Water-Resources Investigations Report 88-4176

GEOLOGY OF AN AREA NEAR BRENTWOOD, WILLIAMSON COUNTY, TENNESSEE

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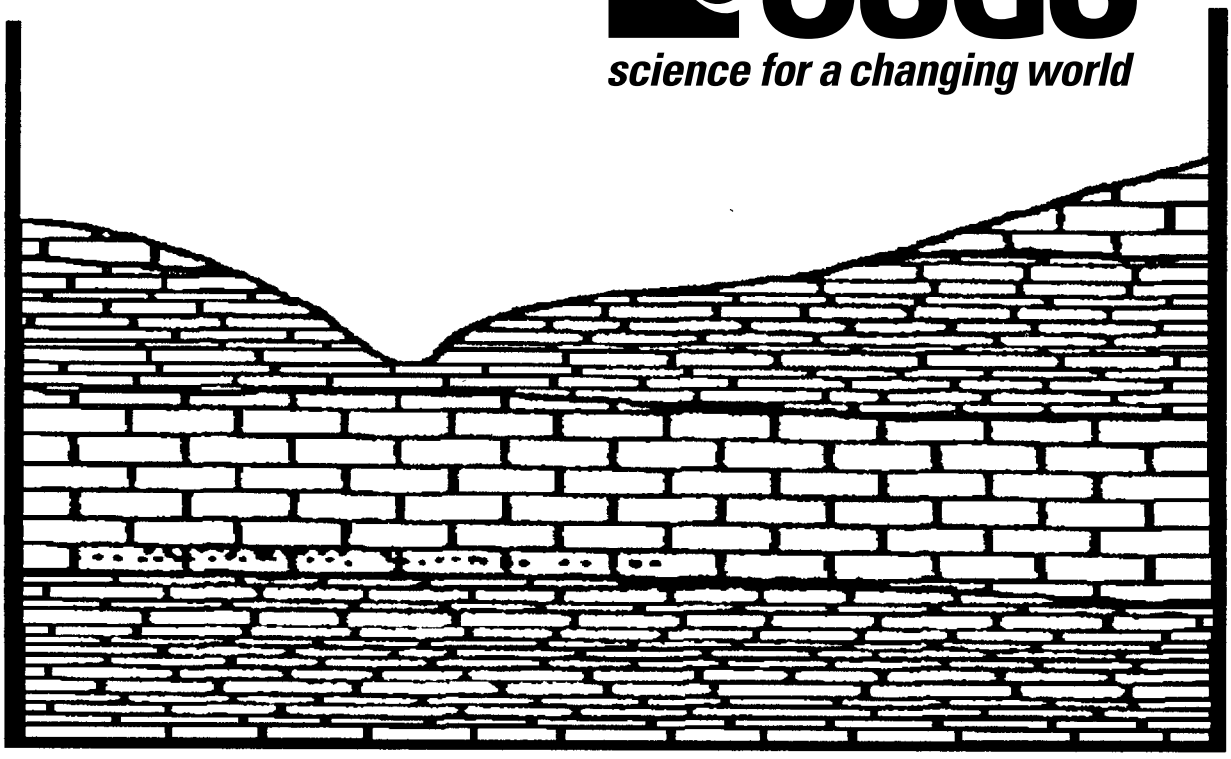

Prepared by the
U.S. GEOLOGICAL SURVEY

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

GEOLOGY OF AN AREA NEAR BRENTWOOD, WILLIAMSON COUNTY, TENNESSEE

By Dorothea Withington Hanchar

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TENNESSEE DEPARTMENT OF HEALTH AND ENVIRONMENT,
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1988

DEPARTMENT OF THE INTERIOR

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U.S. GEOLOGICAL SURVEY

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CONVERSION FACTORS

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

Multiply inch-pound unit	By	To obtain metric unit
foot (ft)	0.3048	meter (m)
foot per mile (ft/mi)	0.1894	meter per kilometer (m/km)
mile (mi)	1.609	kilometer (km)

Sea level: In this report "sea level" refers to the National Geodetic Vertical Datum 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."

GEOLOGY OF THE AREA AROUND A HAZARDOUS-WASTE DISPOSAL SITE IN WILLIAMSON COUNTY, TENNESSEE

By Dorothea Withington Hanchar

ABSTRACT

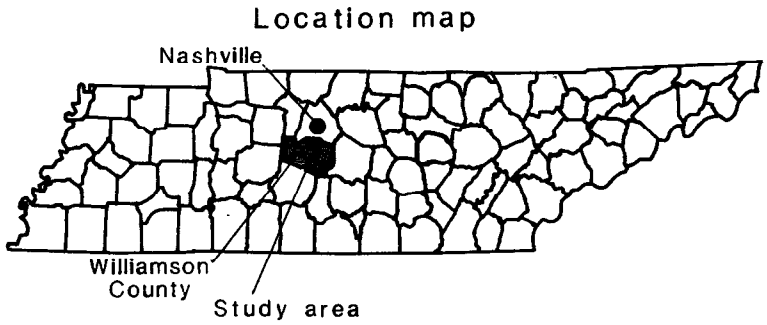
The lithology and geologic structure of an area near Brentwood, Williamson County, Tennessee, were studied to define the potential aquifers and confining units of the ground-water flow system. Four formations were identified. They are, in descending order, the Bigby-Cannon Limestone, the Hermitage Formation, the Carters Limestone, and the Lebanon Limestone. The Bigby-Cannon Limestone and the Carters Limestone are potential aquifers. The Hermitage Formation and the Lebanon Limestone are confining units. The Bigby-Cannon Limestone and the Hermitage Formation have been affected by recent erosion. Any variation of the Carters Limestone is controlled by pre-Carters erosion of the top of the Lebanon Limestone. The thickness of the Carters Limestone ranges from 65 to 79 feet. Structurally, the area reflects the regional northwest dip. A small scale anticline-syncline pair also is evident. This feature is not a result of erosion and also occurs in the T-3 bentonite bed in the Carters Limestone.

INTRODUCTION

An area near Brentwood, Williamson County, Tennessee (fig. 1), was used to dispose of approximately 800 barrels of industrial waste in 1978. In June 1986, the U.S. Geological Survey, in cooperation with the Superfund Division of the Tennessee Department of Health and Environment, began a study to characterize the hydrogeology of the areas and the surrounding area. This characterization includes a thorough understanding of the geology to define the extent of the potential aquifers and confining units that comprise the ground-water flow system. This report describes the geology of the area and compares it to the regional geology.

Regionally, the study area is located along the northwestern dipping flank of the Nashville Dome (fig. 2) (Wilson, 1948, p. 57). Previous work by Wilson and Miller (1963) has identified four formations of Ordovician age at or within 300 feet of the land surface that underlie the site and are discussed in this report. From youngest to oldest these formations are: the Bigby-Cannon Limestone, and the Hermitage Formation of the Nashville Group, and the Carters Limestone and the Lebanon Limestone of the Stones River Group (fig. 3). These formations have been described in detail by Wilson (1949). Descriptions of the lithologies penetrated during the drilling program are presented by Withington (1988).

A network of 34 observation wells was installed at 17 sites for this project (Withington,



EXPLANATION

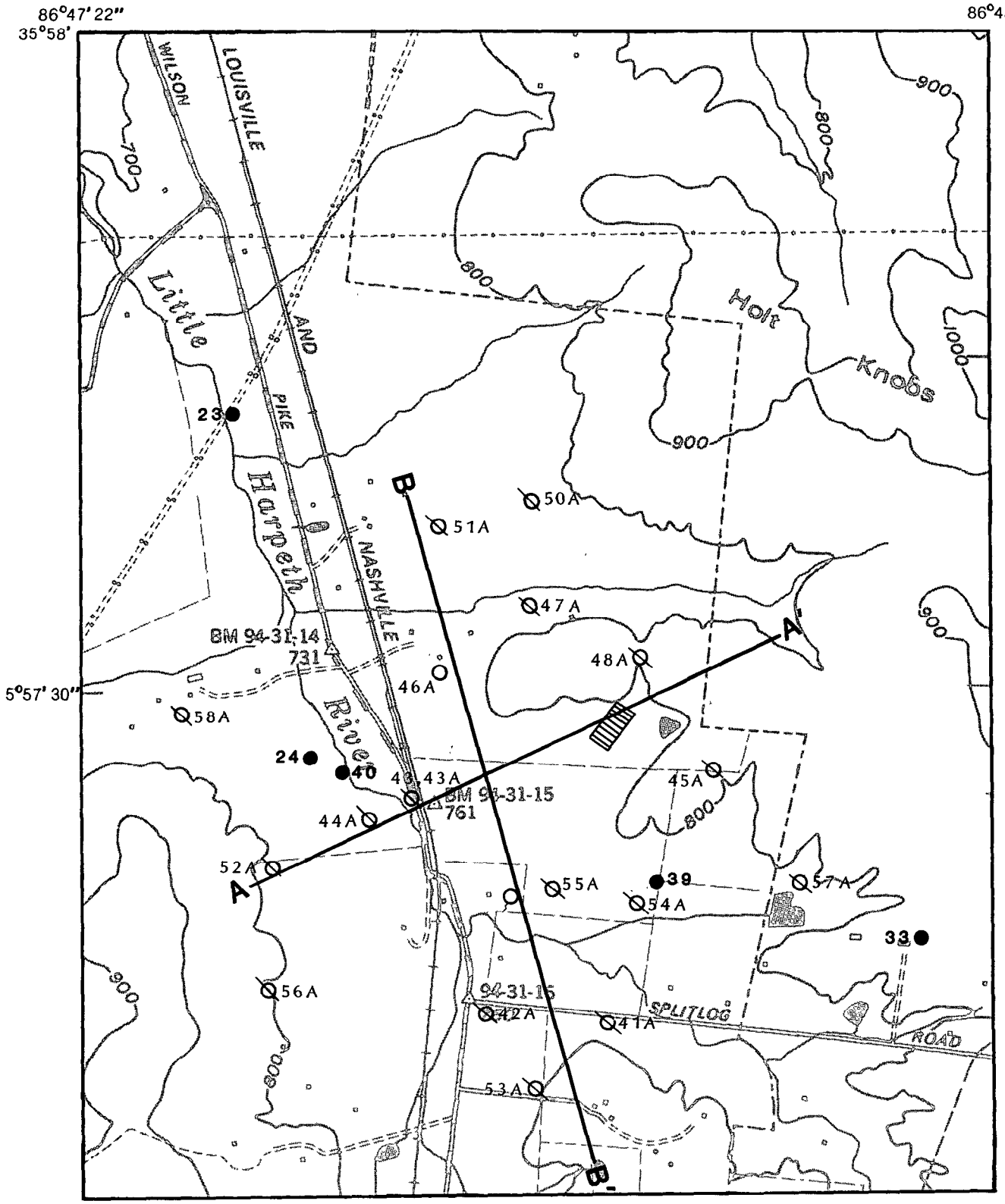
DISPOSAL SITE

A—A' LINE OF SECTION

53A OBSERVATION WELL AND NUMBER--Full well identification includes the prefix Wm:N-##.

33 DOMESTIC WELL AND NUMBER--Full well indentification includes the prefix Wm:N-##.

Figure 1.--Location of study area and observation and domestic wells.



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

0 0.5 MILE

0 0.5 KILOMETER

CONTOUR INTERVAL 100 FEET

DATUM IS SEA LEVEL

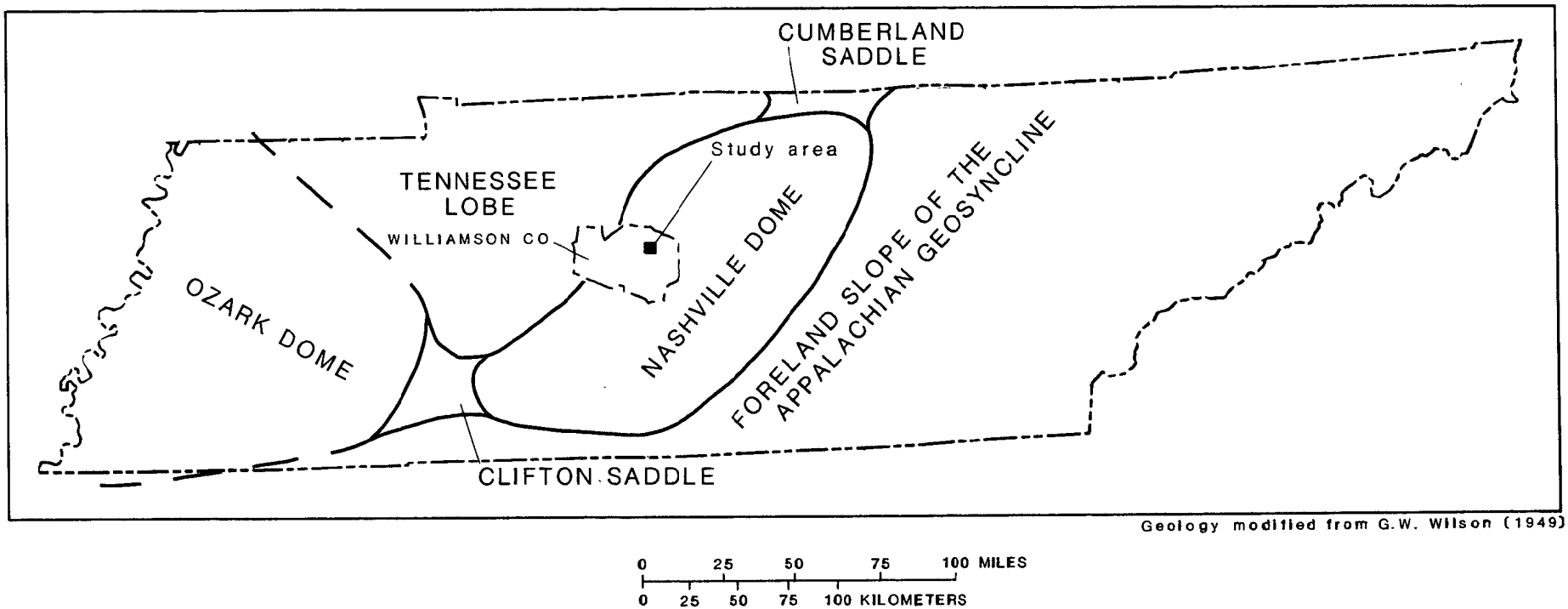


Figure 2.--Structural setting of study area.

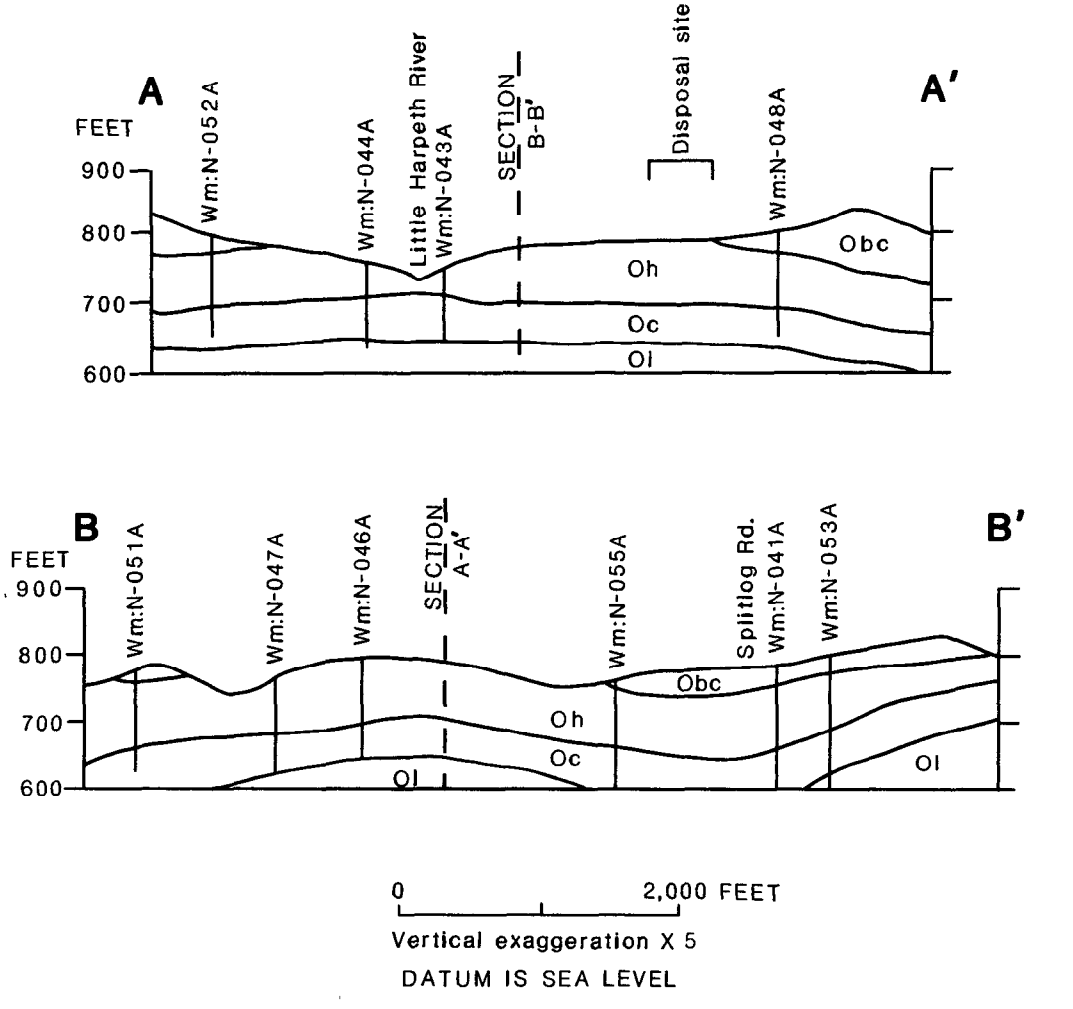


Figure 3.--Generalized geologic section along lines A-A' and B-B' across the study area.

1988). A shallow well and a deep well were drilled at each site. Major changes in lithologic type were identified on the basis of the lithology, texture, and color of the cuttings, which were collected every 5 feet during drilling of the wells. Upon completion of drilling, the deep wells were logged by using caliper, gamma, and neutron borehole-geophysical tools (Withington, 1988). Formation contacts were identified on the basis of interpretation of both lithologic and geophysical logs.

Geophysical logs obtained from five domestic wells near the study area (fig. 1) were used to supplement lithologic data derived from drilling operations. The wells from which these logs were obtained ranged in depth from 148 to 1,050 feet. The geophysical logs from these wells were used in conjunction with the lithologic and geophysical logs of the Geological Survey observation wells to construct structure contour and formation thickness maps.

GEOLOGY

Lithology

The formations in the study area are, in descending order, the Bigby-Cannon Limestone, the Hermitage Formation, the Carters Limestone, and the Lebanon Limestone. These units are overlain by 3 to 15 feet of soil and weathered rock. This material is generally brown to reddish-brown clay and silt. All drilling, once through the weathered rock, began in either the Bigby-Cannon Limestone or the Hermitage Formation.

Regionally, the correlative Bigby and Cannon Limestones (referred to as the Bigby-Cannon Limestone in this report as defined by Wilson, 1947) consists of three major lithologic types: the Bigby facies, the dove-colored facies, and the Cannon facies (Wilson, 1949, p. 107). All three types occur in northern Williamson County (Wilson, 1948, p. 114). The Bigby facies is a coarse-granular limestone, composed of fossil fragments, and is blue-gray in color when fresh (Wilson, 1949, p. 115). The dove-colored facies interfingers with the Bigby and the Cannon facies and is a light-gray ("dove-colored") lithographic limestone (Wilson, 1949, p. 122).

The Cannon facies, which also interfingers with the Bigby facies, is a fine- to medium-grained blue limestone with coarse-grained variations (Wilson, 1949, p. 126). In the study area, the Bigby and the Dove-colored facies were recognized. The formation is predominantly silt-free with solution openings, making this unit a potential aquifer where solution openings are present. The Bigby-Cannon Limestone is a coarse- to medium-grained, dark yellowish-brown limestone with interbeds of dove-colored lithographic limestone. Regionally, the thickness of this formation ranges from 50 to 100 feet. In the study area, this formation has been thinned by recent erosion, and the thickness ranges from 0 to 41 feet (table 1; fig. 4). The maximum thickness does not represent a complete section. The contact between the Hermitage Formation and the Bigby-Cannon Limestone is transitional and is based on texture and color changes seen in the cuttings during drilling as well as changes seen in the geophysical logs. The Bigby-Cannon-Hermitage contact is seen in gamma logs by an increased number of gamma counts per second, which corresponds to an increased shale content in the Hermitage Formation (fig. 5). This contact was determined in neutron logs by an increase in counts per second, indicating decreased porosity with depth (fig. 5). The Hermitage Formation is partially eroded. Depth to the top of the Hermitage ranges from 0 to 41 feet (table 2; fig. 3).

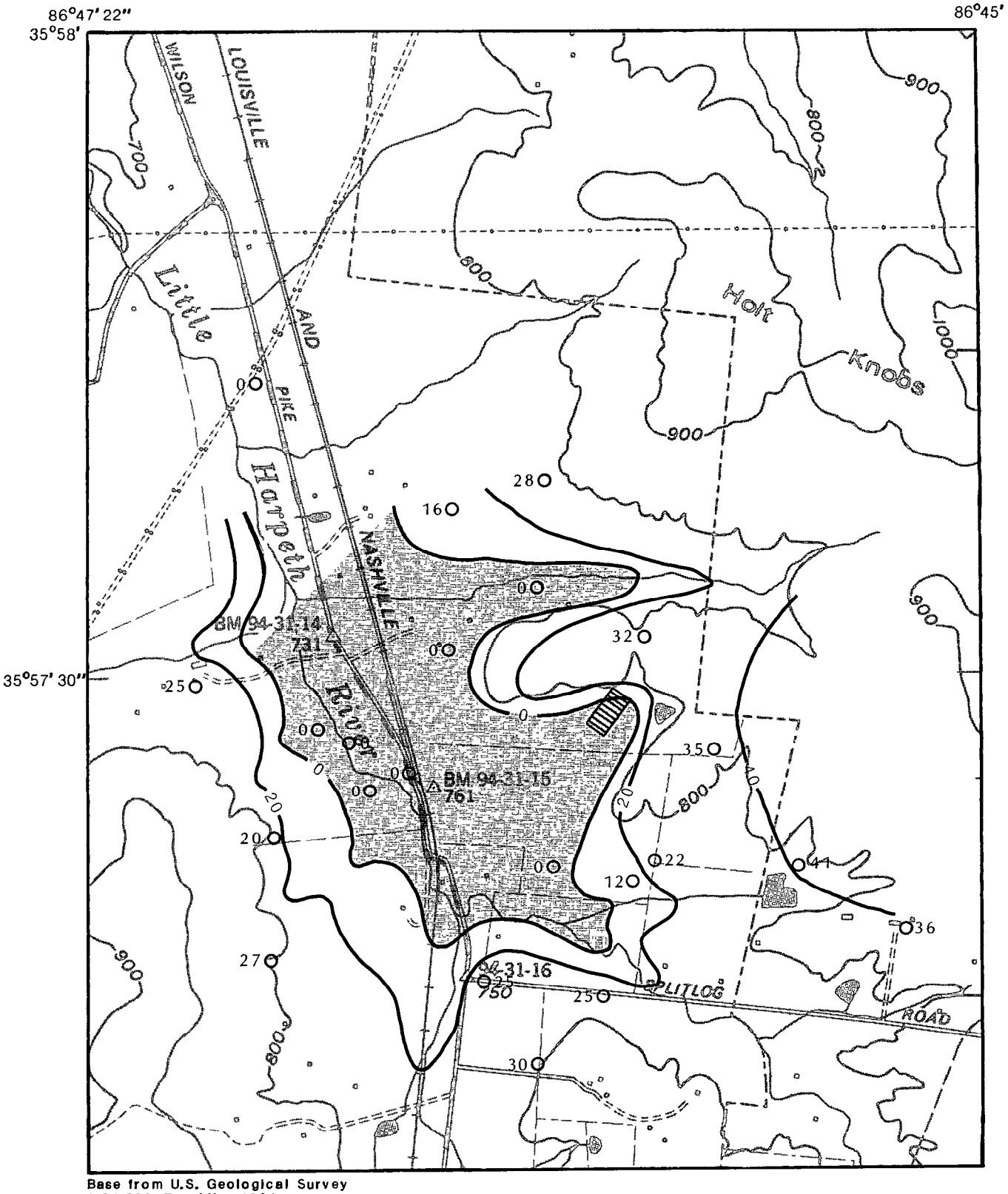
The Hermitage Formation consists of four facies. These are (in descending order): the Dalmenella Coquina limestone, the silty nodular limestone, the granular phosphatic limestone, and the laminated argillaceous limestone. Of

Table 1.--*Thickness of formations*

[Values in feet]

Well No.	Bigby-Cannon Limestone	Hermitage Formation	Carters Limestone
	U.S. Geological Survey Wells		
WM:N-041A	25	101	70
WM:N-042A	25	72	68
WM:N-043A	0	26	65
WM:N-044A	0	26	66
WM:N-045A	35	97	70
WM:N-046A	0	57	71
WM:N-047A	0	78	77
WM:N-048A	32	80	71
WM:N-050A	28	103	71
WM:N-051A	16	79	77
WM:N-052A	20	80	68
WM:N-053A	30	74	79
WM:N-054A	12	99	70
WM:N-055A	0	102	72
WM:N-056A	27	87	70
WM:N-057A	41	83	71
WM:N-058A	25	78	72
	Domestic Wells		
WM:N-023	0	88	78
WM:N-024	0	39	78
WM:N-033	36	86	--
WM:N-039	22	102	72
WM:N-040	0	37	77

these four, only the laminated argillaceous and the Granular Phosphatic limestones are present in the study area. These are respectively a thin-bedded, or laminated argillaceous bluish-gray limestone, interbedded with thin shale partings; and a coarse-grained gray limestone composed entirely of ground-up fragments, pellets, or uncomminuted shell particles (Wilson, 1962, p. 485-486). The high argillaceous contact makes this formation a confining unit. In the study area, the Hermitage Formation is a predominantly fine-grained, dusky yellowish-brown, argillaceous limestone with shale partings and fossil fragments. This facies corresponds to the laminated argillaceous limestone. Variations include an overlying coarser-grained, salt-and-pepper, dark to dusky-yellowish-brown limestone, possibly the granular phosphatic limestone. The Hermitage Formation also is distinctly odoriferous, and


86°47'22"
35°58'
86°45'
35°57'30"
WILSON
LOUISVILLE
AND
NASHVILLE
PIKE
Little
Harpeth
River
Holt
Knobs
BM 94-31-14
731
BM 94-31-15
761
94-31-16
750
SPLITLOG
ROAD
700
800
900
1000
0
16
28
32
25
35
20
22
41
12
36
27
30
Base from U.S. Geological Survey
1:24,000, Franklin, 1981
0
0.5 MILE
0
0.5 KILOMETER
CONTOUR INTERVAL 100 FEET
DATUM IS SEA LEVEL

EXPLANATION

DISPOSAL SITE

AREA OF HERMITAGE FORMATION OUTCROP

—20— LINE OF EQUAL THICKNESS OF THE BIGBY-CANNON LIMESTONE--Interval 20 feet. Datum is sea level

25 O WELL LOCATION AND THICKNESS OF THE BIGBY-CANNON LIMESTONE, IN FEET

Figure 4.--Thickness of the Bigby-Cannon Limestone.

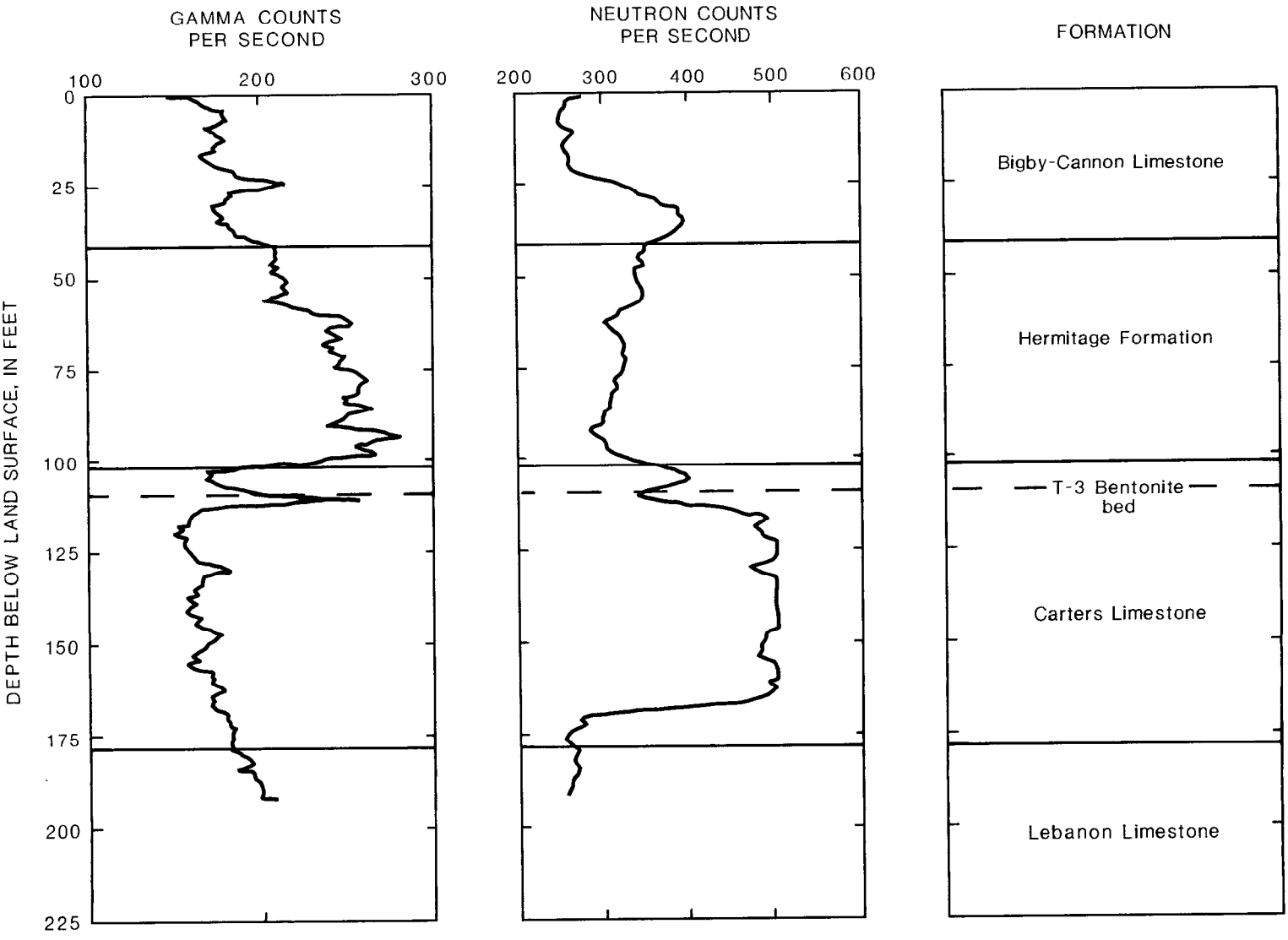


Figure 5.--Gamma and neutron geophysical logs for well Wm:N-053A.

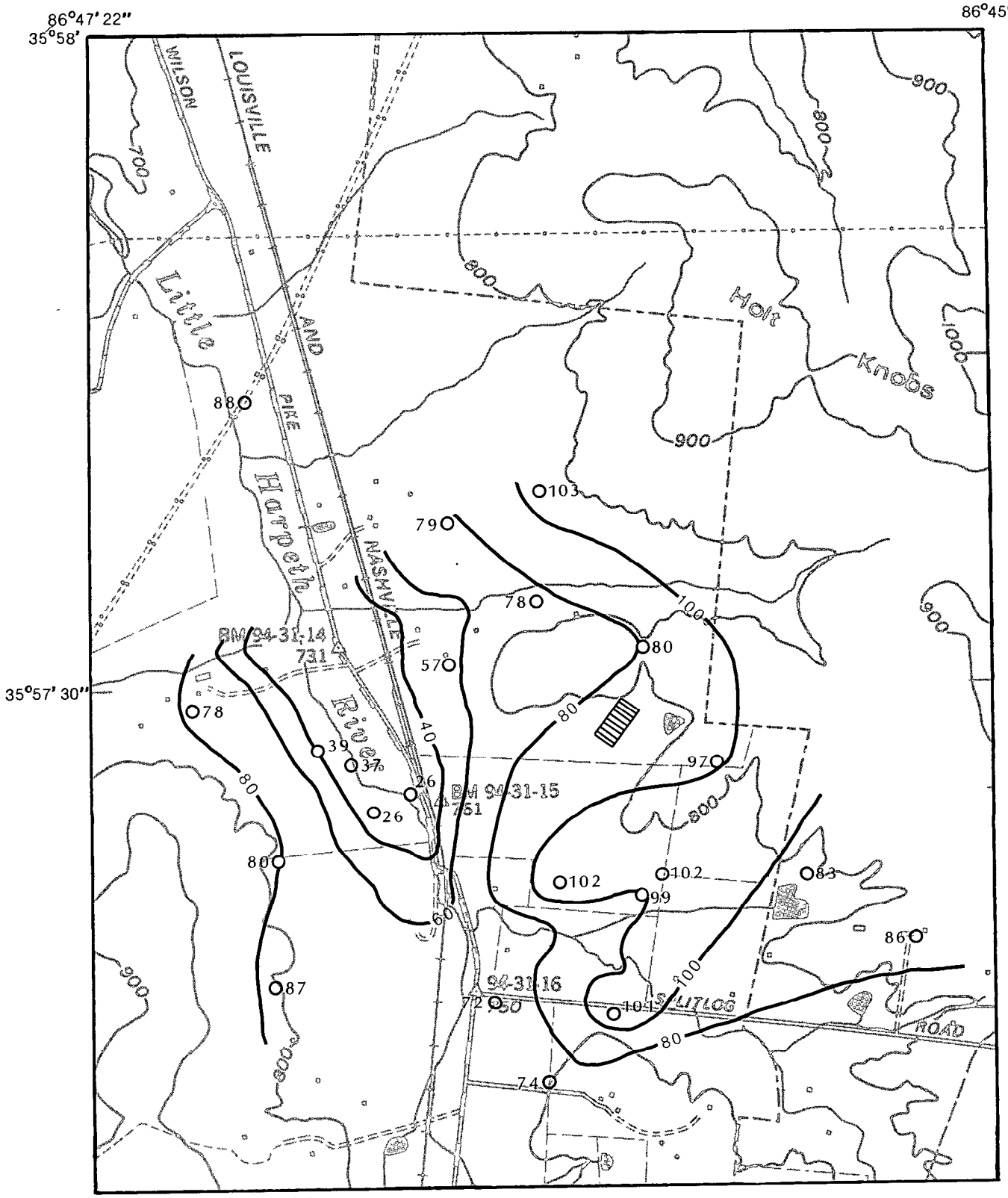
Table 2.--*Depth to top of formation or unit*

[Values in feet below land surface]

Well No.	Hermitage Formation	Carters Limestone	T-3 bentonite bed of Carters Limestone	Lebanon Limestone
		U.S. Geological Survey Wells		
WM:N-041A	25	101	136	196
WM:N-042A	25	97	105	165
WM:N-043A	0	25	32	90
WM:N-044A	0	26	32	92
WM:N-045A	35	132	143	--
WM:N-046A	0	57	65	128
WM:N-047A	0	78	90	153
WM:N-O48A	32	112	123	--
WM:N-050A	28	131	141	--
WM:N-051A	16	95	105	172
WM:N-052A	20	100	107	--
WM:N-053A	30	104	113	183
WM:N-O54A	12	111	120	--
WM:N-055A	0	102	110	174
WM:N-056A	27	114	120	--
WM:N-057A	41	124	132	195
WM:N-058A	25	103	111	--
		Domestic Wells		
WM:N-023	0	95	104	166
WM:N-024	0	56	117	
WM:N-033	31	132	141	--
WM:N-039	15	117	126	189
WM:N-040	0	46	54	115

possibly petroliferous, which was evident during drilling by a strong sulphur smell. This formation has been extensively eroded in the study area. Thicknesses of the Hermitage Formation range from 26 to 103 feet (table 1; fig. 6).

The Hermitage Formation-Carters Limestone contact was also determined from a combination of lithologic and geophysical logs. During drilling, this contact was placed at the depth when the overflow changed from medium gray (Hermitage Formation) to pale yellowish-brown (Carters Limestone). The contact is sharp and easy to pick. Drill cuttings change from a medium- to fine-grained dusky yellowish-brown argillaceous limestone, the Hermitage, to a very-fine to cryptocrystalline, dark yellowish-brown limestone, characteristic of the upper member of



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

CONTOUR INTERVAL 100 FEET
DATUM IS SEA LEVEL

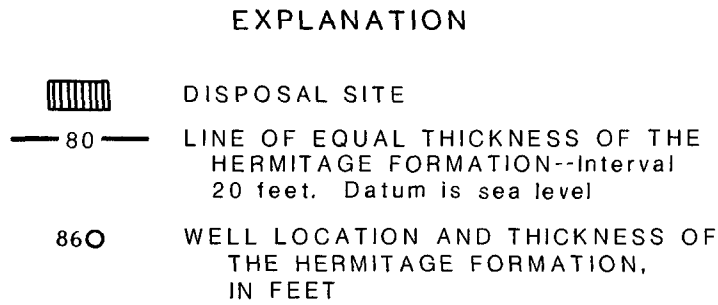


Figure 6.--Thickness of the Hermitage Formation.

the Carters Limestone. This contact is also evident in the gamma logs as a decrease in counts per second (fig. 5). The depth to the contact between the Hermitage Formation and the Carters Limestone ranges from 26 to 132 feet below land surface (table 1).

The Carters Limestone, the uppermost formation of the Stones River Group, consists of an upper and a lower member. These are separated by a bentonite bed named the T-3 bentonite bed. The upper member of the Carters Limestone observed during drilling is a dark yellowish-brown, cryptocrystalline limestone with characteristic conchoidal fracturing. This corresponds to the description given by Wilson (1949). The lower member consists of a dark yellowish-brown, crystalline, pelletal limestone. Both the upper and lower members of the Carters Limestone are aquifers where solution openings are present. The average thickness of the Carters Limestone regionally has been reported as 70 feet (Wilson, 1949; p. 54). In the study area, the upper member of the Carters Limestone has an average thickness of 10 feet, while the lower member of the Carters Limestone has an average thickness of 60 feet. The total thickness of the Carters Limestone in the study area ranges from 65 to 79 feet, and averages 72 feet (table 1; fig. 7).

The T-3 bentonite bed, which separates these two members, is the thickest and most continuous of the regionally persistent bentonite beds within the Carters Limestone (Wilson, 1949). The reported thickness of this bentonite ranges from 1 to 21 inches. In the study area, the thickness of the T-3 bentonite bed ranges from 12 to 18 inches. The T-3 bentonite is readily recognized during drilling. Local drillers named this bed "pencil cave" because of the ease of drilling and because of the resemblance of the cuttings to carpenters' lumber-marking pencils. The T-3 bentonite bed is also obvious in gamma logs, where it is indicated by a sudden increase in the number of counts per second (fig. 5).

The contact between the Carters Limestone and the Lebanon Limestone is defined both by lithologic change and gamma logs. The Lebanon Limestone consists of interbedded argillaceous limestone and shale, which is evident during drilling by the different rates of drilling and the change in lithology. In the gamma logs, this interbedded nature is evidenced by the alternating high and low counts per second, which correspond to shale and limestone layers, respectively (fig. 5). The depth to the Carters Limestone–Lebanon Limestone contact in the study area ranges from 90 to 196 feet below land surface (table 2). As is the contact between the Bigby-Cannon Limestone and the Hermitage Formation, this contact is transitional.

The Lebanon Limestone, also of the Stones River Group, is a thin-bedded, fossiliferous limestone with shale partings (Wilson, 1949). A maximum of 20 feet of this formation was penetrated in this study during the drilling phase. This upper part of the Lebanon Limestone consists of a fine-grained, dusky to dark yellowish-brown fossiliferous limestone with shale partings. Because of this shaley nature, the Lebanon Limestone is a confining unit. This formation is characterized by alternating slow and fast drilling rates. Lebanon Limestone was penetrated in only 8 out of 17 deep wells drilled (table 2). Reported average thickness of the Lebanon Limestone in northeast Williamson County is 100 feet (Wilson, 1949). Thicknesses obtained from gamma logs of local domestic wells indicate an average thickness of 110 feet of Lebanon Limestone in the study area.

Structure

The study area is located on the northwestern flank of the Nashville Dome (fig. 2). Regional dips in this area are 15 feet per mile to the northwest (Piper, 1932; Wilson, 1948). Secondary folds are common along this

northwest margin (Piper, 1932; Wilson, 1948), and large scale folds occur in southern Williamson County (Piper, 1932).

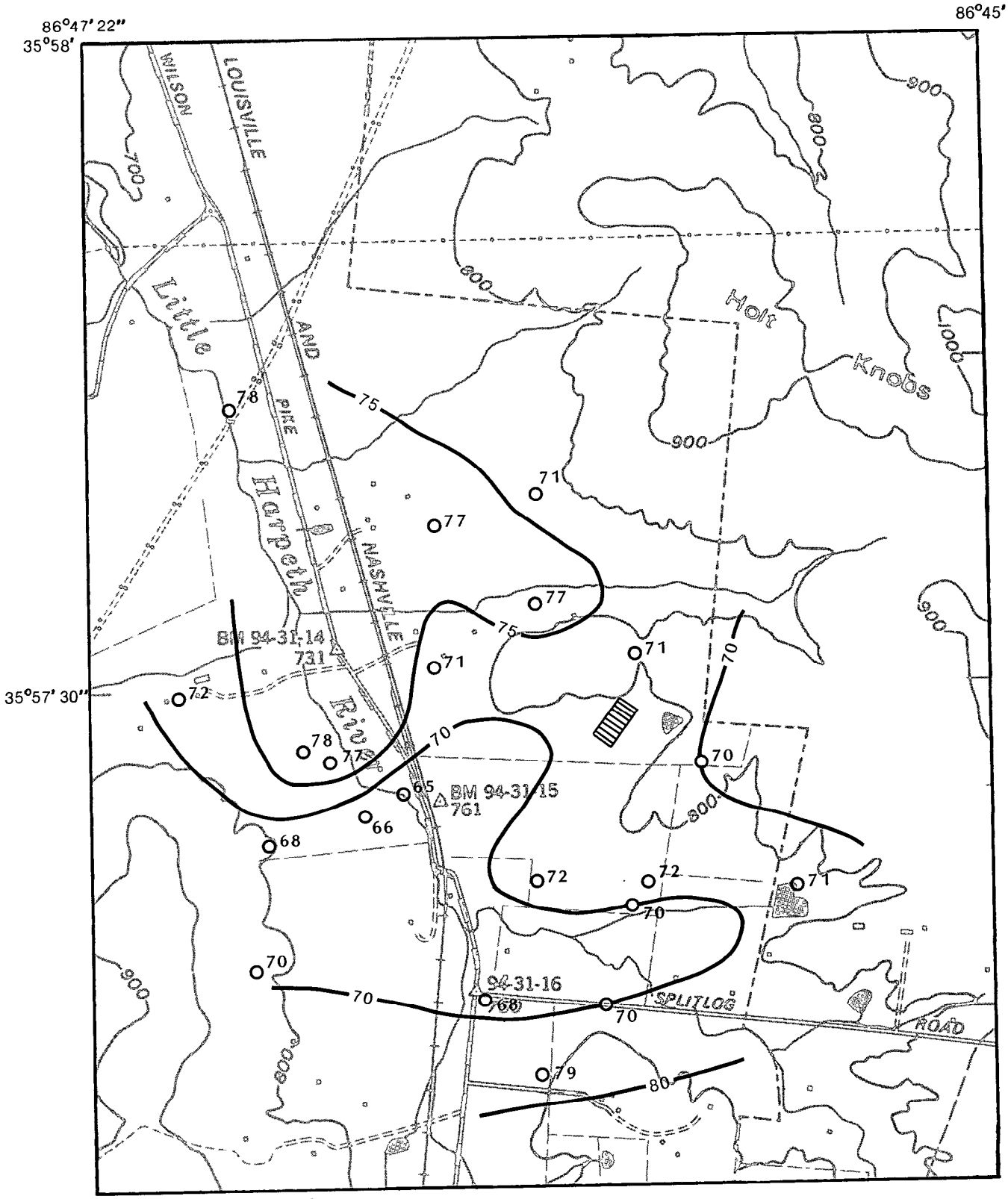
Structure contour maps were constructed for the top of each formation penetrated. Contact depths derived from geophysical logs and lithologic descriptions were used together with surveyed elevations to calculate elevations of the tops of formations.

The top of the Bigby-Cannon Limestone and the Hermitage Formation are controlled by erosion; thus, the elevations of the exposed top of these formations do not reflect local structure. At many well sites, the Bigby-Cannon Limestone is missing and the Hermitage Formation has been thinned as a result of erosion (figs. 4 and 6).

The structure of the study area is apparent in the contour maps of the altitude of the tops of the Carters and Lebanon Limestones (figs. 8, 9, and 10). From these maps, a regional northwest dip is evident, as well as an anticline-syncline pair. The axes of these folds trend northeast, which is consistent with the orientation of other folds in the area reported by Piper (1932) and Bassler (1932).

SUMMARY

As part of a study of the hydrogeology of an area near Brentwood, Williamson County, Tennessee, 34 wells were drilled at 17 sites in the surrounding area. The area is underlain by Ordovician limestones, of which four formations were identified. These are, from youngest to oldest, the Bigby-Cannon Limestone and the Hermitage Formation of the Nashville Group, and the Carters Limestone and the Lebanon Limestone of the Stones River Group. Of these formations, the Bigby-Cannon Limestone and the Carters Limestone have been identified as potential aquifers because of the occurrence of solution openings. The Lebanon Limestone and the Hermitage Formation are defined as confining units because of their argillaceous nature. Based upon data collected both during drilling operations and from borehole geophysical investigations, depths to contacts of the different formations were determined. From these depths, structure contour and thickness maps were constructed. The thickness maps show that the Bigby-Cannon Limestone and the Hermitage Formation have been affected by erosion. The slight variability of thickness of the Carters Limestone is due to erosion following deposition and is probably controlled by the erosion surface on the Lebanon Limestone. Because the Hermitage Formation has been affected by modern erosion, the upper surface of this formation does not reflect the structure of individual rock layers. Some structure is obvious in the contour maps of the top of the Carters Limestone, the altitude of the T-3 bentonite bed, and the altitude of the top of the Lebanon Limestone. These maps indicate a small anticline-syncline pair. Such small folds are consistent with the regional structural setting identified in previous work.



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

0 0.5 MILE

0 0.5 KILOMETER

CONTOUR INTERVAL 100 FEET

DATUM IS SEA LEVEL

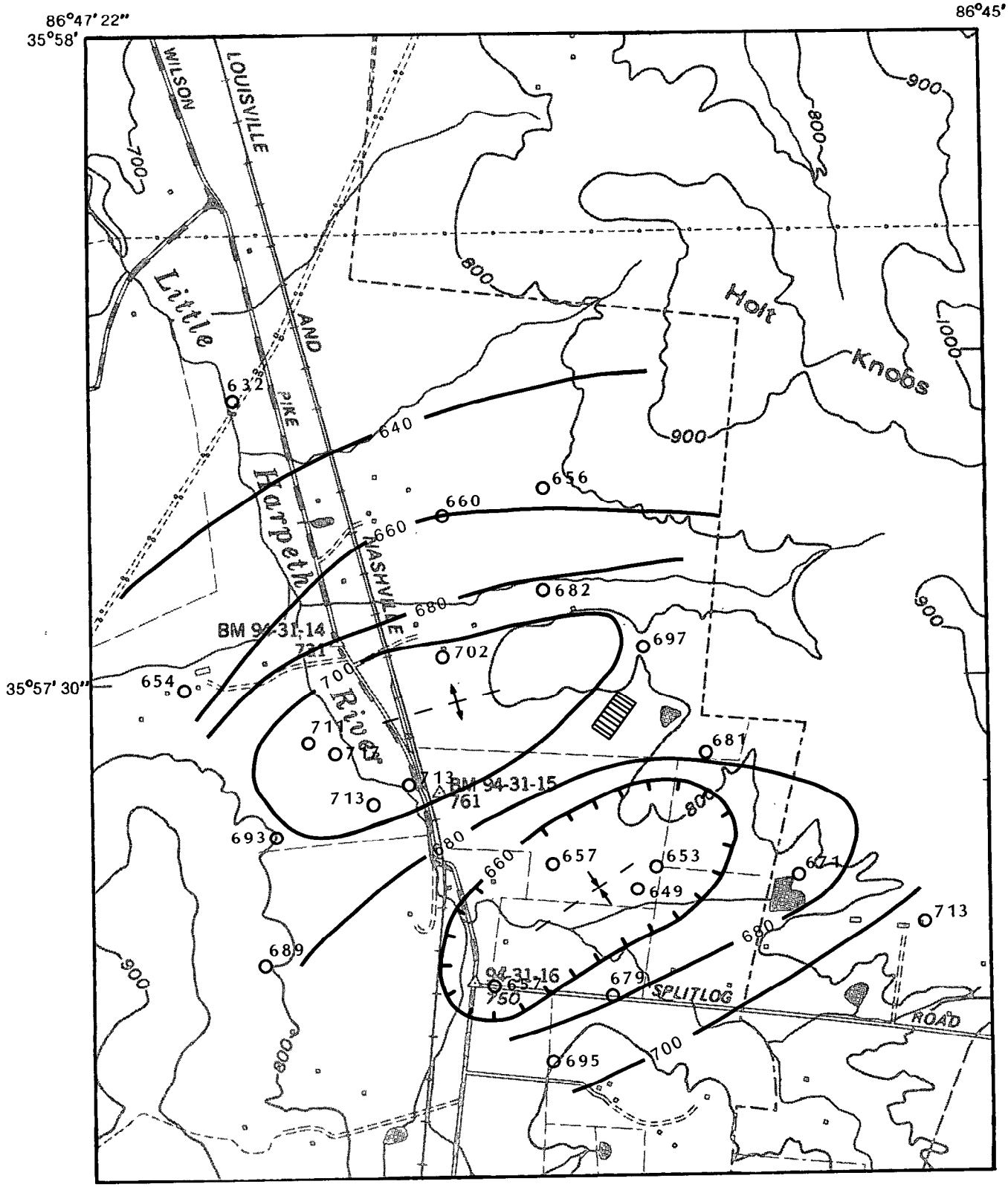
EXPLANATION


DISPOSAL SITE

—70— LINE OF EQUAL THICKNESS OF THE CARTERS LIMESTONE--Interval 10 feet. Datum is sea level

o72 WELL LOCATION AND THICKNESS OF THE CARTERS LIMESTONE, IN FEET

Figure 7.--Thickness of the Carters Limestone.



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

0 0.5 MILE

0 0.5 KILOMETER

CONTOUR INTERVAL 100 FEET

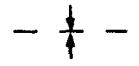
DATUM IS SEA LEVEL

EXPLANATION


DISPOSAL SITE

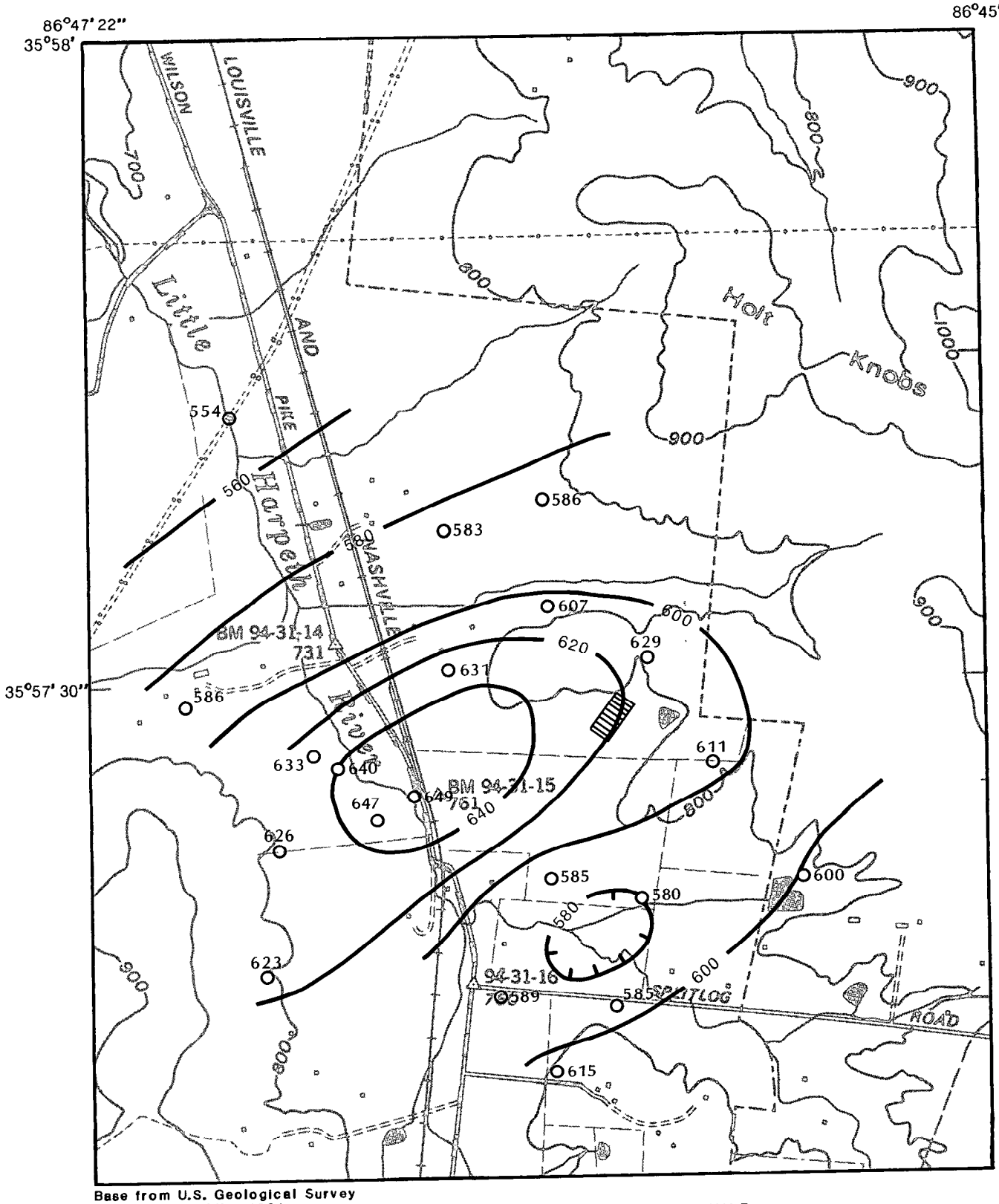
—660— STRUCTURE CONTOUR--Shows altitude of the Carters Limestone. Hachures indicate depression. Contour interval 20 feet. Datum is sea level


ANTICLINE--Showing trace of crestal plane. Dashed where approximately located


SYNCLINE--Showing trace of trough plane. Dashed where approximately located

6570 WELL LOCATION AND ALTITUDE OF THE CARTERS LIMESTONE

Figure 8.--Structure of the top of the Carters Limestone.



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

0 0.5 MILE

0 0.5 KILOMETER

CONTOUR INTERVAL 100 FEET

DATUM IS SEA LEVEL

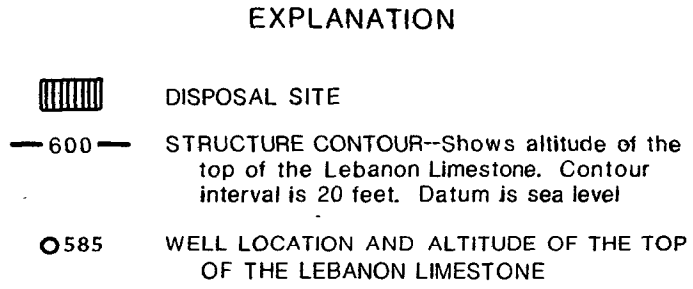
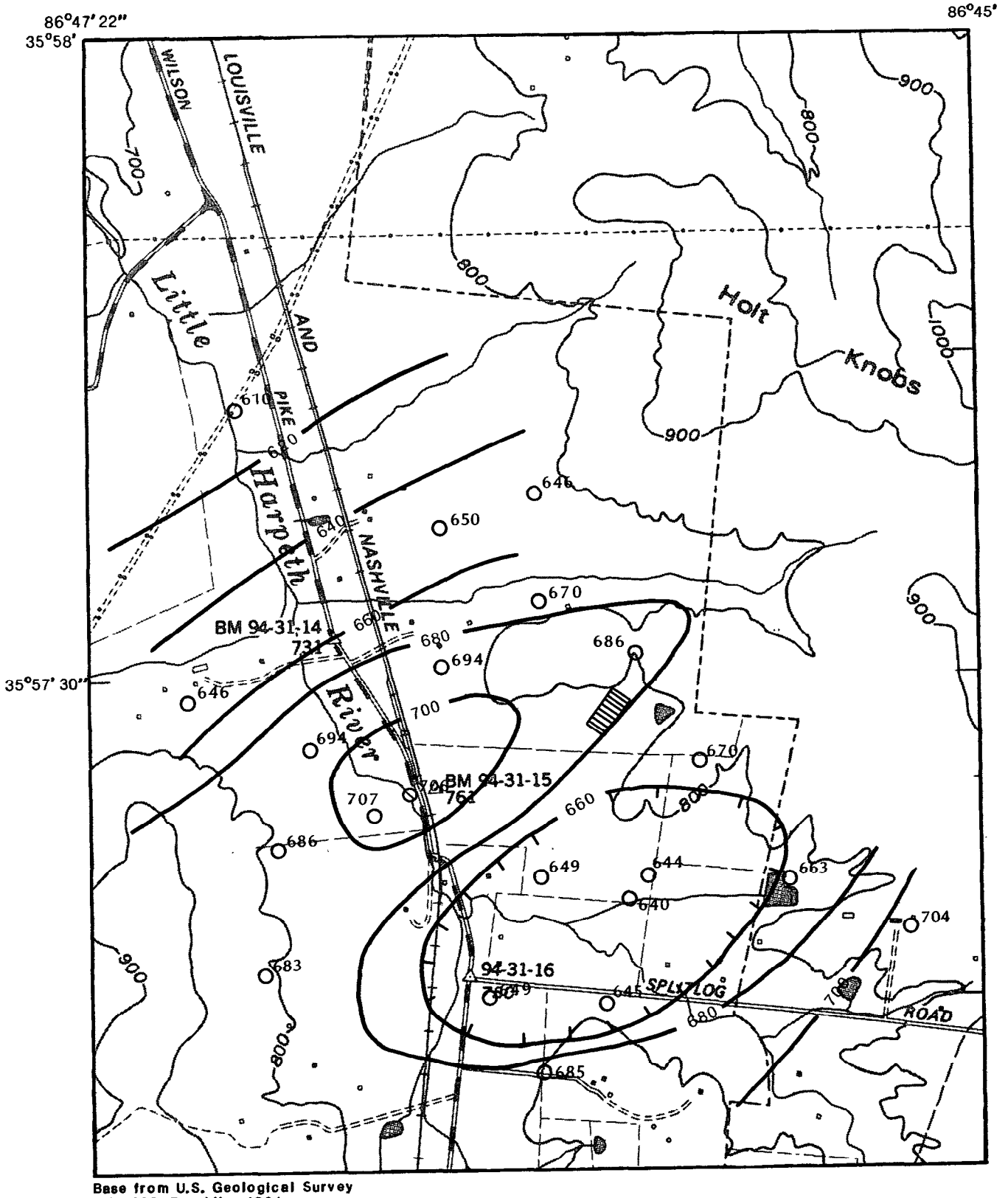


Figure 9.--Structure of the top of the Lebanon Limestone.



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

0 0.5 MILE

0 0.5 KILOMETER

CONTOUR INTERVAL 100 FEET
DATUM IS SEA LEVEL

EXPLANATION

DISPOSAL SITE

— 700 — STRUCTURE CONTOUR--Shows the altitude of the top of the T-3 bentonite bed. Contour interval 20 feet. Hachures indicate depression. Datum is sea level

O686 WELL LOCATION AND ALTITUDE OF THE T-3 BENTONITE BED

Figure 10.--Structure of the top of the T-3 bentonite bed of the Carters Limestone.

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