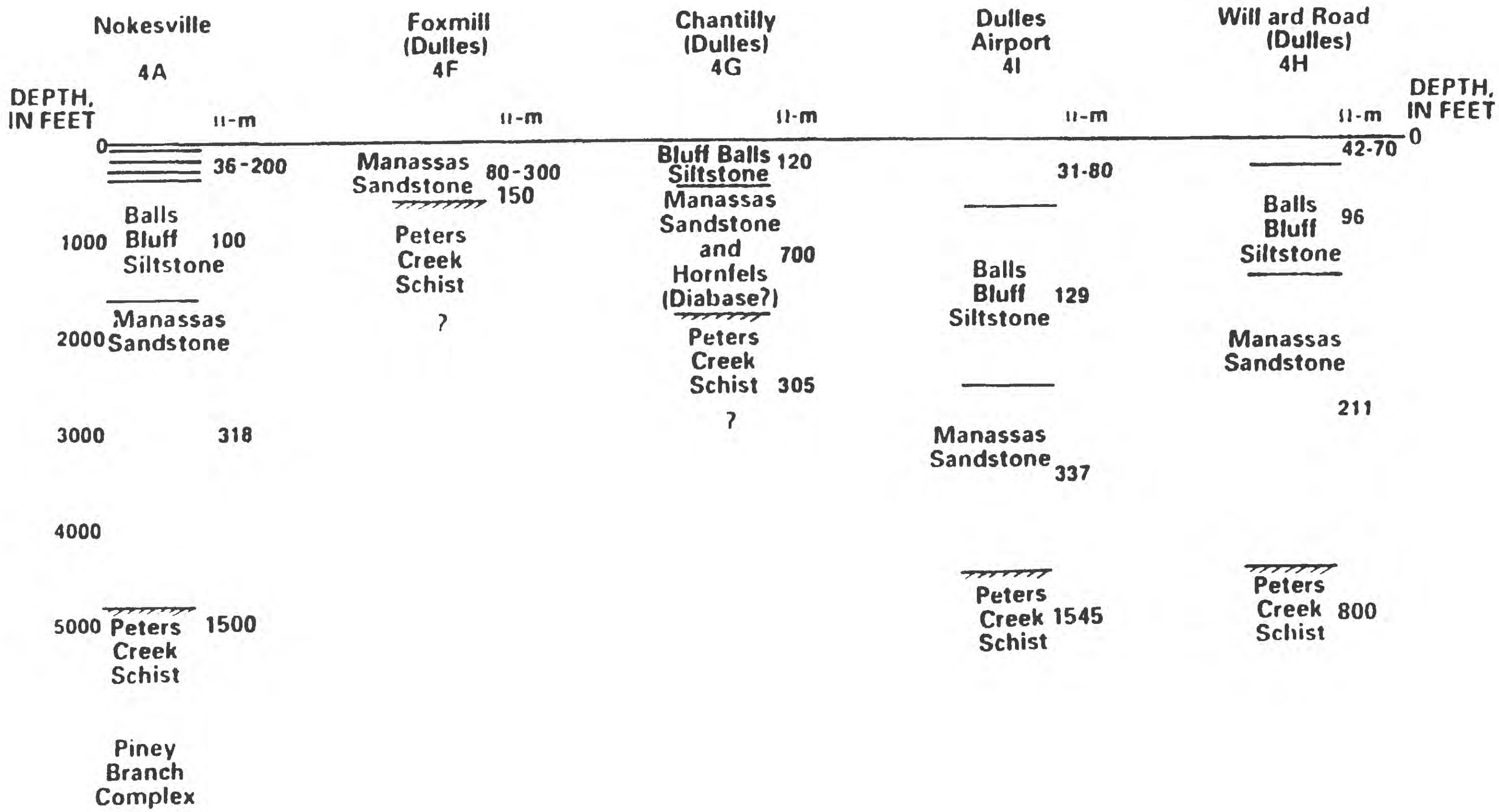
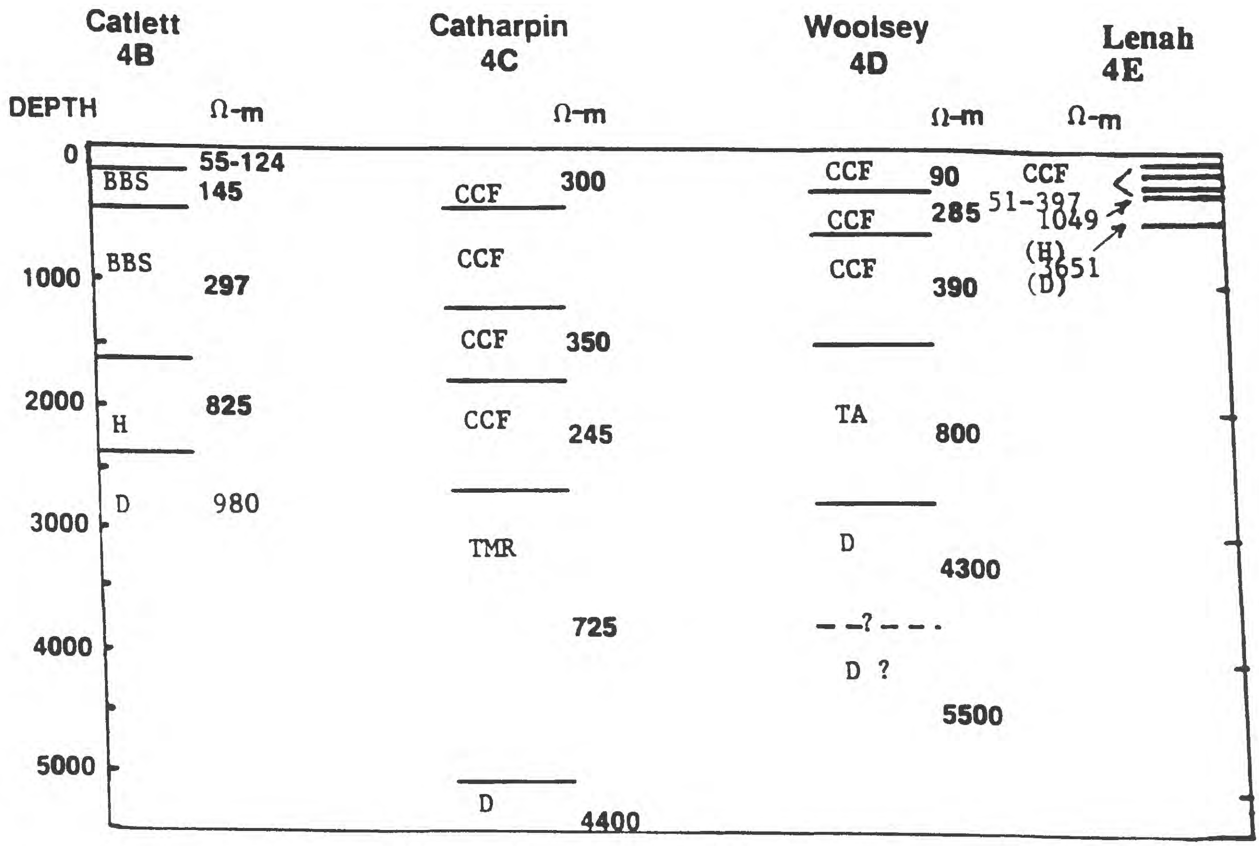


Figure 14. Condensed geoelectrical model for eastern Culpeper basin that is underlain by geoelectrically resistive Peters Creek Schist.



EXPLANATION

BBS -	Balls Bluff Siltstone	TMR -	Thermally Metamorphosed Rocks
H -	Hornfels	TA -	Thermal Aureole
D -	Diabase	? -	Undefined
CCF -	Cartharpin Creek Formation	----- -	Uncertain
Catlett 4B -	Electrical resistivity sounding site, shown in figure 4	Ω - m -	Ohm-meters

Figure 15. Condensed geoelectrical models for the central Culpeper basin that is underlain by geoelectrically resistive Jurassic diabase and hornfels.

CONCLUSIONS

Electrical resistivity soundings in the Culpeper basin indicate a wide variability in resistivity of the Triassic sedimentary rock sequence unconformably above geoelectric resistive rock of different compositions, primarily the pre-Mesozoic Peters Creek Schist and Piney Branch Complex. The geologic setting is complicated because the Triassic sedimentary rock is intruded by Jurassic diabase, an igneous intrusive rock which is highly resistive. Pre-Mesozoic crystalline rock comprised mainly of igneous or metamorphic rocks beneath the eastern half of the basin have electrical resistivity values from as low as 150 Ω-m to as high as 4,400 Ω-m in some areas. Thick geoelectrically resistive beds of arkosic sandstone have resistivity values from approximately 500 Ω-m to as high as 700 Ω-m. Sedimentary rocks with lower resistivities, less than about 350 Ω-m have a higher clay content and consist of interbedded thin arkosic sandstones and thick siltstone and shale sequences. Thick sequences of thermally metamorphosed shale and siltstone (hornfels) or sandstone intruded by diabase have moderate to high resistivities, commonly between 725 and 825 Ω-m. The depths to geoelectrically resistive rock ranges from 610 ft to 4,500 ft (186 to 1,372 m) for soundings in the eastern part of the basin. Depths to diabase range from several hundred feet at sounding 4E, and from 2,500 ft to about 5,100 ft (762 to 1,555 m) at sounding sites in the western part. The final models compiled from the geophysical data indicate that the wide range in geoelectrical properties does not allow any unique conclusions or generalizations, and that a sound knowledge of the local geology is required to provide the most likely interpretation at each site investigated.

REFERENCES

Ackerman, H. D., Bain, G. L., and Zohdy, A. R., 1976, Deep exploration at an East Coast Triassic basin using electrical resistivity: Geology, v. 4, no. 4, p. 137-140.

Bain, G. L., 1973, Feasibility study of East Coast Triassic basins for waste storage-data availability: U.S. Geological Survey Open-File Report, 113 p.

Bain, G. L., and Bisdorf, R. J., 1977, Structural reinterpretation of the Durham-Wadesboro basin, North Carolina (abs.): Geological Society of America, Abstracts with Programs, Southeastern Section, v. 9, no. 2. p. 116.

Bain, G. L., and Brown, C. E., 1981, Evaluation of the Durham Triassic basin of North Carolina and techniques used to characterize its waste-storage potential: U.S. Geological Survey Open-File Report 80-1295, 132 p.

Brown, C. E., 1987, Modeling and analysis of direct current-electrical resistivity in the Durham Triassic basin, North Carolina: Journal of Geoexploration, Elsevier Science Publishers, B. V., Amsterdam, p. 429-440.

Cornet, Bruce, 1977, The palynostratigraphy and age of the Newark Supergroup: The Pennsylvania State University, unpublished Ph.D. dissertation, 508 p.

Costain, J. K., Froelich, A. J., and Coruh, Cahit, 1989, Geophysical characteristics of early Mesozoic basins in Eastern United States, in Manspeizer, Warren, Post Paleozoic activity, ch. 6, v. F-2, The Appalachian Ouachita Orogen in the United States: Geological Society of America, p. [319-374] p. 333-343.

Daniels, D. L., 1980, Geophysical-geological analysis of Fairfax County, Virginia: U.S. Geological Survey Open-File Report 80-1165, 66 p.

Drake, A. A., Jr., Nelson, A. E., Force, L. M., Froelich, A. J., and Lyttle, P. T., 1979, Preliminary geologic map of Fairfax County, Virginia: U.S. Geological Survey Open-File Report 79-398, scale 1:48,000.

Drake, A. A., Jr., and Morgan, B. A., 1981, The Piney Branch Complex-A metamorphosed fragment of the Central Appalachian ophiolite in northern, Virginia American Journal of Science, v. 28, p. 484-508.

Drake, A. A., Jr., and Lee, K. Y., 1989, Geologic map of the Vienna Quadrangle, Fairfax County, Virginia, and Montgomery County, Maryland: U.S. Geological Survey Geologic Quadrangle Map, GQ-1670, scale 1:24,000.

Eggleston, R. E., 1975, Preliminary geologic map of the Herndon Quadrangle, Virginia: U.S. Geological Survey Open-File Report 75-386, scale: 1:24000.

Froelich, A. J., and Gottfried, David, 1988, An overview of early Mesozoic intrusive rocks in the Culpeper basin, Virginia and Maryland, in Froelich, A. J., and Robinson, G. R. Jr., eds., Studies of the Early Mesozoic basins of the Eastern United States, U.S. Geological Survey Bulletin 1776, p. 151-165.

Froelich, A. J., and Leavy B. D., 1982, Map showing mineral resources of the Culpeper basin, Virginia and Maryland: Availability and planning for future needs: U.S. Geological Survey Miscellaneous Investigation Series Map I-1313-B, scale 1:125,000.

Froelich, A. J., and Olsen, P. E., 1984, Newark Supergroup, a revision of the Newark Group in Eastern North America; U.S. Geological Survey Bulletin 1537 A, p. A55-A58.

Froelich, A. J., and Robinson, G. R. Jr. (eds.),1988, Studies of early Mesozoic basins of the Eastern United States, U.S. Geol. Survey Bulletin 1776, 423 p.

Johnson, S. S., and Froelich, A. J., 1982, Aeromagnetic contour map of the Culpeper basin and vicinity, Virginia: Virginia Division of Mineral Resources, Pub. no. 41, scale 1:125,000.

Leavy, B. D., Froelich, A. J., and Abram, E. C., 1983, Bedrock, map and geotechnical properties of rocks of the Culpeper basin and vicinity, Virginia and Maryland: U.S. Geological Survey Miscellaneous Investigations Series Map I-1313-C, scale 1:125,000.

Lee, K. Y., 1977, Triassic stratigraphy in the northern part of the Culpeper basin, Virginia and Maryland: U.S. Geological Survey Bulletin 1422-C, 17 p.

Lee, K. Y., 1978, Geologic map of the Arcola quadrangle, Loudoun and Fairfax Counties, Virginia: U.S. Geological Survey Miscellaneous Field Studies Map MF-973, scale 1:24,000.

Lee, K. Y., 1979, Triassic-Jurassic geology of the northern part of the Culpeper basin, Virginia and Maryland: U.S. Geological Survey Open-File Report 79-1557, 29 p., 16 pl., scale 1:24,000.

Lee, K. Y., 1980, Triassic-Jurassic geology of the southern part of the Culpeper basin, Virginia: U.S. Geological Survey Open-File Report 80-468, 19., 18 pl., scale 1:24,000.

Lee, K. Y., and Froelich, A. J., 1989, Triassic-Jurassic stratigraphy of the Culpeper and Barboursville basins, Virginia and Maryland: U.S. Geological Survey Professional Paper 1472, 52 p.

Lindholm, R. C., 1979, Geologic history and stratigraphy of the Triassic-Jurassic Culpeper basin, Virginia: Geological Society of America Bulletin, (pt. 2, microfiche), v. 90, no. 11, p. 1702-1786.

Manspeizer, Warren, and others, 1989, Post Paleozoic activity, in The Geology of North America - The Appalachian - Ouachita Orogens in the United States, ch. 6, vol. F-7, The Geological Society of America Decade of North American Geology, p. 319-374.

Nutter, L. J., 1975, Hydrogeology of the Triassic Rocks of Maryland: Maryland Geological Survey, Report of Investigations No. 26, 37 p.

Smoot, J. P., and Robinson, G. R. Jr., 1988, Base- and precious-metal occurrences in the Culpeper basin, Northern Virginia, in Froelich, A.J., and Robinson, G. R. Jr., (eds.), Studies of Early Mesozoic basins of the Eastern United States, U.S. Geological Survey Bulletin 1776, p. 400-423.

Tollo, R. P., Gottfried, David, and Froelich, A. J., 1988, Field guide to the igneous rocks of the Southern Culpeper basin, in Froelich, A. J., and Robinson, G. R. Jr., eds., Studies of the Early Mesozoic basins of the Eastern United States, U.S. Geological Survey Bulletin 1776, p. 391-403.

Virginia Polytechnic Institute and State University, 1982, Culpeper basin VIBROSEIS survey, Virginia Div. of Mineral Resources, Open File Report 82-1.

Wise, M. A., and Johnson, S. S., 1980, Simple Bouguer gravity anomaly map of the Culpeper basin and vicinity, Virginia: Virginia Division of Mineral Resources Pub. no. 24, scale 1:125,000.

Zohdy, A. A. R., 1973, A computer program for calculation of Schlumberger sounding curves by convolution: U.S. Geological Survey Report No. 74-010, available from National Technical Information Services, Springfield, Virginia, Report PB-232-056.

Zohdy, A. A. R., 1974, The use of Dar Zarrouk curves in the interpretation of VES data: U.S. Geological Survey Bulletin 1313-D, 41 p.

Zohdy, A. A. R., 1989, A new method for the automatic interpretation of Schlumberger and Wenner sounding curves: Geophysics, v. 54, no. 2, p. 245-253.

Zohdy, A. A. R., and Bisdorf, R. J., 1975, Computer programs for the forward calculation and automatic inversion of Wenner sounding curves; available from National Technical Information Service, PB-247265/AS, Springfield, Virginia.

Zohdy, A. A. R., and Bisdorf, R. J., 1989, Programs for the automatic processing and interpretation of Schlumberger sounding curves in Quickbasic 4.0: U.S. Geological Survey OFR 89-137 A and B, 64 p.