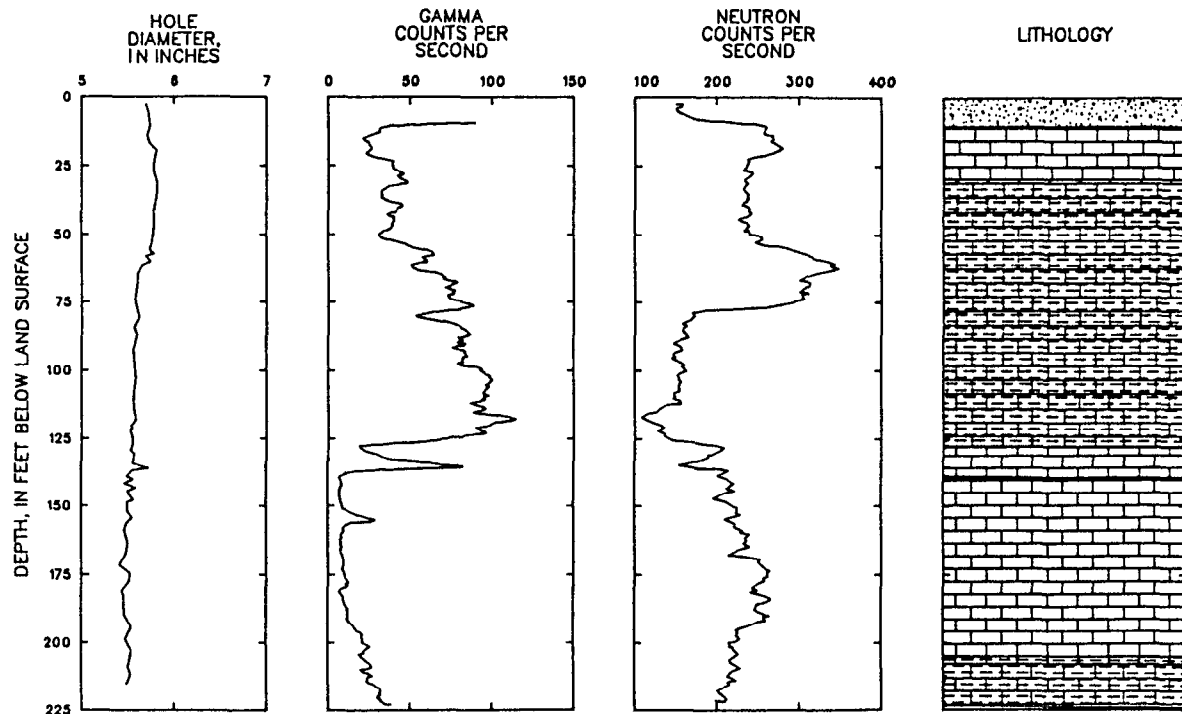


# CONSTRUCTION, GEOLOGIC, AND WATER-LEVEL DATA FOR OBSERVATION WELLS NEAR BRENTWOOD, WILLIAMSON COUNTY, TENNESSEE



Prepared by the  
**U.S. GEOLOGICAL SURVEY**



in cooperation with the  
**TENNESSEE DEPARTMENT OF HEALTH AND ENVIRONMENT**  
**DIVISION OF SUPERFUND**



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**CONSTRUCTION, GEOLOGIC, AND WATER-LEVEL DATA  
FOR OBSERVATION WELLS NEAR BRENTWOOD,  
WILLIAMSON COUNTY, TENNESSEE**

**by Dorothea Withington Hanchar**

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**U.S. GEOLOGICAL SURVEY**

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**Nashville, Tennessee**

**1989**

**DEPARTMENT OF THE INTERIOR**

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**U.S. GEOLOGICAL SURVEY**

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# CONSTRUCTION, GEOLOGIC, AND WATER-LEVEL DATA FOR OBSERVATION WELLS NEAR BRENTWOOD, WILLIAMSON COUNTY, TENNESSEE

By Dorothea Withington Hanchar

## ABSTRACT

Thirty-four observation wells were installed at 17 sites in the area of a hazardous-waste disposal site near Brentwood, in Williamson County, Tennessee. These wells were installed to supplement data collected from domestic wells in the area, to help define the geology of the study area, and to determine water levels. Both lithologic and geophysical logs were obtained for each well drilled to help define the formations encountered. Four limestone units, corresponding to the Bigby-Cannon Limestone, the Hermitage Formation, the Carters Limestone (including the T-3 bentonite), and the Lebanon Limestone, were described from well cuttings and borehole geophysical logs. Water levels have been collected at both the shallow and deep wells at each site.

feet thick on top of limestone bedrock. The limestone formations encountered in this area, in descending order, are the Bigby-Cannon Limestone, Hermitage Formation, Carters Limestone and Lebanon Limestone, all of Ordovician age (Wilson and Miller, 1963). Water-bearing zones occur in the Bigby-Cannon and Carters Limestones, whereas the Hermitage Formation and the Lebanon Limestone are potential confining units. Two wells were drilled at each site in order to determine water levels in each of the potential aquifers. The work was performed in cooperation with the Superfund Division of the Tennessee Department of Health and Environment as part of a more comprehensive study of the hydrogeology of the disposal site and surrounding area.

## INTRODUCTION

This report summarizes geologic and water-level data obtained from well installations in the vicinity of a hazardous-waste disposal site near Brentwood, Williamson County, Tennessee (fig. 1). A network of 34 wells was installed from June 1986 to January 1987 at 17 locations in the area surrounding the disposal site (fig. 1). The disposal site and the surrounding area are underlain by a layer of regolith ranging from 0 to 10

## DATA COLLECTION

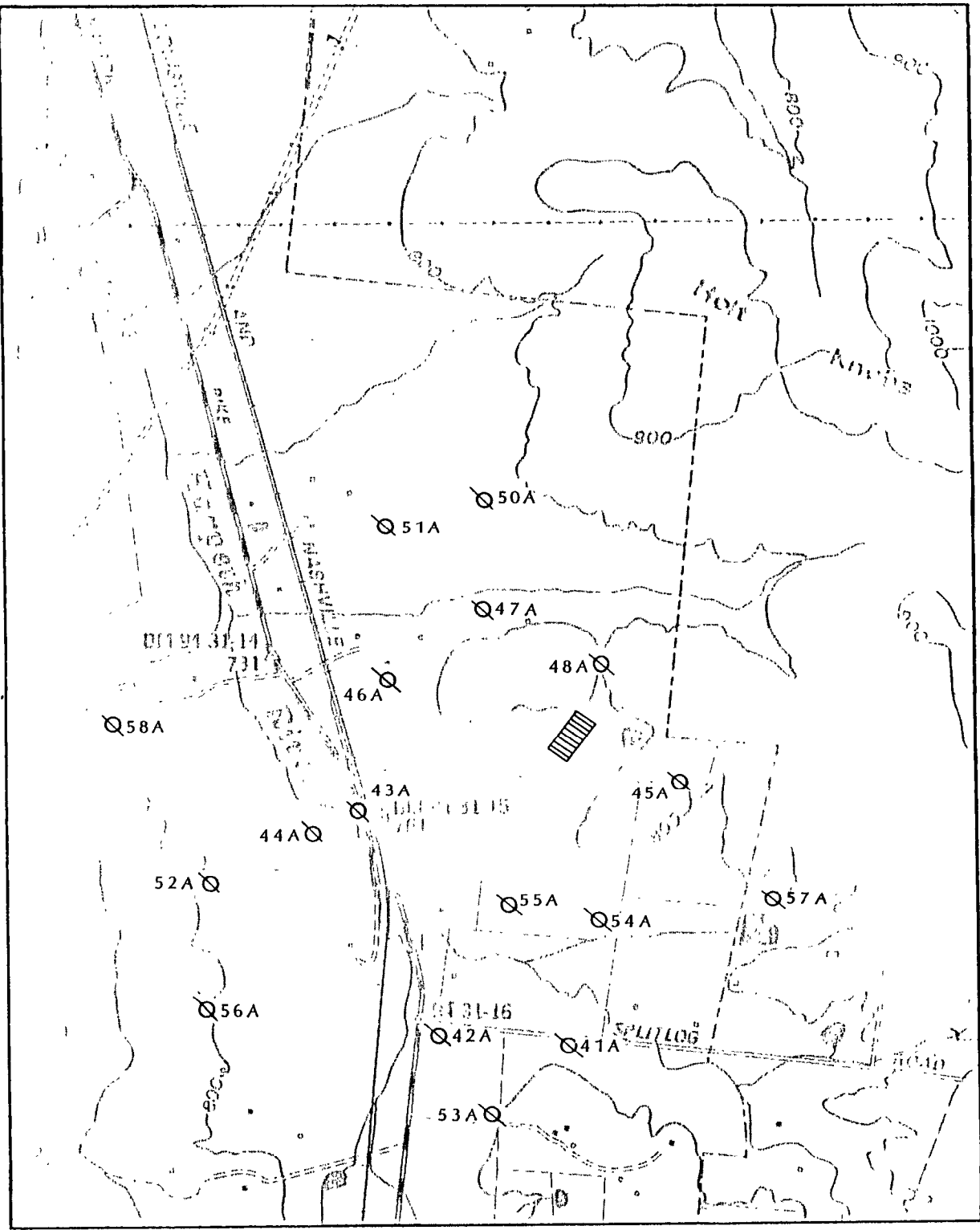
### Well Construction

Among the 34 wells drilled, 17 were shallow wells ranging in depth from 20 to 57 feet; 17 were deep wells ranging in depth from 102 to 225 feet. Location coordinates and construction information for each well are summarized in table 1. For all the wells, drilling was accomplished with little or no rock oil in an attempt to limit the amount of hydrocarbons introduced into the wells.

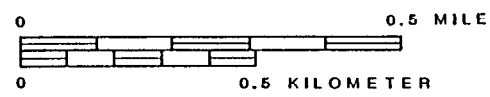
86°47'22"  
35°58'

86°45'

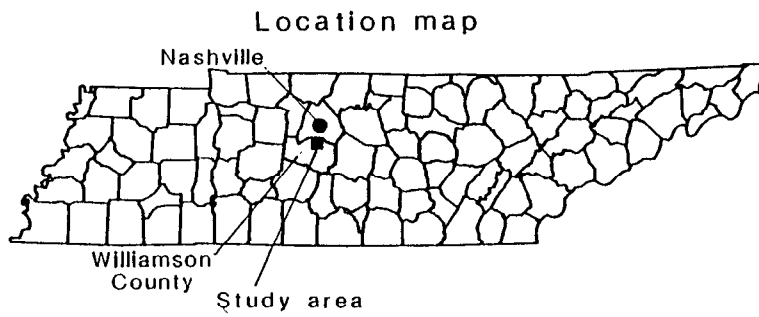
35°57'30"



Base from U.S. Geological Survey  
1:24,000, Franklin, 1981



CONTOUR INTERVAL 100 FEET  
DATUM IS SEA LEVEL



EXPLANATION



-  DISPOSAL SITE
-  OBSERVATION WELL AND NUMBER--Full well  
 Identification includes the prefix Wm:N-# #.

Figure 1.—Location of study area and observation wells.



Table 1.--Summary of observation well construction near disposal site  
 [S = steel casing; p = PVC casing; G = geologist's log; J = gamma log;  
 C = caliper log; N = neutron log; U = bulk density log]

| Local well No. | Latitude<br>0, " " | Longitude<br>0, " " | Altitude<br>of land<br>surface<br>above<br>NGVD of<br>1929,<br>in feet | Date of<br>construction | Depth<br>of well<br>below<br>land<br>surface,<br>in feet | Bottom<br>of<br>casing<br>below<br>land<br>surface,<br>in feet | Diameter<br>of<br>interval,<br>inches | Casing<br>material<br>available | Type<br>of log<br>available | Height of<br>measuring<br>point<br>above land<br>surface,<br>in feet |
|----------------|--------------------|---------------------|--|-------------------------|--|--|---------------------------------------|---------------------------------|-----------------------------|--|
| WM:N-041       | 35 57 00           | 86 45 44            | 780.1  | 6/23/86                 | 45   | 10.0   | 4.00                                  | S                               | G                           | 2.20   |
| WM:N-041A      | 35 57 00           | 86 45 44            | 780.9  | 9/23/86                 | 225  | 62.0   | 6.00                                  | S                               | G                           | 2.50   |
|                |                    |                     |  | --                      | --   | --   | --                                    | --                              | J                           |  |
|                |                    |                     |  | --                      | --   | --   | --                                    | --                              | C                           |  |
|                |                    |                     |  | --                      | --   | --   | --                                    | --                              | N                           |  |
| WM:N-042       | 35 57 01           | 86 45 57            | 754.0  | 6/23/86                 | 35   | 10.7   | 4.00                                  | P                               | G                           | 2.25   |
| WM:N-042A      | 35 57 01           | 86 45 57            | 753.8  | 9/22/86                 | 193  | 34.0   | 6.00                                  | S                               | G                           | 2.29   |
|                |                    |                     |  | --                      | --   | --   | --                                    | --                              | J                           |  |
|                |                    |                     |  | --                      | --   | --   | --                                    | --                              | C                           |  |
|                |                    |                     |  | --                      | --   | --   | --                                    | --                              | N                           |  |
| WM:N-043       | 35 57 20           | 86 46 06            | 737.6  | 6/24/86                 | 28   | 5.00   | 4.00                                  | P                               | G                           | 2.25   |
| WM:N-043A      | 35 57 20           | 86 46 06            | 738.4  | 10/ 7/86                | 102  | 15.0   | 6.00                                  | S                               | G                           | 1.70   |
|                |                    |                     |  | --                      | --   | --   | --                                    | --                              | J                           |  |
|                |                    |                     |  | --                      | --   | --   | --                                    | --                              | C                           |  |
|                |                    |                     |  | --                      | --   | --   | --                                    | --                              | N                           |  |
| WM:N-044       | 35 57 57           | 86 46 10            | 744.1  | 6/25/86                 | 34   | 5.00   | 4.00                                  | P                               | G                           | 2.42   |
| WM:N-044A      | 35 57 57           | 86 46 10            | 738.8  | 10/ 7/86                | 102  | 20.0   | 6.00                                  | S                               | G                           | 1.75   |
|                |                    |                     |  | --                      | --   | --   | --                                    | --                              | J                           |  |
|                |                    |                     |  | --                      | --   | --   | --                                    | --                              | C                           |  |
| WM:N-045       | 35 57 23           | 86 45 33            | 812.6  | 6/27/86                 | 49   | 10.0   | 4.00                                  | P                               | G                           | 2.45   |
| WM:N-045A      | 35 57 23           | 86 45 32            | 812.6  | 10/10/86                | 167  | 59.0   | 6.00                                  | S                               | G                           | 0.82   |
|                |                    |                     |  | --                      | --   | --   | --                                    | --                              | J                           |  |
|                |                    |                     |  | --                      | --   | --   | --                                    | --                              | C                           |  |
|                |                    |                     |  | --                      | --   | --   | --                                    | --                              | N                           |  |
| WM:N-046       | 35 57 32           | 86 46 02            | 758.0  | 6/30/86                 | 30   | 4.50   | 4.00                                  | P                               | G                           | 2.48   |
| WM:N-046A      | 35 57 32           | 86 46 02            | 758.7  | 10/ 9/86                | 135  | 15.0   | 6.00                                  | S                               | G                           | 1.05   |
|                |                    |                     |  | --                      | --   | --   | --                                    | --                              | J                           |  |
|                |                    |                     |  | --                      | --   | --   | --                                    | --                              | C                           |  |
|                |                    |                     |  | --                      | --   | --   | --                                    | --                              | N                           |  |
|                |                    |                     |  | --                      | --   | --   | --                                    | --                              | U                           |  |

Table 1.--Summary of observation well construction near disposal site--Continued

| Local well No. | Latitude<br>O ' " " | Longitude<br>O ' " " | Altitude of land surface above NGVD of 1929, in feet | Date of construction | Depth of well below land surface, in feet | Bottom of casing below land surface, in feet | Diameter of casing, interval, in inches | Casing material available | Type of log available | Height of measuring point above land surface, in feet |
|----------------|---------------------|----------------------|--|----------------------|---|--|---|---------------------------|-----------------------|---|
| WM:N-047       | 35 57 38            | 86 45 51             | 762.4  | 7/ 1/86              | 20  | 3.10   | 4.00                                    | S                         | G                     | 2.14  |
| WM:N-047A      | 35 57 38            | 86 45 51             | 759.9  | 10/ 9/86             | 162                                       | 17.0   | 6.00                                    | S                         | G                     | 1.90  |
|                |                     |                      |  | --                   | --  | --   | --                                      | --                        | J                     | --  |
|                |                     |                      |  | --                   | --  | --   | --                                      | --                        | C                     | --  |
|                |                     |                      |  | --                   | --  | --   | --                                      | --                        | N                     | --  |
| WM:N-048       | 35 57 33            | 86 45 40             | 806.4  | 7/ 1/86              | 45  | 6.00   | 4.00                                    | P                         | G                     | 2.23  |
| WM:N-048A      | 35 57 33            | 86 45 40             | 808.8  | 10/10/86             | 152                                       | 41.0   | 6.00                                    | S                         | G                     | 1.34  |
|                |                     |                      |  | --                   | --  | --   | --                                      | --                        | J                     | --  |
|                |                     |                      |  | --                   | --  | --   | --                                      | --                        | C                     | --  |
|                |                     |                      |  | --                   | --  | --   | --                                      | --                        | N                     | --  |
|                |                     |                      |  | --                   | --  | --   | --                                      | --                        | U                     | --  |
|                |                     |                      |  | --                   | --  | --   | --                                      | --                        | -                     | --  |
| WM:N-050       | 35 57 48            | 86 45 51             | 785.9  | 7/ 4/86              | 45  | 10.0   | 4.00                                    | P                         | G                     | 2.32  |
| WM:N-050A      | 35 57 48            | 86 45 51             | 786.8  | 10/ 8/86             | 162                                       | 55.0   | 6.00                                    | S                         | G                     | 1.10  |
|                |                     |                      |  | --                   | --  | --   | --                                      | --                        | J                     | --  |
|                |                     |                      |  | --                   | --  | --   | --                                      | --                        | C                     | --  |
|                |                     |                      |  | --                   | --  | --   | --                                      | --                        | N                     | --  |
|                |                     |                      |  | --                   | --  | --   | --                                      | --                        | U                     | --  |
| WM:N-051       | 35 57 45            | 86 46 01             | 754.1  | 7/ 8/86              | 25  | 8.70   | 4.00                                    | P                         | G                     | 2.30  |
| WM:N-051A      | 35 57 45            | 86 46 01             | 754.8  | 10/ 8/86             | 137                                       | 34.0   | 6.00                                    | S                         | G                     | 1.15  |
|                |                     |                      |  | --                   | --  | --   | --                                      | --                        | J                     | --  |
|                |                     |                      |  | --                   | --  | --   | --                                      | --                        | C                     | --  |
|                |                     |                      |  | --                   | --  | --   | --                                      | --                        | N                     | --  |
|                |                     |                      |  | --                   | --  | --   | --                                      | --                        | U                     | --  |
| WM:N-052       | 35 57 15            | 86 46 21             | 791.8  | 7/ 7/86              | 35  | 19.5   | 4.00                                    | P                         | G                     | 2.33  |
| WM:N-052A      | 35 57 15            | 86 46 21             | 792.9  | 10/ 6/86             | 132                                       | 33.0   | 6.00                                    | S                         | G                     | 1.73  |
|                |                     |                      |  | --                   | --  | --   | --                                      | --                        | J                     | --  |
|                |                     |                      |  | --                   | --  | --   | --                                      | --                        | C                     | --  |
|                |                     |                      |  | --                   | --  | --   | --                                      | --                        | -                     | --  |
| WM:N-053       | 35 56 54            | 86 45 50             | 795.8  | 7/ 8/86              | 55  | 10.0   | 4.00                                    | P                         | G                     | 2.40  |
| WM:N-053A      | 35 56 54            | 86 45 50             | 798.4  | 9/24/86              | 203                                       | 41.0   | 6.00                                    | S                         | G                     | 1.30  |
|                |                     |                      |  | --                   | --  | --   | --                                      | --                        | J                     | --  |
|                |                     |                      |  | --                   | --  | --   | --                                      | --                        | C                     | --  |
|                |                     |                      |  | --                   | --  | --   | --                                      | --                        | N                     | --  |

Table 1.--Summary of observation well construction near disposal site--Continued

| Local well No. | Latitude<br>0' " " | Longitude<br>0' " " | Altitude<br>of land<br>surface<br>above<br>NGVD of<br>1929,<br>in feet | Date of<br>construction | Depth<br>of well<br>below<br>land<br>surface,<br>in feet | Bottom<br>of<br>casing<br>below<br>land<br>surface,<br>in feet | Diameter<br>of<br>interval,<br>inches | Casing<br>material<br>available | Type<br>of log<br>available | Height of<br>measuring<br>point<br>above land<br>surface,<br>in feet |
|----------------|--------------------|---------------------|--|-------------------------|--|--|---------------------------------------|---------------------------------|-----------------------------|--|
| WM:N-054       | 35 57 10           | 86 45 41            | 759.6  | 7/10/86                 | 30   | 4.50   | 4.00                                  | P                               | G                           | 1.92   |
| WM:N-054A      | 35 57 10           | 86 45 41            | 760.3  | 10/13/86                | 139  | 32.0   | 6.00                                  | S                               | G                           | 2.51   |
|                |                    |                     |  | --                      | --   | --   | --                                    | --                              | J                           |  |
|                |                    |                     |  | --                      | --   | --   | --                                    | --                              | C                           |  |
|                |                    |                     |  | --                      | --   | --   | --                                    | --                              | N                           |  |
| WM:N-055       | 35 57 14           | 86 45 45            | 757.8  | 7/11/86                 | 30   | 5.80   | 4.00                                  | S                               | G                           | 2.51   |
| WM:N-055A      | 35 57 14           | 86 45 45            | 758.6  | 10/13/86                | 177  | 26.0   | 6.00                                  | S                               | G                           | 1.70   |
|                |                    |                     |  | --                      | --   | --   | --                                    | --                              | J                           |  |
|                |                    |                     |  | --                      | --   | --   | --                                    | --                              | C                           |  |
|                |                    |                     |  | --                      | --   | --   | --                                    | --                              | N                           |  |
| WM:N-056       | 35 57 29           | 86 46 18            | 803.4  | 1/ /87                  | 45   | 13   | 6.00                                  | P                               | G                           | 1.7  |
| WM:N-056A      | 35 57 29           | 86 46 18            | 802.9  | 1/12/87                 | 67   | 6.0  | 6.00                                  | P                               | G                           | 1.37   |
|                |                    |                     |  | --                      | --   | --   | --                                    | --                              | J                           |  |
|                |                    |                     |  | --                      | --   | --   | --                                    | --                              | C                           |  |
|                |                    |                     |  | --                      | --   | --   | --                                    | --                              | N                           |  |
|                |                    |                     |  | --                      | --   | --   | --                                    | --                              | U                           |  |
| WM:N-057       | 35 57 13           | 86 45 52            | 793.5  | 1/ 9/87                 | 57   | 10   | 6.00                                  | P                               | G                           | Pressure gage  |
| WM:N-057A      | 35 57 13           | 86 45 52            | 794.8  | 1/ 8/87                 | 204  | 57   | 6.00                                  | P                               | G                           | 0.75   |
|                |                    |                     |  | --                      | --   | --   | --                                    | --                              | J                           |  |
|                |                    |                     |  | --                      | --   | --   | --                                    | --                              | C                           |  |
| WM:N-058       | 35 57 11           | 86 46 31            | 756.5  | 1/ 8/87                 | 35   | 13   | 6.00                                  | P                               | G                           | 1.33   |
| WM:N-058A      | 35 57 11           | 86 46 31            | 757.0  | 2/ 9/87                 | 165  | 35   | 6.00                                  | P                               | G                           | 1.49   |
|                |                    |                     |  | --                      | --   | --   | --                                    | --                              | J                           |  |
|                |                    |                     |  | --                      | --   | --   | --                                    | --                              | C                           |  |

Well construction was completed in two stages. During the first stage of drilling, 14 shallow wells were installed using the water-air rotary method. A 6-inch diameter hole was drilled and 4-inch diameter steel or PVC surface casing was installed at least 1 foot into bedrock. Casing lengths in these shallow wells ranged from 4 to 20 feet. Bentonite pellets were poured down the annulus of the well to the base of the casing to form a seal at least 1 foot thick. A Portland type 1 cement slurry was poured into the annulus around the casing with a tremie pipe to form a seal from the top of the bentonite to ground surface. Drilling continued through the casing into the shallow bedrock aquifer. The open-hole diameter of the shallow wells was 4 inches and total depths ranged from 20 to 49 feet below land surface.

During the second stage of drilling, the remaining wells were air-rotary drilled to a final diameter of 6 inches. For three shallow wells drilled during this stage, 6-inch PVC casing was set at least 1 foot into bedrock. The depths of these wells ranged from 35 to 57 feet. For the 17 deep wells, 6-inch steel or PVC casing was installed in a 9- or 10-inch diameter hole through the upper aquifer. Casing was set 5 to 10 feet into the Hermitage Formation in order to avoid water exchange between the upper and lower aquifers. A seal of bentonite pellets was poured at the base of the casing to a thickness of at least 1 foot. The annular space was grouted from the top of the bentonite seal to land surface. Drilling continued below the casing depth after allowing the grout to set for at least 24 hours.

### Lithologic Descriptions

Rock cuttings were collected during well construction and were used to determine the lithology of the formations. The samples were collected at 5-foot intervals, and a geologic log was kept for each well. Four general limestone

lithologies were identified: the Bigby-Cannon Limestone, the Hermitage Formation, the Carters Limestone (with T-3 bentonite), and the Lebanon Limestone.

Description of the lithologies was based on previous work by Wilson and Miller (1963). Generally, the Bigby-Cannon Limestone consists of three facies: The Cannon facies, which consists of medium dark-gray to brownish-black microcrystalline to medium-grained limestone; the Dove-colored limestone facies which is medium light-gray cryptocrystalline limestone; and the Bigby facies, which is a medium light-gray to brownish-gray coarse-grained calcarenite. The Hermitage Formation consists of two facies, the coquina facies at the top of the section, which is medium-gray to brownish-gray limestone disseminated with silt and shale partings and brachiopod shell fragments (*Resserella fertilis*). The laminated argillaceous limestone facies is silty to sandy, medium- to dark-gray in color, and very fine to medium grained. The Carters Limestone consists of the upper member, which is brownish-gray and yellowish-brown, very fine-grained to cryptocrystalline limestone; the T-3 bentonite, known as "Pencil Cave" in driller's terminology; and the lower member, which is brownish-gray to yellowish-brown cryptocrystalline limestone with some medium- to coarse-grained beds. The Lebanon Limestone is medium dark-gray to yellowish-brown cryptocrystalline limestone. Lithologic data for each site are summarized in Appendix A.

### Geophysical Logs

Geophysical logs were obtained for all the deep wells. Caliper and gamma logs were obtained at each site. Gamma-gamma density and (or) neutron logs were obtained from wells Wm:N-041A, Wm:N-042A, Wm:N-045A, Wm:N-046A, Wm:N-047A, Wm:N-048A,

Wm:N-050A, Wm:N-51A, Wm:N-53A, Wm:N-054A, Wm:N-055A, and Wm:N-058A. The suite of logs for each well is presented in Appendix A.

The gamma log for each well was used in conjunction with the geologic log obtained in the field to determine geologic contacts. For example, the gradual increase in counts per second of the gamma logs suggests that the Hermitage Formation has a high clay content. The Carters Limestone is almost pure limestone and, as such, shows a very low number of counts per second. As depth increases, this overall low count is followed by a sudden increase in the number of counts per second, denoting the T-3 bentonite, which is a particularly distinct marker bed.

### **Water-Level Data**

Water-level measurements were made periodically after completion of the drilling. Measurements are from a standard measuring

point using a steel tape. A summary of the water-level data is presented in table 2.

Variability of water levels in the shallow system range from 36 feet below land surface to 14 feet above land surface. Variability of water levels in the deep system range from 144.52 feet to about 9 feet below land surface. Fluctuations of water levels within individual shallow and deep wells can be seen in table 2. All but one well are fully recovered. Well Wm:N-056A, completed in January 1987, was not fully recovered as of April 1987.

### **REFERENCES**

- Wilson, C.W., Jr., and Miller, R.A., 1963, Geologic map and mineral resources summary for the Franklin quadrangle, Tennessee: Tennessee Department of Conservation, Division of Geology, scale 1:24,000, 1 sheet.

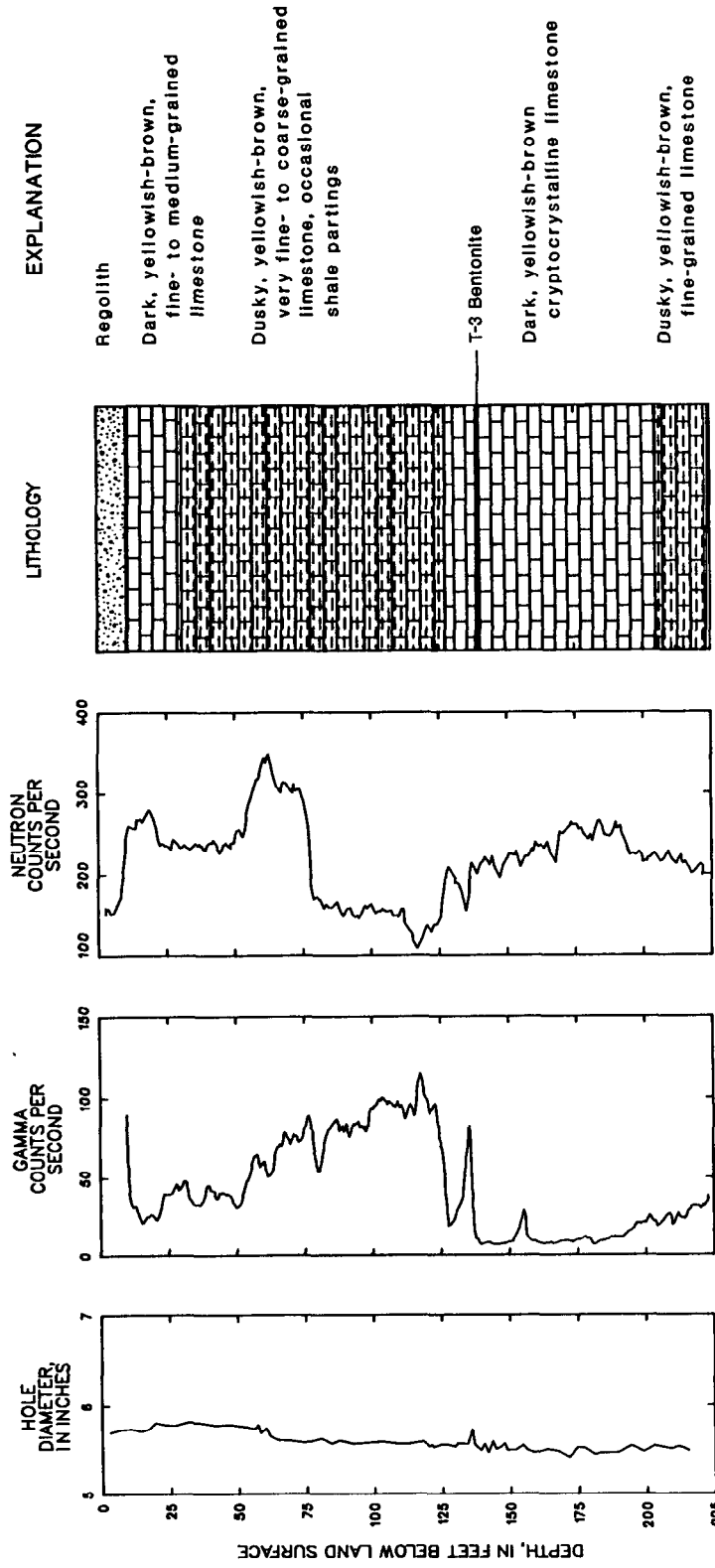
Table 2.--Depth to water, in feet below land surface, in observation wells near disposal site  
 [+ , indicates water level above land surface]

| Well No.  | Dates of measurements |         |         |         |         |        |         |          |          |          |          |          |        |        |         |        |         |
|-----------|-----------------------|---------|---------|---------|---------|--------|---------|----------|----------|----------|----------|----------|--------|--------|---------|--------|---------|
|           | 7/25/86               | 7/29/86 | 8/11/86 | 8/18/86 | 8/25/86 | 9/5/86 | 9/19/86 | 10/20/86 | 10/28/86 | 11/10/86 | 11/18/86 | 11/28/86 | 2/5/87 | 3/6/87 | 3/17/87 | 4/6/87 | 4/20/87 |
| WM:N-041  | 28.97                 | 29.48   | 29.14   | 28.27   | 28.18   | 27.37  | 27.75   | 27.54    | 27.24    | 10.50    | 10.02    | 9.78     | 10.05  | 9.99   | 21.70   | 22.44  | 22.28   |
| WM:N-041A | --                    | --      | --      | --      | --      | --     | --      | 78.01    | 96.73    | 61.70    | 53.71    | 49.02    | 39.13  | 36.69  | 36.97   | 38.02  | 38.35   |
| WM:N-042  | 18.42                 | --      | 17.92   | 17.17   | 17.79   | 16.22  | 17.28   | 17.17    | 17.00    | 9.04     | 15.76    | 8.63     | 16.06  | 12.57  | 16.48   | 16.76  | 15.52   |
| WM:N-042A | --                    | --      | --      | --      | --      | --     | --      | 17.48    | 16.99    | 12.80    | 16.17    | 12.62    | 15.76  | 14.42  | 16.68   | 16.78  | 16.60   |
| WM:N-043  | 24.43                 | 24.44   | 24.44   | 24.24   | 24.40   | 24.39  | 19.03   | 19.03    | 19.02    | 18.46    | 17.90    | 16.72    | 25.53  | 22.67  | 22.51   | 22.38  | 22.86   |
| WM:N-043A | --                    | --      | --      | --      | --      | --     | --      | 10.79    | 10.27    | 8.89     | 9.08     | 8.54     | 9.27   | 8.80   | 9.70    | 10.43  | 9.59    |
| WM:N-044  | 17.27                 | 16.19   | 15.19   | 10.12   | 10.46   | 9.95   | 10.39   | 10.27    | 10.12    | 7.85     | 10.06    | 8.82     | 10.06  | 10.03  | 10.20   | 10.45  | 10.05   |
| WM:N-044A | --                    | --      | --      | --      | --      | --     | --      | --       | 10.47    | 9.18     | 9.52     | 8.90     | 9.57   | 9.17   | 10.02   | 10.74  | 10.47   |
| WM:N-045  | 33.83                 | --      | 33.19   | 33.93   | 33.93   | 33.88  | 33.93   | 33.10    | 32.54    | 18.54    | 30.16    | 16.76    | 30.94  | 24.69  | 31.00   | 31.49  | 29.50   |
| WM:N-045A | --                    | --      | --      | --      | --      | --     | --      | 107.16   | 106.15   | 94.96    | 86.93    | 82.25    | 71.46  | 69.14  | 68.95   | 69.90  | 70.26   |
| WM:N-046  | 24.11                 | --      | 22.84   | 22.17   | 21.76   | 20.33  | 19.43   | 17.85    | 16.92    | 4.47     | 4.77     | 4.73     | 4.98   | 4.91   | 5.51    | 9.21   | 10.45   |
| WM:N-046A | --                    | --      | --      | --      | --      | --     | --      | 56.26    | 37.29    | 31.83    | 30.50    | 30.14    | 29.57  | 27.04  | 26.21   | 25.74  | 21.61   |
| WM:N-047  | 12.20                 | --      | 13.03   | 13.14   | 13.17   | 13.33  | 9.07    | 11.70    | 11.00    | 4.12     | 5.54     | 4.45     | 5.92   | 5.41   | 6.98    | 7.91   | 8.43    |
| WM:N-047A | --                    | --      | --      | --      | --      | --     | --      | 78.64    | 48.17    | 48.96    | 47.28    | 45.48    | 35.83  | 33.65  | 32.97   | 31.81  | 31.25   |
| WM:N-048  | 21.57                 | --      | 21.51   | 21.51   | 21.48   | 21.45  | 21.47   | 28.00    | 21.35    | 11.10    | --       | 21.71    | --     | --     | 27.55   | 21.38  | 21.53   |
| WM:N-048A | --                    | --      | --      | --      | --      | --     | --      | 100.19   | 99.08    | 95.14    | 89.15    | 84.23    | 71.81  | 69.86  | 68.78   | 68.90  | 69.01   |
| WM:N-050  | 12.02                 | --      | 12.06   | 12.02   | 12.02   | 11.74  | 12.02   | 12.06    | 12.01    | 11.60    | 11.65    | 11.61    | 11.70  | 15.67  | 11.91   | 12.03  | 11.97   |
| WM:N-050A | --                    | --      | --      | --      | --      | --     | --      | 144.52   | 134.89   | 124.29   | 115.76   | 108.94   | 80.82  | 74.97  | 73.22   | 70.38  | 69.02   |
| WM:N-051  | 13.27                 | --      | 13.31   | 13.04   | 13.28   | 12.30  | 13.02   | 13.00    | 12.88    | 9.86     | 10.76    | 10.40    | 11.63  | 10.54  | 11.71   | 12.40  | 12.26   |
| WM:N-051A | --                    | --      | --      | --      | --      | --     | --      | 76.86    | 58.43    | 47.66    | 44.29    | 41.93    | 36.46  | 35.48  | 35.09   | 34.58  | 34.29   |
| WM:N-052  | 19.62                 | --      | 19.66   | 19.68   | 19.67   | 19.70  | 19.58   | 19.69    | 19.83    | 19.78    | 19.77    | 19.56    | 19.50  | 19.30  | 19.51   | 19.53  | 19.54   |
| WM:N-052A | --                    | --      | --      | --      | --      | --     | --      | 96.13    | 83.73    | 71.44    | 66.65    | 62.70    | 57.94  | 61.91  | 63.16   | 64.76  | 65.47   |
| WM:N-053  | 35.72                 | --      | 35.69   | --      | 35.71   | 35.77  | 35.68   | 35.62    | 35.50    | 19.44    | 35.09    | 27.54    | 35.09  | 28.38  | 35.29   | 35.35  | 35.32   |
| WM:N-053A | --                    | --      | --      | --      | --      | --     | --      | 137.25   | 120.55   | 101.39   | 92.56    | 84.07    | 63.79  | 62.30  | 61.76   | 61.49  | 62.43   |
| WM:N-054  | 3.59                  | 3.55    | 3.47    | 2.80    | 3.14    | 1.57   | 2.68    | 2.54     | 2.17     | .83      | 3.12     | 1.92     | 2.69   | 2.53   | 2.87    | 2.85   | 2.66    |
| WM:N-054A | --                    | --      | --      | --      | --      | --     | --      | 57.00    | 55.70    | 40.59    | 32.07    | 27.38    | 17.85  | 15.36  | 15.66   | 16.73  | 17.04   |
| WM:N-055  | 14.20                 | 14.48   | 14.86   | 14.58   | 14.46   | 13.80  | 13.77   | 14.93    | 14.84    | 13.24    | 13.35    | 12.78    | 14.32  | 13.47  | 15.09   | 14.40  | 14.08   |
| WM:N-055A | --                    | --      | --      | --      | --      | --     | --      | 54.49    | 53.35    | 39.96    | 32.44    | 27.73    | 18.03  | 15.78  | 14.94   | 16.78  | 17.00   |
| WM:N-056  | --                    | --      | --      | --      | --      | --     | --      | --       | --       | --       | --       | --       | 22.24  | 17.04  | 22.06   | 23.31  | 23.19   |
| WM:N-056A | --                    | --      | --      | --      | --      | --     | --      | --       | --       | --       | --       | --       | 113.22 | 100.78 | 96.83   | 97.11  | 96.26   |
| WM:N-057  | --                    | --      | --      | --      | --      | --     | --      | --       | --       | --       | --       | --       | --     | --     | --      | --     | +14.00  |
| WM:N-057A | --                    | --      | --      | --      | --      | --     | --      | --       | --       | --       | --       | --       | 51.69  | 48.75  | 49.52   | 50.71  | 57.27   |
| WM:N-058  | --                    | --      | --      | --      | --      | --     | --      | --       | --       | --       | --       | --       | 16.84  | 20.88  | 16.99   | 17.08  | 17.01   |
| WM:N-058A | --                    | --      | --      | --      | --      | --     | --      | --       | --       | --       | --       | --       | 16.42  | 16.43  | 17.09   | 16.59  | 16.34   |

## **Appendix A**

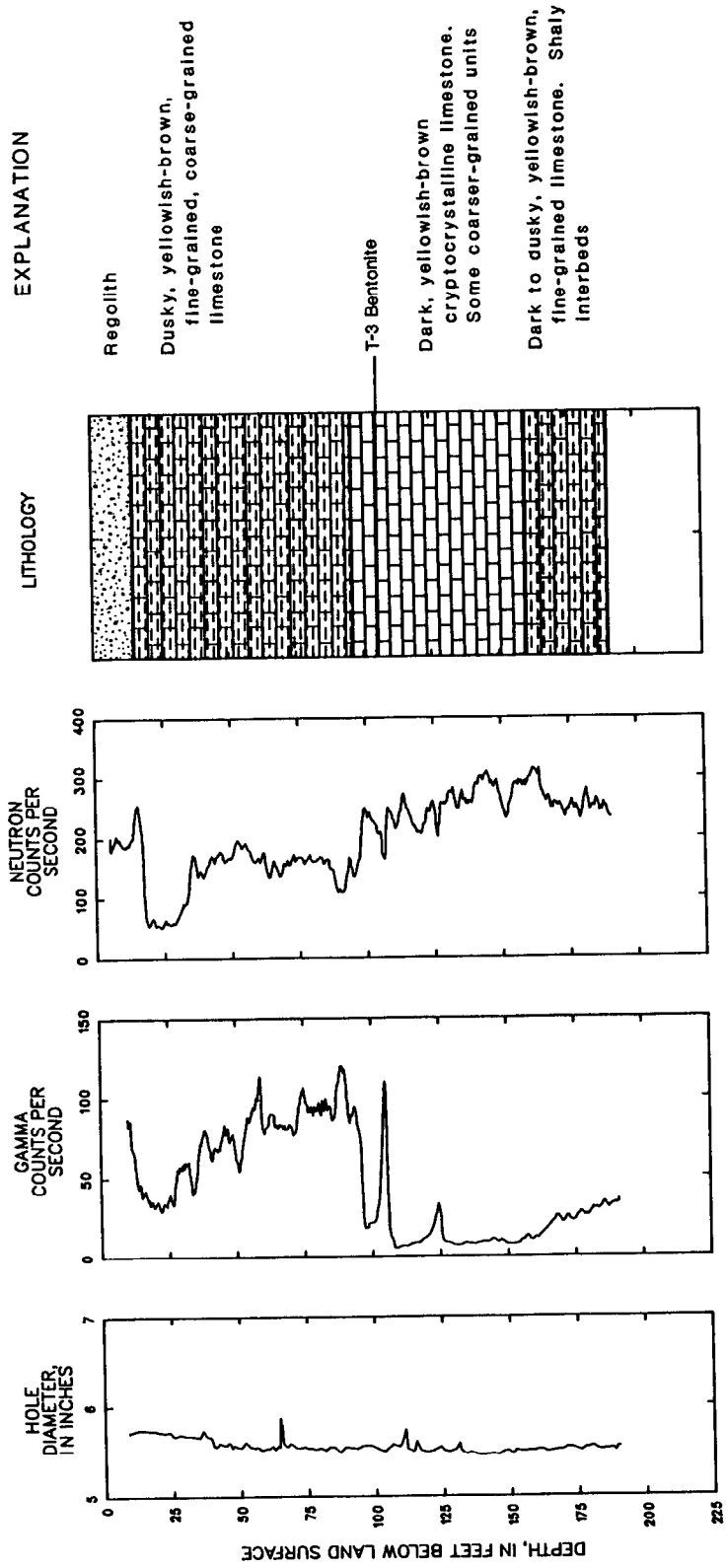
Geophysical and lithologic logs for deep observation wells

WELL WM:N-041A

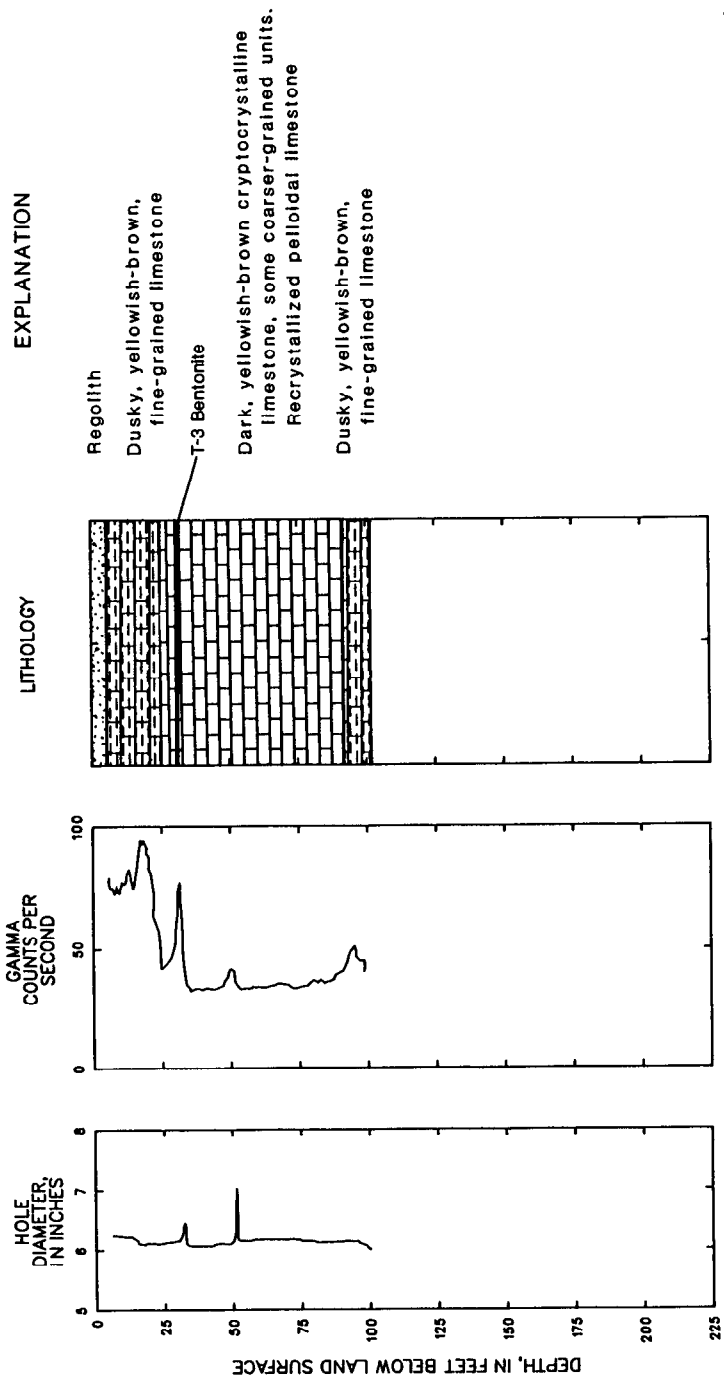




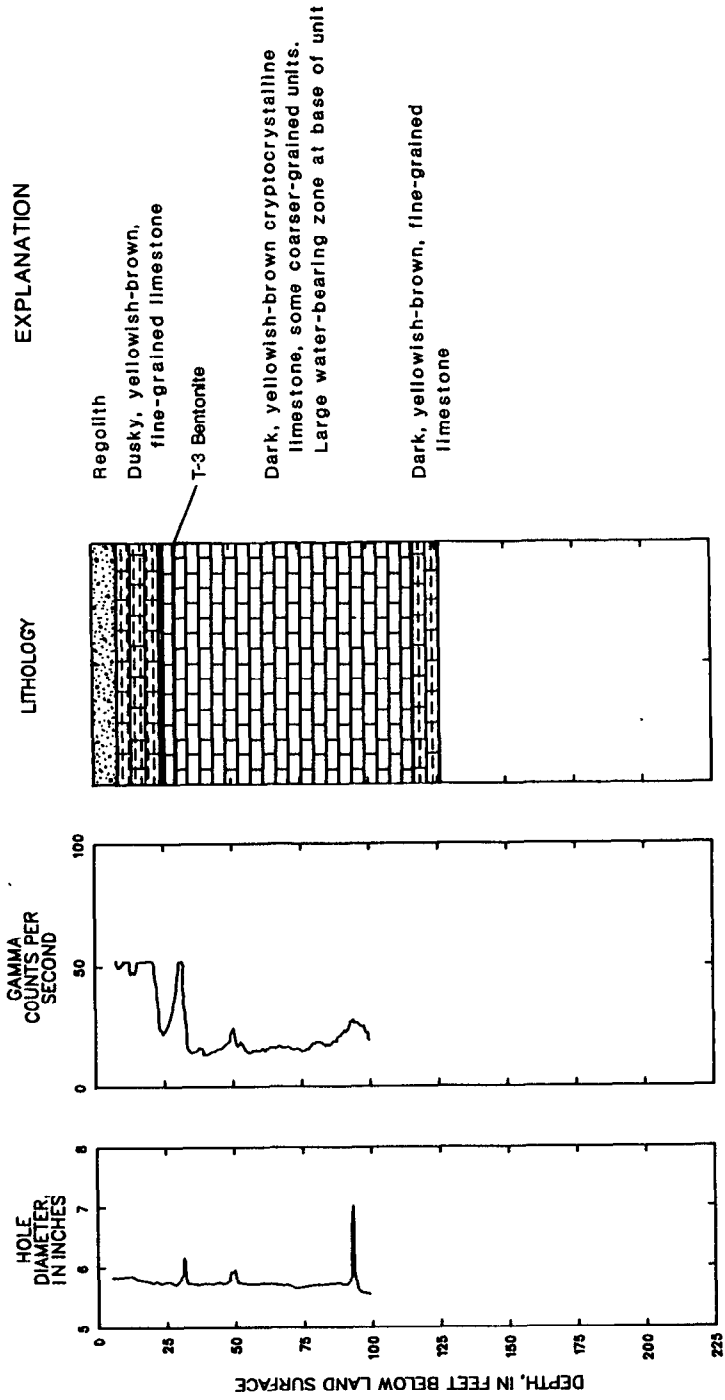
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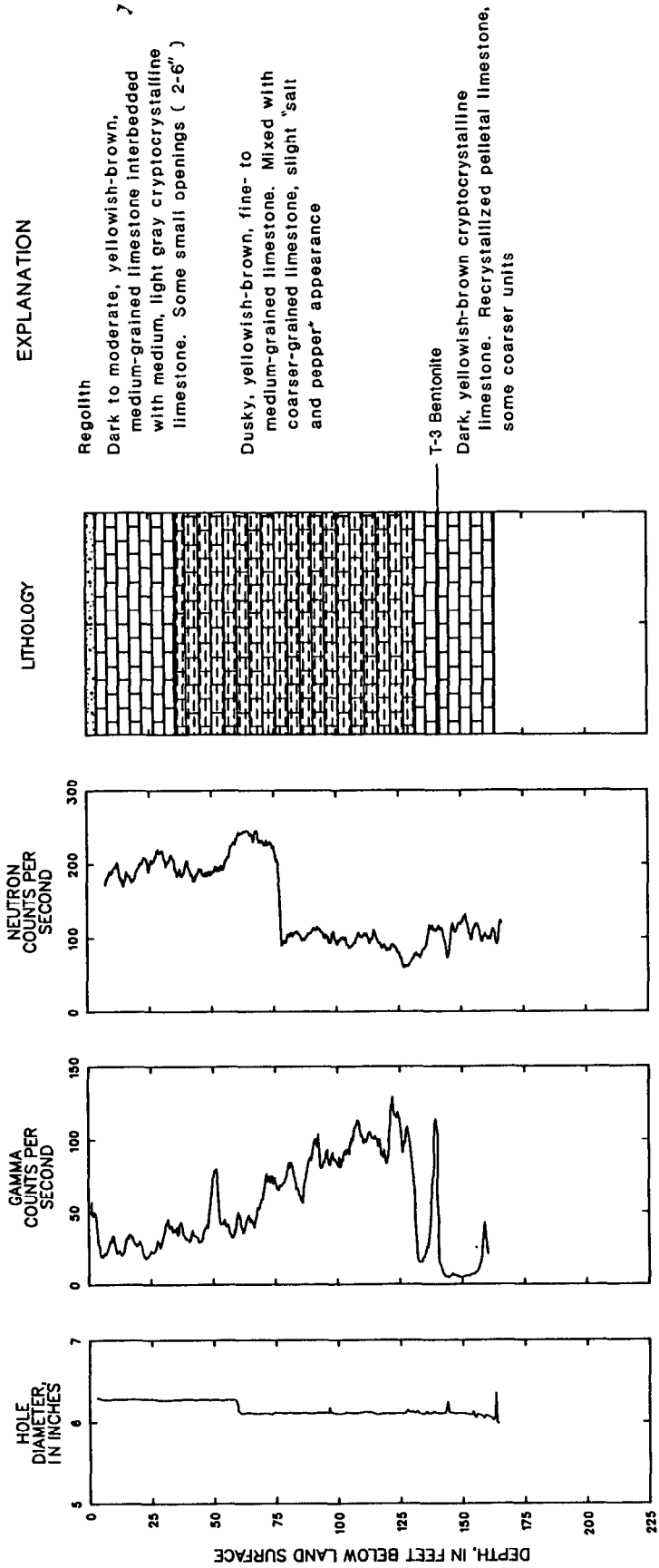
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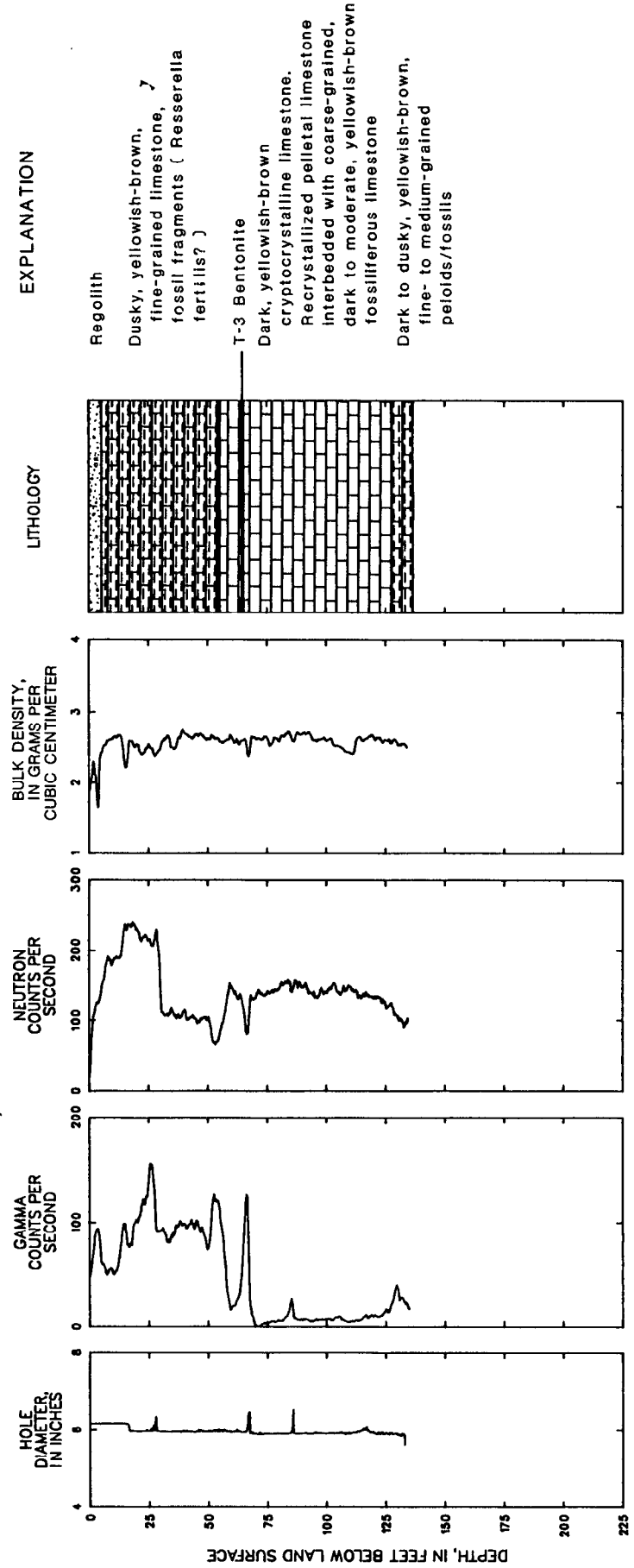
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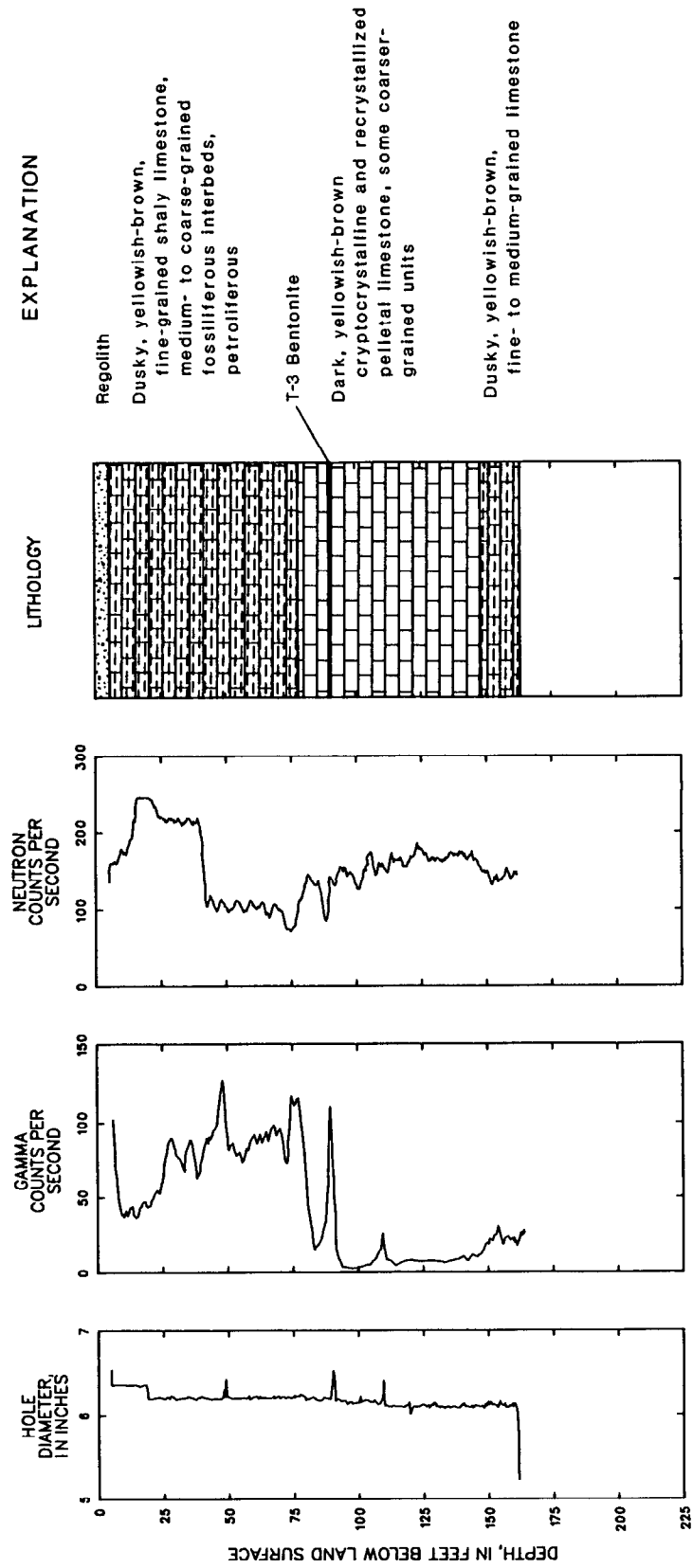
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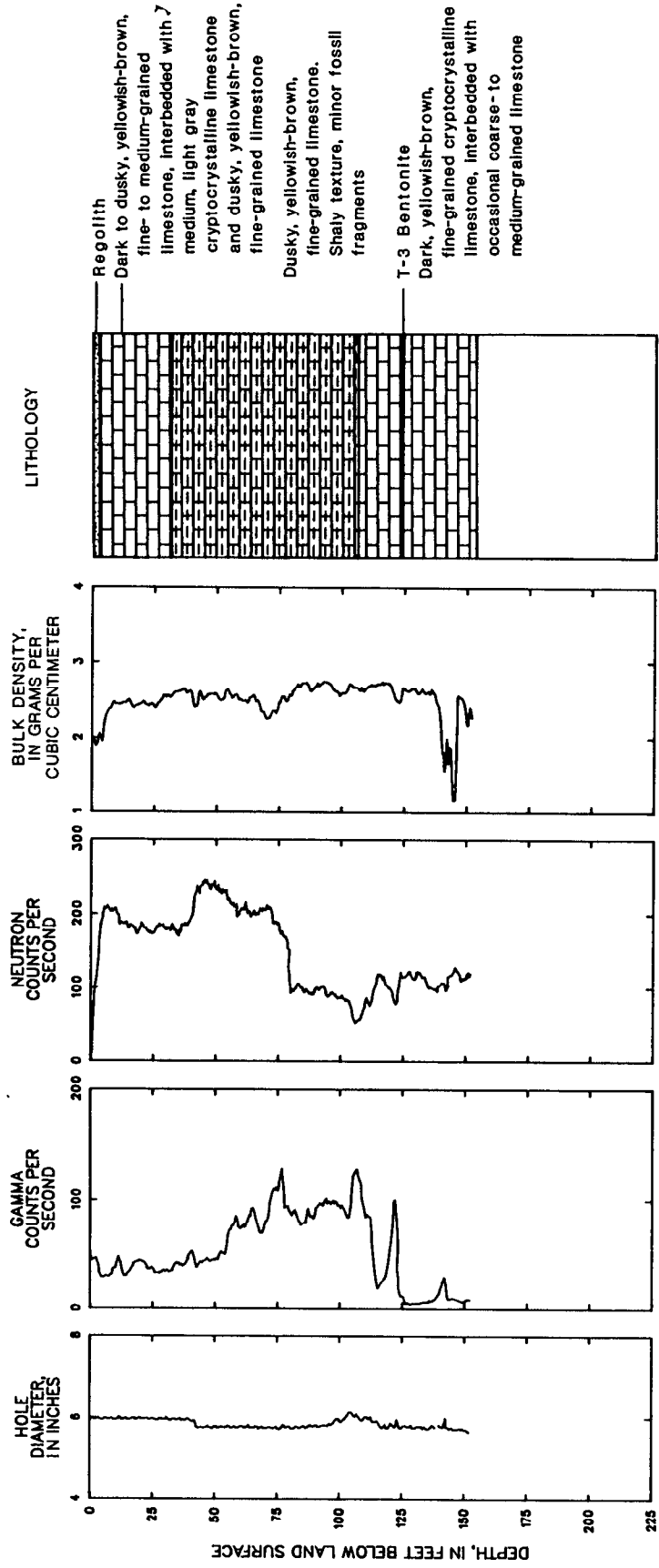
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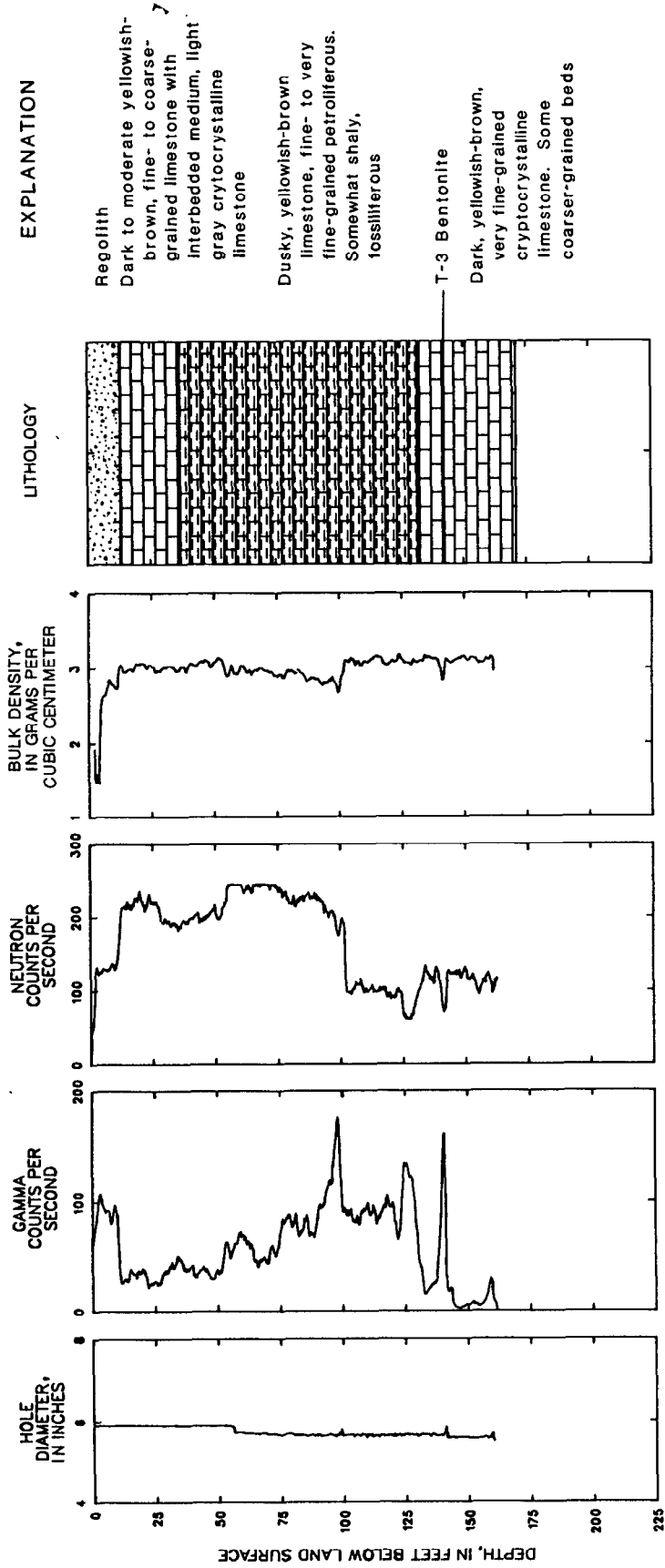
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WELL WM:N-048A

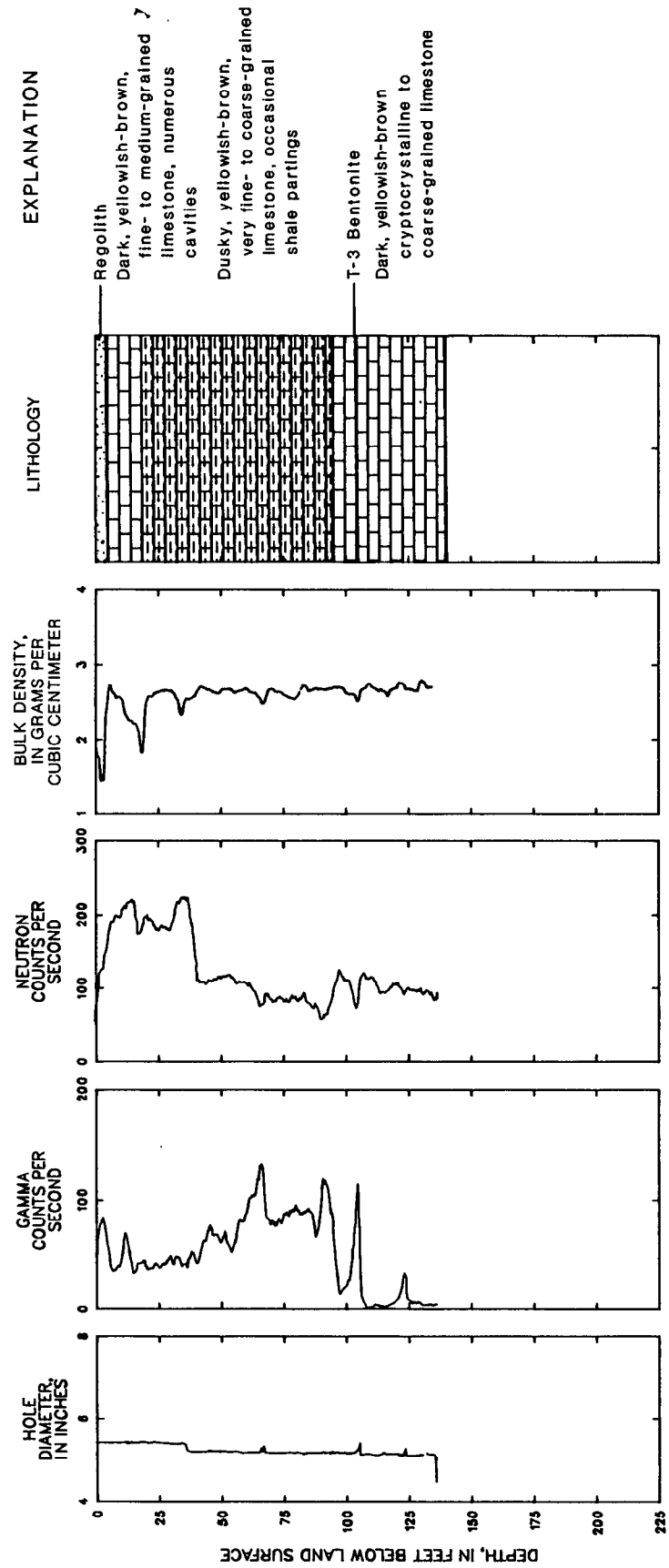


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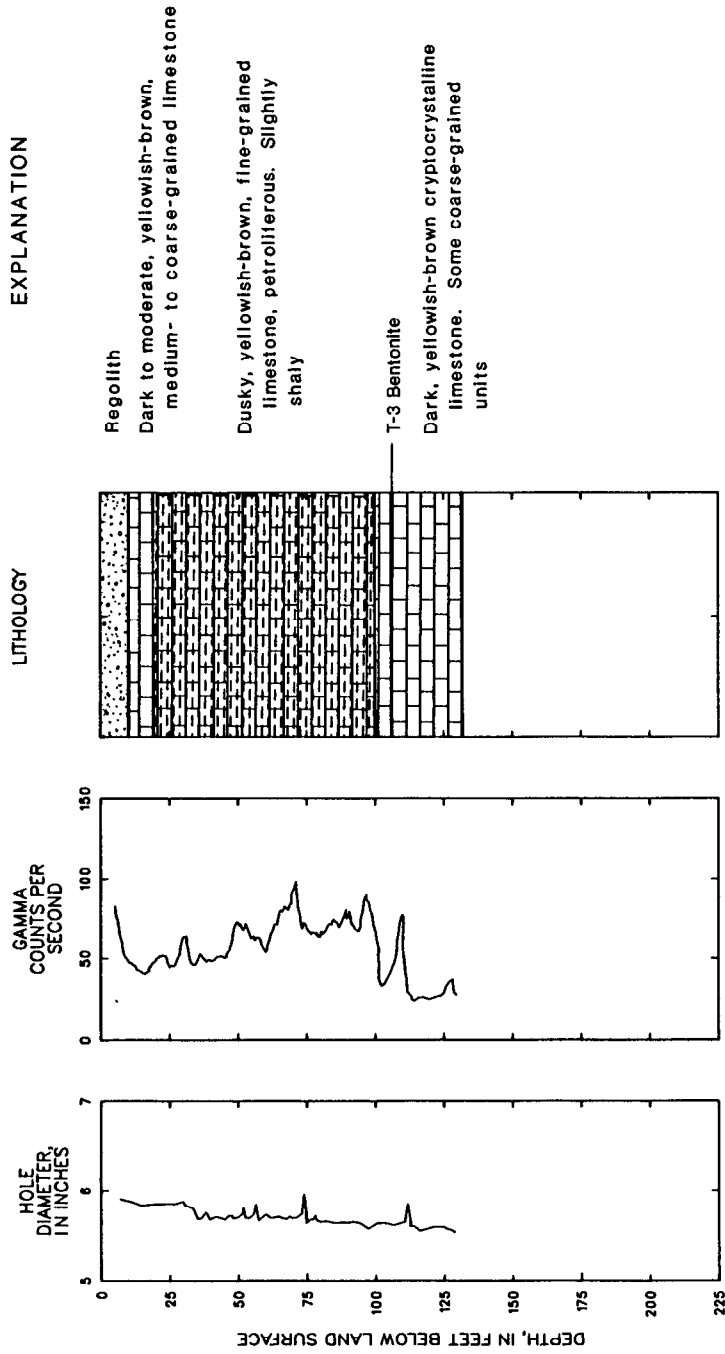




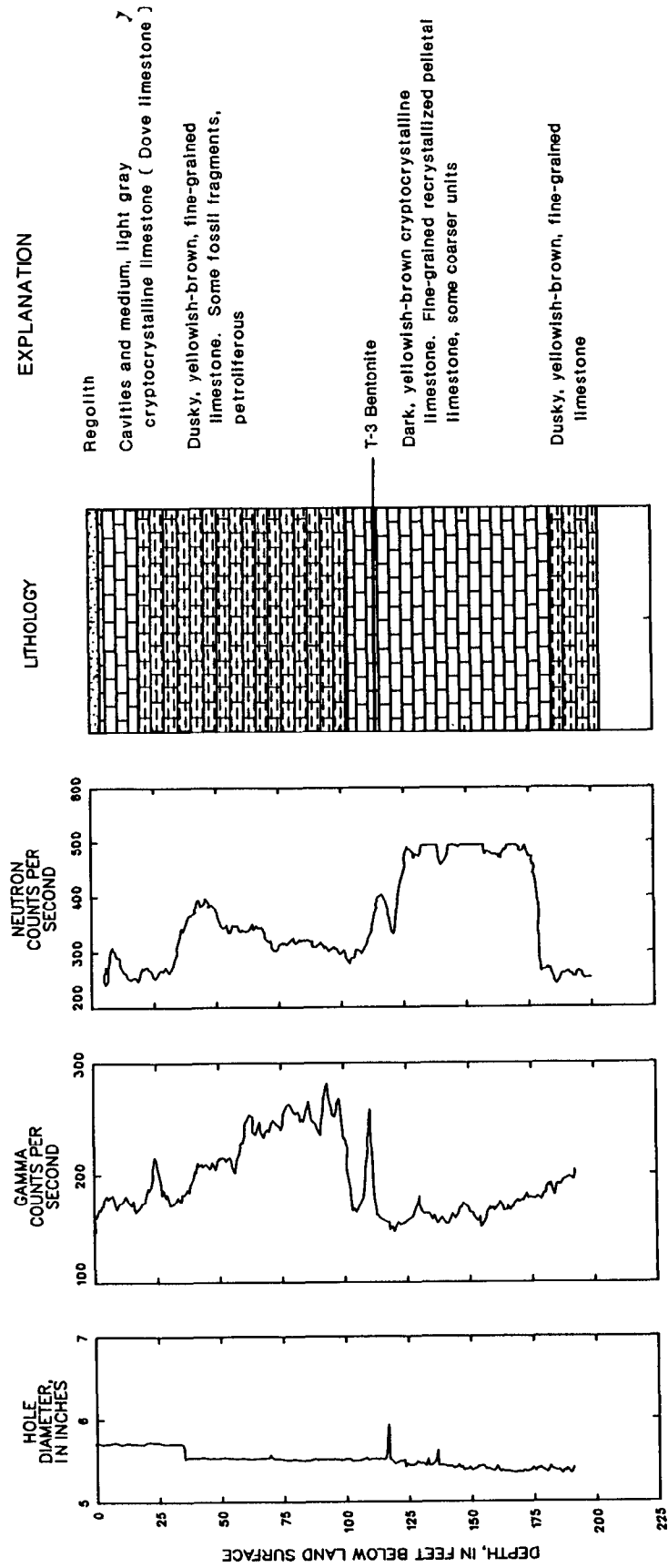
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WELL WM:N-052A



WELL WM:N-053A

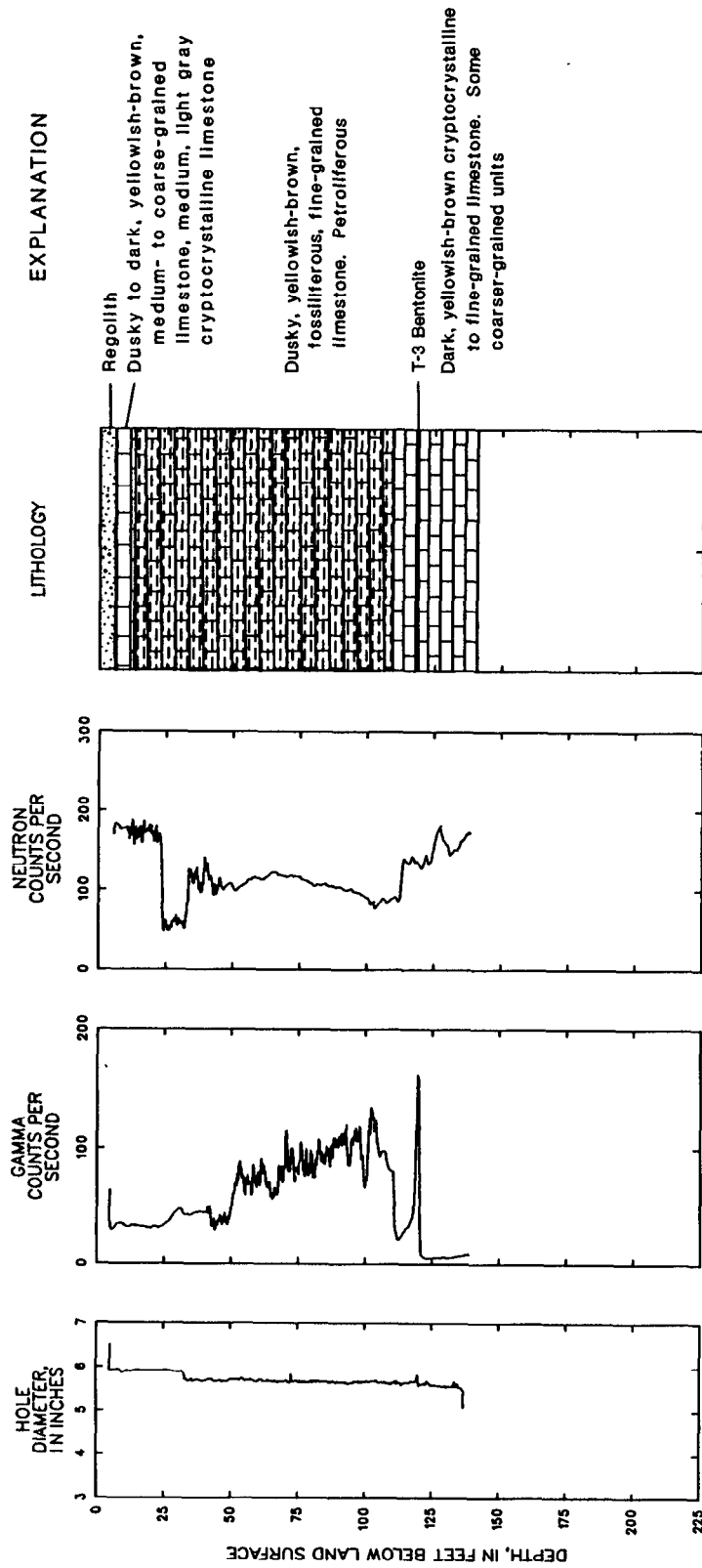


EXPLANATION

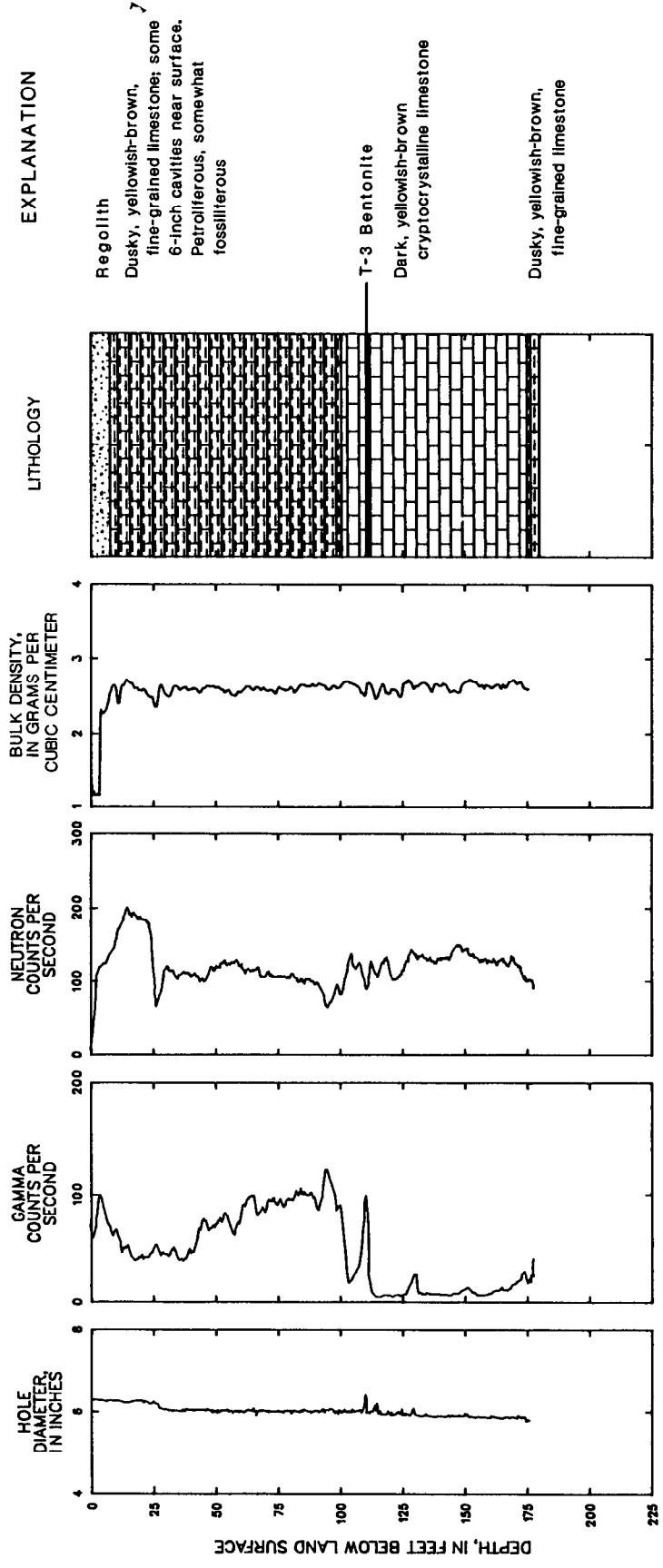
- Regolith
- Cavities and medium, light gray cryptocrystalline limestone ( Dove limestone )
- Dusky, yellowish-brown, fine-grained limestone. Some fossil fragments, petrocliferous
- T-3 Bentonite
- Dark, yellowish-brown cryptocrystalline limestone. Fine-grained recrystallized pelletal limestone, some coarser units
- Dusky, yellowish-brown, fine-grained limestone

LITHOLOGY

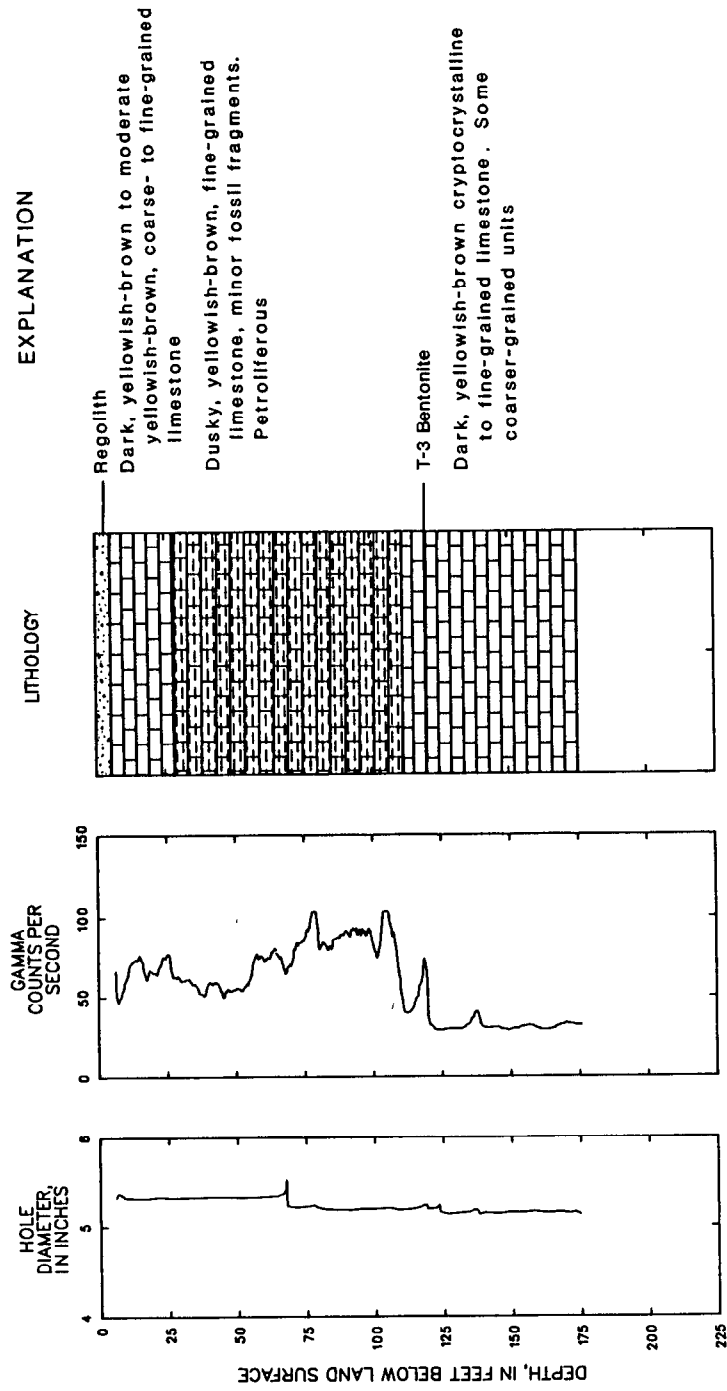
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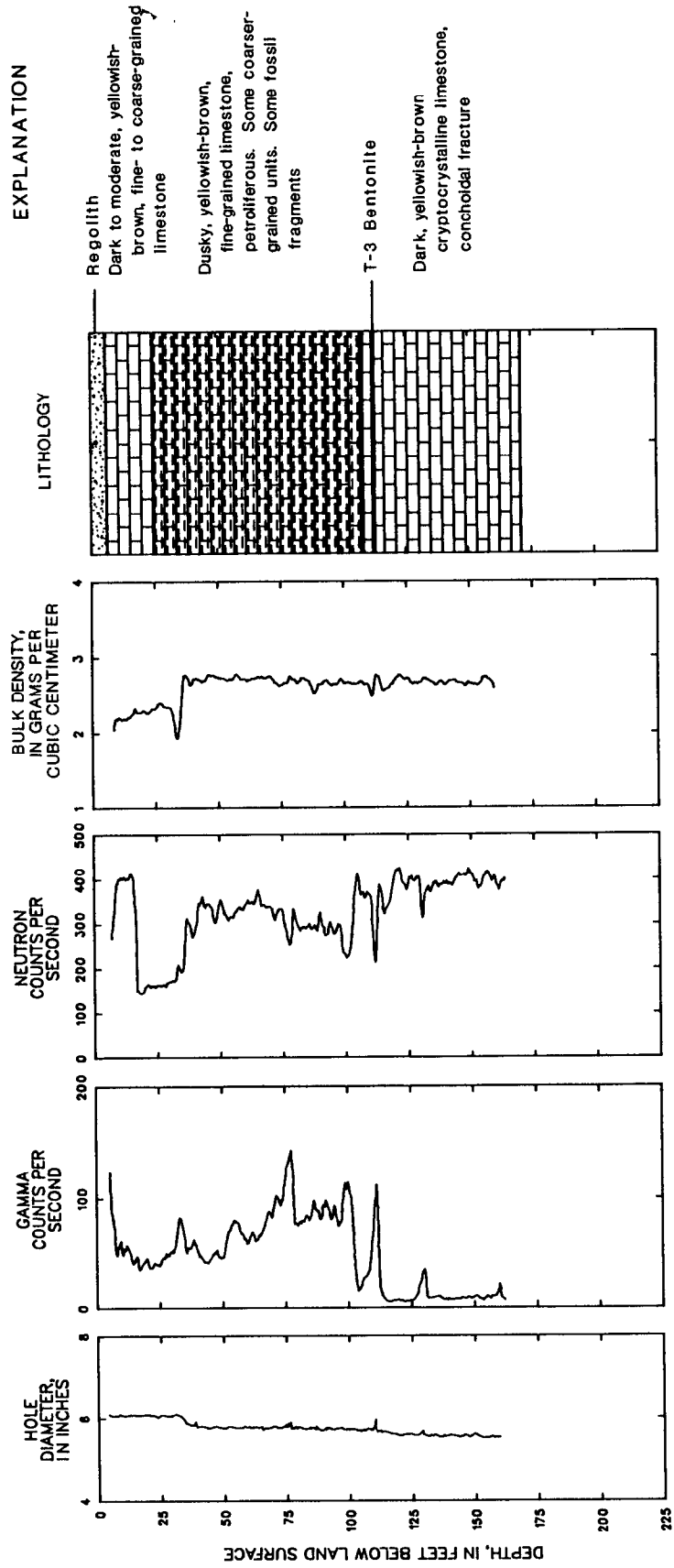
WELL WM:N-055A



WELL WM:N-056A



WELL WM:N-058A



WELL WM:N-057A

