LITHOLOGIC, GEOPHYSICAL, AND WELL-CONSTRUCTION DATA FOR OBSERVATION WELLS IN THE MELTON VALLEY AREA, OAK RIDGE RESERVATION, TENNESSEE

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CONVERSION FACTORS

For use of readers who prefer to use metric units, conversion factors for terms used in this report are listed below:

Multiply inch-pound unit	By	To obtain metric unit
inch (in.)	25.4	millimeter (mm)
foot (ft)	0.3028	meter (m)

Sea level: In this report "sea level" refers to the National Geodetic Vertical Datus of 1929 (NGVD of 1929)--a geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called "Sea Level Datum of 1929."

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ABSTRACT

Nineteen wells were installed at nine sites in the Melton Valley area. The wells are intended to provide information on water levels in both regolith and bedrock, aquifer characteristics, and subsurface lithology. Well depths range from 24 to 86 feet for shallow wells, and from 126 to 301 feet for deep wells. Four-inch diameter cores were obtained from four of the deep wells. Caliper, gamma, neutron, and gamma-gamma density borehole-geophysical logs were obtained for each deep well.

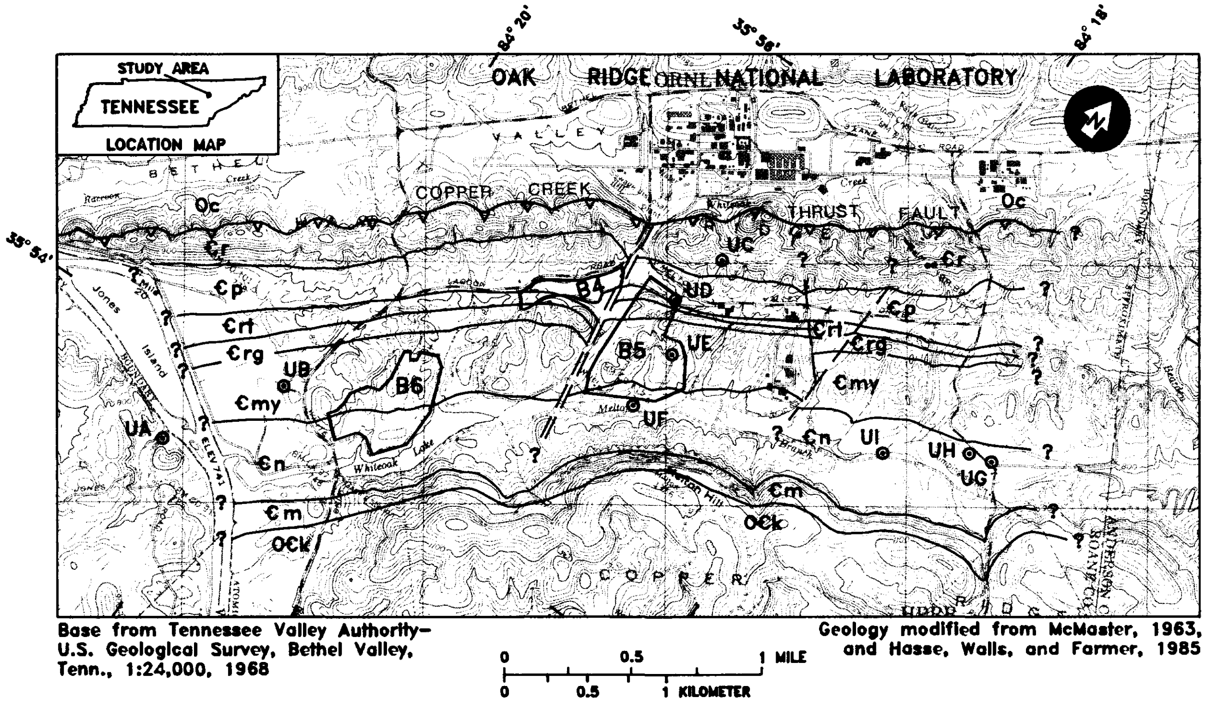
Lithologic descriptions of cores and analyses of geophysical logs indicate that well UA2 is completed entirely within the Nolichucky Shale; well UD2 is completed entirely within the Pumpkin Valley Shale; wells UB2 and UE2 are completed entirely within the Maryville Limestone; wells UF2, UG2, UH2, and UI2 penetrate both the Nolichucky Shale and the Maryville Limestone. Well UC2, located near the crest of Haw Ridge, penetrates an imbricate splay of the Copper Creek thrust fault, which places the older Rome Formation above the younger Chickamauga Limestone, at a depth of about 100 to 117 feet.

INTRODUCTION

Shallow-land burial of low-level radioactive waste in Melton Valley (fig. 1) has been practiced by Oak Ridge National Laboratory since 1951. The U.S. Geological Survey, in cooperation with the Department of Energy, is conducting a study of the geohydrology of the burial grounds. Tucci (1986, p.18) identified several types of data, particularly data from bedrock, that were needed to better understand the geohydrologic system of the valley.

In order to fill some of the data gaps, 19 wells were installed from October 1986 to March 1987 at nine sites in the Melton Valley area (fig. 1). The wells are intended to provide information for the on-going studies on: (1) water levels in both regolith and bedrock, in order to determine both horizontal and vertical ground-water flow directions, (2) aquifer characteristics, and (3) subsurface lithology. This report documents well-construction details, describes lithology of cores obtained from four wells, and presents borehole-geophysical data for deep wells (126 to 301 feet) at each site.

Four-inch diameter cores were obtained from wells UB2, UD2, UF2, and UG2 (fig. 1).



Base from Tennessee Valley Authority–U.S. Geological Survey, Bethel Valley, Tenn., 1:24,000, 1968

Geology modified from McMaster, 1963, and Hasse, Walls, and Farmer, 1985

EXPLANATION

Oc	CHICKAMAUGA LIMESTONE		ORDOVICIAN
OЄk	KNOX GROUP		ORDOVICIAN AND CAMBRIAN
Єm	MAYNARDVILLE LIMESTONE	CONASAUGA GROUP	CAMBRIAN
Єn	NOLICHUCKY SHALE	CONASAUGA GROUP	CAMBRIAN
Єmy	MARYVILLE LIMESTONE	CONASAUGA GROUP	CAMBRIAN
Єrg	ROGERSVILLE SHALE	CONASAUGA GROUP	CAMBRIAN
Єrt	RUTLEDGE LIMESTONE	CONASAUGA GROUP	CAMBRIAN
Єp	PUMPKIN VALLEY SHALE	CONASAUGA GROUP	CAMBRIAN
Єr	ROME FORMATION		CAMBRIAN

B4 — BURIAL GROUND AND NUMBER

?———? APPROXIMATE GEOLOGIC CONTACT——Queried where uncertain

UG — WELL SITE AND DESIGNATION

?— — —? APPROXIMATE LOCATION OF TEAR FAULT——Queried where uncertain

THRUST FAULT——Triangles on upper structural plate

Figure 1.——Well locations and generalized geology of Melton Valley.

Cuttings were collected periodically during drilling of the remaining five deep wells; however, sampling frequency was insufficient to provide lithologic information for wells UA2, UC2, UE2, UH2, and UI2. Borehole-geophysical logs were obtained for each deep well and were used to provide additional lithologic and stratigraphic information. Some caliper and gamma logs were obtained prior to setting casing, but most logs were obtained after well completion.

Acknowledgements

The authors wish to express their appreciation to Dr. C.S. Haase, Martin Marietta Energy Systems, Oak Ridge, Tennessee, for access to the Joy-2 core and for helpful discussions on the geology of the Conasauga Group. Most of the borehole-geophysical logs obtained for this study were obtained by G.E. Idler, U.S. Geological Survey, Atlanta, Georgia. The computer program to plot the digitized geophysical logs was written by S.A. Leake, U.S. Geological Survey, Tucson, Arizona.

Geologic Setting

Melton Valley is bounded on the northwest by Haw Ridge, which is underlain by the Rome Formation of Cambrian age (fig. 1). The Rome Formation consists of massive sandstone, thinly-bedded siltstone, shale, and mudstone (Haase, Walls, and Farmer, 1985). Copper Ridge, which bounds the valley on the southeast, is underlain by the Knox Group of Cambrian and Ordovician age (fig. 1). The Knox Group consists of carbonates, principally dolomite with subordinate amounts of limestone and locally abundant sandstone.

Melton Valley is underlain by the Conasauga Group of Cambrian age (fig. 1), which consists of six formations (in ascending order): Pumpkin Valley Shale, Rutledge Limestone, Rogersville Shale, Maryville Limestone, Nolichucky Shale, and Maynardville Limestone (Davis and others, 1984, p.16). Although formation names indicate single lithologic types, the formations are composed of several rock types. For example, the Nolichucky Shale contains interbedded limestone beds, particularly in the lower part of the formation, and the Maryville Limestone contains abundant interbedded shale in the lower part. A more detailed description of the formation lithologies of the Conasauga Group is presented by Haase, Walls, and Farmer (1985).

The formations strike northeast at about 56 degrees from north, and dip southeast generally between 10 and 45 degrees, although local variations are common (Haase, Zucker, and Stow, 1985, p. 475). The Copper Creek thrust fault underlies Haw Ridge and places the Rome Formation over the younger, Ordovician Chickamauga Limestone. Several tear faults cross Melton Valley (Haase, Zucker, and Stow, 1985), two of which are shown on figure 1.

Depth of weathering within the Conasauga Group is variable and ranges from less than 5 feet in low-lying areas to more than 60 feet on the ridges (J.K. Carmichael, U.S. Geological Survey, written commun., 1987). The weathered zone, referred to as "regolith" in this report, generally consists of silty clay with increasing residual rock fragments with depth.

WELL CONSTRUCTION

Nineteen wells were installed at nine sites in the Melton Valley area (fig. 1). Shallow wells (24 to 86 feet) at each site were installed to measure water levels in the regolith (table 1). Deep wells (126 to 301 feet) were installed to provide hydrologic information on the bedrock part of the ground-water flow system (table 1). At site UG, an additional 200-foot deep well was installed to provide information on hydraulic

Table 1.--*Well-construction data*

[All values in feet, depth intervals referenced to land surface, and elevations referenced to sea level]

Well name	Latitude	Longitude	Ground elevation	Screened or open-hole interval	Depth of surface casing
UA1	35°53'43"	84°20'15"	761.97	45-51	18.9
UA2	35°53'43"	84°20'14"	761.94	140-169	19.3
UB1	35°54'06"	84°19'57"	760.67	28-34	21.8
UB2	35°54'05"	84°19'58"	760.97	101-126	25.1
UC1	35°55'19"	84°18'43"	959.83	81-86	0.0
UC2	35°55'19"	84°18'42"	957.36	188-207	26.6
UD1	35°55'07"	84°18'47"	802.22	24-29	0.0
UD2	35°55'06"	84°18'47"	801.35	187-207	19.7
UE1	35°54'57"	84°18'40"	864.02	71-76	0.0
UE2	35°54'58"	84°18'40"	860.92	176-198	19.5
UF1	35°54'44"	84°18'41"	766.30	18-24	0.0
UF2	35°54'44"	84°18'42"	766.97	183-211	12.0
UG1	35°55'17"	84°17'17"	864.22	26-32	0.0
UG2	35°55'16"	84°17'18"	864.09	246-301	12.0
UG3	35°55'16"	84°17'19"	862.65	186-200	11.5
UH1	35°55'15"	84°17'24"	846.95	21-26	0.0
UH2	35°55'15"	84°17'25"	847.04	231-289	10.0
UI1	35°55'05"	84°17'42"	803.59	20-25	0.0
UI2	35°55'05"	84°17'43"	802.68	186-210	6.0

Note: Core available for wells UB2, UD2, UF2, and UG2.

heads at a depth between the 32-foot deep well and the 301-foot deep well at this site.

All wells were drilled or cored by the air-rotary method with water-spray injection. Ten-inch diameter steel surface casing was set and cemented into a 14-inch diameter borehole in most of the wells. Depths of surface casing ranged from 0 to 26.6 feet (table 1). The shallow wells were drilled with a 9.6-inch diameter bit. A 6-inch inside-diameter steel casing and 5-foot long well screen, attached to the bottom of the casing, were then installed in each of the shallow boreholes. The screened interval was sand packed to a height of about 2 feet above the top of the screen, and the casing was cemented from the top of the sand pack to ground level.

Four-inch diameter cores were obtained from wells UB2, UD2, UF2, and UG2. After coring was completed, the hole was reamed to 9.6 inches, and 6-inch diameter steel casing was installed and cemented from the bottom of the casing to ground level. An open-hole interval of 5.6-inch diameter was drilled below the casing after the cement had hardened. Open-hole intervals range from 16 to 93 feet. The longer open-hole intervals were drilled in order to intersect more water-bearing fractures in low-yielding formations. The remaining deep wells (UA2, UC2, UE2, UG3, UH2, and UI2) were drilled with a 9.6-inch diameter bit. Using the same procedures as the cored wells, 6-inch diameter steel casing was installed and cemented, and the 5.6-inch diameter open-hole interval was drilled below the casing in all wells except UC2. The open-hole section of UC2 is 9.6 inches in diameter. Steel-casing centralizers were attached at casing collars at 20-foot intervals and to the top and bottom of the casing string.

Deep-well casings were cemented in the borehole by injection of expanding cement into the casing and through a floatshoe attached to the bottom of the casing string. The cement then filled the casing-borehole annulus from the bottom to the ground surface. Additional well-construction data are shown in table 1.

LITHOLOGIC DESCRIPTION OF CORES

The formations encountered during coring operations were the Pumpkin Valley Shale, Maryville Limestone, and Nolichucky Shale. The Maryville Limestone and the Nolichucky Shale are in direct stratigraphic contact, but the Pumpkin Valley Shale occurs lower in the section (fig. 1).

Continuous coring was attempted for wells UB2, UD2, UF2, and UG2. Cored segments ranged from 5 to 21 feet in length, and recovery for individual segments ranged from 18 to 100 percent. Percentage of recovery was generally greater in limestone, and less in shale and mudstone. Structural features observed include small-scale fractures, displaced bedding, fault zones, and folding. Because the wells may not be precisely vertical, dip of the rocks is considered "apparent." Apparent dip ranges from 0 to 90 degrees. Dip directions could not be determined due to rotation of the core during coring. Cores are described by general lithology, color, and sedimentary and geologic structures. Most core depths are approximate, due to incomplete recovery; however, depths are probably accurate to within 5 feet.

Well UB2

Well UB2 is located in the south end of Melton Valley, east of the flood plain of the Clinch River (fig. 1). This well was cored from 25 to 126 feet below land surface. Core recovery for indiviual core segments ranged from 37 to 68 percent, and averaged 48 percent for the entire core. Well UB2 was begun and completed entirely within the Maryville Limestone.

Lithologies encountered in this core include (1) finely-laminated limestone and shale interbeds with occasional rip-up clasts; (2) massive, medium-gray, intraclastic mudstone, described by Haase, Walls, and Farmer (1985), and referred to in this report as flat-pebble conglomerate; (3) olive-gray to medium-dark-gray, medium-grained, massive pelletal or oolitic limestone; (4) a massive unbedded mudstone; and (5) a lenticular limestone with minor clay drapes (fig. 2). Bedding varies from thinly laminated to massive, and ranges from 0.25 inch to 1 foot thick.

The upper 45 feet of core in well UB2, from 25 to approximately 70 feet below land surface, consists of alternating beds of parallel- to wavey-laminated limestone, shaley limestone, and shale interbeds, and massive oolitic limestone or flat-pebble conglomerate. In this interval, limestone is the most abundant rock type (fig. 2). In the interval from about 70 to 114 feet, shale and mudstone become more abundant. The major lithologies in this interval consist of interbedded, finely laminated to lenticular shale and shaley limestone, alternating with occasional massive mudstone. Shaley limestone is more abundant in the bottom 12 feet of core (114 to 126 feet). The dominant rock type in this interval consists of massive flat-pebble conglomerate with interbeds of wavey-laminated to lenticular shaley limestone and shale. Contacts between these various lithologies generally are gradational. The characteristics of the contacts were obscured where core recovery was poor.

Comparison of the core with the description of the Maryville Limestone by Haase, Walls, and Farmer (1985, p. 32-35), indicates that well UB2 penetrated the lower part of the Maryville Limestone, which is characterized by more abundant mudstone interbedded with calcareous lithologies (Haase, Walls, and Farmer, 1985, p. 32).

Geologic structures are present throughout the core from well UB2. Apparent dips range from 30 to 90 degrees, and average 50 degrees (fig. 2). Some small-scale folds and local deformation were observed, especially in the finely laminated units. Zones of more intense deformation and fracturing, which could have resulted from faults or fracturing, are also present. Evidence for this deformation includes features such as slickensides, secondary calcite fracture fill, and preferential breaking of the core perpendicular to bedding planes. Such zones occur at depths of 27 to 28, 54 to 59, 63, 77, 100 to 104, and 118 to 120 feet below land surface.

Well UD2

Well UD2, located at the base of Haw Ridge near the entrance to Burial Ground 5 (fig. 1), was cored from 28 to 183 feet below land surface. Core recovery ranged from 18 to 88 percent and averaged about 60 percent for the entire core. UD2 was completed entirely in the Pumpkin Valley Shale. Lithologies in this core consist entirely of alternating blackish-red and greenish-gray, very fine-grained silty mudstone and mudstone with shale interbeds (fig. 3). Coarse-grained interbeds often contain glauconite. Horizontal and vertical bioturbation, sedimentary structures (such as cross bedding), and soft-sediment deformation occur throughout the core, and bedding varies from parallel to lenticular (fig. 3).

Comparison of this core with the description of the Pumpkin Valley Shale by Haase, Walls, and Farmer (1985, p. 42), indicates that UD2 is completed in the upper part of the Pumpkin Valley Shale.

Small-scale geologic structures occur throughout the core from well UD2. Apparent dip ranges from 0 to 55 degrees, and averages 30 degrees. Minor calcite-filled fractures and small-scale displacement of beds are ubiquitous in this section. Zones of intense deformation, which may indicate fault or fracture zones, occur at depths of 33 to 38, 60 to 62, 70 to 75, 142 to 143, 160 to 162, and 166 to 168 feet below land surface. Highly deformed, friable shale layers probably indicate small-scale faults. A small-scale fold occurs from 180 to 182 feet.

Well UF2

Well UF2 is located at the base of Copper Ridge along Melton Branch (fig. 1). This well was cored from 28 to 190 feet below land surface. Core recovery ranged from 46 to 100 percent, and averaged 81 percent. UF2 was begun in the Nolichucky Shale and completed in the Maryville Limestone. In this core, the Nolichucky Shale is characterized by thin, parallel- to wavey-interbeds of dark, greenish-gray shale and silty mudstone, mudstone, and medium-gray shaley limestone (fig. 4). The Maryville Limestone in this core consists of interbedded limestones, shaley limestone, and shale. Lithologies vary from parallel- to wavey-laminated, dark greenish-gray shale with fine-crystalline, medium-gray to medium light-gray limestone lenses, to medium- to light-gray limestone with mudstone lenses (fig. 4). These lithologies alternate with massive flat-pebble conglomerate interbeds.

From 28 to 75 feet, the core from UF2 consists primarily of shale, both massive and thinly bedded with minor limestone lenses, interspersed with 1- to 1.5-foot thick beds of flat-pebble conglomerate (fig. 4). From 75 to 95 feet, the core consists of thinly bedded, wavey-laminated shaley limestone with shale interbeds. The contact between the Nolichucky Shale and the Maryville Limestone is gradational and is characterized by an increase in carbonate content. The contact is indicated by a glauconite-rich, pelletal limestone bed at the top of the Maryville Limestone. This bed is at a depth of 95 feet at well UF2 (fig. 4).

The lithologies described for this core generally agree with the descriptions of the lower Nolichucky Shale and the upper Maryville Limestone by Haase, Walls, and Farmer (1985, p. 28-30). They describe the upper Maryville as 80 percent flat-pebble conglomerate, which is greater than the 30 percent observed in core from UF2.

Small-scale geologic structures occur throughout this core, and some apparent soft-sediment deformation has occurred in both the Nolichucky Shale and the Maryville Limestone. Examples of this deformation occur at 30, 72, and 102 feet below land surface. Apparent dips range from 0 to 60 degrees; however, the units are predominantly gently dipping and have an average apparent dip of 20 degrees (fig. 4). Evidence for structural deformation also includes such features as slickensides, calcite-filled fractures that cut across bedding, friable and broken shale beds, and apparent folds. Zones of intense deformation that might indicate faulting or large-scale fracturing occur at depths of 33, 42, 54, 104, and 175 feet below land surface.

Well UG2

Well UG2 is located at the northeastern end of Melton Valley (fig. 1). Coring was begun at 11 feet and completed at 253 feet below land surface. Recovery ranged from 30 to 100 percent, and averaged 66 percent. The core from this well is similar to the core from well UF2. Well UG2 was begun in the lower Nolichucky Shale and completed in the Maryville Limestone. The contact between these two formations is the characteristic pelletal limestone with interstitial glauconite, and occurs at 182 feet below land surface (fig. 5). At this site, the Nolichucky Shale consists of blackish-red shale that is both massive and laminated (fig. 5). Throughout this shale are

EXPLANATION FOR FIGURES 2-10

- SC- BOTTOM OF SURFACE CASING
- IC- BOTTOM OF INNER CASING
- WL- WATER LEVEL

SEDIMENTARY STRUCTURES

- CONTINUOUS PARALLEL LAMINATION
- DISCONTINUOUS PARALLEL LAMINATION
- MASSIVE TO POORLY LAMINATED
- WAVY LAMINATED
- LENTICULAR BEDDING
- FLASER BEDDING
- CROSS BEDDING
- CURRENT-RIPPLED LAMINATION
- MICRO HUMMOCKY CROSS-STRATIFICATION
- OOIDS
- INTRA CLASTS
- BRECCIA
- MOTTLED, IRREGULAR BEDDING
- BIOTURBATION
- ALGAL BIOHERMS

LITHOLOGY

- CONGLOMERATE
- SANDSTONE
- SHALE
- SILTSTONE
- MUDSTONE
- SILTY MUDSTONE
- CALCAREOUS MUDSTONE
- LIMESTONE
- DOLOMITE
- SHALEY LIMESTONE
- SILTY LIMESTONE
- GLAUCONITIC
- TRACE FOSSILS
- NO CORE RECOVERY

Modified from Haase, Walls, and Farmer, 1985

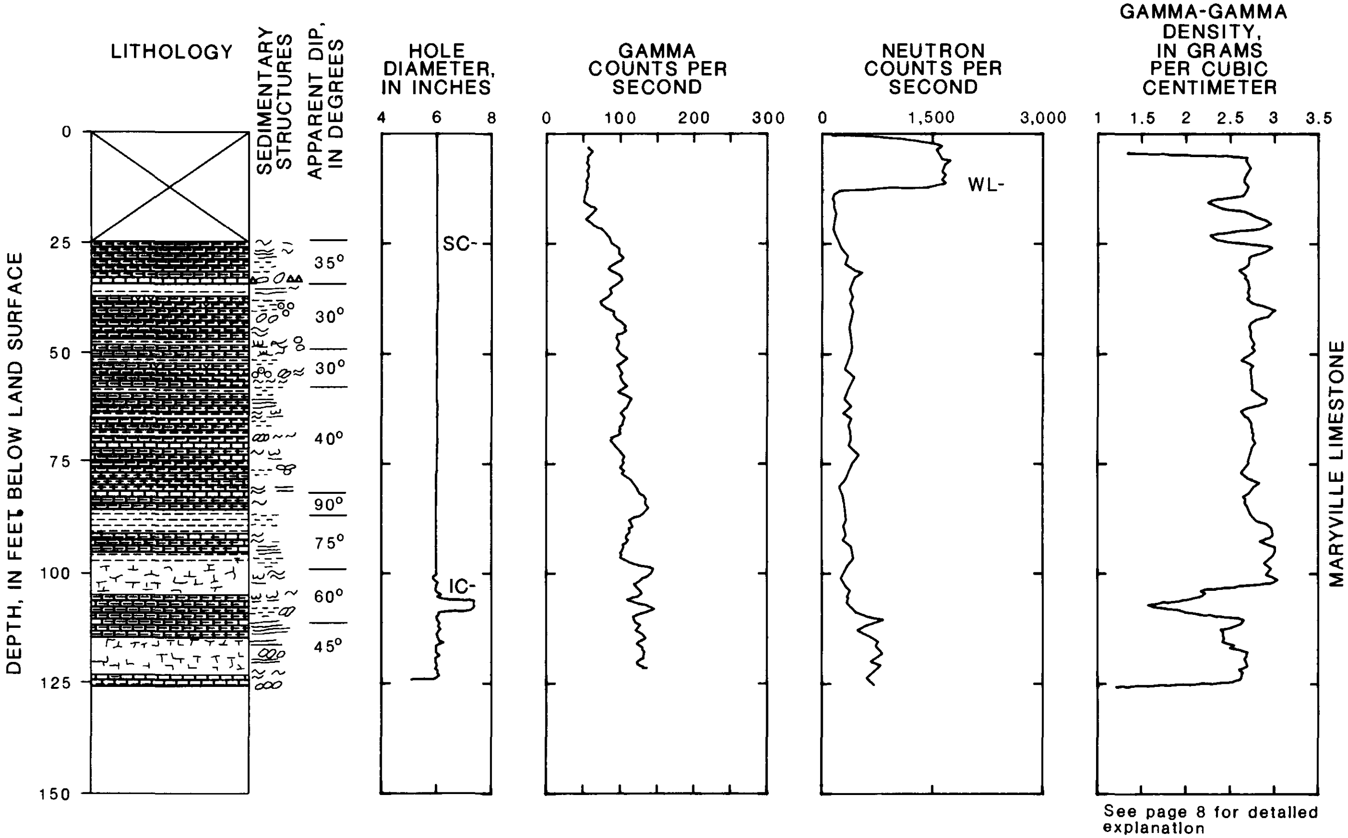


Figure 2.--Lithologic descriptions and geophysical logs for well UB2.

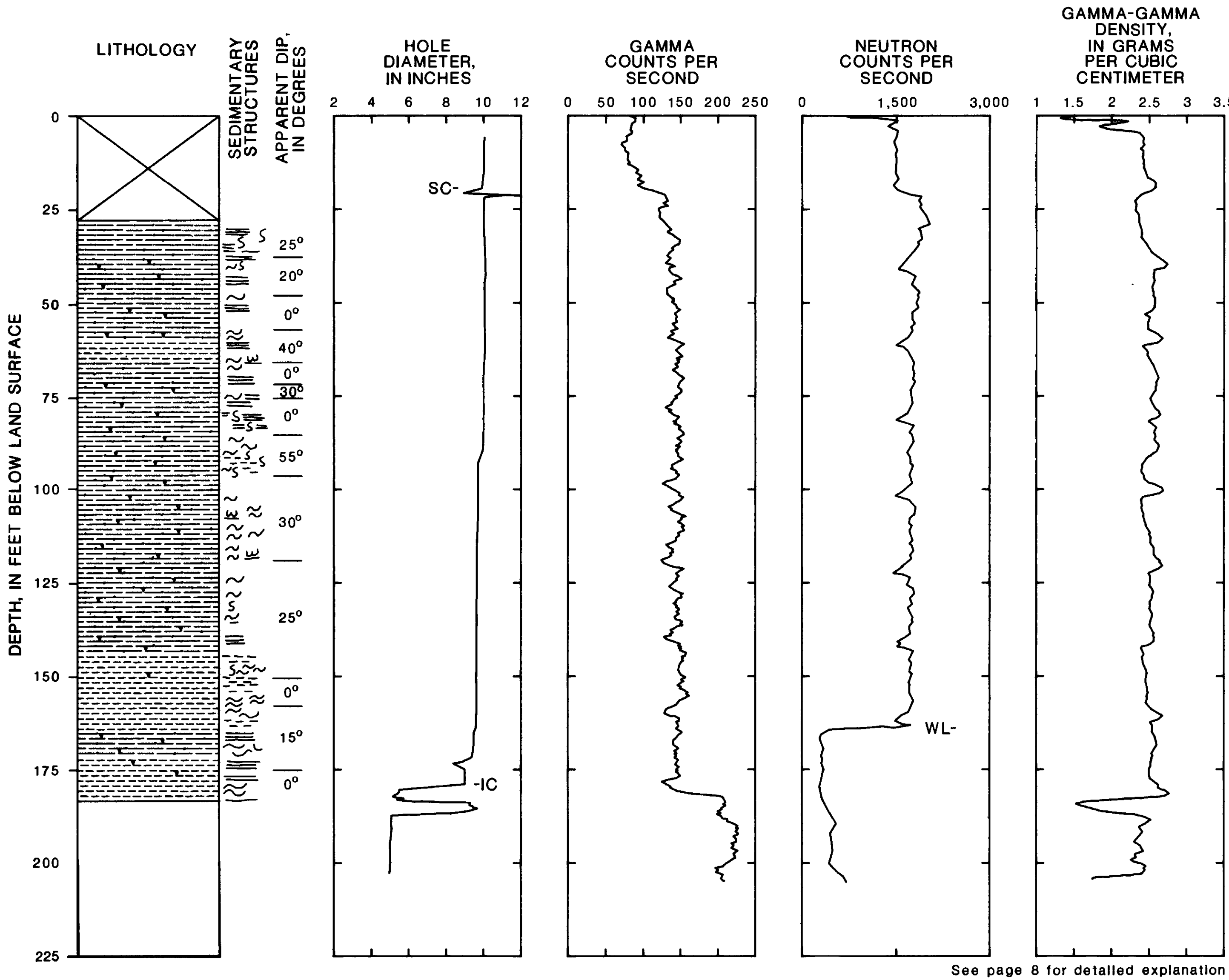


Figure 3.--Lithologic descriptions and geophysical logs for well UD2.

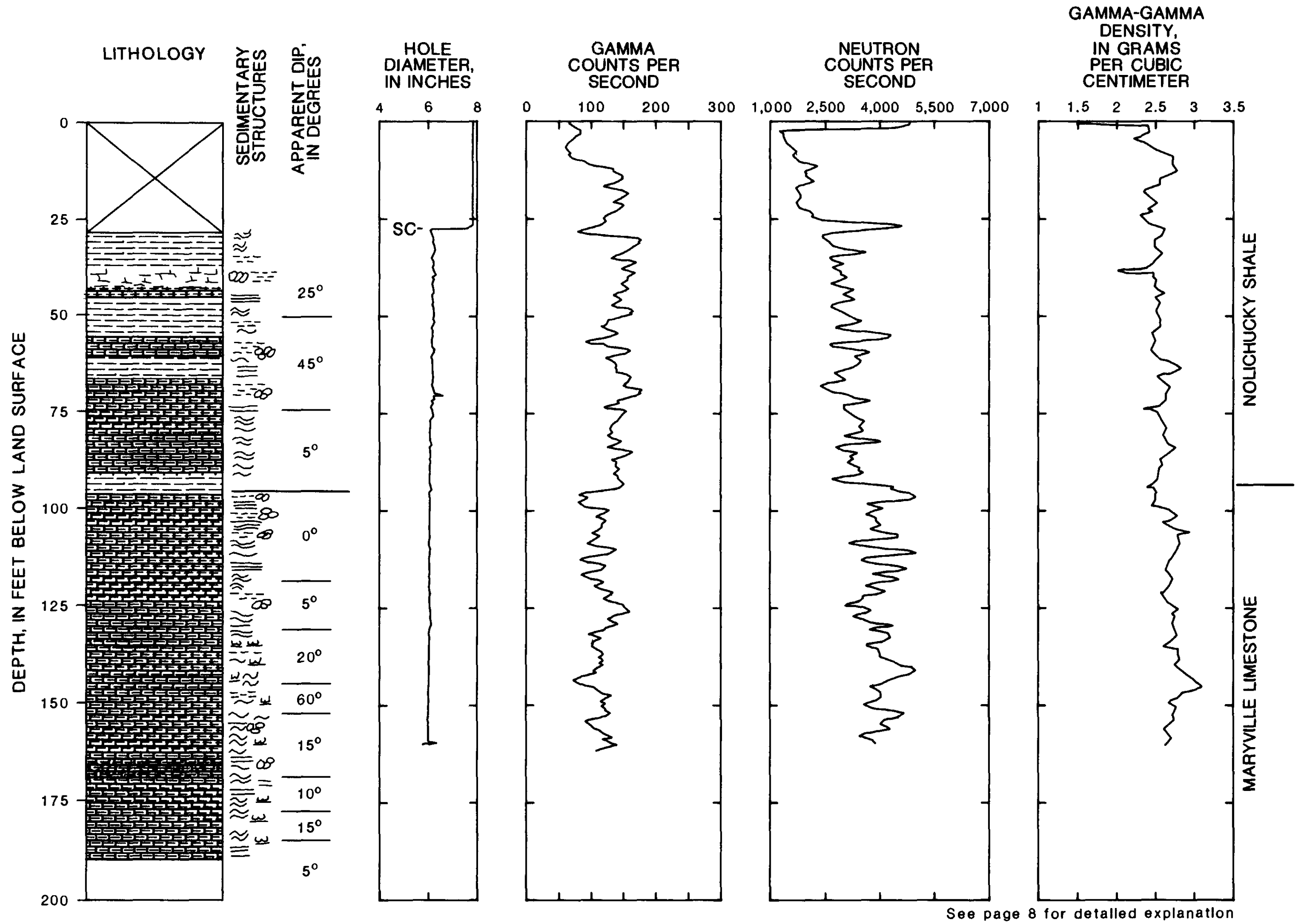
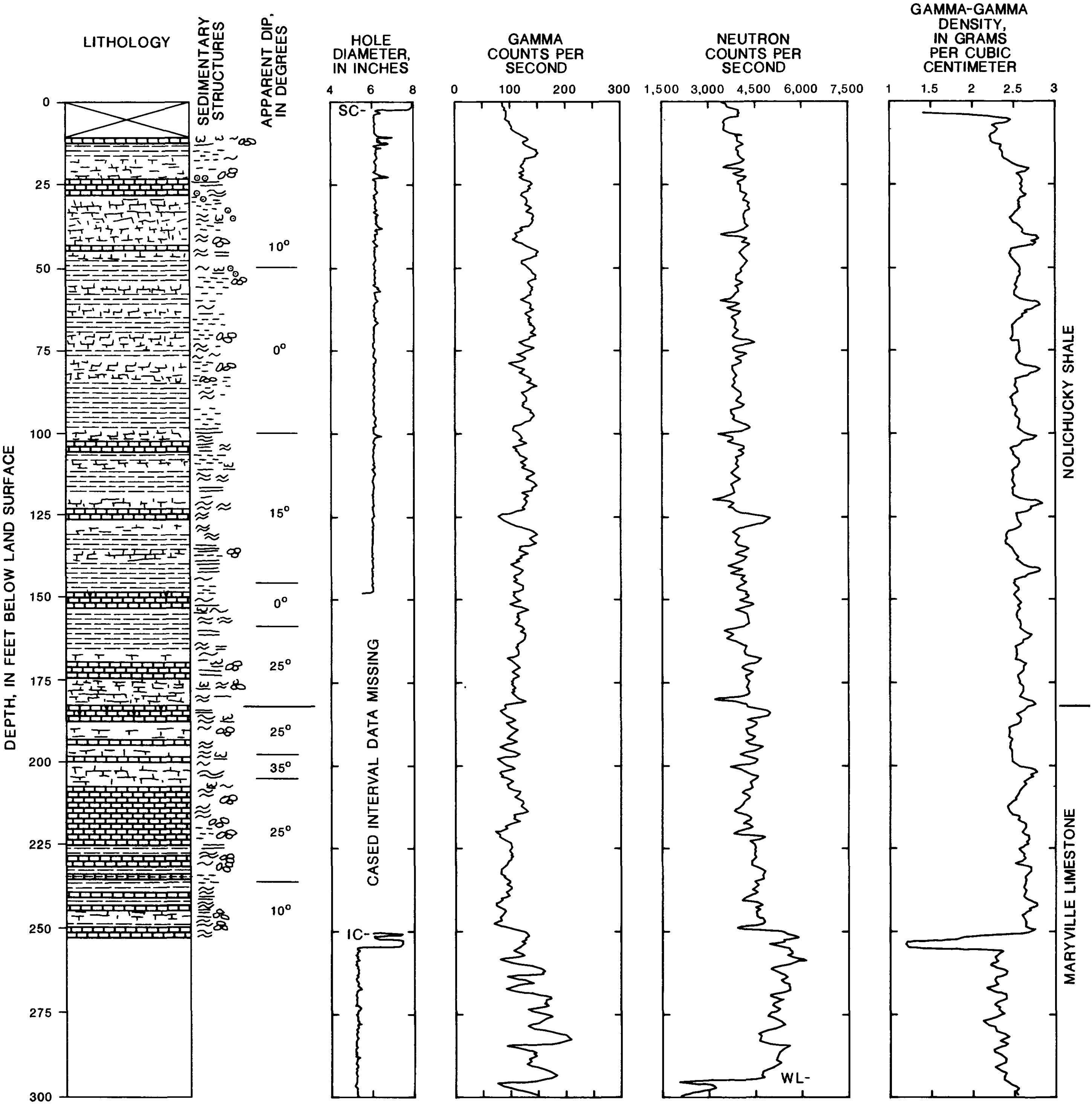


Figure 4.--Lithologic descriptions and geophysical logs for well UF2.



See page 8 for detailed explanation

Figure 5.--Lithologic descriptions and geophysical logs for well UG2.

interbeds of olive-gray pelletal limestone with interstitial mineralization, as well as more massive interbeds of intraclastic limestone (fig. 5). The Maryville Limestone consists mainly of interbedded limestone and shale, similar in mineralogy and structure to those found in core from well UF2.

Structural features in UG2 are similar to those observed in UF2. Apparent dips range from 0 to 35 degrees, and average 15 degrees. Zones of intense deformation occur at 24, 40, 43, 60, 70, 95, and 190 feet below land surface.

GEOPHYSICAL LOGS

Borehole-geophysical logs provide a continuous record of the physical properties of the rocks encountered in a well and can provide indirect information on the lithology and hydraulic properties of the rock. The logs obtained for this study include caliper, gamma, neutron, and gamma-gamma. With the exception of wells UA2, UB2, and UI2, caliper logs were obtained prior to setting casing in the wells. Gamma logs were obtained in wells UE2 and UG2 prior to setting casing, and the complete suite of logs for well UF2 was obtained to a depth of 160 feet before casing was emplaced. Neutron logs for wells UA2, UB2, UC2, and UD2 were obtained several weeks after other logs for those wells. All other logs were obtained after casing was set and cemented in the wells.

The following discussion on interpretation of the various types of logs is generalized. A more detailed discussion of the theory and interpretation of geophysical logs is beyond the scope of this report, but may be found in various texts on the subject, such as Keys and MacCary (1971).

Caliper logs provide a record of the diameter of the borehole. Increases in borehole diameter, such as those caused by large fractures or solution openings, appear as a deflection to the right on the caliper log. The caliper tool used in this study was the three-arm type, which provides a more accurate measurement of the borehole diameter than single-arm types.

Gamma logs measure the amount of gamma radiation present in the rock. Increases in gamma radiation appear as deflections to the right (increase in counts per second) on the log, and are usually caused by clay or shale lithologies. Limestone and clean sandstone typically have very low gamma values.

Neutron logs record the hydrogen content in the rocks and provide an indirect measurement of the moisture content or porosity of the rocks. A decrease in the number of counts per second recorded by the tool (deflection to the left on the log) is caused by an increase in the attenuation of neutrons by hydrogen in the rock. In water wells, the increased hydrogen is associated with increased water content (higher porosity) within the rock mass. The tool used in this study was not calibrated for quantitative measurement of porosity, and only relative changes in porosity can be inferred by deflections in the neutron log.

Gamma-gamma logs provide information on the attenuation of gamma radiation through the rock. The amount of attenuation is directly related to the bulk density of the rock, so that an increase in attenuation (decrease in counts per second, and deflection to the right on the log) is caused by an increase in bulk density. The tool used in this study is calibrated to read density directly in grams per cubic centimeter.

Gamma and neutron logs proved to be the most useful for lithologic interpretations in this study, because of their response to shale and limestone lithologies. These logs were particularly helpful for locating the contact between the Nolichucky Shale and the Maryville Limestone. Gamma-gamma logs provided additional information, but generally were not useful in determining lithology or stratigraphy.

Logs of Wells UB2, UD2, UF2, and UG2

Cores obtained from wells UB2, UD2, UF2, and UG2 were compared to the geophysical logs for these wells. These comparisons were then used to interpret geophysical logs of the remaining wells that were completed in similar geologic units, but for which no cores were available.

The effects of large-diameter surface casing, open-hole intervals, and standing water, if present, can be seen in the suite of logs for each borehole. A 10-inch diameter surface casing is present in the upper part of each borehole and is seen as low count rates on the gamma and neutron logs and low densities on the gamma-gamma logs. Open-hole intervals cause larger gamma and neutron count rates and lower density values, because of the absence of steel casing and cement. Standing water in the wells caused an abrupt shift to left (lower count rates) on the neutron logs.

The contact of the upper, limestone-rich, and the lower, shale- and mudstone-rich parts of the Maryville Limestone is at a depth of about 70 feet below land surface in well UB2. Geophysical logs of this well show an increase in gamma values and a decrease in neutron values at a depth of about 82 feet (fig. 2) that correlates with this contact. Average count rates for the gamma log are about 100 cps (counts per second) for the upper Maryville and about 125 cps for the lower Maryville. The increase in limestone content at 114 feet is shown by a shift to the right on the neutron log at 110 feet (fig. 2). Peaks to the right in the gamma-gamma log probably correspond to dense limestone beds within the Maryville, because they correspond to decreases in gamma values, indicative of limestone, at similar depths.

Well UD2 is completed entirely within the Pumpkin Valley Shale. Gamma log count rates for this well (fig. 3) are about 150 cps, which is indicative of mudstone and shale in the study area. Mudstone and shale content appears to be greater below a depth of 60 feet on the basis of small baseline shifts on the gamma and neutron logs. Neutron count rates are fairly consistent and average about 1,700 cps. The consistency of both the gamma and neutron logs below 60 feet reflects the general similarity of lithologies within the Pumpkin Valley Shale in this borehole. Regularly-spaced spikes (20 feet apart) in both the neutron and gamma-gamma logs are probably a result of casing joints and centralizers.

Geophysical logs for well UF2 were obtained during coring operations, when the hole depth was 160 feet. The gradual decrease in gamma values and gradual increase in neutron values in the upper 95 feet (fig. 4) reflect the gradual increase in limestone content in the Nolichucky Shale with depth. Abrupt deflections in the gamma and neutron logs at 95 feet represent the contact between the Nolichucky Shale and the Maryville Limestone. An increase in density, associated with this contact, is also seen at about 95 feet.

Similar correlations between geophysical logs and rock types are seen in the logs of well UG2 (fig. 5), which penetrates the same geologic units as well UF2. The Nolichucky Shale-Maryville Limestone contact is at a depth of 182 feet at this site (fig. 5). Although the deflections in the gamma and neutron logs are not as pronounced in UG2 as in UF2, they are apparent at 182 feet (fig. 5). The gradual increase in limestone content with depth in the Nolichucky Shale is also reflected in the gamma and neutron logs (fig. 5). Regularly-spaced peaks in the gamma-gamma log are probably due to casing joints and centralizers.

Logs of Wells UA2, UC2, UE2, UH2, and UI2

Geophysical logs provide the main source of lithologic and stratigraphic information for wells UA2, UC2, UE2, UH2, and UI2, because information from cuttings were insufficient to provide complete lithologic descriptions. Comparisons of logs from non-cored wells to logs of wells that were cored provide a means of extrapolating geophysical data to lithologic and stratigraphic interpretation for these five wells.

Well UA2 is probably completed entirely within the Nolichucky Shale. This conclusion is based primarily on the location of this site, and the relatively high gamma values (fig. 6). Well UA2 is located on the south side of the Clinch River, and geologic mapping of the valley has not been extended to that area. Extrapolation of geologic contacts across the river showed UA2 to be within the Nolichucky Shale outcrop area. Gamma values for UA2 generally are greater than 100 cps, and tend to be slightly greater at depths less than 62 feet (fig. 6). These values are similar to those obtained for the Nolichucky Shale in wells UF2 and UG2. The greater count rate above 62 feet may indicate a greater mudstone or shale content at shallow depths. Neutron values are also slightly less at depths less than 62 feet. The Nolichucky appears to contain interbedded lithologies at this site. Limestone beds are indicated by low gamma and high neutron peaks, such as those at 55 and 100 feet (fig. 6).

Well UC2 is located near the crest of Haw Ridge, which is underlain by the Rome Formation and the Copper Creek thrust fault (fig. 1). The gamma log for UC2 (fig. 7) shows evidence of this fault, or an imbricate splay of the fault (R.B. Dreier, Martin Marietta Energy Systems, written commun., 1987). Gamma values in the upper 100 feet average about 150 cps and are typical of values for the Rome Formation. Cuttings from this interval consist of medium-gray to grayish-red, fine-grained sandstone and siltstone typical of the Rome Formation. Gamma values decrease abruptly beginning at about 100 feet, and the S-shaped curve of the gamma log between 100 and 117 feet may represent a fault zone (fig. 7). Gamma values below 117 feet are very low (less than 50 cps) and are typical of values for limestone. Cuttings obtained below 100 feet are mainly composed of medium- to dark-gray, dolomitic limestone, and are probably a part of the Chickamauga Limestone. Neutron count rates are also greater below 117 feet, although the deflection on this log is much less pronounced than on the gamma log (fig. 7).

All of the logs for well UC2 were affected by a cavity encountered during drilling and shown on the caliper log between 28 and 33 feet (fig. 7). Regularly-spaced (20 feet) spikes on the gamma-gamma log are probably the result of casing joints and centralizers.

Well UE2 is located in the northeastern part of burial ground 5 and is within the outcrop area of the Maryville Limestone (fig. 1). On the basis of its location and the gamma log, this well is probably entirely within the Maryville Limestone. Gamma count rates are low, consistently less than 100 cps (fig. 8), and are typical of limestone. Gamma values generally are greater below 37 feet, and may indicate the change from the upper, limestone-rich part to the lower, mudstone- and shale-rich part of the Maryville. Recent geologic mapping (R.B. Dreier, Martin Marietta Energy Systems, written commun., 1987) supports this conclusion. Neutron values for UE2 are higher than those of other wells, but this may be because a different probe was used at this site. The sharp spike to the left on the neutron log at 116 feet (fig. 8) might indicate the presence of a fracture zone. However, the caliper log shows no increase in borehole diameter at that depth, and a corresponding decrease in density that would be associated with a fracture at that location is not present on the gamma-gamma log.

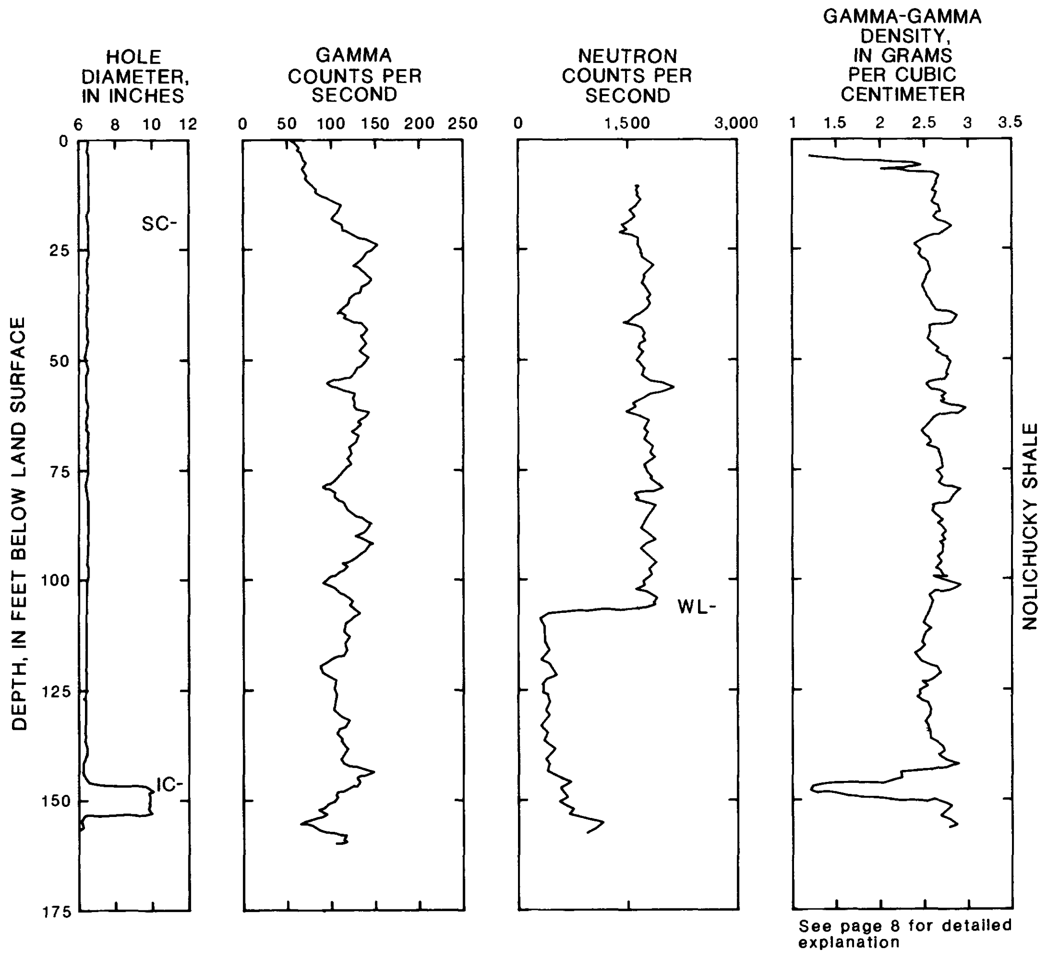


Figure 6.--Geophysical logs for well UA2.

Well UH2 is located at the northeastern end of Melton Valley, about 500 feet west of well UG2 (fig. 1). This well probably penetrates both the Nolichucky Shale and the Maryville Limestone, and the contact between these formations is at a depth of about 73 feet. Gamma values generally decrease and neutron values generally increase below a depth of 73 feet (fig. 9). An increase in average gamma values below 185 feet (fig. 9) may indicate a change from the upper to the lower part of the Maryville Limestone.

Well UI2 is located on the south side of Melton Branch, about 2,000 feet southwest of UH2, and is within the outcrop area of the Nolichucky Shale (fig. 1). Shifts in the gamma

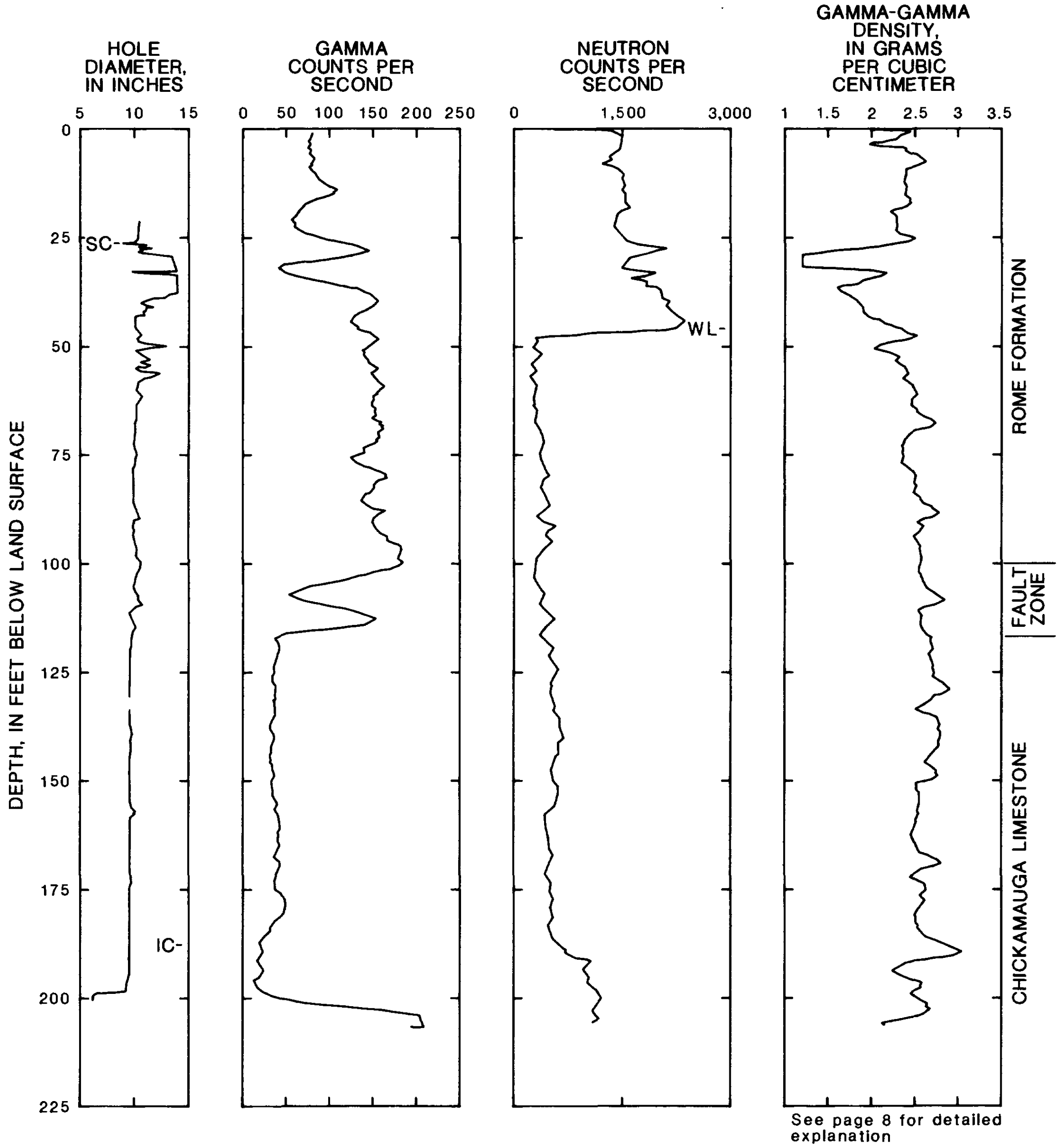


Figure 7.--Geophysical logs for well UC2.

and neutron logs that might indicate the contact between the Nolichucky Shale and the Maryville Limestone are subtle, and occur at depths of 85 and 118 feet (fig. 10). Recent geologic mapping (R.B. Dreier, Martin Marietta Energy Systems, written commun., 1987) places the Nolichucky Shale and Maryville Limestone contact at a depth of about 120 feet at this site. Therefore, the contact at UI2 is believed to be at 118 feet. Density values reported for this well are much greater than for any other site (fig. 10), but are believed to be a result of an equipment malfunction.

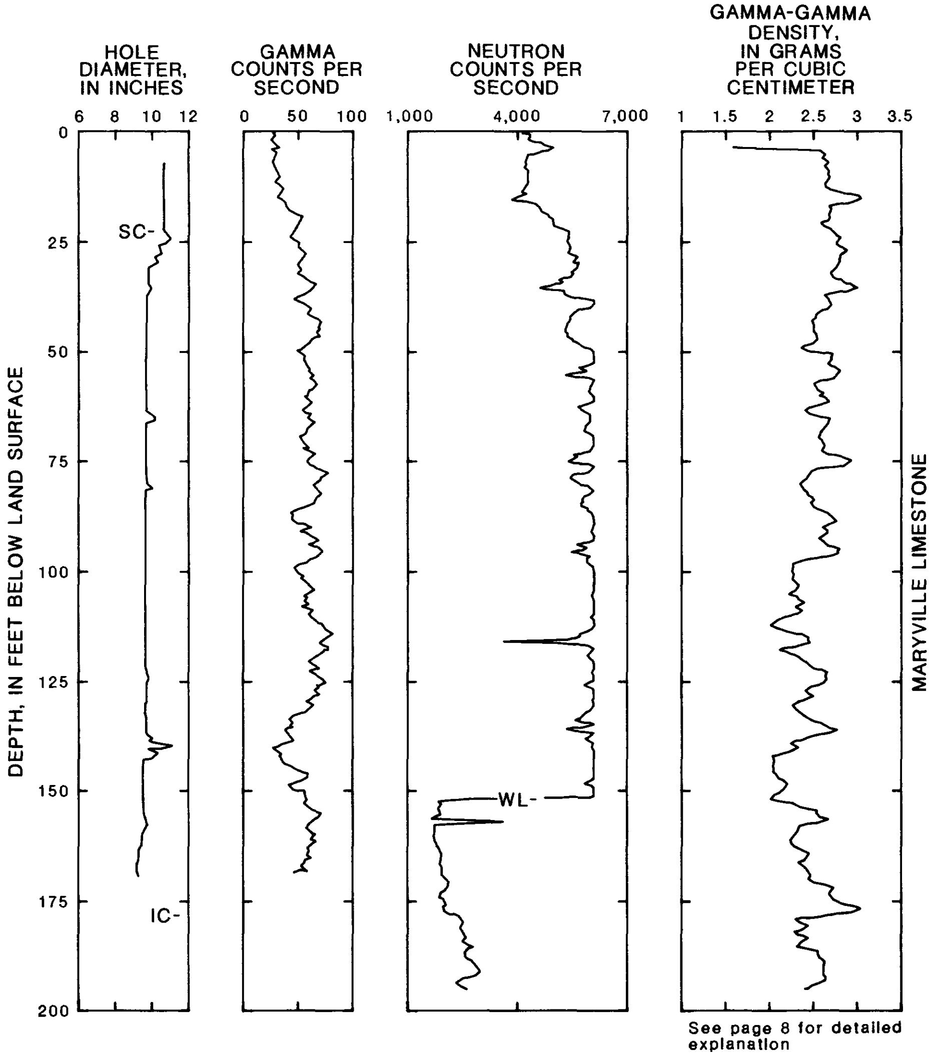


Figure 8.--Geophysical logs for well UE2.

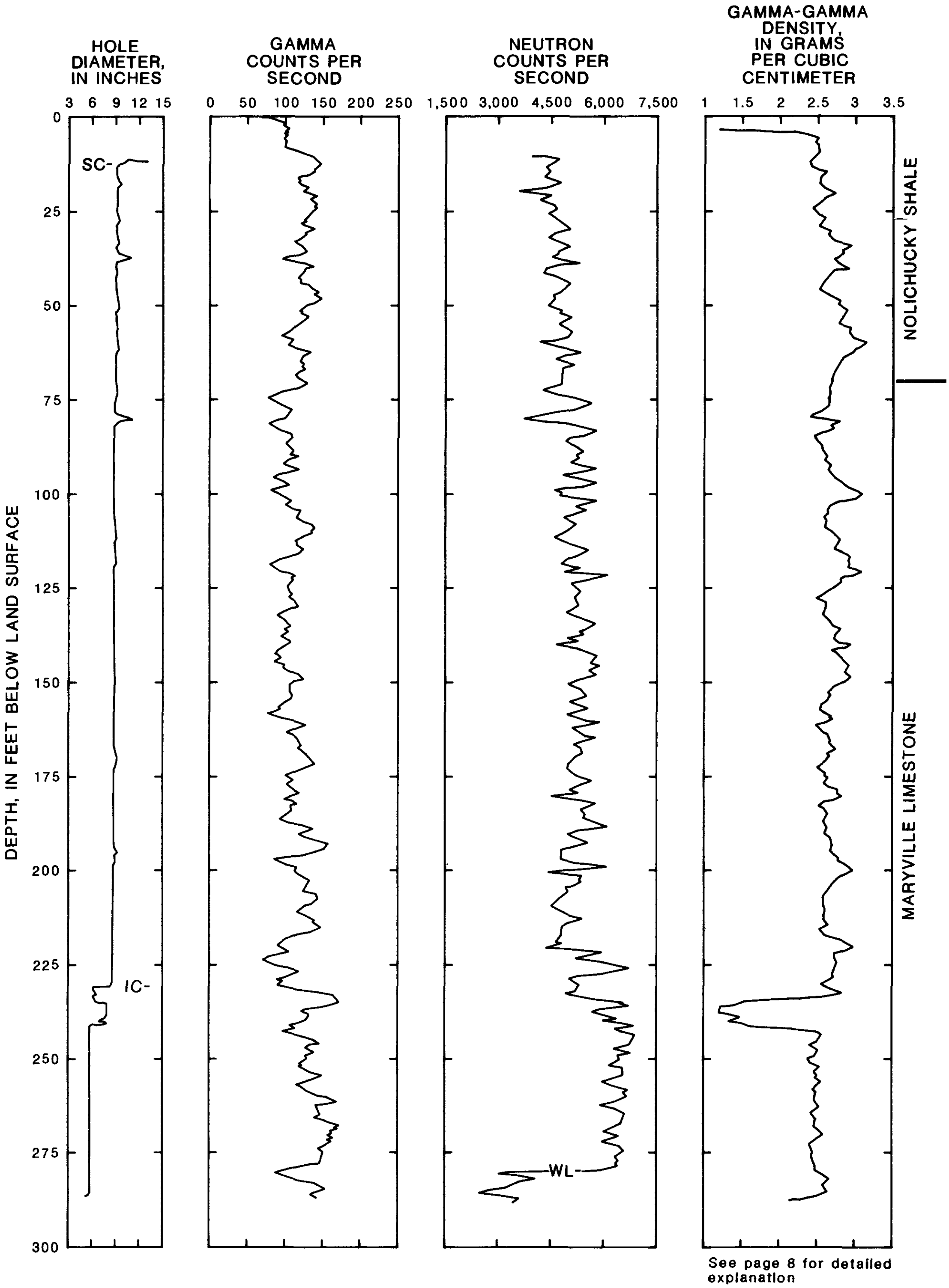


Figure 9.--Geophysical logs for well UH2.

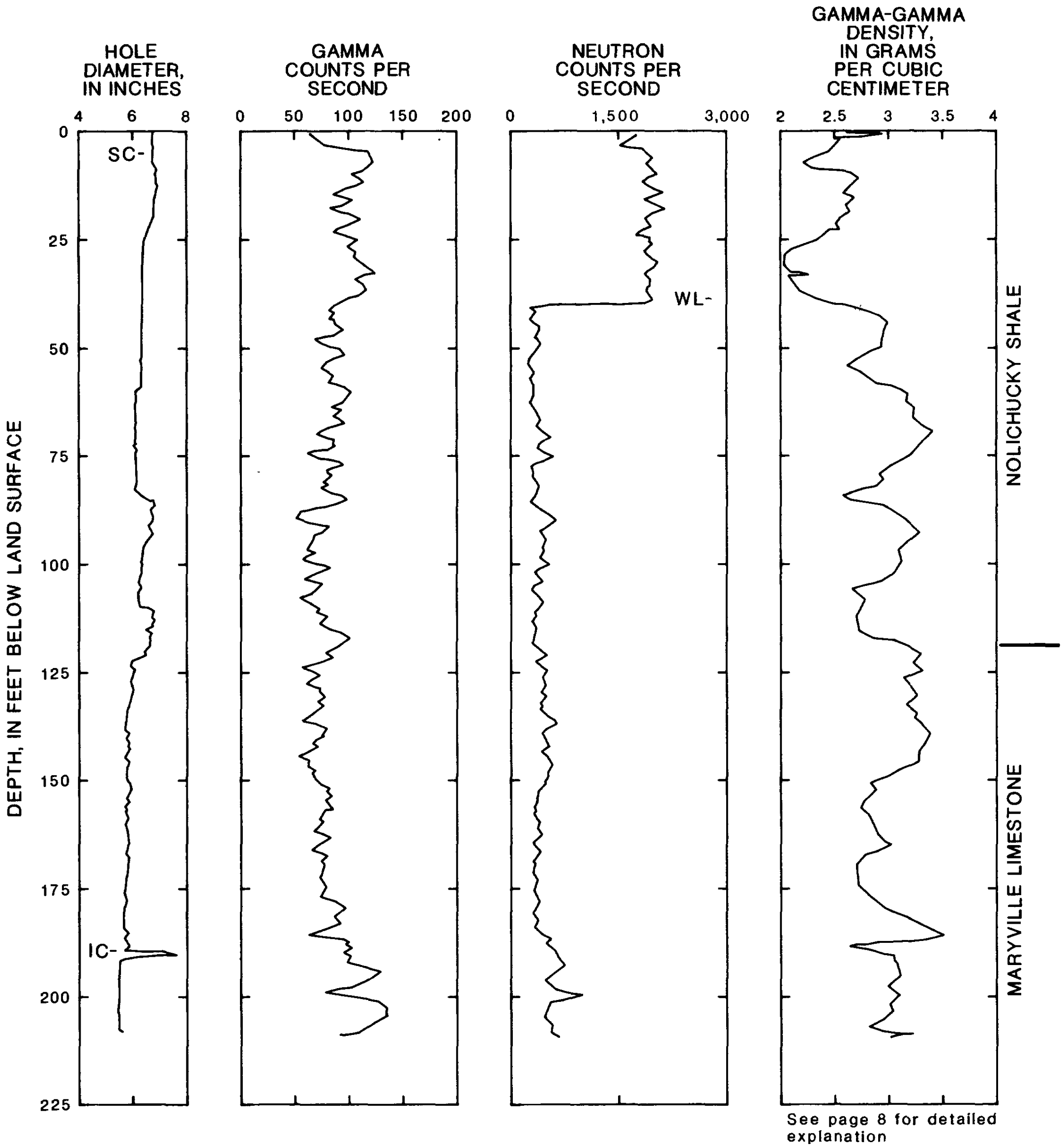


Figure 10.--Geophysical logs for well UI2.

SUMMARY

Nineteen wells were installed by the U.S. Geological Survey at nine sites in the Melton Valley area. The wells are intended to provide information on: (1) water levels in both regolith and bedrock in order to determine both lateral and vertical ground-water flow directions, (2) aquifer characteristics, and (3) subsurface lithology. Well depths range from 24 to 86 feet for shallow wells, and from 126 to 301 feet for deep wells. Four-inch diameter cores were obtained from wells UB2, UD2, UF2, and UG2. Caliper, gamma, neutron, and gamma-gamma density borehole-geophysical logs were obtained for each deep well.

Lithologic descriptions of core and analysis of geophysical logs indicate that well UB2 is completed entirely within the Maryville Limestone, and UD2 is completed entirely within the Pumpkin Valley Shale. Wells UF2 and UG2 penetrate both the Nolichucky Shale and the Maryville Limestone. The contact between the Nolichucky Shale and the Maryville Limestone is at a depth of 95 feet in UF2 and 182 feet in UG2.

Geophysical logs provide the main source of lithologic and stratigraphic information for wells UA2, UC2, UE2, UH2, and UI2, because they were not cored, and cuttings that were collected at these sites were insufficient to provide complete lithologic descriptions. Comparison of logs to cores obtained in other wells provides a means of extrapolating geophysical data to obtain lithologic and stratigraphic information for these five sites.

Well UA2 is probably completed entirely within the Nolichucky Shale. Well UC2 probably penetrates an imbricate splay of the Copper Creek thrust fault, which places the older Rome Formation above the younger Chickamauga Limestone, at a depth of about 100 to 117 feet. Well UE2 is completed entirely within the Maryville Limestone, and the contact between the upper and lower parts of the Maryville is probably at a depth of 37 feet. Wells UH2 and UI2 penetrate both the Nolichucky Shale and the Maryville Limestone. The contact between the Nolichucky Shale and the Maryville Limestone is at a depth of about 73 feet in UH2 and 118 feet in UI2.

SELECTED REFERENCES

Davis, E.C., Boegly, J.W., Jr., Rothschild, E.R., Spaulding, B.P., Vaughan, W.D., Haase, C.S., Huff, D.D., Lee, S.Y., Walls, E.C., Newbold, J.D., and Smith, E.D., 1984, Site characterization techniques used at a low-level waste shallow land burial field demonstration facility: Oak Ridge-National Laboratory, Environmental Sciences Division Publication no. 2306, ORNL/TM-9146, 173 p.

Haase, C.S., Walls, E.C., and Farmer, C.D., 1985, Stratigraphic and structural data for the Conasauga Group and Rome Formation on the Copper Creek Fault Block near Oak Ridge, Tennessee: Preliminary results for test borehole ORNL-JOY no. 2: Oak Ridge National Laboratory, Environmental Sciences Division Publication no. 2392, ORNL/TM-9159, 88 p.

Haase, C.S., Zucker, C.L., and Stow, S.H., 1985, Geology of the host formation for the new hydraulic fracturing facility at Oak Ridge National Laboratory, *in* Post, R.G., and Wacks, M.E., eds., Proceedings of Waste Management 85: Tucson, Arizona, University of Arizona, v. 2, p. 473-480.

Keys, W.S., and MacCary, L.M., 1971, Application of borehle geophysics to water-resources investigations: U.S. Geological Survey Techniques of Water-Resources Investigations, book 2, chapter E1, 126 p.

McMaster, W.M., 1963, Geologic map of the Oak Ridge Reservation, Tennessee: U.S. Atomic Energy Commission, Oak Ridge National Laboratory, ORNL/TM-713, 25 p.

Tucci, Patrick, 1986, Ground-water flow in Melton Valley, Oak Ridge Reservation, Roane County, Tennessee--Preliminary model analysis: U.S. Geological Survey Water-Resources Investigations Report 85-4221, 20 p.