HYDROGEOLOGY OF THE GATLINBURG AREA, TENNESSEE

By Ann Zurawski

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FACTORS FOR CONVERTING INCH-POUND UNITS TO S.I. UNITS

Multiply Inch-pound Units	by	To obtain S.I. Units
ft (foot)	0.3408	m (meter)
ft^2/d (foot squared per day)	0.0929	m^2/d (meter squared per day)
gal/min (gallon per minute)	0.06309	L/s (liter per second
(gal/min)/ft (gallon per minute per foot)	0.2070	(L/s)/m (liter per second per meter)
$(gal/min)/mi^2$ (gallon per minute per square mile	0.02436	$(L/s)/km^2$ (liter per second per square kilometer)
in (inch)	25.40	mm (millimeter)
Mgal/d (million gallons per day)	3785	m^3/d (cubic meter per day)
$(Mgal/d)/mi^2$ (million gallons per day per square mile)	1461	$(m^3/d)/km^2$ (cubic meter per day per square kilometer)
mi (mile)	1.609	km (kilometer)

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ABSTRACT

A study of ground-water availability in the Gatlinburg area was undertaken to improve concepts of ground-water occurrence in the Blue Ridge and demonstrate that ground water is present in sufficient quantities to provide an alternative to surface water as a source of supply. Of 25 test wells, 8 produced between 50 and 116 gallons per minute.

The Gatlinburg area, located on the northern flank of the Great Smoky Mountains, is underlain by fractured, variably-metamorphosed, sedimentary rocks. The most effective criteria for choosing well sites were valley areas with 7 percent or less land slope, presence of fracture traces, and deep overburden. Mapped faults were not a good indicator of ground-water occurrence.

The largest amounts of ground water occur in irregularly shaped zones of deep and intense weathering in the rocks underlying broad, fracture-controlled valleys. Permeable zones along fractures at depths of 170 feet or less supply most of the water.

INTRODUCTION

Objective

This report concerns the geologic and hydrologic factors controlling the occurrence of productive aquifers in the fractured crystalline rocks of the Blue Ridge province, specifically, in the vicinity of Gatlinburg. It is based on field observations and data from 25 test wells, including five aquifer tests. The study was undertaken in April of 1978, in cooperation with the Tennessee Valley Authority, the Tennessee Division of Water Resources and the city of Gatlinburg. The objectives of the study were:

1. to test and refine concepts of ground-water occurrence in the fractured rocks of the Blue Ridge and criteria for selecting sites favorable for drilling high-yielding wells,

2. to identify the specific geologic and hydrologic controls on the occurrence of large ground-water supplies in the vicinity of Gatlinburg,

3. to demonstrate that ground water occurs in this area in sufficient quantities to be considered as a source of supplies as great as several hundred gallons per minute, and

4. to obtain high-quality well records in a part of the state for which ground-water records are inadequate for planning and water management purposes.

Previous Studies

The complex geology of the Gatlinburg area was mapped and described in a series of U.S. Geological Survey Professional Papers by Warren Hamilton (1961), Jarvis B. Hadley and Richard Goldsmith (1963), and Philip B. King (1964).

H. E. LeGrand (1967) developed a method for evaluating potential well-drilling sites in the Blue Ridge and Piedmont provinces of the Southeastern states based on factors controlling ground-water distribution. McMaster and Hubbard (1970) mapped areas of high potential for ground-water development in the Great Smoky Mountains National Park. They found from the results of test drilling that major valley locations in the vicinity of faults and in areas with thick overburden were favorable locations for wells. Tributary valleys had moderate potential, and ridges were the least favorable sites.

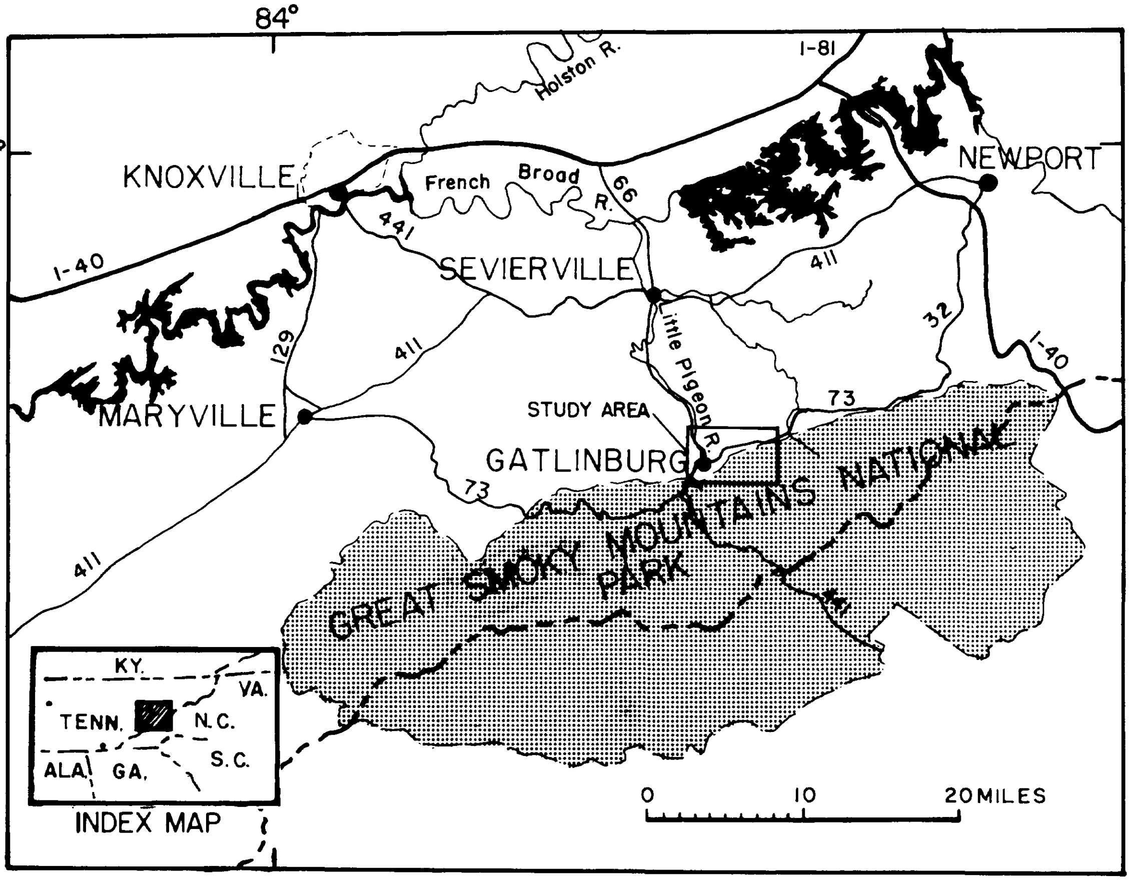


Figure 1.--Location of Gatlinburg, Tennessee.

DESCRIPTION OF THE STUDY AREA

Topographic Setting

The Gatlinburg area is located in the foothills of the Smoky Mountains (fig. 1). Topographic relief in the immediate vicinity of Gatlinburg is as much as 1000 ft, although maximum regional relief exceeds 5000 ft. Because of the ruggedness of the terrain, most of the developable land is confined to the valley bottoms. The city lies in the flat-bottomed valley of the West Prong Little Pigeon River and its tributaries Le Conte Creek, Roaring Fork and Dudley Creek. Downstream from Gatlinburg the river valley is sharply constricted between high ridges.

Geology

The Gatlinburg area is underlain by Precambrian sedimentary rocks which have been very slightly to moderately metamorphosed. The most extensively exposed formations are the Roaring Fork Sandstone and the overlying Pigeon Siltstone (fig. 2). King (1964) describes the Roaring Fork Sandstone as fine-grained gray or blue-gray sandstone, interbedded with dull greenish siltstone and phyllitic clayey rocks. The main part of the Pigeon Siltsone is a dull blue-green laminated siltstone.

Overlying the Pigeon Siltstone are the Rich Butt Sandstone, the Elkmont Sandstone and the Thunderhead Sandstone. Except for a small area near the junction of the Gatlinburg bypass and U.S. Highway 441 on the north end of town all major valleys are underlain by Pigeon Siltstone or Roaring Fork Sandstone. These two formations are the only significant aquifers in the area, not because of their lithology but because of their topographic situation.

Where the bedrock is not exposed at land surface, it is covered by a layer of weathered rock and soil overburden. The thickness of the overburden varies from a few feet to more than 100 ft. A veneer of alluvium, or stream-transported material, ranging from boulders to fine sand and clay covers the bottom of major valleys (fig. 2).

Faults are a major control not only on the sequence of rock units but also on the topography. The eastern segment of the Gatlinburg Fault (fig. 2) is marked by a chain of deep depressions in the foothills. The fault itself appears as a zone of severely crushed and fractured rock such as a 75-ft wide zone observed in Gatlinburg by King (1964). Numerous lesser faults and fractures crisscross the area. Line segments formed by such features as aligned valleys, notches in ridges, and straight reaches of streams can be observed on aerial photography (fig. 3). They are thought to be the surface manifestation of almost vertical zones of fracture concentration (Parizek and Drew, 1966). These natural linear features are called fracture traces when less than 1 mi long and lineaments when they extend a greater distance (Lattman, 1958).

Climate

Gatlinburg has a warm, humid climate (fig. 4). Mean monthly temperatures range from 38° to 75° F. The average annual precipitation is about 56 inches in Gatlinburg itself, increasing with altitude to about 80 inches on the higher mountain slopes (TVA, 1975). There is a relatively dry period in September and October when precipitation averages about 3 inches per month. Precipitation increases through the winter to a spring peak in March. Another period of high precipitation occurs in midsummer, as a result of thunderstorms. Over half of the annual precipitation is returned to the atmosphere by evaporation and by transpiration of plants. This is illustrated by comparing the mean monthly runoff curve and the precipitation distribution curve. For most of the year, runoff is roughly proportional to precipitation. However, the runoff for June, July, and August is significantly less than expected because of the high evapotranspiration rate at that time of year.

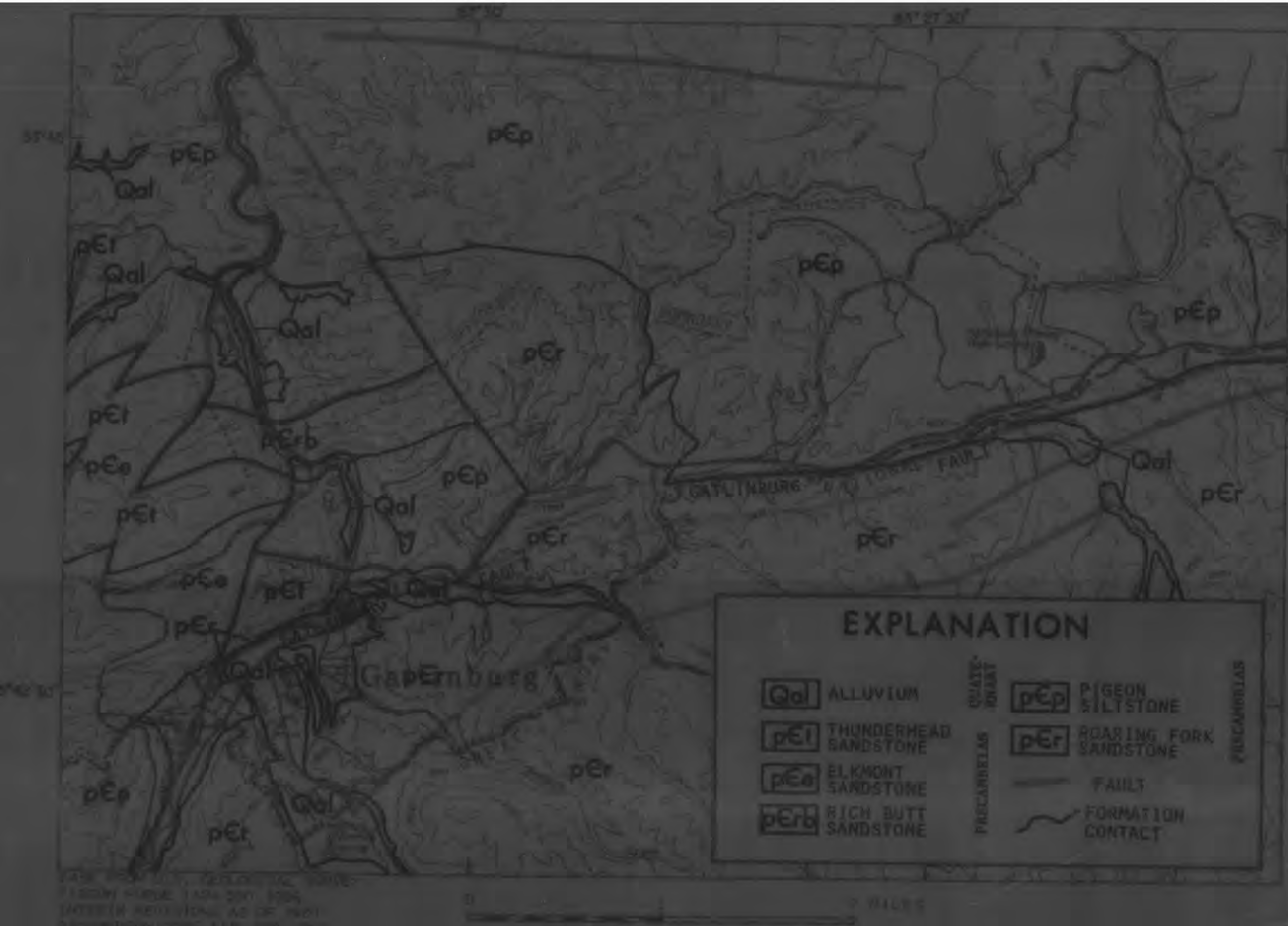


Figure 2.--Geology of Gatlinburg area. The area is underlain by metamorphosed sedimentary rocks. Geology modified from Hadley and Goldsmith (1963), Hamilton (1961), and King (1964)

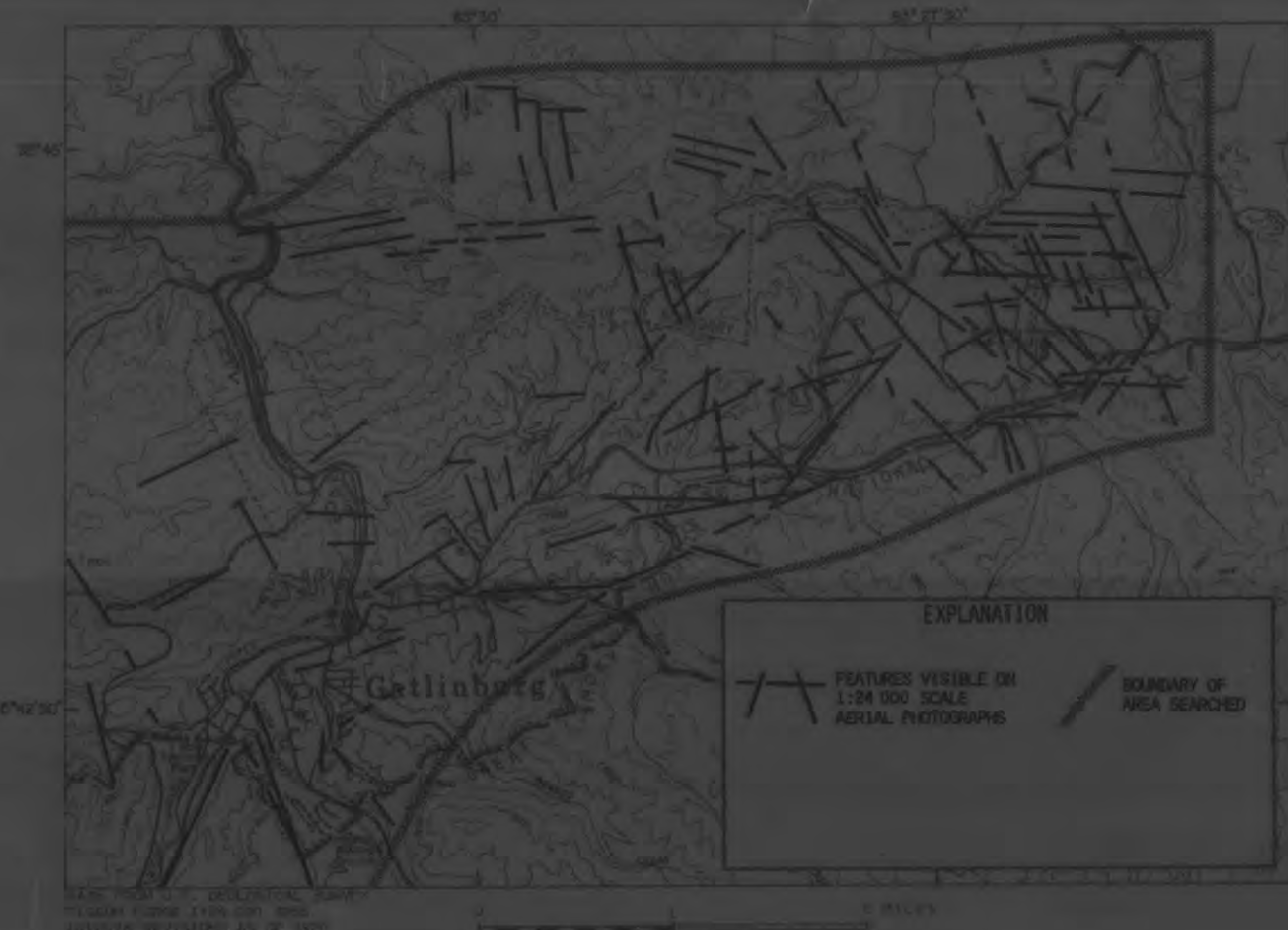


Figure 3.--Linear features and fracture traces in the Gatlinburg area. The line segments within the area outlined represent features visible on 1:24,000 scale aerial photographs. These features are thought to be the topographic expression of joints and fractures in the bedrock.

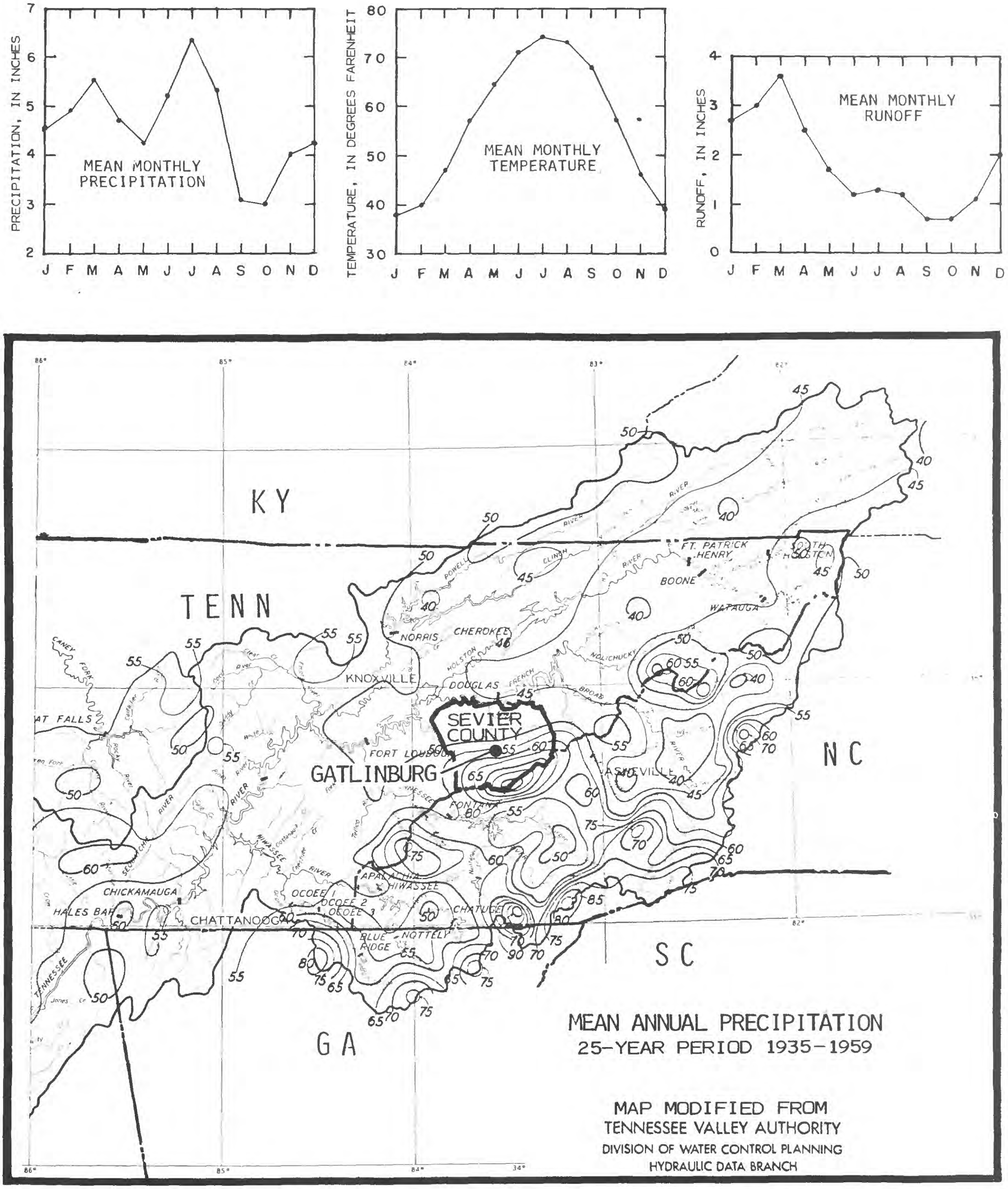


Figure 4.--Mean monthly precipitation, temperature and runoff at Gatlinburg, and mean annual precipitation for eastern Tennessee and adjacent states. Gatlinburg has a mild, humid climate with an average annual precipitation of about 56 inches.

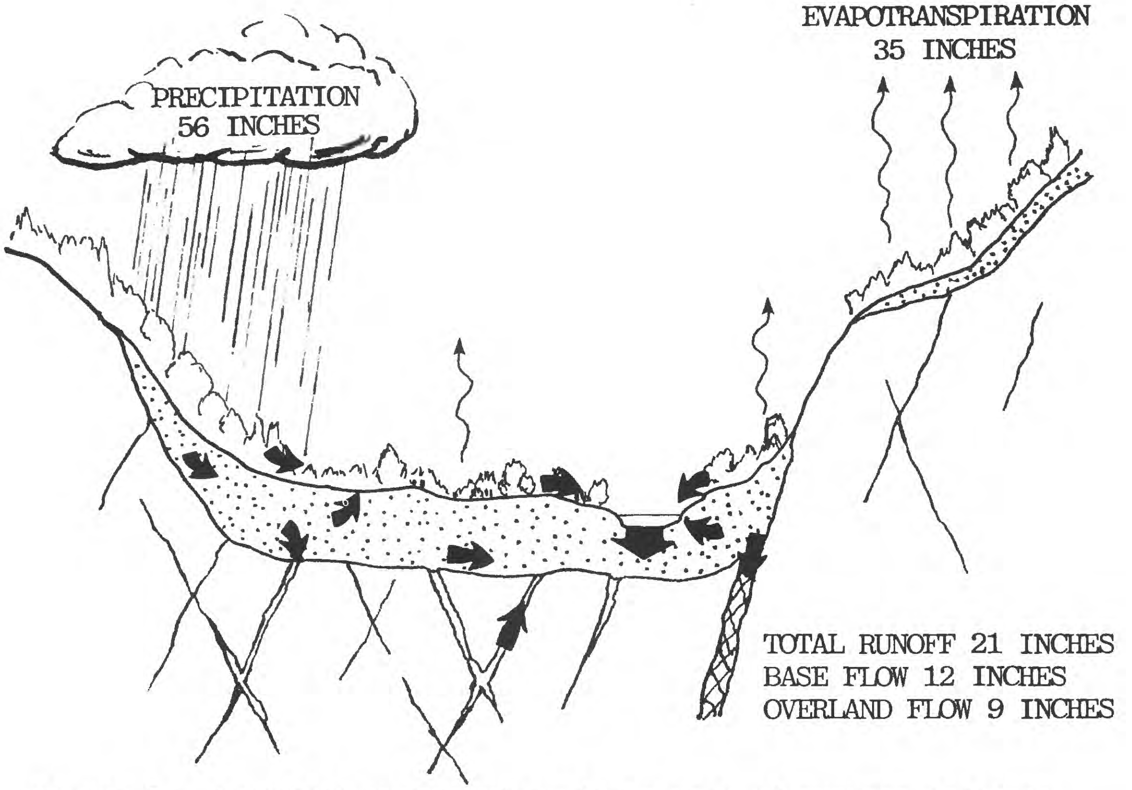


Figure 5.--A typical water budget for a year of average rainfall, derived from precipitation and streamflow records. These values are from records for the Little Pigeon River at Sevierville for 1968, a year of average runoff.

Runoff is composed of two parts - overland flow and base flow. Overland flow (or storm runoff) leaves a drainage basin within days after the precipitation occurs but the continuing flow or base flow of the stream is derived from the storage in ground-water reservoirs.

Precipitation is the source of recharge to the ground-water system. Ground-water levels rise during the winter and spring rainy seasons. Very little of the water from the summer thunderstorms ever reaches the subsurface reservoirs. The excess water built up during the recharge season is discharged to streams, sustaining their flow through dry periods. Thus, the base flow of streams is an indication of the amount of water circulating annually through the ground-water system. It is approximately equal to the average annual recharge.

A representative water budget for the part of the Little Pigeon River basin above Sevierville is shown in figure 5. Average precipitation for the basin as a whole is 56 inches per year. Total runoff at the gage at Sevierville for 1968 was 21 inches, a figure very close to the long-term average discharge of 22 inches for that station. Assuming 1968 to be an average year, the difference between the precipitation and runoff, 35 inches, is an approximate measure of the evapotranspiration. The estimated average annual base flow of 12 inches is equivalent to a recharge rate of 400 (gal/min)/mi^2, or just over 0.5 (Mgal/d)/mi^2.

HYDROGEOLOGY

Rock Weathering

The process of rock weathering is intimately related to the occurrence of ground water in the Gatlinburg area. The weathering occurs where fractures in the bedrock admit ground water. The solution of some minerals such as sulfides and the breakdown of metamorphic minerals gradually increase the size and permeability of the fractures, and hence the porosity of the host rock, accelerating the weathering process. Fractures having vertical dimensions of several feet were penetrated during test drilling.

For the purpose of discussing ground water in the Gatlinburg area, it is more relevant to describe earth materials in terms of the degree to which they are weathered rather than formation name and lithology of the parent rock. Four stages of weathering can be distinguished in what is actually a gradational process.

1. Unweathered rock, in the areas tested, is dark gray or greenish gray, typically laminated and containing preferentially oriented mica particles. Although fractures are present in the unweathered rock, they are tightly sealed and not water bearing.

2. Slightly weathered rock is similar in color but fractures and cleavage planes are dark reddish brown from oxidation of iron and manganese minerals. It usually appears duller than the unweathered material. This slight weathering indicates some exposure to ground water.

3. Fully weathered rock is light brown, rather soft, silty to sandy in texture, clay rich and stained red, orange, and black along cleavage planes. Most of the enlarged, water-bearing fractures occur in the weathered rock. This material differs from the overburden in that it is still indurated to some degree.

4. The overburden is similar to the weathered rock but considerably softer and friable. It is composed of clay and other insoluble residues from the parent rock. Although most of the overburden is formed in place, in some places the uppermost part consists of material carried in by streams or by downslope movement.

A hypothetical cross section (fig. 6) illustrates the variation in depth of weathering from place to place. There are two typical sequences of materials underlying the valleys around Gatlinburg. For example, some wells, such as well B in figure 6, penetrate a layer of unsaturated overburden, several feet to a few tens of feet thick, a zone of fully weathered rock and then abruptly, unweathered rock. This sequence is typical of low-yielding sites. In some cases, the overburden rests directly on unweathered rock. In areas where ground-water circulation has been more active, such as the site of the high-yielding well A, the overburden and weathered rock are apt to be much thicker. In addition, there is commonly a transition zone where sequences of slightly weathered or unweathered rock are interrupted by fully weathered intervals above and below fractures.

Ground-Water Occurrence

Well yields are largely determined by the number, size and degree of interconnection of the openings encountered in the rocks (McMaster and Hubbard, 1970). Most of the water-bearing fractures penetrated by test wells were in the weathered rock. Generally, fractures in the unweathered rock did not produce water. This suggests that, in their unweathered state, the fractured rocks are nearly impermeable and that some type of chemical activity is required to enlarge the fractures to the point where they will freely transmit water. The greatest water-yielding potential exists, therefore, in places where the rock is highly fractured and the fully-weathered zone extends to considerable depth, as at the site of well A in figure 6.

Another factor in determining well yields is the thickness of saturated overburden overlying the bedrock. Water that percolates downward through the unsaturated zone is stored in the overburden and slowly released. Because the fractures occupy such a small part of the bedrock volume, their storage capacity is limited. However, they act as collectors and transmitters of water stored in the porous overburden.

In the Gatlinburg area, ground-water circulation patterns are localized rather than regional in extent (LeGrand, 1967). Recharge is areally distributed, and discharge areas are springs and major streams. The average water level in the valleys away from the streams is about 20 ft below land surface.

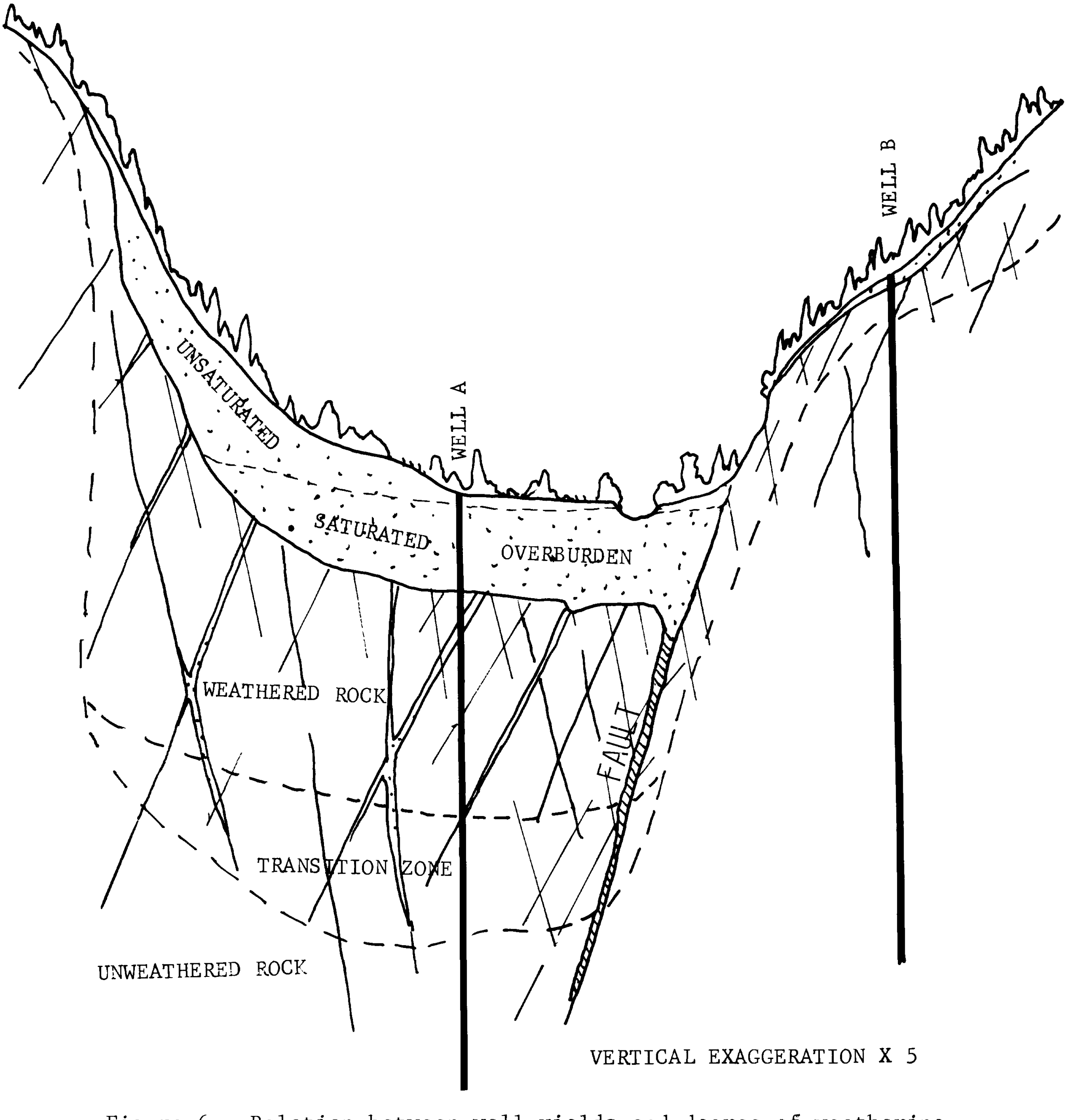


Figure 6.--Relation between well yields and degree of weathering. Well yields are highest at sites with a thick layer of overburden, considerable depth of weathering and abundant fractures, such as the site of well A. Well B would have a low yield. Fractures are present in the unweathered rock but are commonly so tightly closed that they do not contribute significantly to the permeability of the rock.

RESULTS OF TEST DRILLING

Drilling Site Selection

Based on the foregoing concept of ground-water occurrence, certain factors were thought to indicate sites with a greater probability of yielding a sizeable ground-water supply. These factors were as follows:

1. Wells at sites on or near a mapped fault would produce water from the fault itself or the highly fractured rock nearby.

2. At sites on or near a fracture trace or linear feature, especially at the intersection of such features, one would have more chance of drilling through a fracture and of encountering greater depth of weathering than in intervening areas.

3. Sites in topographically low valley areas with gentle land slopes are likely to be in or near ground-water discharge areas and have greater saturated thickness of aquifer material. In addition, the ground-water circulation system is most highly developed in these areas. Unusually broad flat valleys tend to develop where fracturing is pronounced.

4. Areas known to have deep overburden would be apt to have greater depth of weathering and greater water-storage capacity than areas with shallow bedrock.

5. Sites on talus fans deposited by streams draining Mount Le Conte might have considerable depth of alluvial material which would enhance the water-bearing properties of the site.

Some of these criteria were modified during the course of the test drilling. The initial thrust of the drilling was to test sites along the Gatlinburg Fault. Later drilling tested flat-bottomed valleys and fracture traces. The talus fan criterion (factor 5) was developed after the drilling of several successful wells in such an area.

Test Drilling

Between April 10 and June 20, 1978, 24 test wells were drilled by a water-well contractor under the supervision of Tennessee Valley Authority and U.S. Geological Survey personnel. In addition, an old well at Holston Assembly Grounds was cleaned out for testing. The wells are numbered 1 through 25 in the order they were drilled with the old well as number 25. Because well 20 was abandoned after drilling 80 feet, its yield is unknown.

The 6-1/4 inch-diameter test holes were drilled using air rotary rigs and cased with 6-1/2-inch-inside-diameter steel pipe set into bedrock. Representative samples of the rock cuttings were collected from each well to supplement the geologist's log. Various geophysical logs for 18 of the wells are presented as supplemental data following this report. Seven of the wells were backfilled upon completion.

Nine of the test wells are located in downtown Gatlinburg. The others are spread out along State Highway 73 on the east side of town, with a cluster in the vicinity of Gatlinburg-Pittman High School (figure 7). The sites chosen meet one or more of the criteria described in the previous section and were also on land either owned by the city or accessible through agreement with the land owner. The area near the high school is adjacent to a part of the national park mapped by McMaster and Hubbard (1970) as an area of high ground-water favorability.

Well discharges measured during drilling ranged from 3 to 116 gal/min (table 1). Of the 23 completed test wells, 8 produced 50 gal/min or more.

The wells range in depth from 80 to 300 feet; (the 80-foot well could not be completed due to difficulties unrelated to the drilling). All but seven of the wells were 200 to 250 feet deep, but all the major water-bearing openings were less than 170 ft below land surface. The major water-bearing zones in the wells that produced 50 gal/min or more were between 76 and 170 ft below land surface.

The water-bearing openings are fractures of various sizes and orientations. Some are only a fraction of an inch high whereas others are enlarged to as much as several feet. The enlarged fractures are usually within the weathered rock zone. Most of the fractures are rather steeply inclined at angles between 40° and 80°. The direction of dip is generally easterly (fig. 8). Results of this study indicate that hydraulic connection between nearby wells is the rule; in addition, the major water-bearing zones in nearby wells commonly occur in the same 50-ft depth interval. This occurs although most of the fractures dip so steeply that wells even as little as a hundred feet apart must be aligned along the strike of the fracture plane in order for both wells to tap the same fracture. Given an extensive network of fractures, it appears that as the weathering process proceeds, certain fracture connections are preferentially enlarged as a result of the movement of ground water in directions determined by the hydraulic gradient.

Table 1.-- Record of test wells, Gatlinburg, Tennessee.

Well No.	Location	Altitude (ft)	Depth of well (ft)	Overburden depth (ft)	Depth to water-bearing zones (ft)	Yield (blowing with drill rig) (gal/min)	Remarks
1	City fire station, Newman Lane	1360	200	14	35, 67	20	---
2	Sewage lift station, U.S. 73	1440	200	16	16	5	Destroyed
3	Amoco service station, U.S. 73	1330	200	10	10	3	Destroyed
4	Reagan property, 200 ft south of well 2	1440	100	18	18	5	---
5	City waterworks	1325	230	52	90, 115-200	70	Pumped 7 hr; maximum rate 80 gal/min
6	City Hall parking lot	1360	255	70	91, 115, 198, 230	50	Pumped 7 hr; maximum rate 60 gal/min
7	Ski lift property	1310	200	50	50	20	Destroyed
8	River Road	1300	200	35	40, 55	25	Destroyed
9	City parking lot, Reagan Drive	1380	230	56	106, 108, 122, 144, 148	60	Pumped 8 hr; maximum rate 60 gal/min
10	City parking lot, Bishop Lane	1320	200	26	78, 140	30	Destroyed
11	City parking lot, 200 ft north of well 9	1380	300	67	76, 169, 280	50	---
12	Mynatt Park, at lift station	1460	207	18	35, 160	18	---
13	Mynatt Park, at tennis courts	1490	228	60	90, 159	23	---
14	Mills Park	1615	250	129	55, 146, 167	14	---
15	Glades Road and U.S. 73	1475	205	16	45, 60, 65	10	---
16	U.S. 73 across from Proffitt Road	1650	270	65	120, 155, 165	20	---
17	Hunter Hills Theater parking lot	1680	255	43	75, 120, 150, 227	50	---
18	Hunter Hills Theater parking lot, 100 ft north of well 17	1685	230	48	94, 120, 148	97	Pumped 8 hr; maximum rate 68 gal/min
19	Fire service station, Newman Lane	1360	155	10	37, 55	18	Destroyed
20	Proffitt Road and U.S. 73	1670	80	70	Unknown	Unknown	Destroyed
21	Trout Creek campground, U.S. 73	1540	205	35	55, 67, 86	25	---
22	Proffitt property near Mills Park	1660	230	82	105	10	---
23	Proffitt property about 500 ft north of well 22	1620	212	79	99, 118, 120	116	Pumped 8 hr; maximum rate 67 gal/min
24	Proffitt property, about 300 ft east of well 23	1610	230	64	90, 120, 165, 185	60	---
25	Holston Assembly Grounds well	1570	200	?	90, 99, 102	Unknown	Well drilled in 1930's, abandoned; pumped 7½ hr at 20 gal/min.

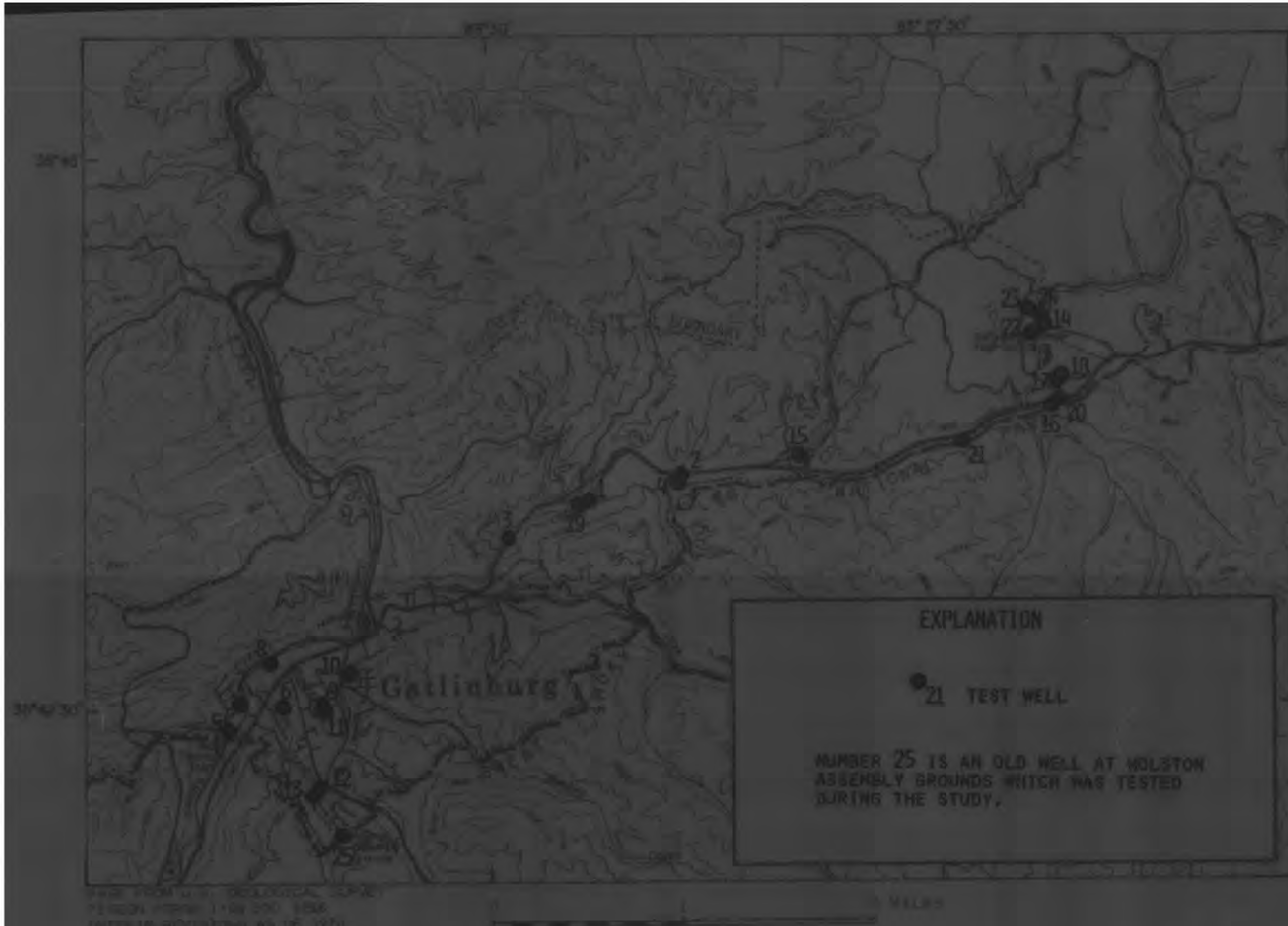


Figure 7.--Location of test wells in the Gatlinburg area.

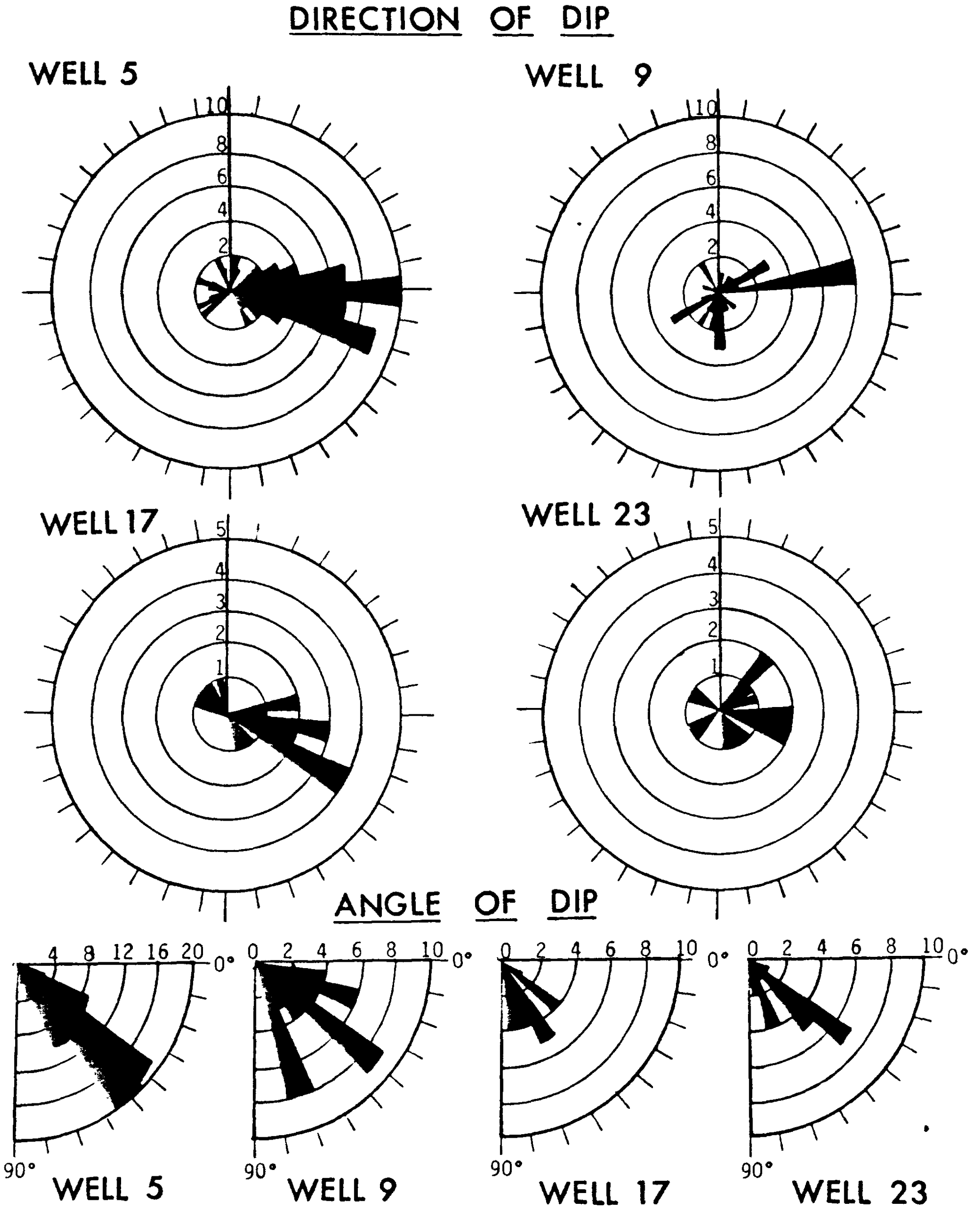


Figure 8.--Angle and direction of dip of fractures in four test wells. The fractures dip predominantly toward the east at angles between 20 and 70 degrees. Circumferential scales show the compass direction of dip or the angle in degrees below horizontal. Radial scales show number of fractures in each 10 degree interval. For example, in well 9, eight fractures are dipping in a compass direction between N75°E and N85°E; nine fractures dip at an angle between 35° and 45° below horizontal. Data on the orientation of the fractures was obtained from acoustic televiewer logs of the wells.

In the resulting system a water-bearing zone is not areally restricted to a particular fracture but occurs at a particular level in the network through interconnection of multiple fractures.

Four high-yielding wells are in the Gatlinburg-Pittman High School area (fig. 9). Wells 17 and 18 are closely spaced wells in the parking lot of Hunter Hills Theater. They produced 50 and 95 gal/min, respectively, while the wells were blown with compressed air from the drilling rig. Well 23, which produced 116 gal/min (measured while drilling), and well 24, which produced 60 gal/min, are in a small valley transverse to the axis of the large open valley in which the high school is located. Nearby wells 14 and 22 produced less than 20 gal/min. The wells in this area penetrated at least 40 feet of overburden and weathered zones extending from 144 to over 200 feet below land surface. A block diagram through the northern cluster of wells illustrates the abundance of fractures in the higher yielding wells (fig. 10).

Four wells in downtown Gatlinburg produced 50 gal/min or more during drilling (fig. 11). Well 5 is located at the city water plant, about 30 ft from the river. It produced 70 gal/min during drilling and is the best of the downtown wells. Well 6, in the parking lot of City Hall, produced 50 gal/min. Well 9, on Reagan Drive, produced 60 gal/min, and nearby well 11 produced 50 gal/min. Wells 6, 9, and 11 are all located in the foot of the Le Conte Creek talus fan, and all four of the wells are in the broad-flat valley formed by the junction of Le Conte Creek and Baskins Creek with the West Prong Little Pigeon River. Le Conte Creek valley is characterized by rather deep overburden, as shown by the cross sections (figs. 12 and 13).

Six wells in the Gatlinburg area were tested to evaluate well yields and boundary conditions which would affect well performance. Each well was pumped with a submersible pump for 7 to 8 hours at two or more pumping rates. During these tests water-level measurements were made in the pumped well and any nearby observation wells that were available. These data gave information on the performance of the well and the response of the ground-water system to the stress of pumping. Table 2 summarizes the conditions and results of these tests. Specific capacities ranged from 0.54 to 2.1 (gal/min)/ft.

Hydrologic characteristics of aquifers in the Gatlinburg area are in violation of many of the assumptions of aquifer-test analysis. Insofar as these tests can be analyzed, they indicate that the aquifers are unconfined with transmissivities estimated to range from less than 100 ft^2/d to as much as 800 ft^2/d. Storage is highly variable. At the only site with multiple observation wells (test of well 23), water-level elevations and drawdown indicated water movement along a fracture. Recharging boundaries, probably nearby streams, are significant in the downtown area. No-flow boundaries are expected to be evident after longer periods of pumping at the Gatlinburg-Pittman High School area, which is enclosed by high hills. A full discussion of the tests is in the supplementary data following this report (pages 38 through 46).

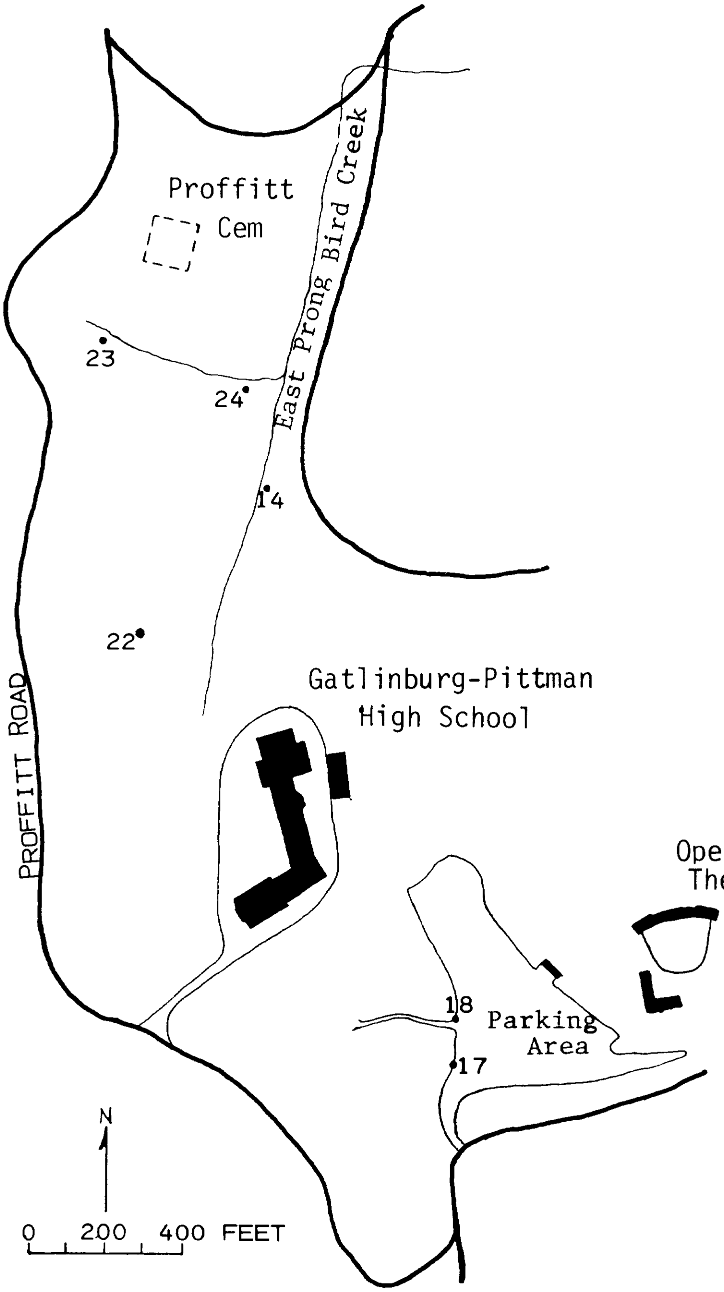


Figure 9.--Location of test wells in the Gatlinburg-Pittman High School area, on the east side of Gatlinburg. Wells 17, 18, 23, and 24 produced over 50 gal/min; wells 14 and 22 produced less than 20 gal/min.

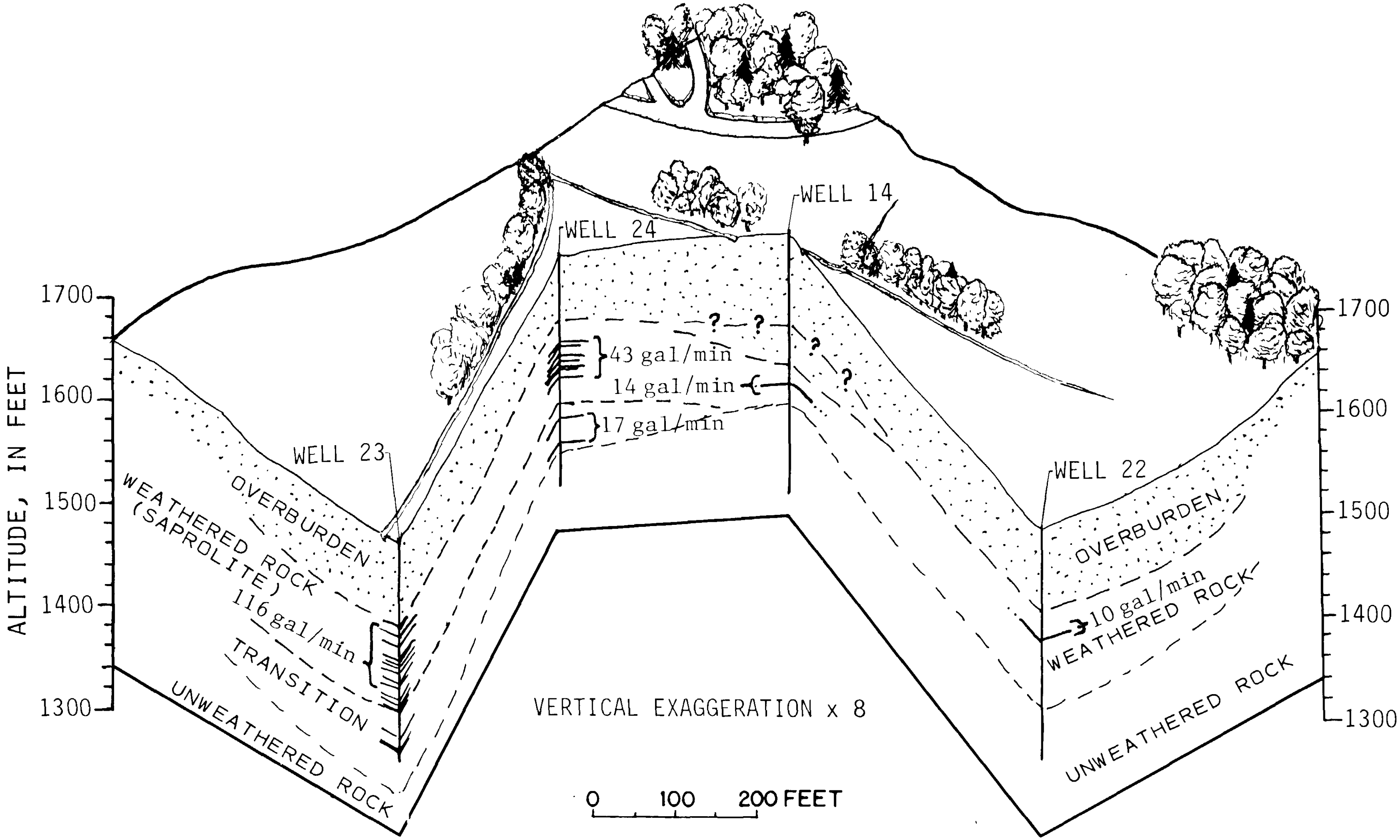


Figure 10.--Depth of weathering and fracture density in the Gatlinburg-Pittman High School area. The higher-yielding wells are characterized by abundant fractures and great depth of weathering. The transition from weathered to unweathered bedrock is gradual, as opposed to abrupt transition in the lower-yielding wells.

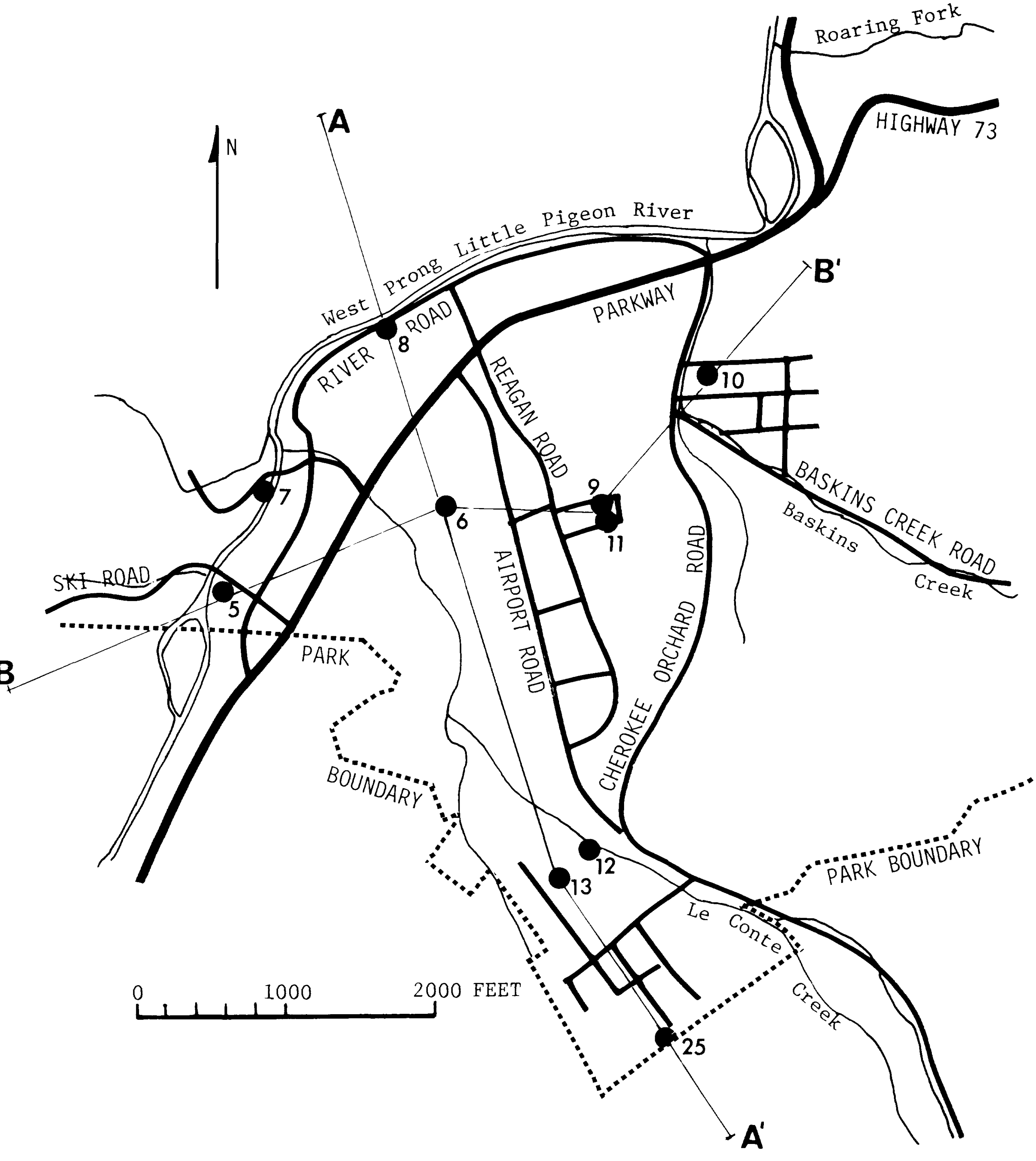


Figure 11.--Location of nine test wells and one preexisting well in downtown Gatlinburg. Le Conte Creek and Baskins Creek flow into the West Prong Little Pigeon River forming a wide valley in which the city is located. A-A' and B-B' are cross section lines.

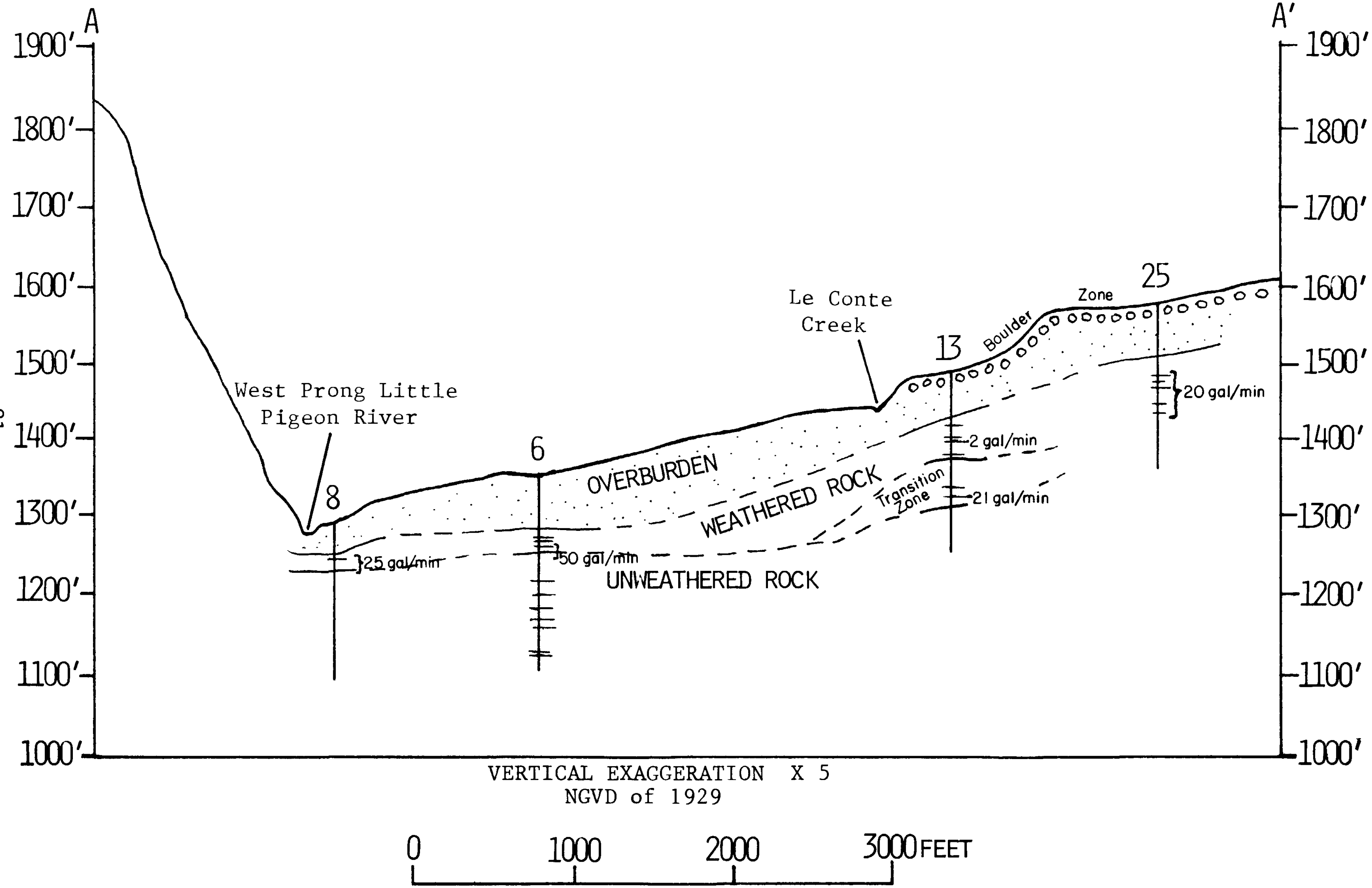


Figure 12.--Cross section A-A' down Le Conte Creek valley, showing deep overburden and the thin veneer of boulders which typifies the talus fan of Le Conte Creek valley.

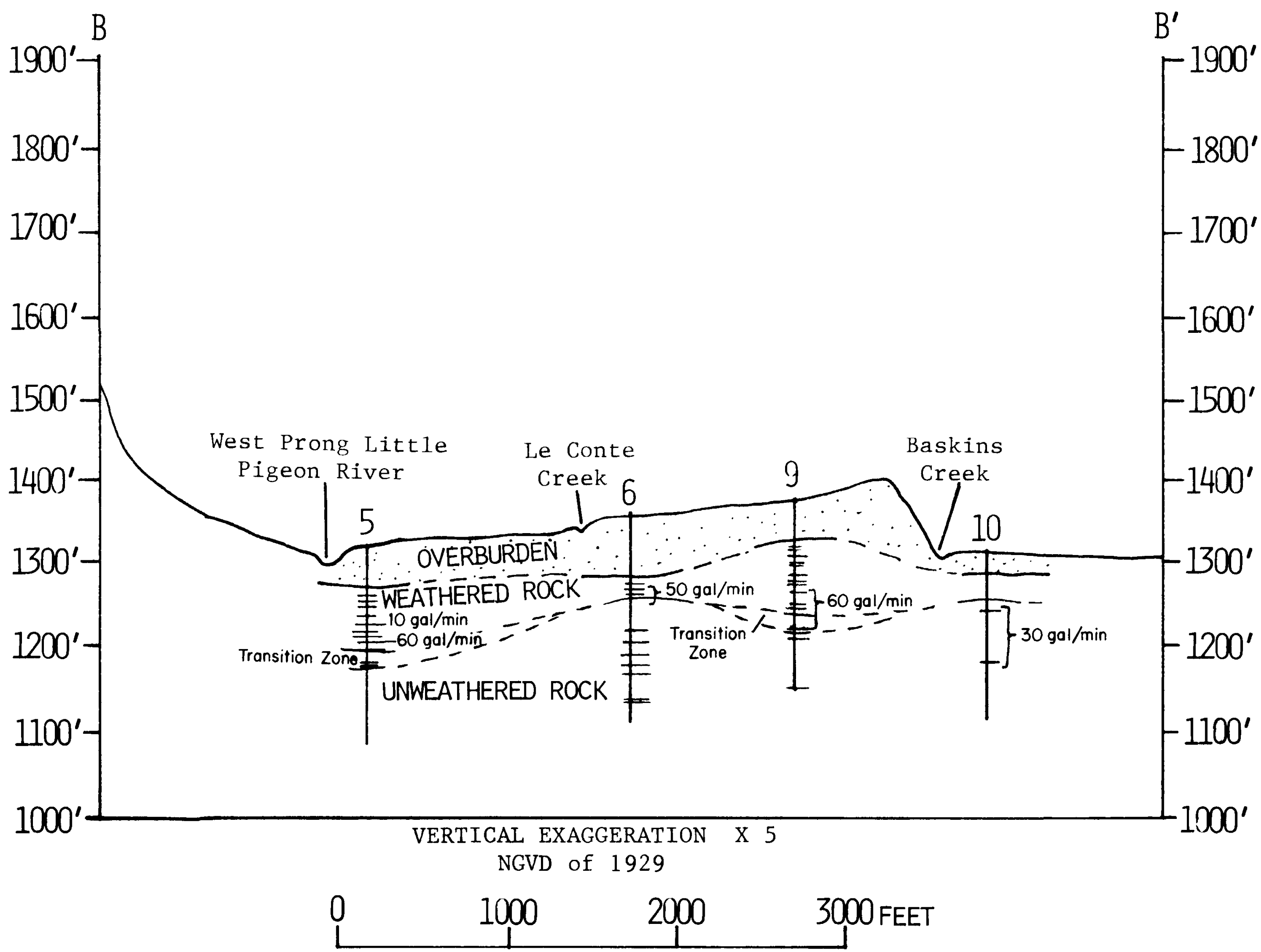


Figure 13.--Cross section B-B' showing depth of weathering, fractures, and water-bearing zones. The depth of weathering is considerably greater in wells 5 and 9 than in 6 or 10.

Table 2.--Summary of aquifer test conditions and specific capacities.

Well no.	Date tested	Prepumping water level (feet below land surface)	Water-bearing zones: Depth (feet)	Water-bearing zones: Yield (percent)	Pumping rate (gallons per minute)	Duration (hours)	Drawdown at end of step (feet)	Specific capacity[1] (gallons per minute per foot)
5	5-5-78	15	90	14	20	0.5	11.1	1.8
			115-120	86	40	0.5	25.7	1.2
					56	1.0	45.5	0.95
					80	5.0	74.8	0.92
6	5-6-78	36	91	100	20	0.5	16.7	1.2
			115		40	0.5	55.4	0.54
			198	less than 1 percent	60	6.0	92.8	0.60
			230					
9	5-4-78	18	106		20	0.5	10.1	2.0
			108		35	0.5	25.0	1.1
			122	100	57	7.0	97.9	0.54
			144					
			148					
25	6-22-78	38	90		20	7.5	100+	--
			98	100				
			102					
18	6-21-78	23.0	94	53	36	3	7.5	4.8
			120	40	67	5	20.1	2.1
			148	7				
23	6-23-78	[2]+0.3	99	26	36	4	22.0	1.6
			118	74	67	4	46.0	1.1

[1]Calculated as actual volume pumped ÷ pumping period ÷ total drawdown.
[2]Above land surface.

Evaluation of Site-Selection Criteria

McMaster and Hubbard (1970) found that in the Great Smoky Mountains National Park, the chances of obtaining large well yields are best near faults, but large openings do not occur near all faults and good well yields can be obtained where there are no faults. In the Gatlinburg area eight test wells produced 50 gal/min or more and only one was located on a mapped fault. Of the 25 test wells, 8 were drilled within 200 feet of a mapped fault (fig. 14). Three of these are believed to penetrate the fault. Only well 5 produced more than 50 gal/min; five wells produced less than 20 gal/min. Results of this study indicate that although there is a patent relationship between faults and topography, the presence of faults is not a useful criterion for choosing drilling sites in Gatlinburg.

Linear features played an important role in the selection of sites for wells 14 through 24. Many of these features were observed in the field or on topographic maps. Well locations and fracture traces observed on areal photography are shown in figure 15.

A total of 16 test wells are within 500 ft of a fracture trace. However, most of these could not be considered to lie exactly on fracture traces. Five of the wells associated with fracture traces produced 50 gal/min or more and nine produced less than 20 gal/min.

It is significant that the four highest yielding wells are not only very close to fracture traces but they are also at fracture-trace intersections. There are only five wells within 500 ft of a fracture-trace intersection including these four. Based on this sample, the presence of an intersection at a site is a more powerful criterion than the presence of a single trace. Fracture-trace intersections are probably most useful when considered in combination with other criteria.

McMaster and Hubbard (1970) noted that the potential for developing large yields is greater in broad valley floors and gentle valley slopes than other areas. In the Gatlinburg area, the slope of the land is a good index to topographic position because the highland areas characteristically have very steep slopes and only valley floors are relatively flat. Land slope can be measured approximately on a topographic map. The ratio of the contour interval to the horizontal distance between two contour lines is expressed as a percentage using this formula:

$$\frac{\text{Vertical rise}}{\text{Horizontal distance}} \times 100 = \text{percent slope.}$$

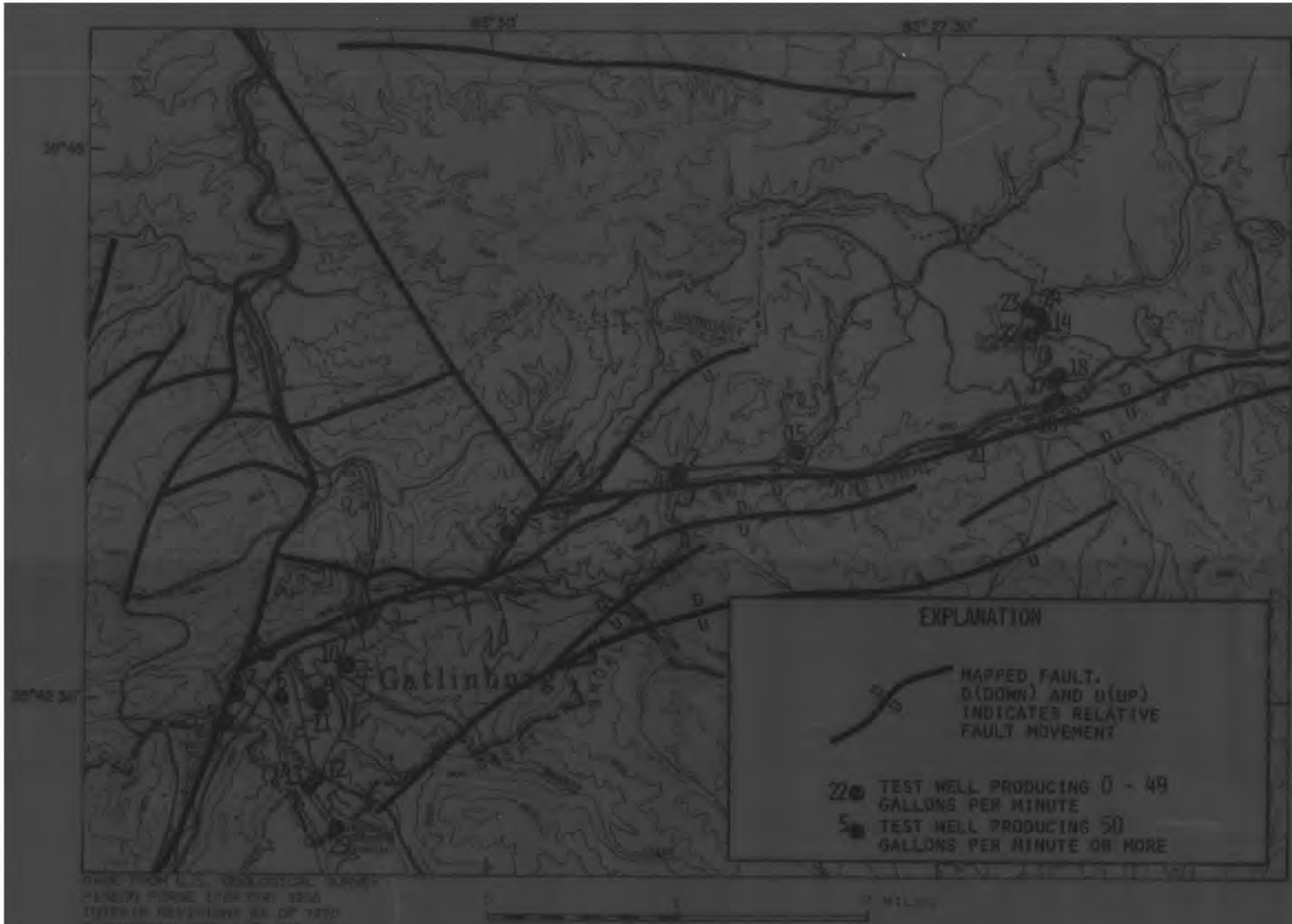


Figure 14.--Relation between well yield and faults. More than 40 percent of the test wells were drilled on or near a mapped fault. Only one of these produced 50 gallons per minute.

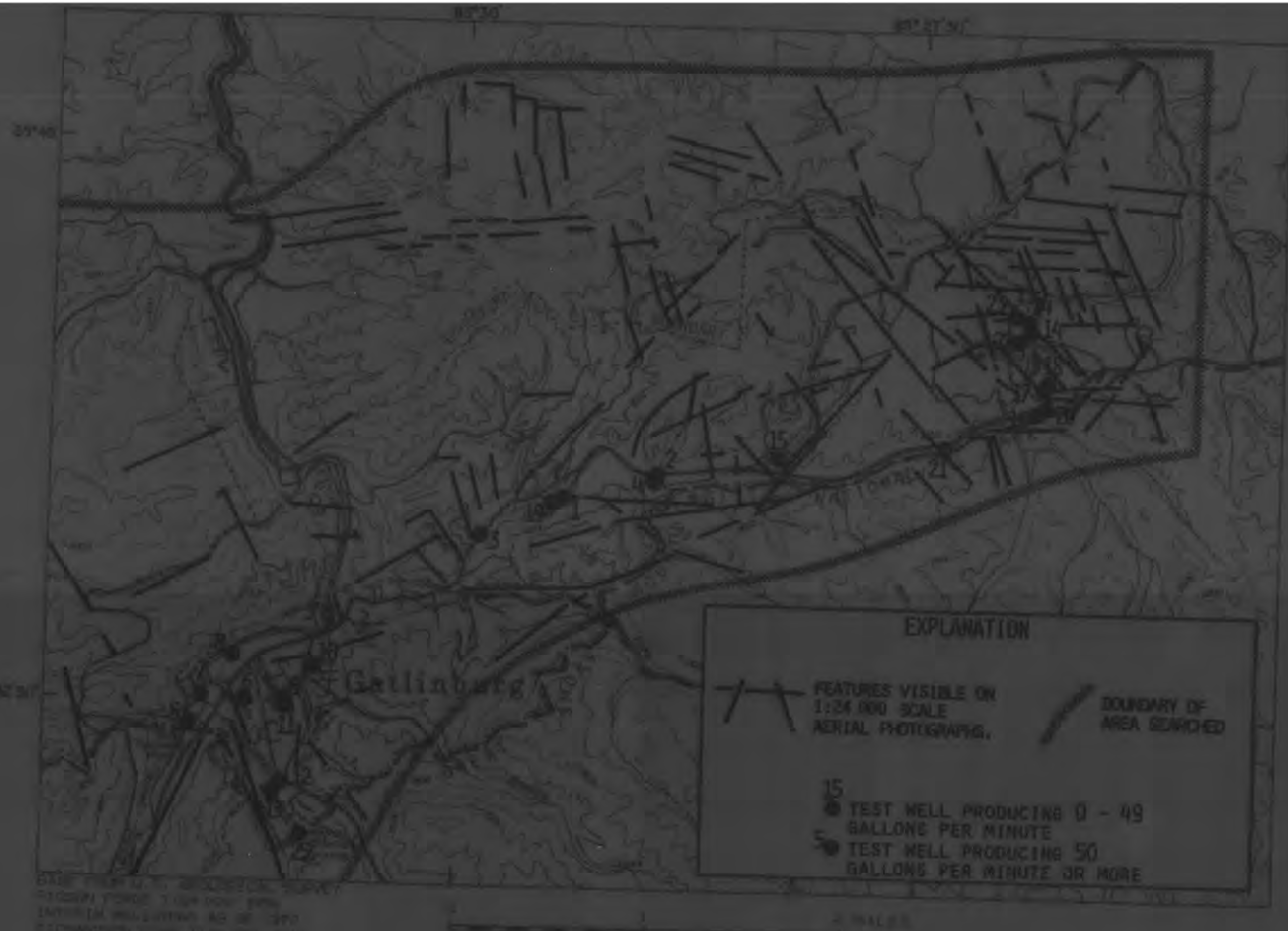


Figure 15.—Relation between well yield and fracture traces. Wells near fracture traces did not produce significantly more than those away from fracture traces. However, five wells were within 500 ft of a fracture trace intersection. Four of them produced 50 gallons per minute or more.

Thirteen test wells are in the areas of 7 percent or less slope (fig. 16). All eight wells that produced 50 gal/min or more are in this group, but only three wells that produced 20 gal/min or less are included. The other test wells are located at sites with 8- to 20-percent slope. Not including well 20, which was not completed, 82 percent of the wells in areas with greater than 7 percent slope produced 20 gal/min or less, none produced as much as 50 gal/min.

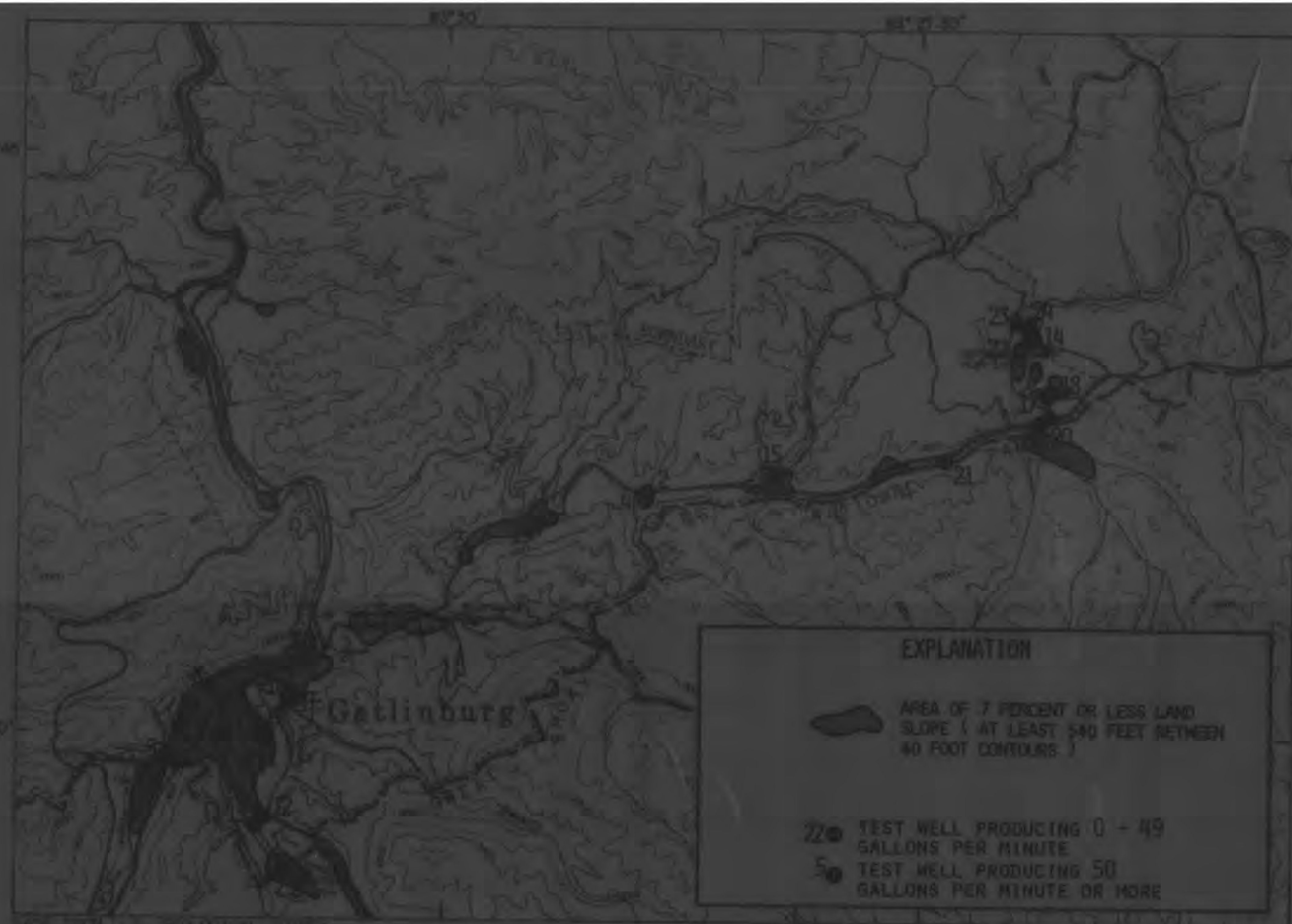
The major talus fans in the Gatlinburg area are shown on figure 17. They are composed of material transported from Mount Le Conte by Le Conte Creek, Roaring Fork and the upper reaches of Dudley Creek. Wells 6, 9, and 11, that produced 50 gal/min or more (measured during drilling), are located in the foot of the Le Conte Creek fan where it spreads into the Little Pigeon River valley. However, two wells drilled farther up the fan and well 25 at Holston Assembly Grounds yield less than 25 gal/min. Alluvial material is thin in this part of the fan. The association of high-yielding wells with the lower part of the fan may be coincidental.

Overburden depths penetrated by test wells ranged from 10 to 129 ft. All the wells that produced more than 30 gal/min during drilling had overburden between 40 and 80 ft thick (fig. 18). However, thick overburden does not necessarily indicate the presence of ground water. Of 15 wells producing 30 gal/min or less, 10 had overburden less than 40 ft thick, but the remaining 5 wells had overburden 50 to 129 ft thick. As a site-selection criterion, thick overburden has limited usefulness since the only feasible way of determining it in this area is by well records or exploratory drilling. A summary of the comparison between site-selection criteria and well yields is given in table 3.

In summary, this study indicates that high-yielding wells can be drilled in valleys with 7 percent or less land slope known or suspected to have deep overburden (or having existing high-yielding wells). Within such areas good wells are located along a fracture trace or linear feature, or more commonly, at the intersection of such features. Areas outlined in figure 19 meet some or all of these criteria.

Table 3.--Summary of comparison between test-well yields and site-selection criteria for all the test wells except well 20. (Production figures obtained during drilling, except for yield of well 25, which was determined by pumping.)

Criterion	Number of wells meeting this criterion	Wells producing 50 gal/min or more		Wells producing 20 gal/min or less	
		Number	Percent	Number	Percent
1. Mapped fault:					
Within 500 ft	11	1	9	7	64
More than 500 ft away	13	7	54	5	38
2. Fracture trace:					
Within 500 ft	16	5	31	9	56
More than 500 ft away	8	3	38	4	50
3. Intersection of fracture traces:					
Within 500 ft	5	4	80	1	20
More than 500 ft away	19	4	21	11	58
4. Land slope:					
7 percent or less	13	8	62	3	23
More than 7 percent	11	0	0	9	82
5. Overburden thickness:					
40 ft or more	15	8	53	6	40
Less than 40 ft	9	0	0	6	67
6. Talus fan:					
On talus fan	6	3	50	2	33
Away from talus fan	18	5	28	10	56
7. Land slope + overburden thickness:					
7 percent or less, 40 ft or more	11	8	73	3	27
More than 7 percent, less than 40 ft	7	0	0	6	86
8. Land slope + overburden thickness + fracture trace intersection:					
7 percent or less, 40 ft or more, less than 500 ft away	4	4	100	0	0
More than 7 percent, less than 40 ft, more than 500 ft away	7	0	0	6	86



BASE FROM U.S. GEOLOGICAL SURVEY
PIGEON FORGE 1:24,000 1956
INTERIM REVISIONS AS OF 1970
RICHARDSON COVE 1:24,000 1940
GATLINBURG 1:24,000 1956
MOUNT LE CONTE 1:24,000 1964

Figure 16.—Relation between well yield and land slope. Eight of the 13 wells in areas of 7 percent or less land slope produced 50 gallons per minute or more. These relatively flat areas occur in broad valleys.

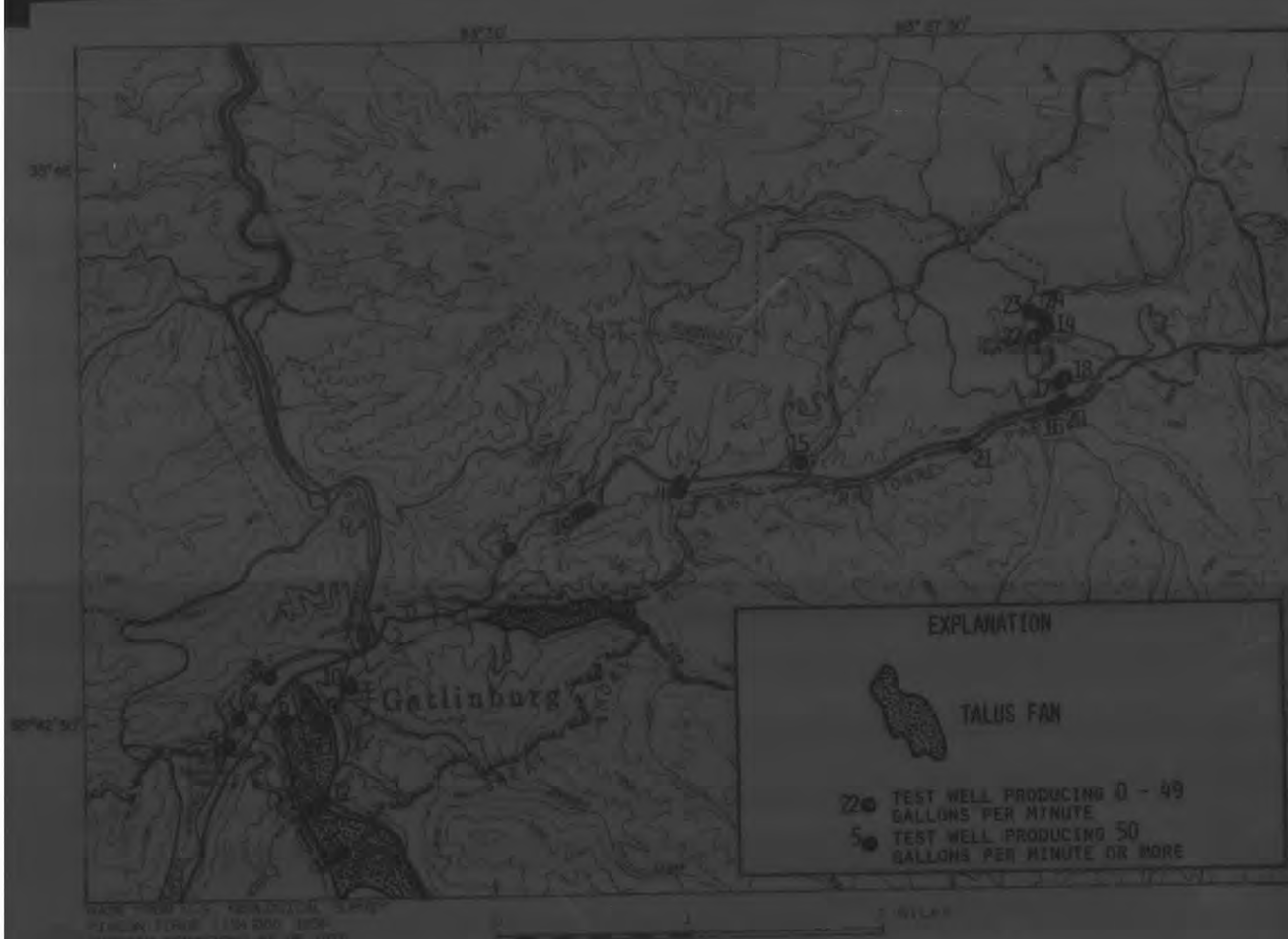


Figure 17.—Relation between well yields and talus fans. Six wells are located in the talus fan of Le Conte Creek valley. The three drilled in the toe of the fan produced 50 gallons per minute or more.

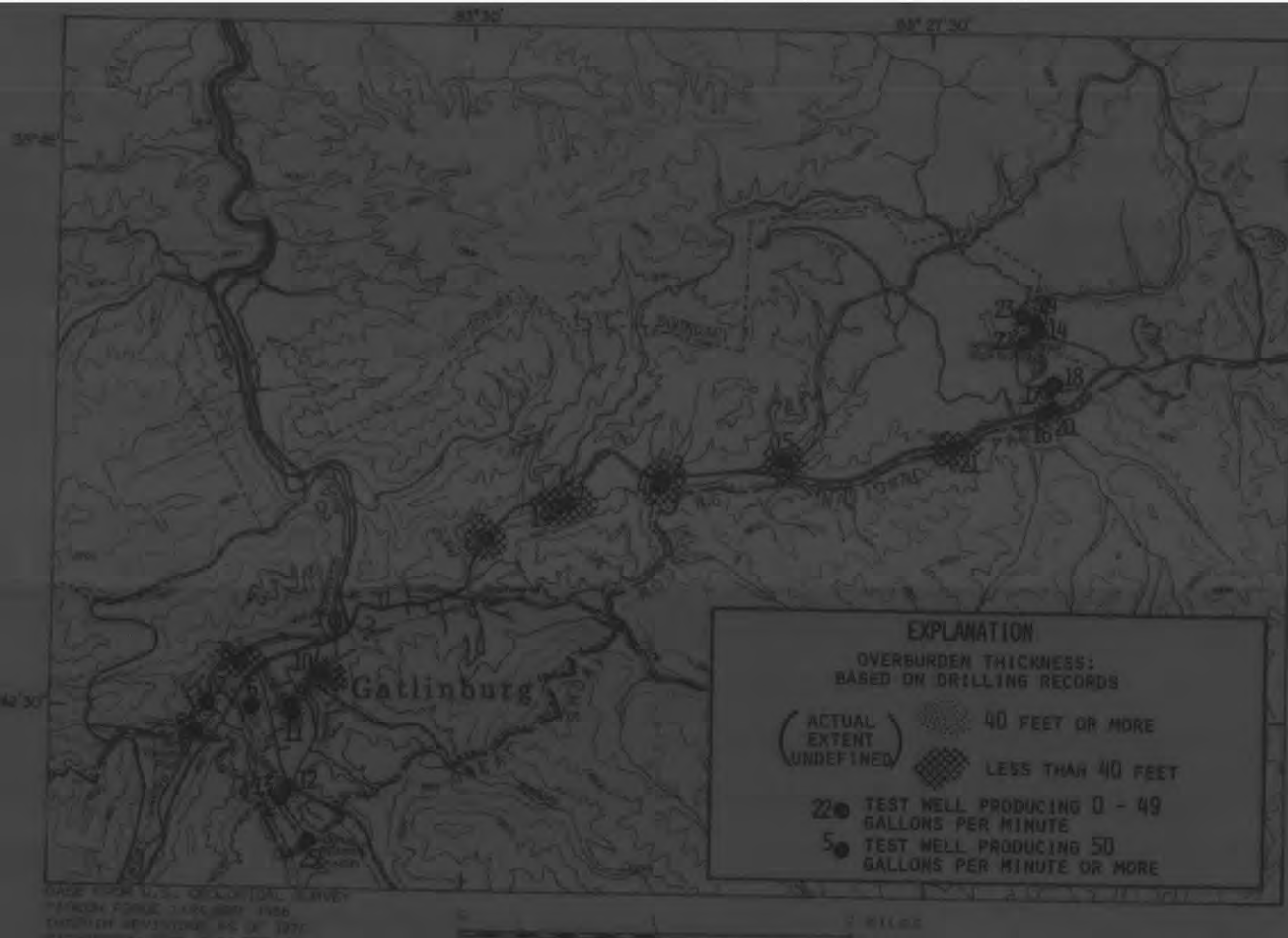


Figure 16.--Relation between well yields and overburden depth. Test wells penetrated deep overburden in two areas. Deep overburden is generally associated with high well yields.

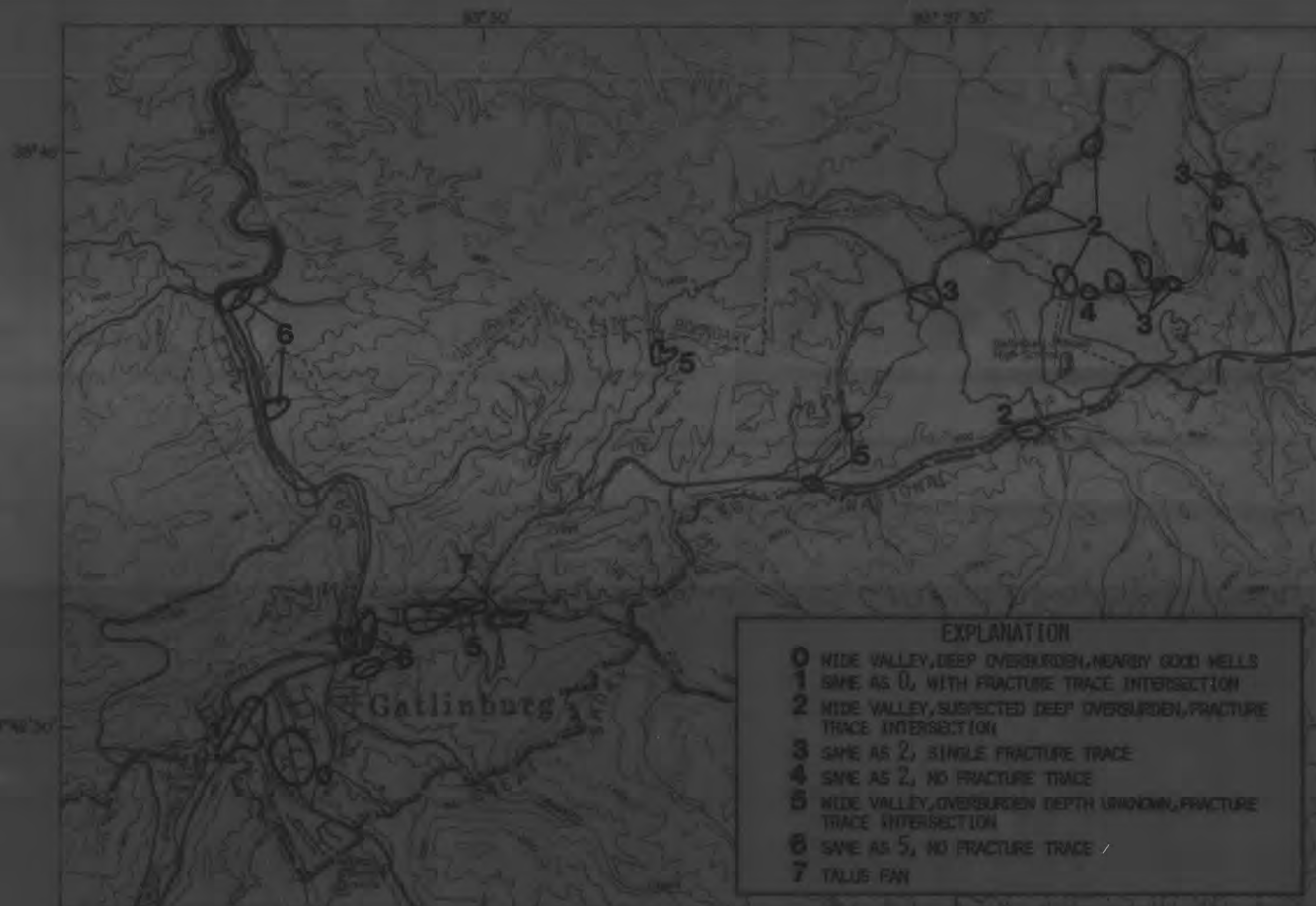


Figure 19.--Areas that meet one or more of the most definitive site-selection criteria for obtaining wells with the highest yields.

WATER QUALITY

Water samples were collected near the end of the pumping tests of five test wells. They were analyzed for some 40 constituents and properties including the major anions and cations, pH, dissolved solids and a variety of health-related substances. The complete analyses are included in the supplemental data section (page 47).

Both the ground water and the surface water in the Gatlinburg area are of high quality. They are very low in dissolved minerals. Figure 20 shows the major dissolved constituents of a representative sample of surface water and the average of the five samples of ground water. The water is relatively rich in bicarbonate, silica and calcium, and especially in the case of the ground water, sodium. It contains very little sulfate, and is acidic.

As drinking water, the ground water in Gatlinburg generally compares favorably with both health standards and with the raw water supplies of the 100 largest cities in the United States (table 4). One sample, from well 6, contained excessive iron. All other constituents were within the U.S. Environmental Protection Agency standards except phenols, which were present in measurable amounts in all five samples. Some possible sources of phenols are petroleum products, agricultural and industrial chemicals, or decaying organic material. Because it is possible that these phenols were in some way introduced during the sampling or analyzing process it would be appropriate to resample the wells before concluding that the ground water is contaminated.

CONCLUSIONS

Ground water in the Gatlinburg area occurs in the weathered upper part of the rock underlying the area. The depth and degree of weathering are variable depending on combinations of such factors as the abundance of fractures and the topographic situation. As a result, the highest yielding aquifers are deep, irregularly-shaped zones of weathered rock located in broad fracture-controlled valleys. Water occurs in open, weathered fractures usually 55 to 170 feet below land surface. Circulation patterns are shallow and localized with recharge occurring by percolation through the thick clayey overburden.

Eight of the 25 wells produced 50 gal/min or more. Specific capacities of the five wells that were test pumped ranged from 0.54 to 2.1 (gal/min)/ft of drawdown. The high-yielding wells are in two areas: lower Le Conte Creek valley and the Gatlinburg-Pittmen High School area.

Several different site-selection criteria were tested during the study. The most effective criteria were location in valley areas with 7 percent or less land slope, presence of fracture traces, and presence of deep overburden. All eight of the test holes that produced 50 gal/min or more met two or more of these criteria. The least effective of the criteria tested was proximity to a mapped fault.

Water-quality parameters for the pumped wells were within drinking-water standards with two exceptions. One sample contained excessive dissolved iron, and a detectable amount of phenol was present in all five samples. The phenol could have been introduced during or after sampling, however.

The successful test drilling in the Gatlinburg area demonstrates that ground water can be considered as an alternative or supplement to surface water for supplies in the Blue Ridge.

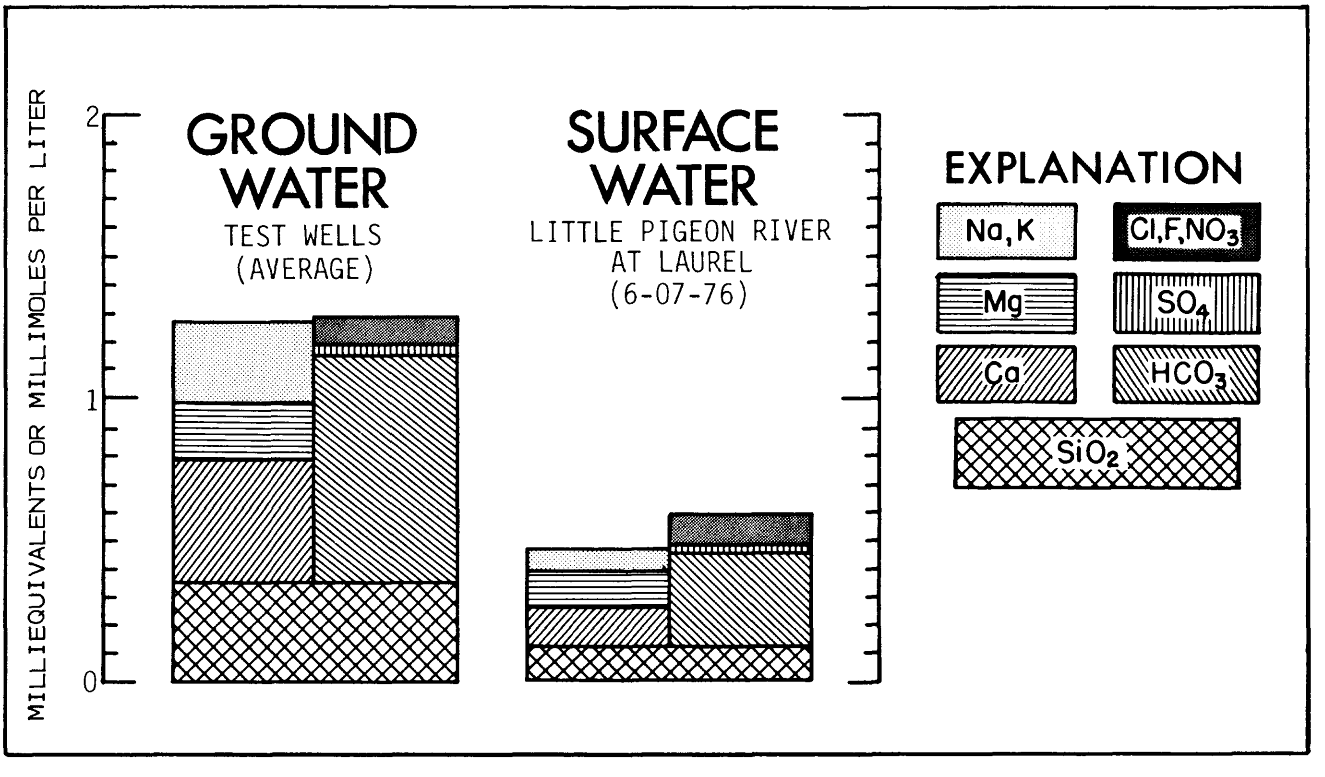


Figure 20.--Major dissolved constituents in ground water and surface water in the Gatlinburg area.

Table 4.--Ranges and median values for six chemical constituents or properties of ground water compared to drinking water standards (U.S. Environmental Protection Agency, 1975) and the raw water supplies of the 100 largest cities in the United States (Dufor and Becker, 1964).

(Constituents in milligrams per liter except where indicated.)

Constituent or property	Standard acceptable level in treated drinking water	Gatlinburg test wells		100 major cities in United States (raw water)	
		range	median	range	median
Chloride	Not to exceed 250	1.5-5.6	1.9	0-540	13
Fluoride	Not to exceed 2.0 (for Tennessee)	0-0.2	0.1	0-7.0	0.4
Iron	Not to exceed 0.3	0-0.4	0.07	0-1.3	0.02
pH (units)	5.0-9.0	5.9-7.5	6.6	5.0-10.5	7.5
Nitrate and nitrite	Not to exceed 10	0.1-3.3	0.5	0-23	0.7
Sulfate	Not to exceed 250	1.0-2.6	1.1	0-572	26

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SUPPLEMENTAL DATA

A considerable amount of data concerning individual wells is included in this section for the convenience of those interested in additional details regarding specific sites. A discussion of the aquifer tests of wells 5, 6, 9, 18, and 23 begins on page 38. (This material is summarized on page 17 of this report.) The field data for the tests are on file in Nashville at the Tennessee District Office of the U.S. Geological Survey, Water Resources Division. Complete chemical analyses of water from these five wells are given in Table 5. Geophysical logs for 18 test wells begin on page 50.

Aquifer Tests

The tested wells are in two groups: Well 18 and well 23 near Gatlinburg-Pittman High School and wells 5, 6, and 9 in the downtown area. Well 25, the old well, can be included with the latter. The wells in each group are not only relatively close together but their responses to pumping are similar.

Gatlinburg-Pittman High School Area

Well 23

Well 23 was pumped in two consecutive 4-hour steps at 36 and 67 gal/min, respectively. The higher pumping rate was the limit imposed by the pumping equipment.

Ground-water levels before pumping began were lowest along the transverse valley in which wells 23, 24, and 14 are located, indicating the presence of a preferred avenue of ground-water flow from well 23 in the direction of wells 24 and 14 (fig. 21). This southeasterly trending valley coincides with a fracture trace (fig. 15) and the low potentiometric surface probably indicates preferential movement along a fracture. The same configuration was evident after eight hours of pumping. Drawdown in the three closest test wells, 24, 14, and 22, at distances of 420, 600, and 780 ft, respectively, from the pumped well ranged from 0.6 ft in well 22 to a maximum of 1.1 ft in well 14. The water level in well 23 (the pumped well) declined a total of 46 ft by the end of the test. Although the rate of recovery was rapid during the first few minutes after pumping ceased, the water level was still 9 ft below the prepumping level 1 hour after the pump was turned off. Recovery was complete by the following morning. Figure 22 shows the response of wells 23 and 24 to the pumping of well 23.

The specific capacity of well 23 at the end of the test was 1.1 (gal/min)/ft. An additional 53 ft of available drawdown remained above the uppermost water-bearing zone which supplies approximately 25 percent of the yield. The major water-bearing zone, supplying 75 percent of the yield, is 19 ft below the upper zone. However, projections of drawdown for longer pumping periods or higher rates based on the specific capacity obtained from this test may lead to serious underestimates of the actual drawdown under those conditions.

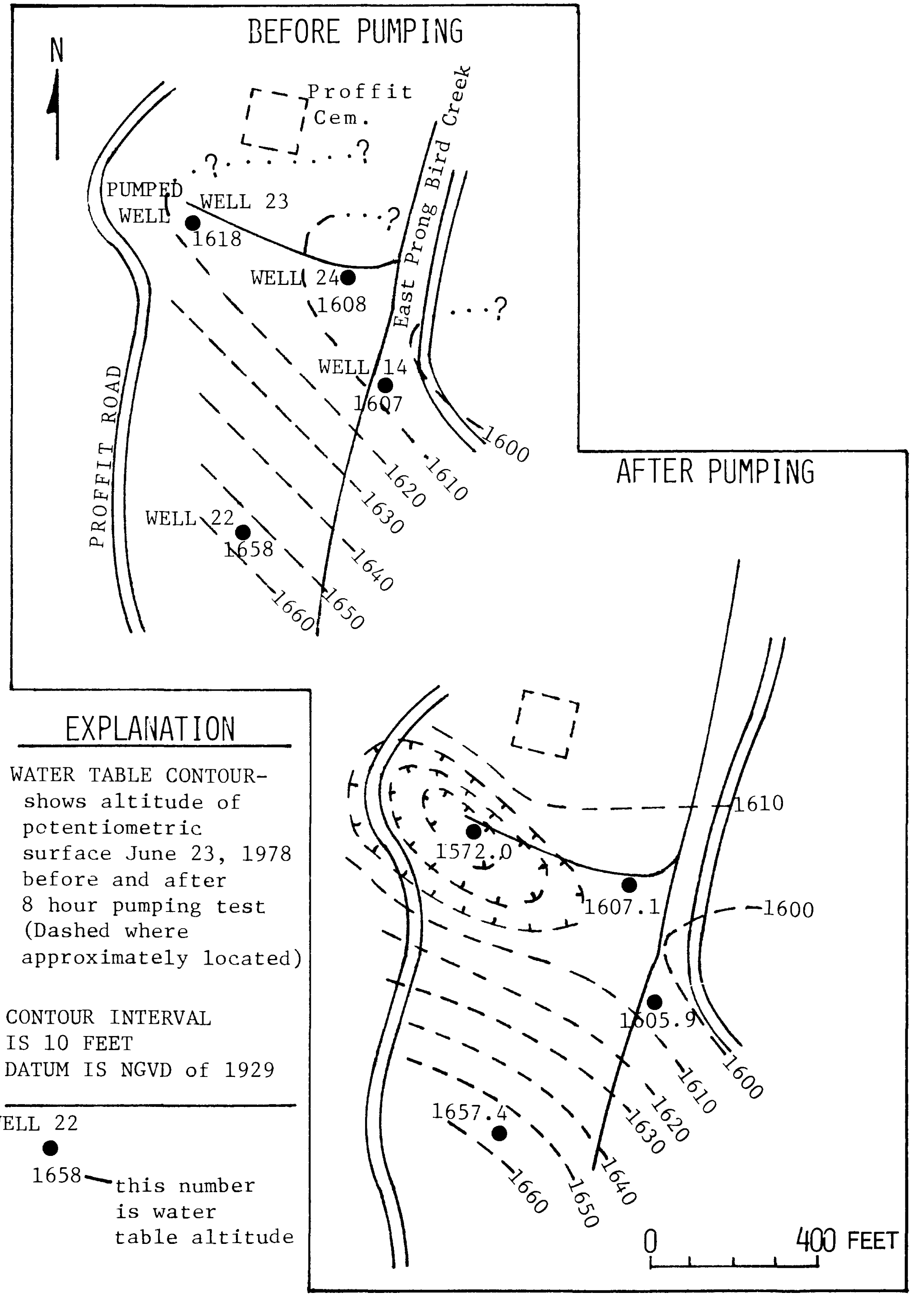


Figure 21.-- The potentiometric surface in the vicinity of well 23 before and during the aquifer test indicates what may be a zone of greater permeability oriented NW-SE.

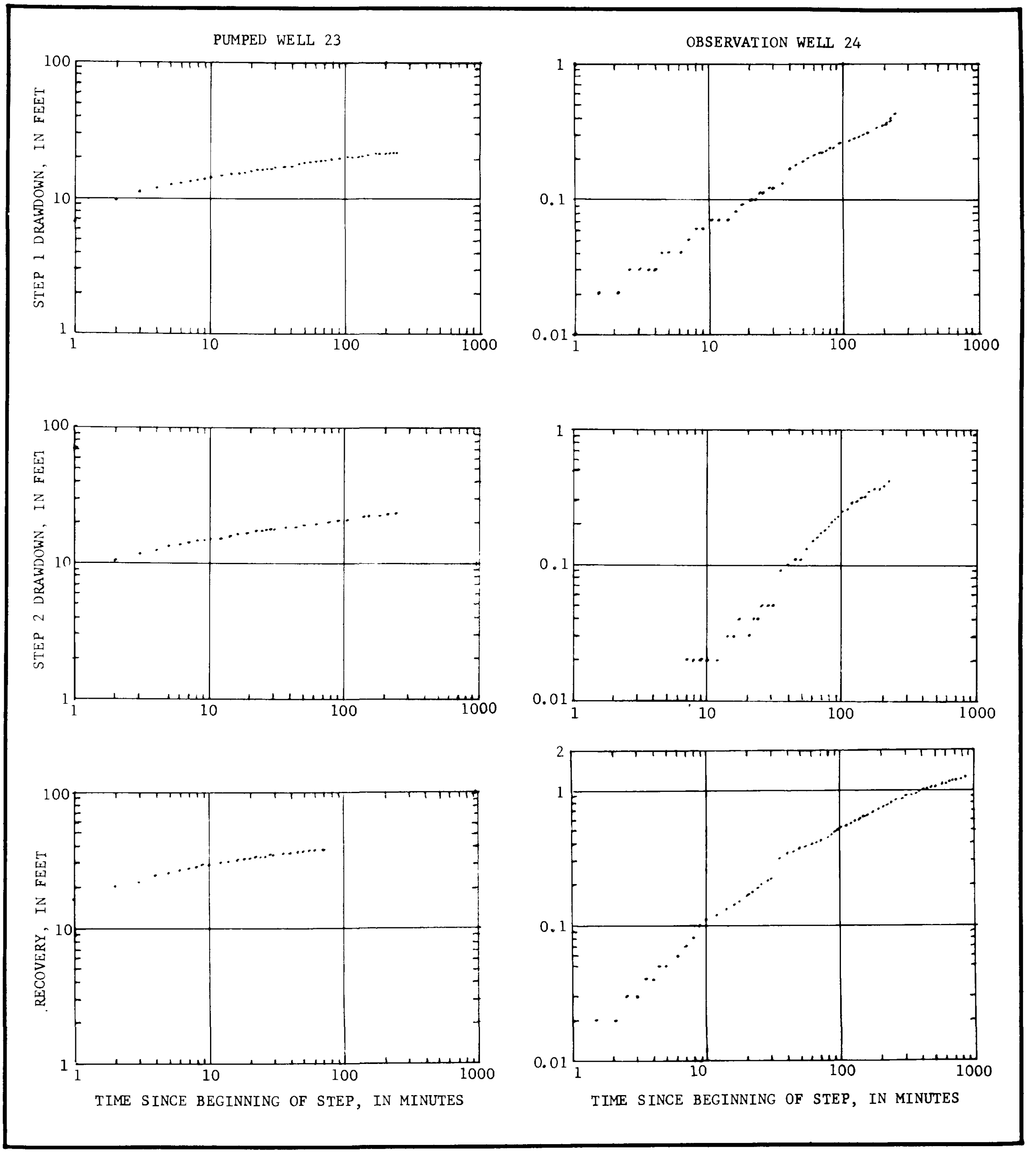


Figure 22.--Log-log plots of drawdown and recovery in pumped well 23 and observation well 24, 420 feet away.

It should be noted that several additional factors have an effect on the maximum pumping capacity of the well.

1. For a longer pumping period, hydrologic boundaries might play an increasing role in determining the drawdown. The effects of pumping reach an ever-larger area as the hydraulic gradient within the aquifer system adjusts to the stress. The net effect of hydrologic boundaries is determined by the transmissive properties of the aquifer and by the nature of and distance to its boundaries. These boundaries can be categorized generally either as barriers to ground-water flow or as sources of water. In the Gatlinburg area, the unweathered rock underlying the steep hills could be expected to act as a barrier, or no-flow boundary. Intercepting a no-flow boundary causes the rate of drawdown to increase. In contrast, perennial streams could act as source boundaries. This type of boundary, referred to as a recharging boundary, causes the rate of drawdown to decrease either because of interception of natural ground-water outflow to the stream or by the inducing of stream water to enter the aquifer system. Although data obtained from this test do not clearly identify the influence of either type of boundary, it is expected that the valley walls (no-flow boundaries) would eventually increase the rate of drawdown by limiting the flow of water to the well.

2. Available drawdown in the well is subject to change as water levels fluctuate from season to season and year to year. If, for example, the water level declined 10 ft below its level at the time of the test, the available drawdown, and, therefore, the well's potential yield would be reduced by 14 percent. If the area north of the high school is a ground-water discharge area, as is apparently indicated by the presence of springs, then the natural water-level fluctuations would be considerably less than in highland areas. The only records of natural water-level fluctuations are two sets of water-level measurements made during a rainy period in June 1978 (shown in fig. 21), and a dry period in October 1978. Water-level declines during this interval for wells 14, 23, and 24, respectively, were 1.30, 0.95, and 0.57 ft. This is significant because at the time the October measurements were made, streamflow was at its seasonal low. These October ground-water levels, then are representative of what could be expected during an extended period of dry weather.

3. An intermittent pumping schedule would permit higher discharges than continuous pumping. Ultimately, the impact of pumpage on the aquifer will be determined by the total volume of water removed, not the schedule of withdrawals.

4. Production well design, in particular the well diameter, would affect the efficiency of the well.

Well 18

The 8-hour test of well 18 consisted of two steps: 3 hours pumping at 36 gal/min, followed by 5 hours pumping at 67 gal/min. The higher rate was limited by the equipment used.

Water levels were lowered during the test a total of 20.1 ft, and recovered within two hours after the cessation of pumping to less than a foot below the prepumping level. Well 17, at a distance of 110 ft, experienced 6.3 ft or drawdown by the end of the test (fig. 23). The specific capacity of well 18 was 2.1 (gal/min)/ft of drawdown at the end of the test, using only about one third of the available drawdown. As in the case of well 23, the optimum pumping rate for this well is dependent on boundary effects, available drawdown, pumping schedule, and well construction.

Boundaries and natural water-level fluctuations are likely to be significant factors due to the location of well 18. It is located in an arm of the broad valley in which the Gatlinburg-Pittman High School is situated. This smaller valley is about 60 ft higher than the floor of the main valley and is walled with high hills. The geometry of the aquifer is poorly defined at present. It is probably bounded on the north and south by the dense rock of the hills and is elongated in an east-west direction. Ground water may move preferentially along a fracture oriented in this direction. The long-term effect of the geometry of the aquifer on well yield could not be evaluated from the test data.

Ground-water levels in wells 17 and 18 are approximately 40 ft higher in altitude than in wells 23 and 24. Declines of 6 and 8 ft were noted in wells 17 and 18, respectively, between June and October 1978 whereas the average decline for this period in all the test wells was 2 ft. The greater fluctuation is characteristic of the topographically higher position of these wells. If the June and October water levels truly represent the extremes that can be expected annually, then the seasonal decline will amount to no more than about a 9-percent reduction in the available drawdown.

Downtown Area

Well 5

Well 5 was pumped a total of 7 hours at four different rates: 20, 40, 56, and 80 gal/min (table 2). Total drawdown was 75 ft. The specific capacity decreased from 1.8 (gal/min)/ft at the end of step 1 to 0.92 (gal/min)/ft at the conclusion of the test. The water level had been lowered to the uppermost water-bearing zone at 90 ft below land surface, an opening in highly weathered rock which produced about 14 percent of the discharge measured during drilling. The major water-bearing zone is at 115 to 120 ft.

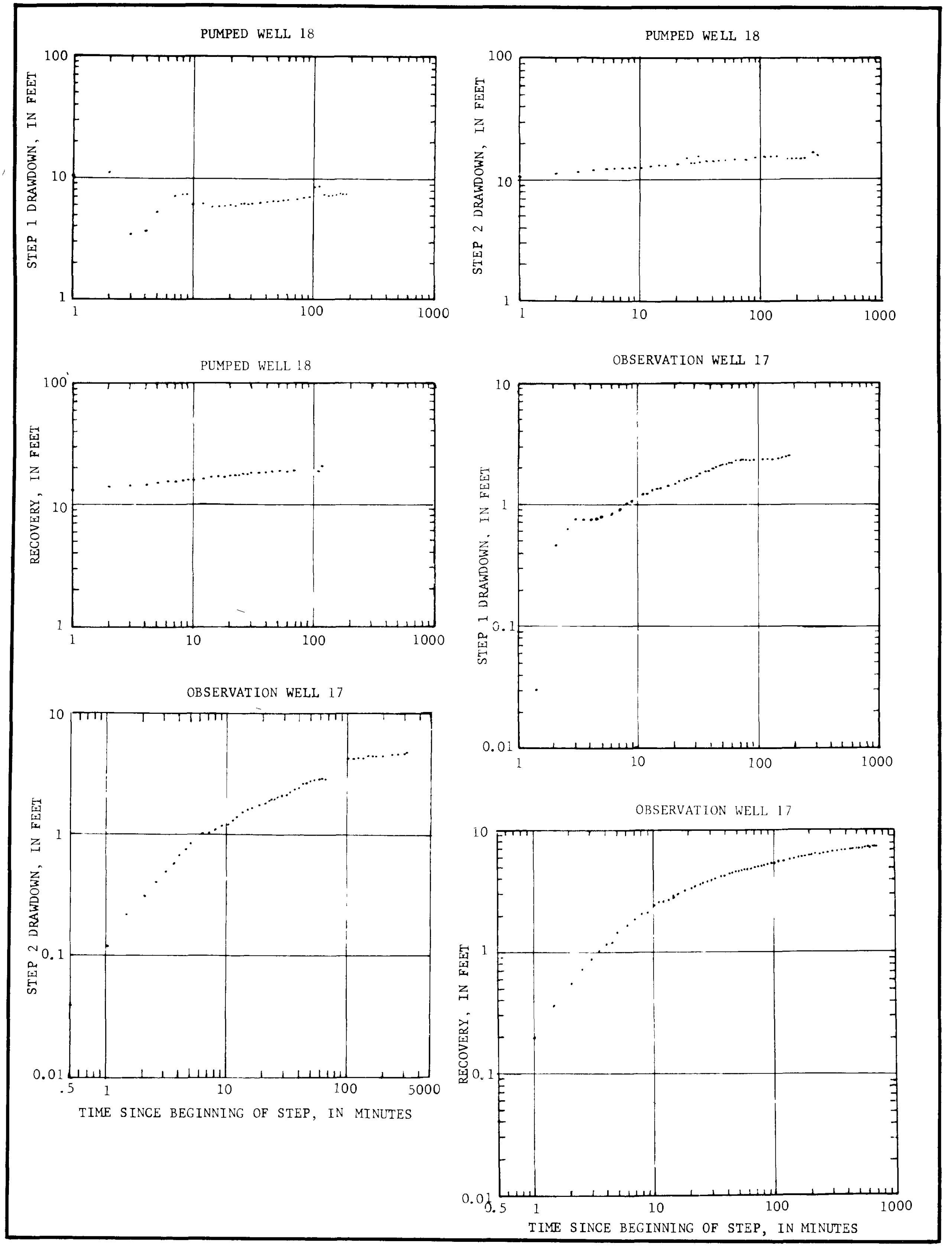


Figure 23.--Log-log plots of drawdown and recovery in pumped well 18 and observation well 17. The aquifer test consisted of pumping for 4 hours at 36 gallons per minute and an additional 4 hours at 67 gallons per minute.

The well is only about 30 ft from the West Prong Little Pigeon River. As expected, the aquifer response indicates the influence of a recharging boundary beginning 4 to 5 minutes after each pumping rate increase (fig. 24). Pumping this well would cause river water to enter the ground-water system; however, the well would probably also be supplied by ground water which normally discharges to the stream. If infiltration of surface water occurs, any change in water quality would be gradual and would become apparent over a period of several months of pumpage.

Well 6

The well was pumped at 20, 40, and 60 gal/min for a total of 7 hours. The specific capacity declined from 1.2 (gal/min)/ft at the end of the first step to 0.60 (gal/min)/ft at the end of the third (table 2). During the test the water level reached the deepest major water-bearing opening shortly after the discharge was increased to 60 gal/min. From that time to the end of the test these openings were supplying water to the well at their maximum rate. Well 6, like 5, showed the effect of a recharging boundary, possibly Le Conte Creek (fig. 25). Well 6 has less available drawdown than well 5 owing to a lower natural water level.

Well 9

The pumping test of well 9 was similar to that of 6, with the exception of the use of well 11, 200 ft away, as an observation well. Three pumping rates, with a maximum of 57 gal/min, were used in the 8-hour test. Specific capacity declined from 2.0 (gal/min)/ft at the end of the first step to 0.54 (gal/min)/ft at the end of the test (table 2). Drawdown of 98 ft lowered the water level below water-bearing zones at 106 and 108 ft. For a longer pumping period, the well is likely to produce less than the highest rate tested. The response of well 9 to pumping (fig. 26) showed the influence of a recharging boundary.

Total drawdown in well 11, the observation well, was 1.3 ft; its response showed the effects of water-table conditions. It has not been pump tested but a preliminary yield of 50 gal/min was estimated during drilling (table 1). The test of well 9 indicates that mutual interference would occur if both wells were pumped simultaneously.

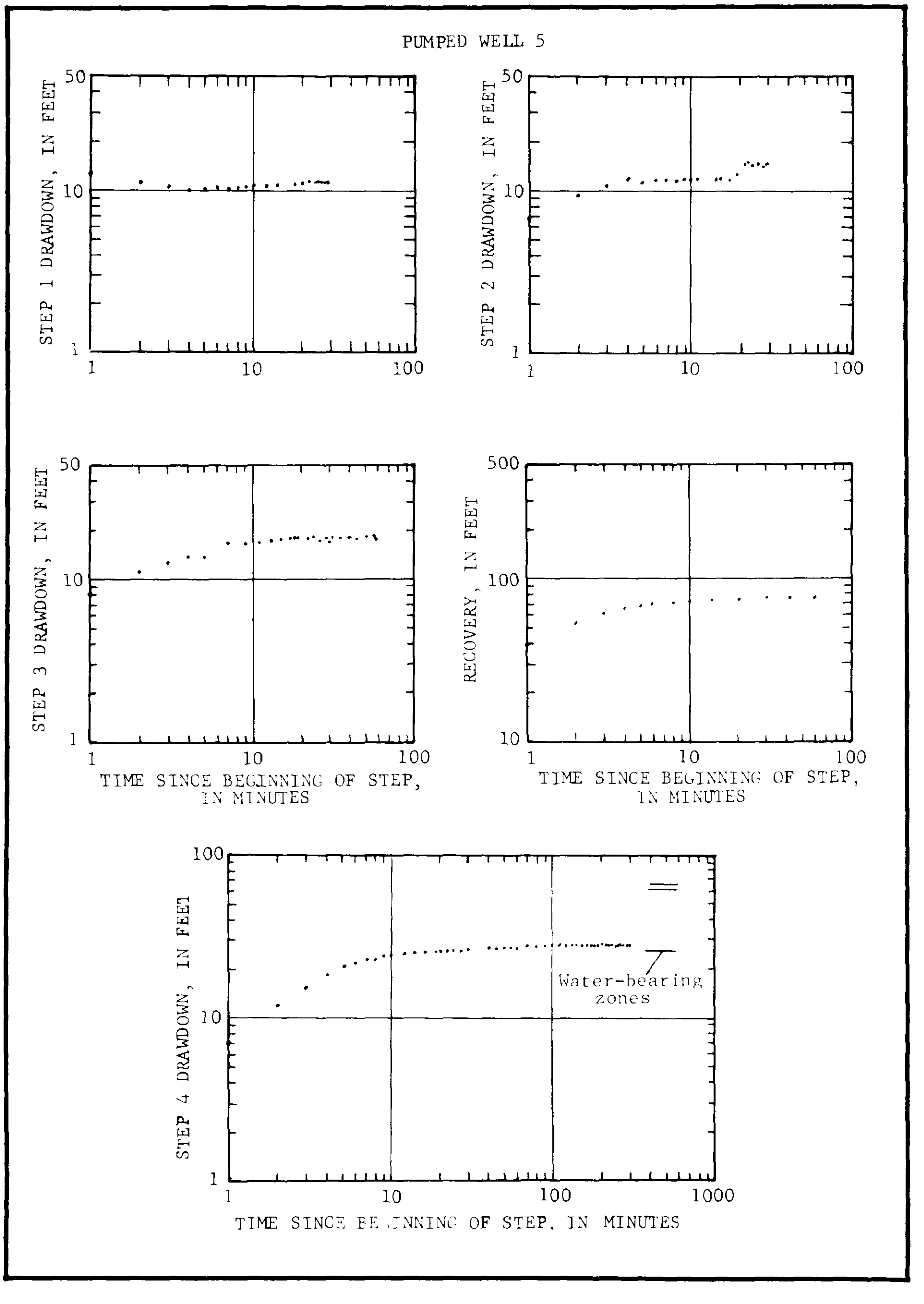


Figure 24.--Log-log plots of drawdown and recovery in well 5. Well 5 was pumped at a maximum rate of 80 gallons per minute for a total of 7 hours. Water levels had been lowered to the first water-bearing fractures by the end of the test.

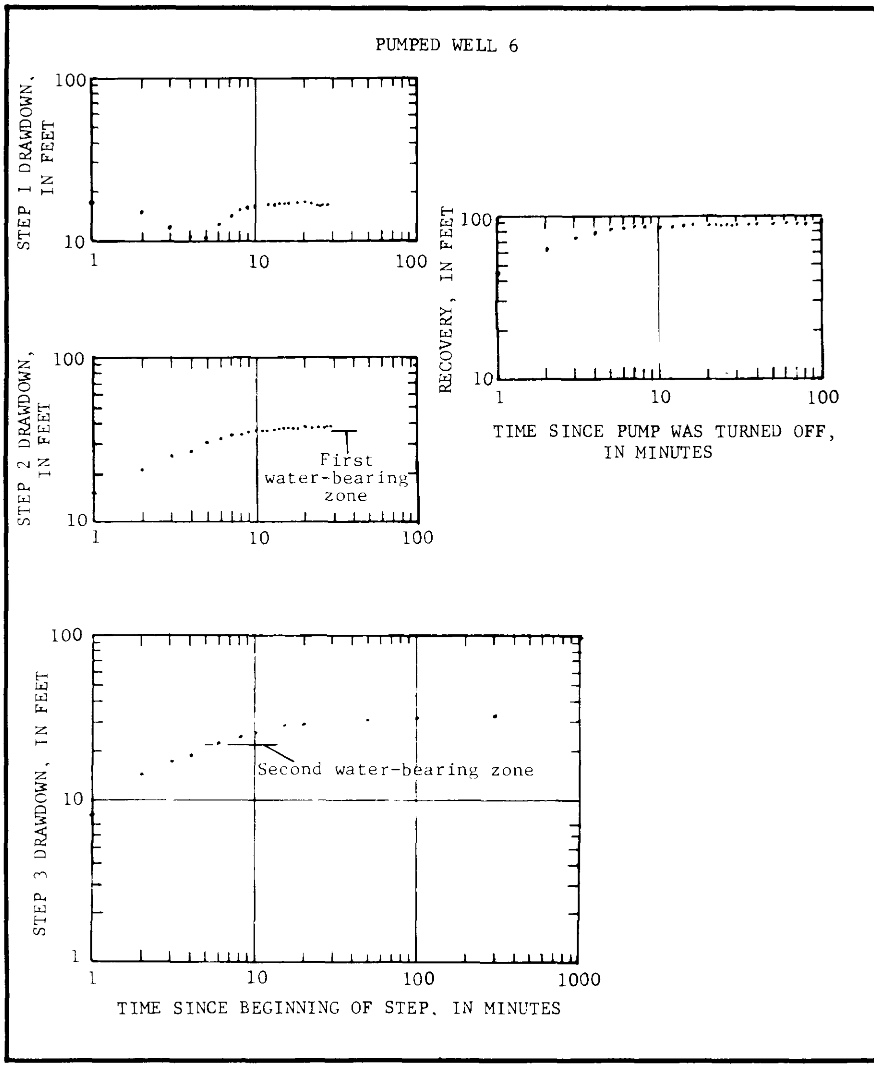


Figure 25.--Log-log plots of drawdown and recovery in well 6. Water levels in well 6 dropped below the major water-producing fractures early in the third step of the pumping test.

Well 25

This well, drilled in the 1930's to supply the Holston Assembly Grounds, has been unused since soon after World War II, according to a local resident. It was reputed to be a good well, but a pumping test showed that it could not sustain pumping at 20 gal/min. In 7.5 hours, the water level dropped to the pump intake (fig. 27, table 2). This test confirmed what had been suspected from the yields of test wells 12 and 13, farther down the valley, that the Le Conte Creek talus fan has only a thin covering of alluvial material and is not a major aquifer.

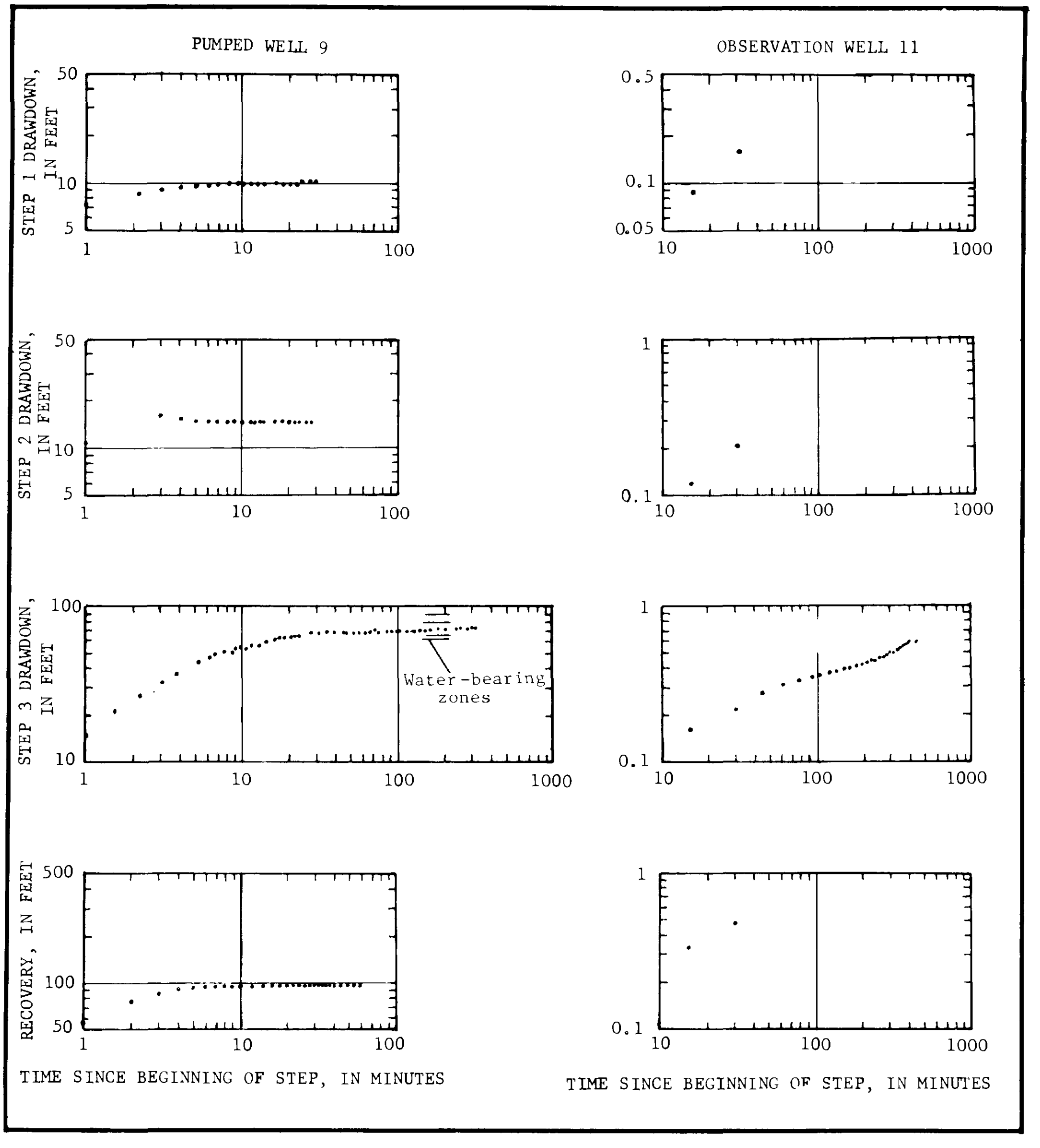


Figure 26.--Log-log plots of drawdown and recovery in wells 9 and 11. Well 9 was pumped at three rates, with a maximum of 57 gallons per minute, for 8 hours. Drawdown in observation well 11, 200 feet from well 9, was 1.3 feet.

Chemical Analyses

Five test wells were sampled after 5¼ to 7 hours of pumping. Results of analysis of these samples by the U.S. Geological Survey National Water Quality Laboratory in Atlanta are given in table 5.

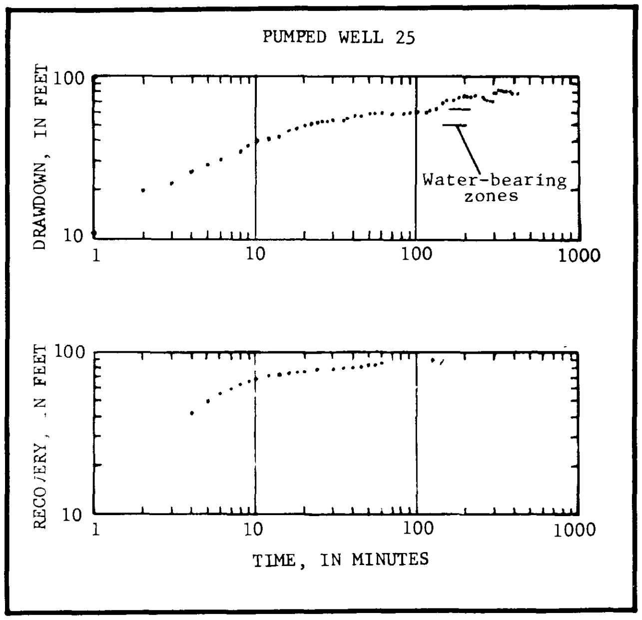


Figure 27.--Log-log plots of drawdown and recovery in well 25. The old well at Holston Assembly Grounds was pumped at 20 gallons per minute for 7.5 hours. The test was terminated when the water level dropped rapidly to the level of the pump intake between 420 and 450 minutes.

Geophysical Logs

The following geophysical logs were made of Gatlinburg test wells:

Well no.	Caliper	Temperature	Fluid resistivity	Neutron	Gamma	Gamma-gamma	Acoustic velocity	Guard resistivity	Long-short normal
1	x	-	-	x	x	x	x	-	-
2	none								
3	none								
4	x	-	-	x	x	x	x	-	-
5	x	x	x	x	x	x	x	x	x
6	x	x	x	x	x	x	x	x	x
7	none								
8	none								
9	x	x	x	x	-	x	x	x	x
10	none								
11	x	-	-	x	-	x	-	-	x
12	x	x	x	x	x	x	x	x	x
13	x	-	-	x	x	x	-	-	-
14	x	-	-	x	x	x	x	-	-
15	x	-	-	-	-	-	-	-	-
16	x	-	-	-	x	-	-	-	-
17	x	-	-	-	-	-	-	-	-
18	x	x	x	x	x	x	x	x	x
19	none								
20	none								
21	x	-	-	x	x	x	-	-	-
22	x	x	-	-	-	-	-	-	-
23	x	x	x	x	-	x	x	x	x
24	x	-	-	-	-	-	-	-	-
25	x	-	-	-	-	-	-	-	-

Table 5.-- Analyses of water samples collected in 1978 from five test wells in the Gatlinburg area. Values in milligrams per liter unless otherwise indicated.

Well number	5	6	9	18	23
Date	MAY 5	MAY 6	MAY 4	JUNE 21	JUNE 23
Pumping period (minute)	367	380	315	435	420
Pumping rate (gallons per minute)	75	60	57	67	67
Alkalinity, total, as $CaCO_3$	46	48	34	16	44
Arsenic, total	.001	.000	.001	.001	.003
Barium, total	.000	.000	.000	.000	.000
Bicarbonate	56	72	42	20	54
Cadmium, total	.000	.000	.000	.000	.001
Calcium, dissolved	8.2	15	8.5	3.3	8.0
Carbon, total organic	4.2	5.3	6.0	7.4	8.0
Carbonate	0	0	0	0	0
Chloride, dissolved	1.6	3.9	5.6	1.9	1.5
Chromium, hexavalent	.000	.000	.000	.000	.000
Color (units)	5	5	5	10	5
Copper	.002	.002	.000	.002	.002
Cyanide	.00	.00	.00	.00	.00
Detergents	.0	.0	.0	.0	.0
Dissolved solids, sum of constituents	69	82	67	42	70
Dissolved solids (tons/acre-foot)	.10	.14	.08	.07	0.08
Dissolved solids, residue at 180°C	72	101	58	48	61
Fluoride, dissolved	.1	.0	.1	.1	.2
Hardness, noncarbonate	0	1	0	0	0
Hardness, total	30	49	32	15	32
Iron, dissolved	.010	.010	.020	.000	.000
Iron, total	.070	.400	.130	.020	.060
Lead, total	.014	.007	.000	.009	.006
Magnesium, dissolved	2.2	2.9	2.6	1.6	2.9
Manganese, dissolved	.010	.010	.010	.010	.030
Manganese, total	.010	.010	.010	.010	.020
Mercury, total	< .0005	< .0005	< .0005	< .0005	< .0005
Nitrite, as N, total	.01	.01	.00	.00	.00
Nitrate, as N, total	.38	3.3	1.6	.49	.11
Nitrite plus nitrate, as N, total	.39	3.3	1.6	.49	.11
pH, field (units)	7.4	6.6	6.4	5.9	7.5
Phenols	.001	.003	.002	.005	.002
Phosphorus, total, as P	.03	.05	.06	.11	.08
Phosphorus, total, as PO_4	.09	.15	.18	.34	.25
Potassium, dissolved	.5	.8	.7	.6	.4
Sodium adsorption ratio	.5	.4	.5	.4	.5
Selenium, total	.000	.000	.000	.000	.000
Silica, dissolved	19	22	21	20	22
Silver, total	.000	.001	.004	.000	.000
Sodium, dissolved	6.7	7.0	6.6	3.8	6.6
Sodium, percent	33	23	30	35	31
Specific conductance, field (umho /cm at 25°C)	90	150	110	70	119
Specific conductance, lab	92	137	102	51	93
Sulfate, dissolved	2.6	1.0	1.1	1.0	2.0
Turbidity (JTU)	1	1	1	1	1
Water temperature (degrees Celcius)	16	17	16	16	12
Zinc, total	.020	.180	.140	.060	.030

GEOPHYSICAL LOGS

For those unfamiliar with borehole geophysics, some of the uses for the various types of logs are briefly listed below. (For a complete description of the theory and applications of borehole geophysics to water-resources investigations see Keys and MacCary, 1971).

Caliper log - spring-loaded "fingers" measure the average borehole diameter; can be used to detect fractures in the rock, check casing depth

Temperature log - measures the temperature of the water in the borehole to detect source and movement of the water

Fluid resistivity log - measures the electrical resistance of the water which is related to its dissolved solids content

Neutron log - uses a neutron-emitting source and a detector; can be used to measure total porosity of the rock

Gamma log - records natural gamma radiation from the rock, usually higher for clay-rich rock; used for correlation

Gamma-gamma log - uses a gamma-emitting source and a detector; can be used to measure bulk density of the rock, identify lithology

Acoustic velocity log - records the transit time of a sound pulse; can be used to measure porosity, identify fractures

Guard resistivity and Long-short normal electric logs - measure resistance and potentials between the borehole fluid and surrounding rock; used for correlation and identification of porous rocks; used chiefly in unconsolidated rocks.

Logs of Gatlinburg wells are shown in figures 28 through 45. Scales are consistent on all the illustrations to allow comparison. The original logs are on file in Nashville.

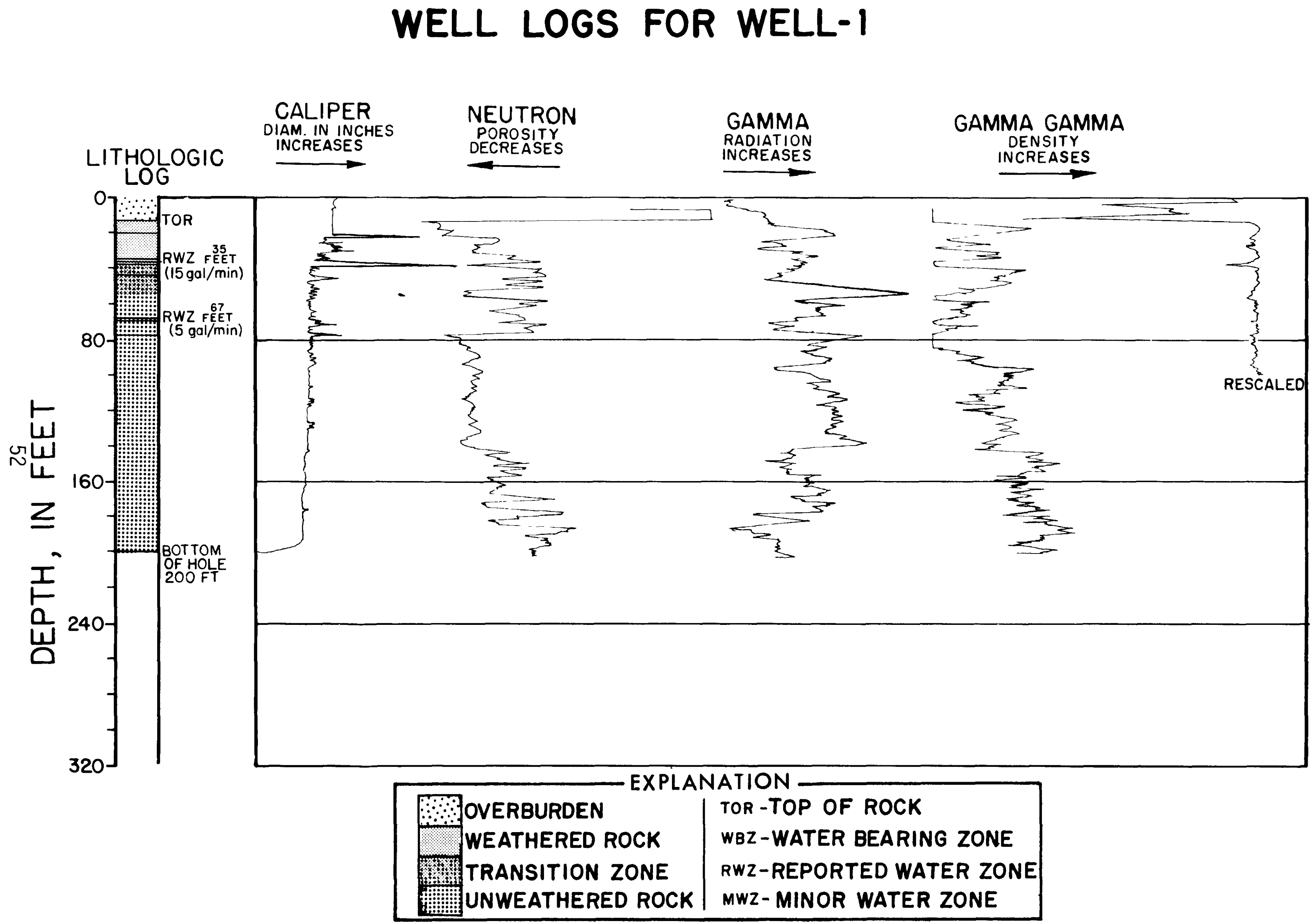
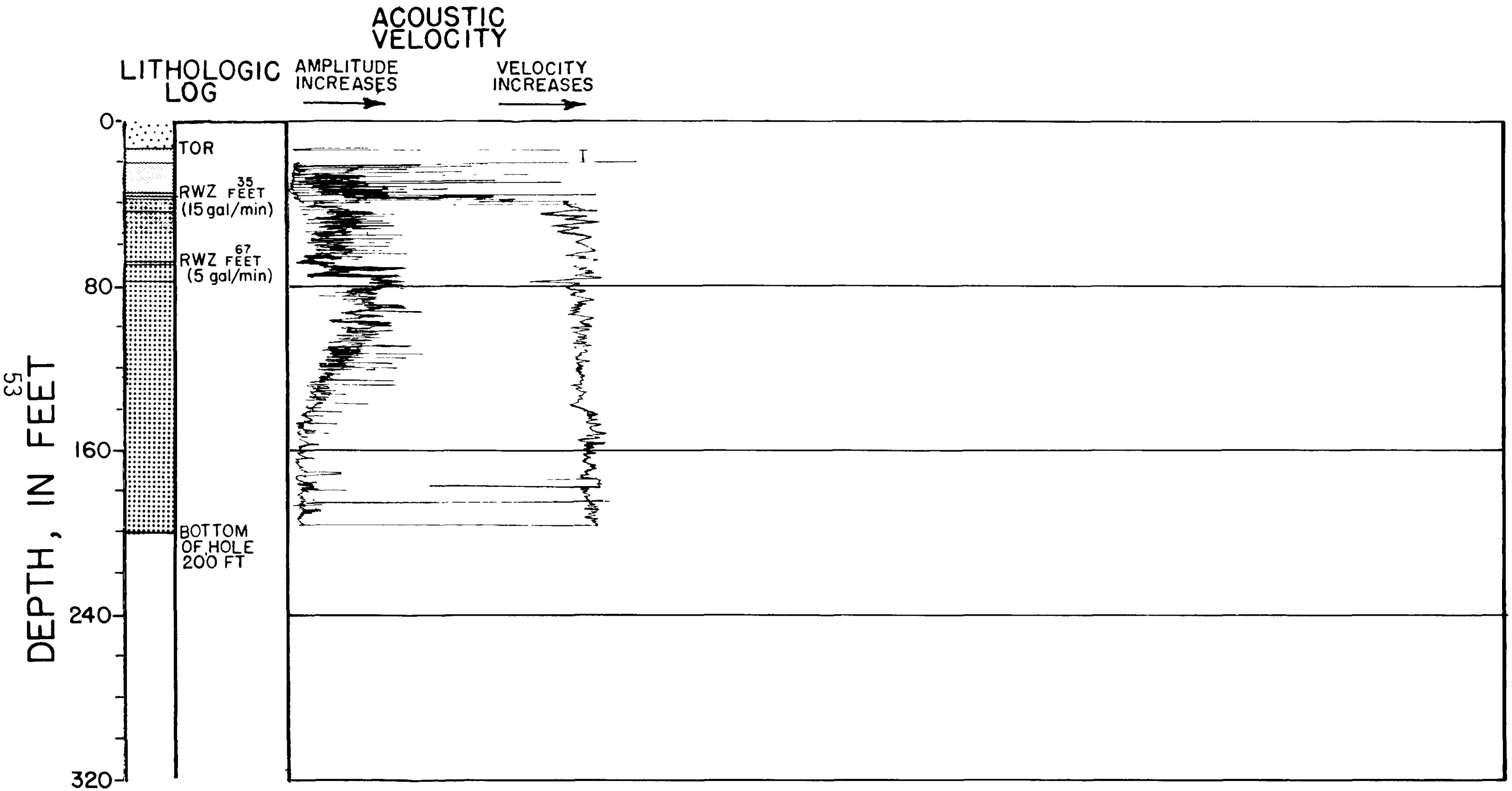


Figure 28.--Logs for well 1.

WELL LOGS FOR WELL-1 (CONT.)



LOGS FOR WELL-4

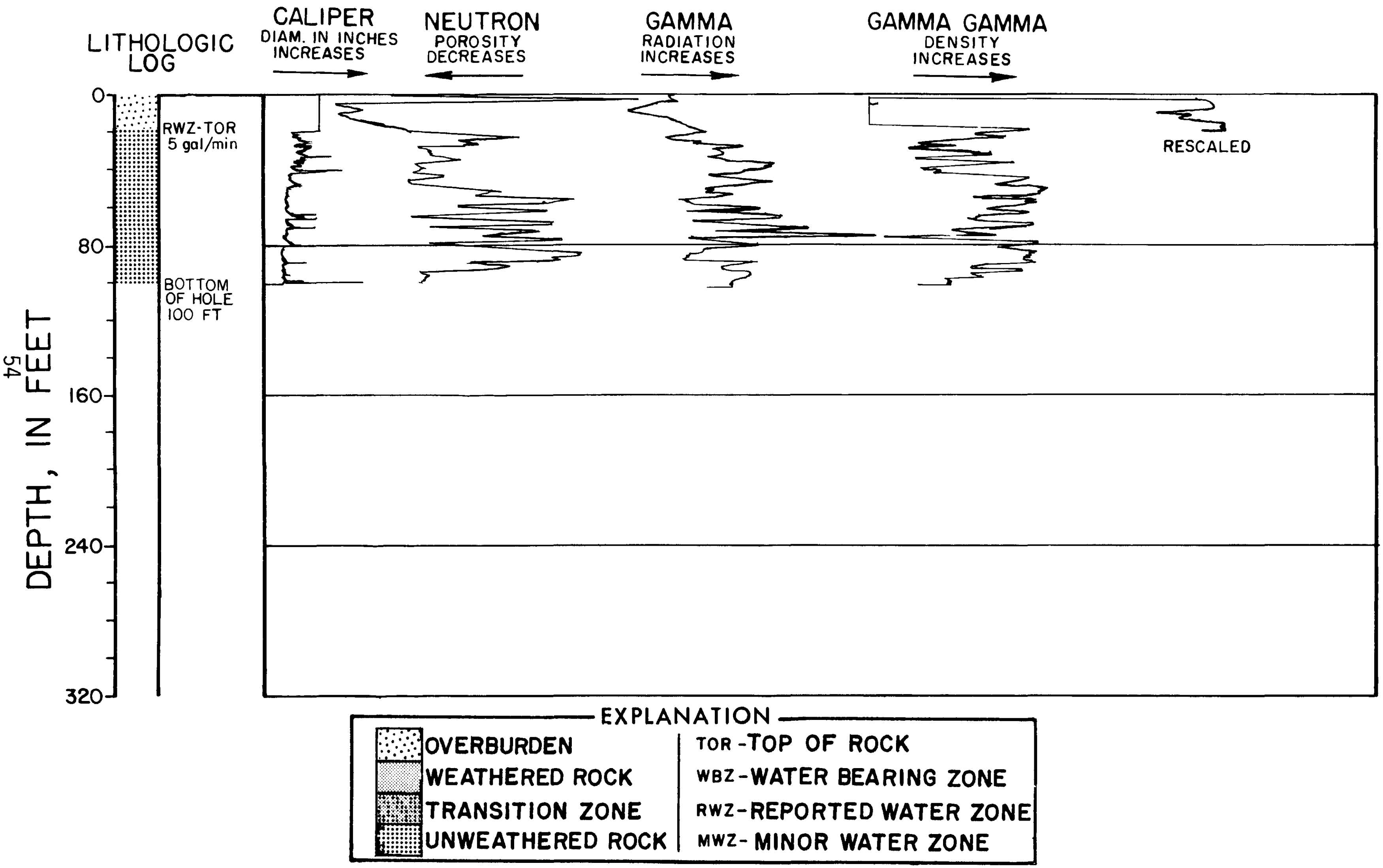
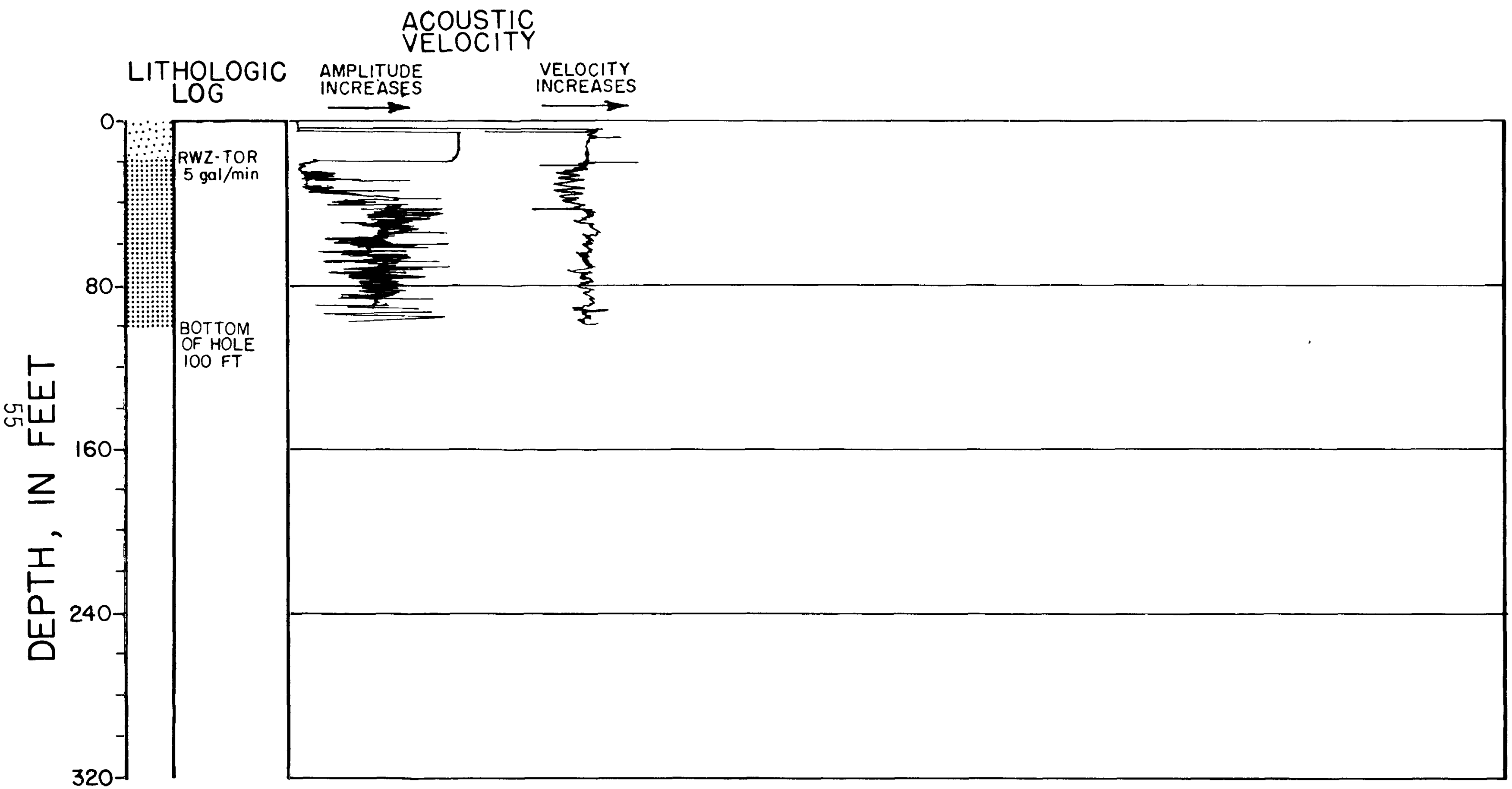


Figure 29.--Logs for well 4.

LOGS FOR WELL-4 (CONT.)



LOGS FOR WELL-5

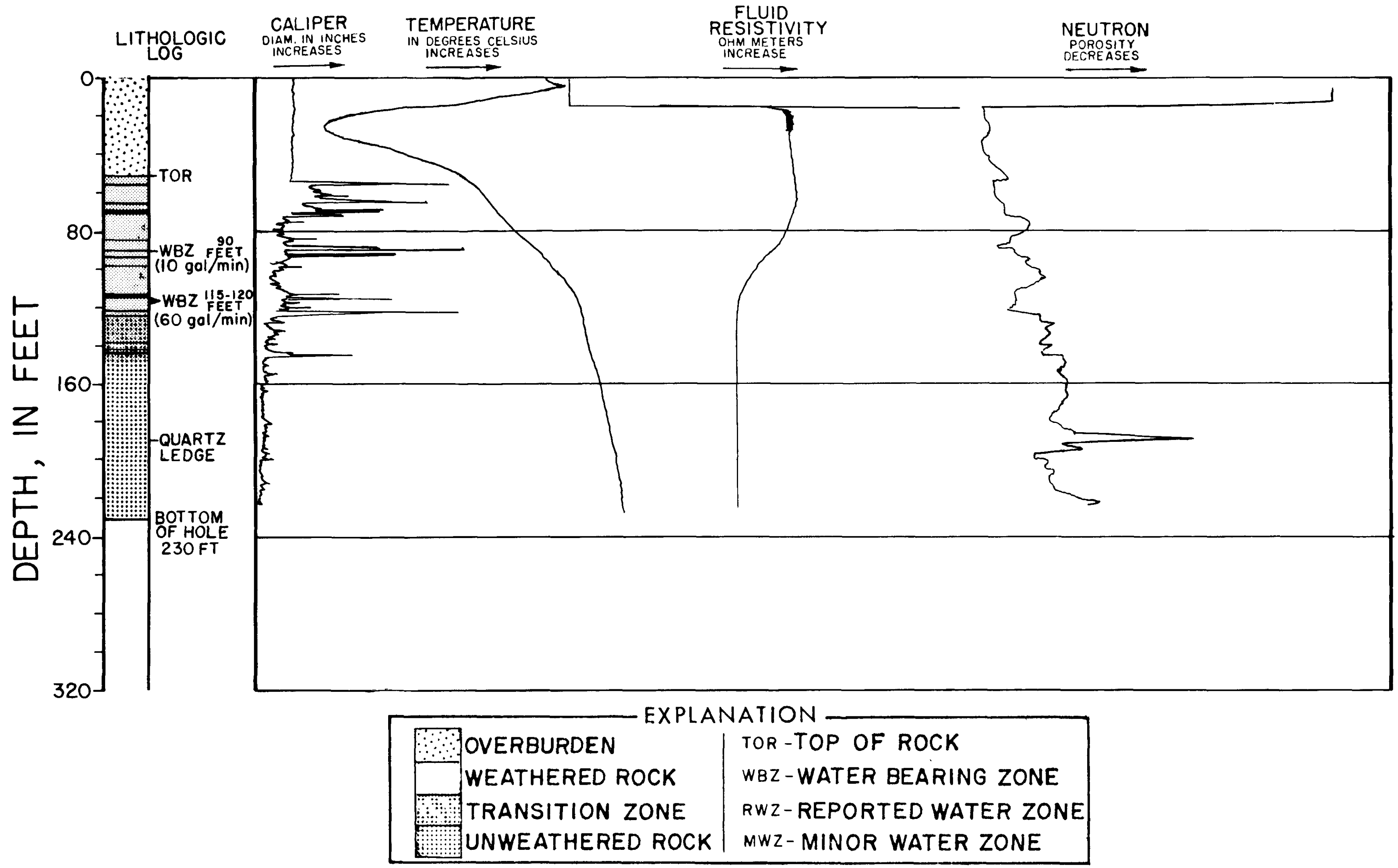
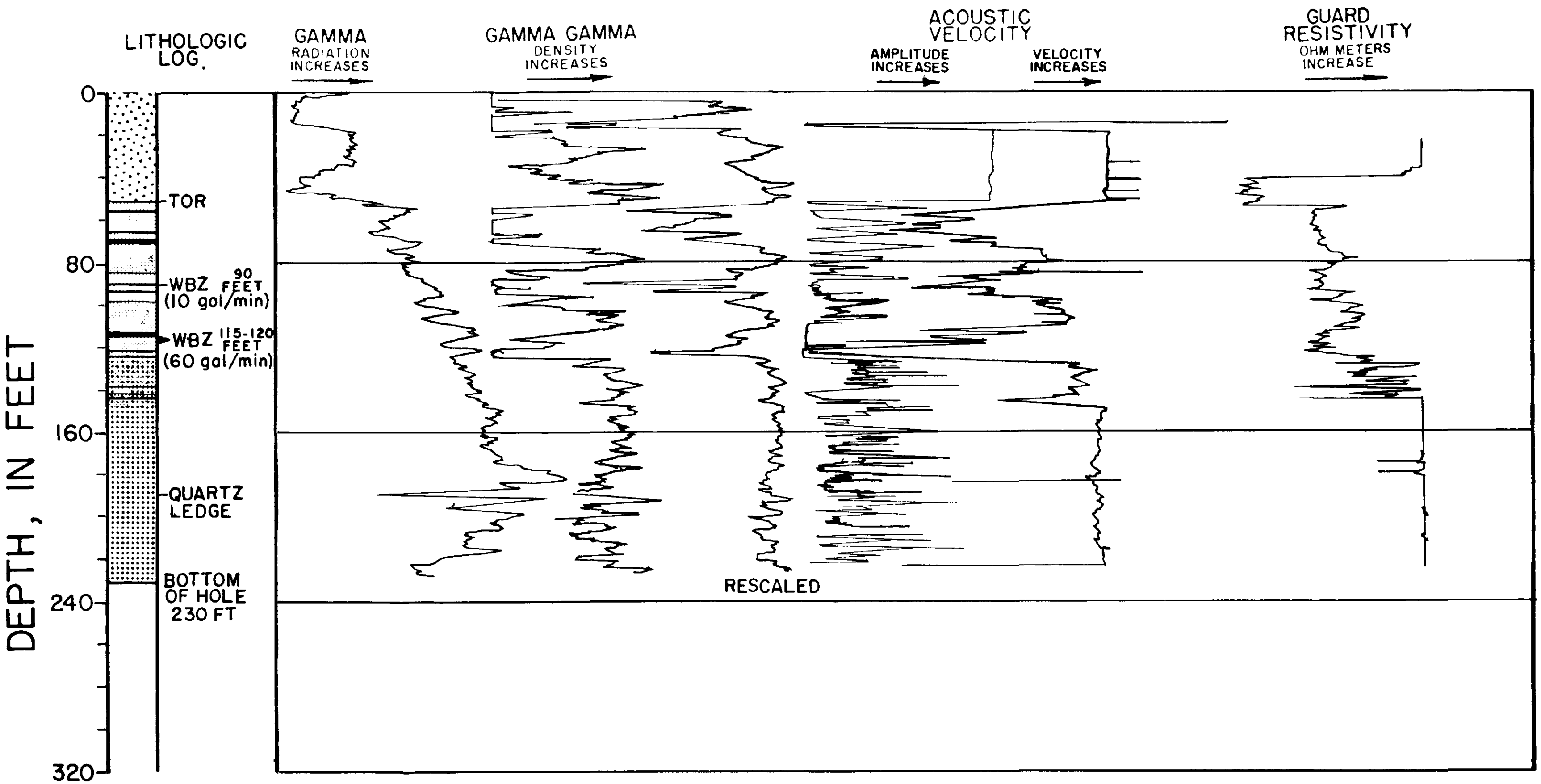
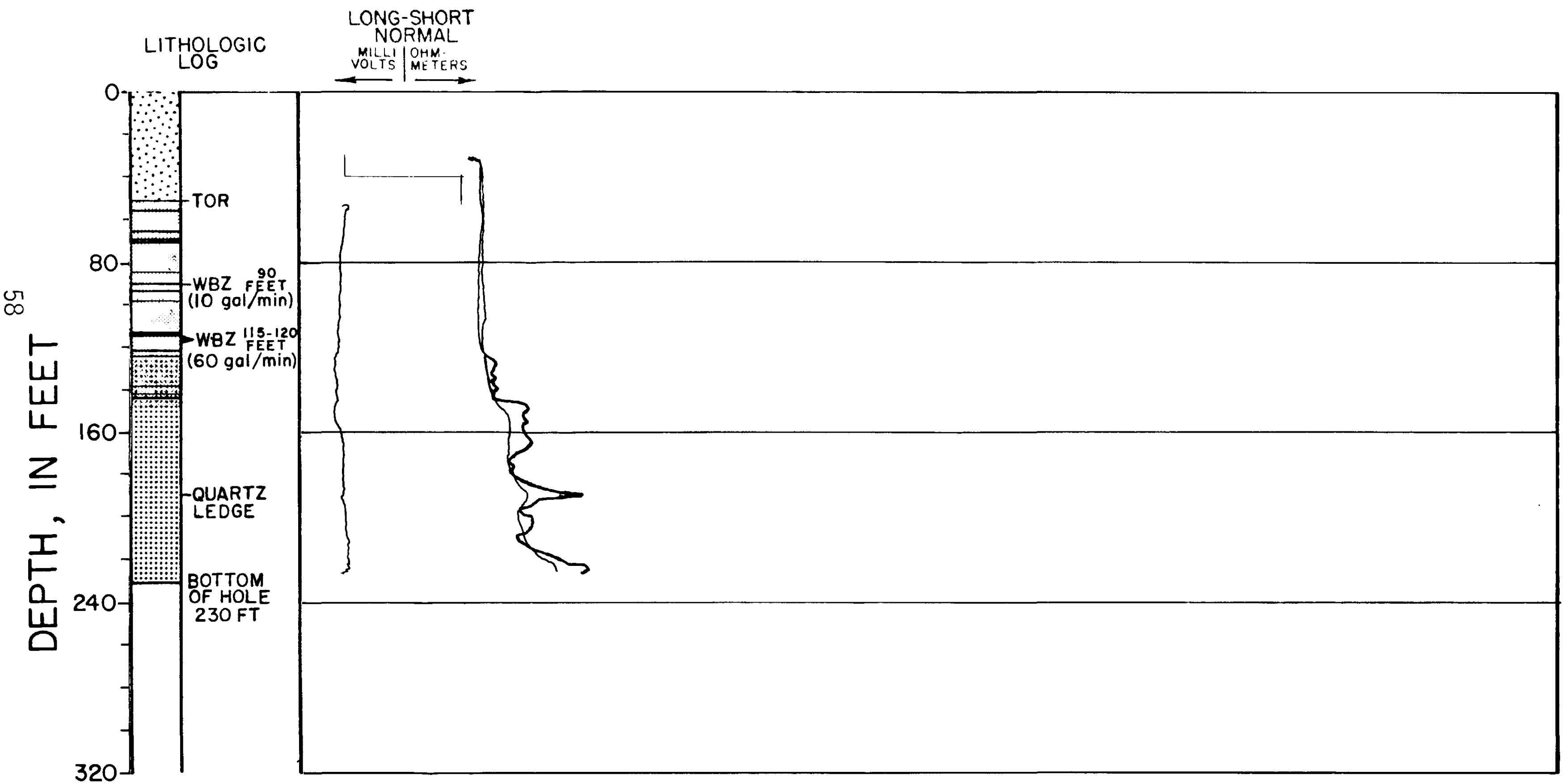


Figure 30.--Logs for well 5.

LOGS FOR WELL-5 (CONT)



LOGS FOR WELL-5 (CONT)



LOGS FOR WELL-6

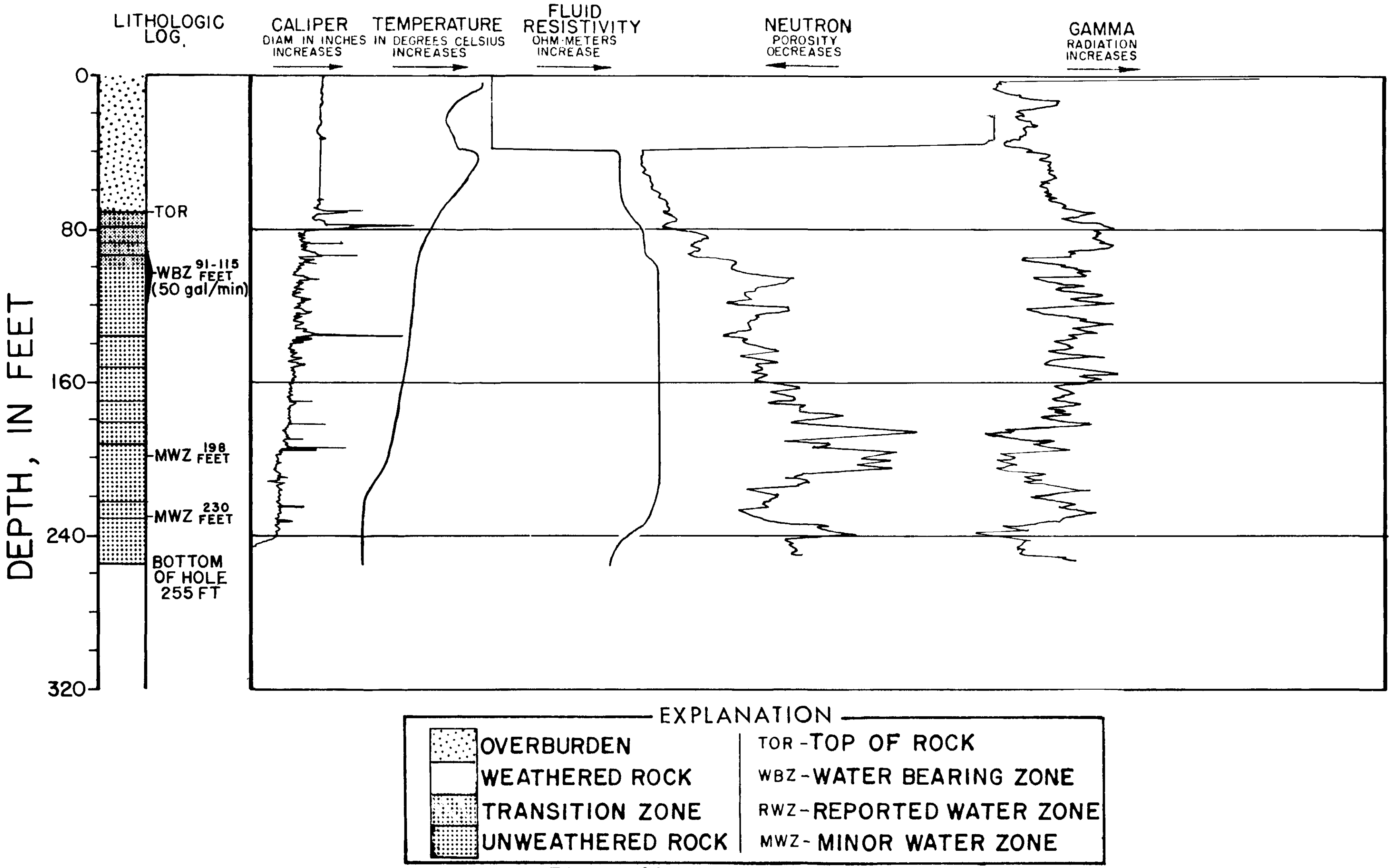
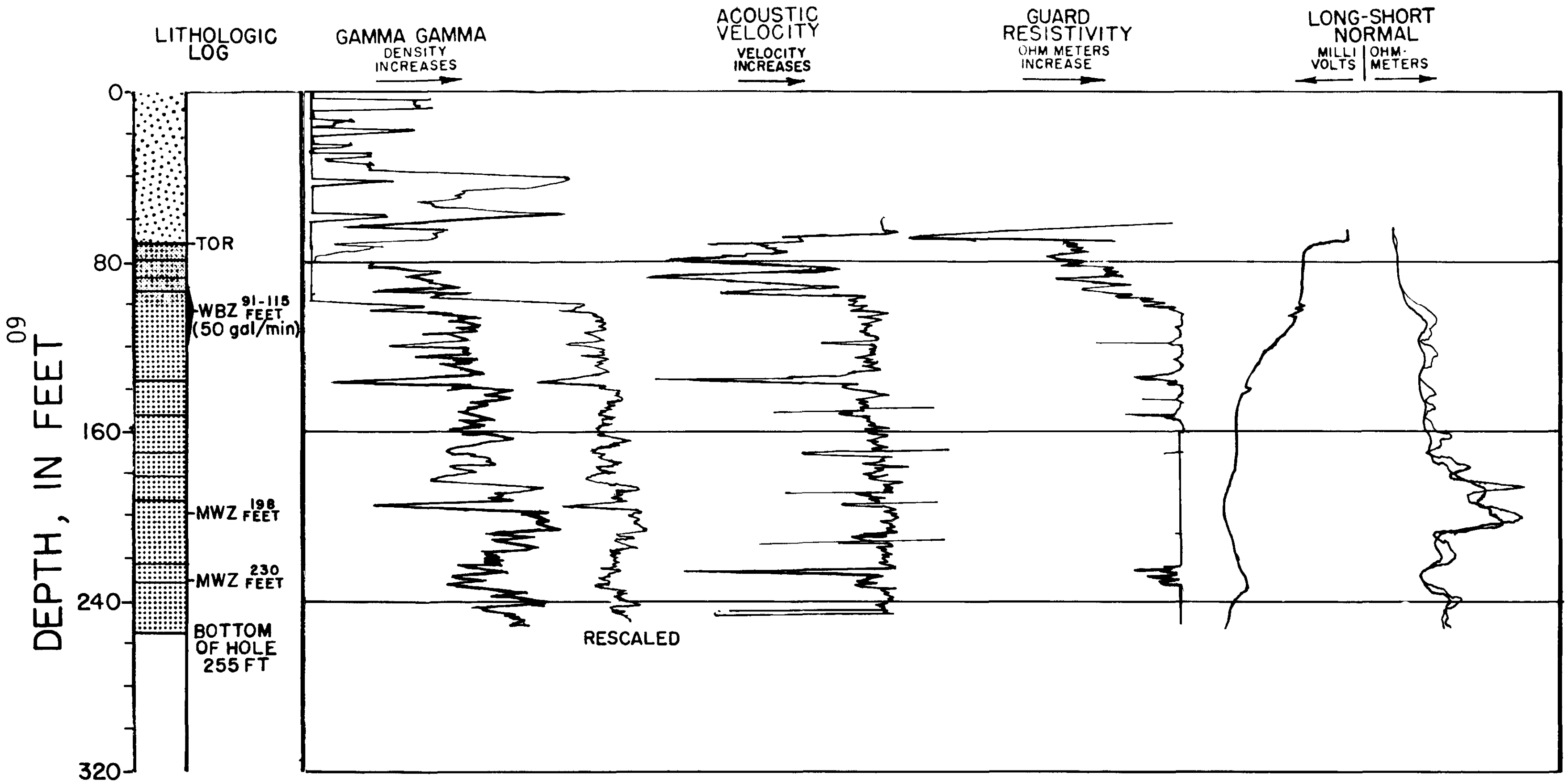


Figure 31.--Logs for well 6.

LOGS FOR WELL-6 (CONT)



LOGS FOR WELL-9

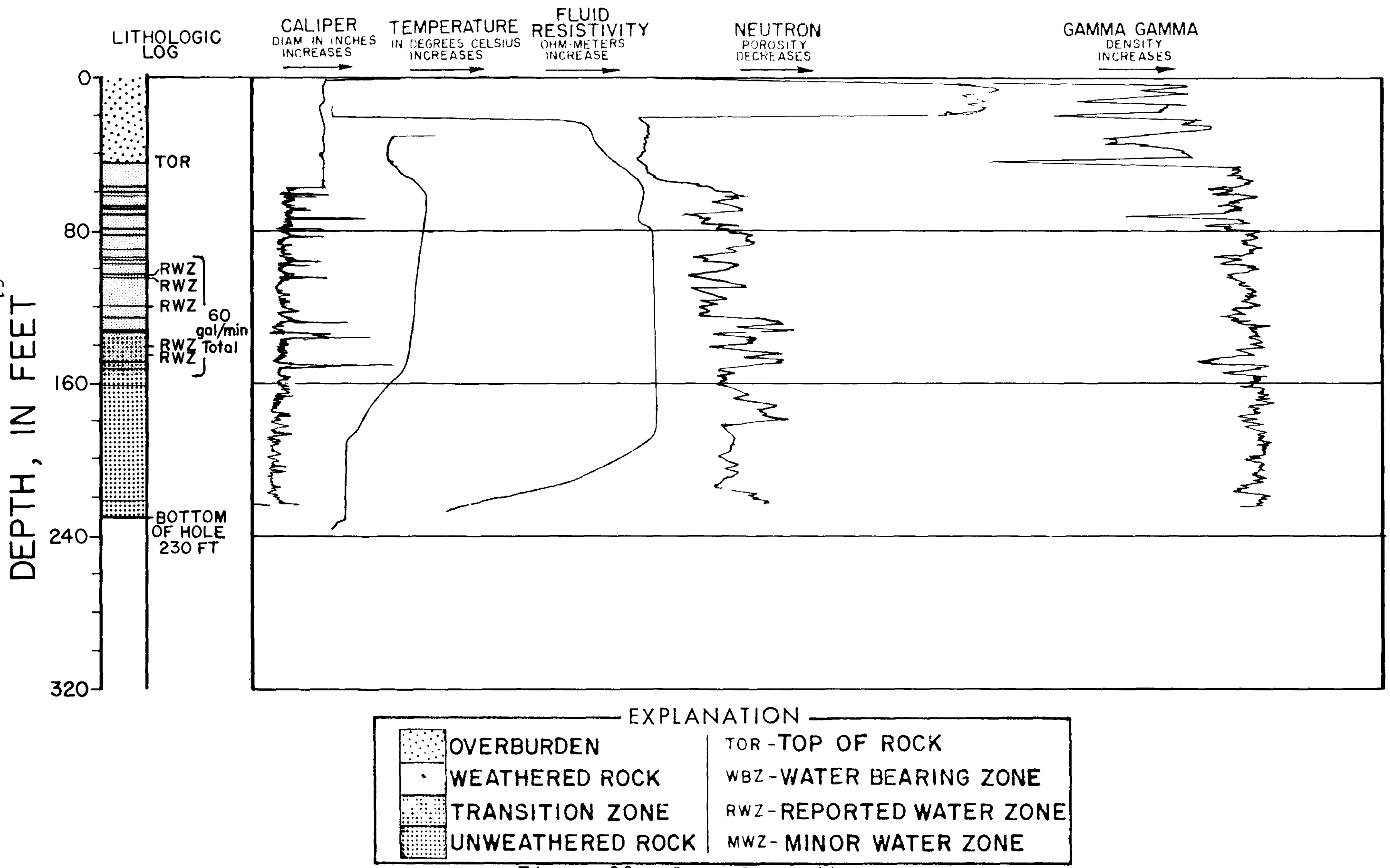
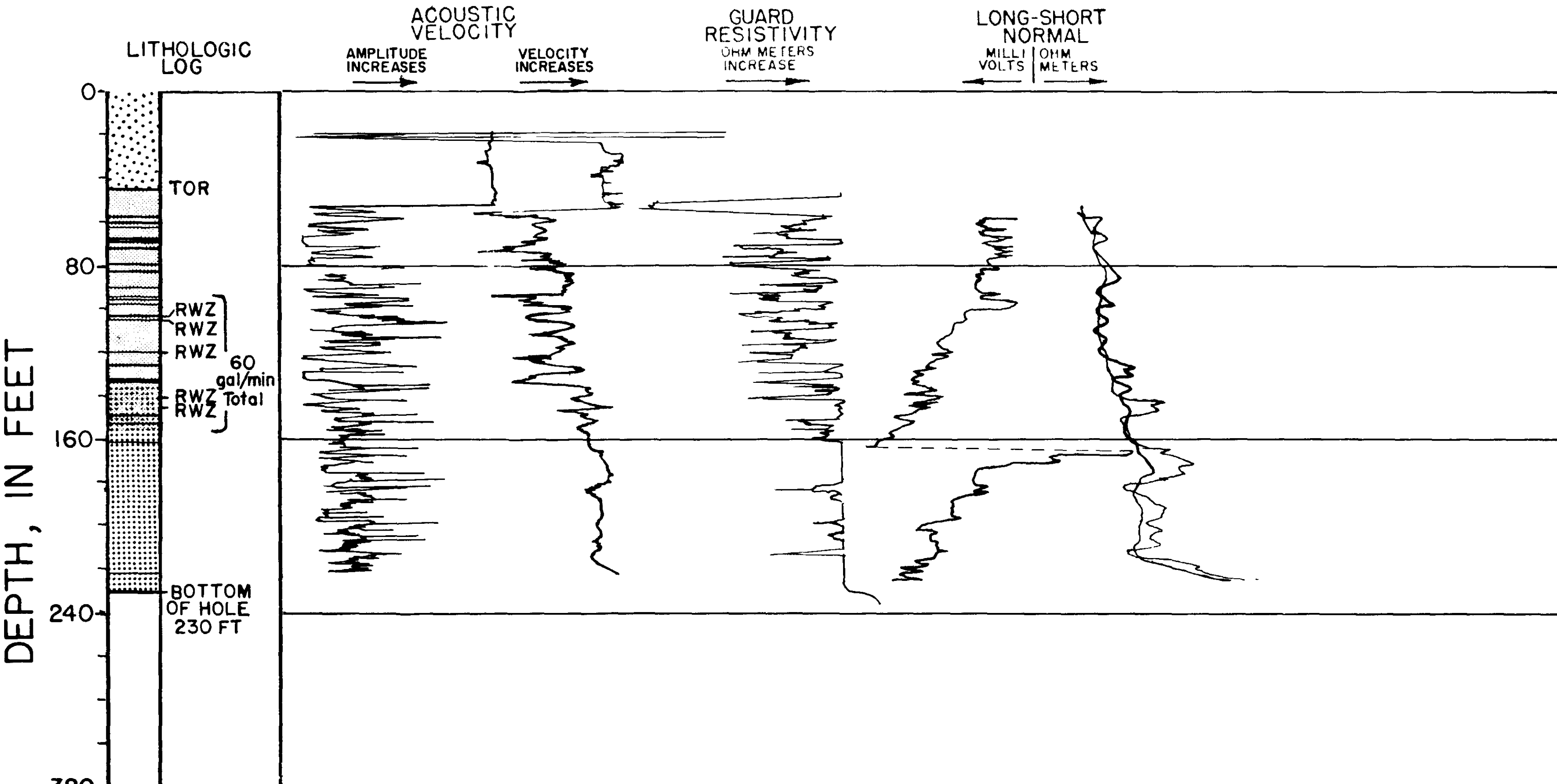


Figure 32.--Logs for well 9.

LOGS FOR WELL-9 (CONT)



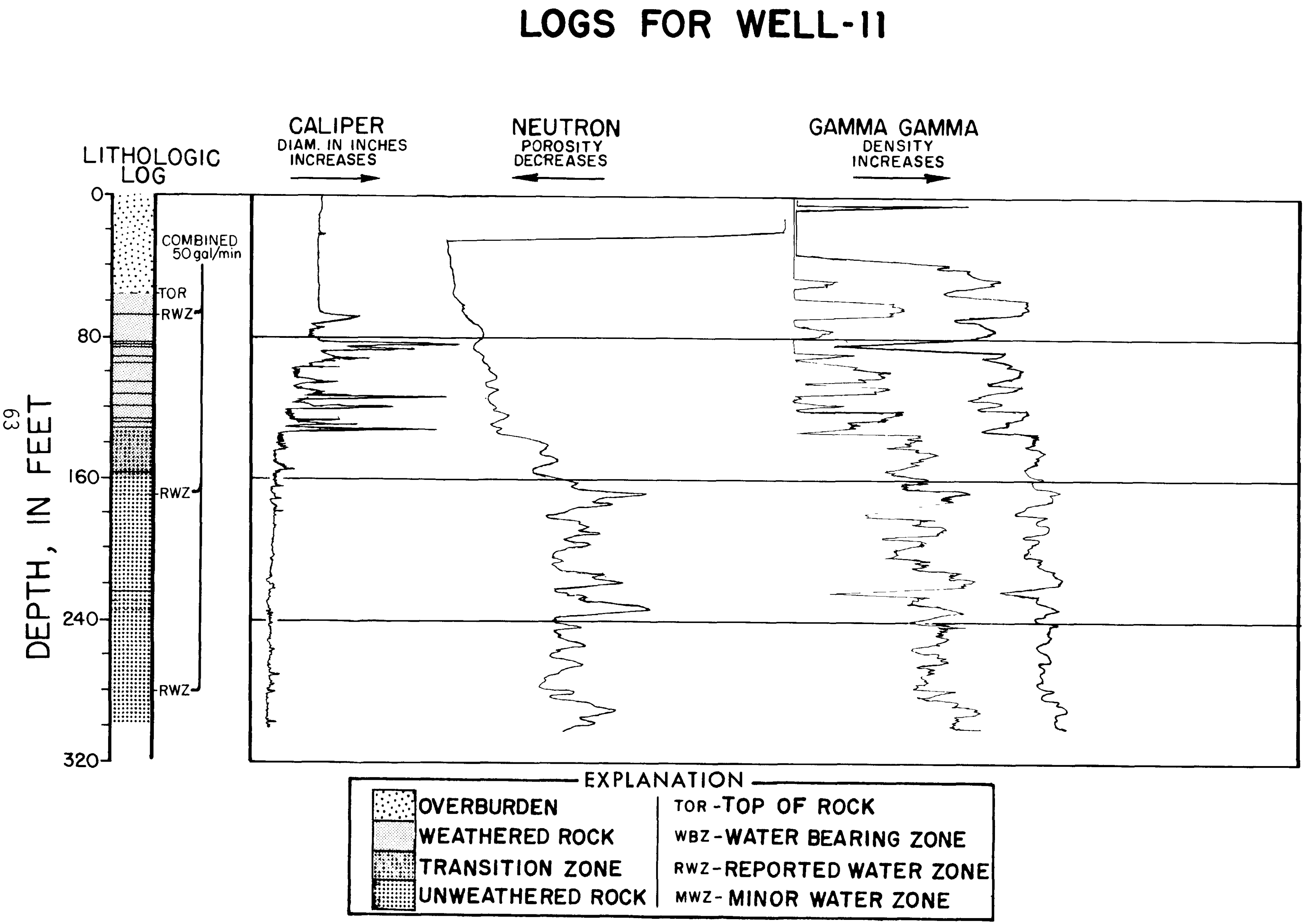
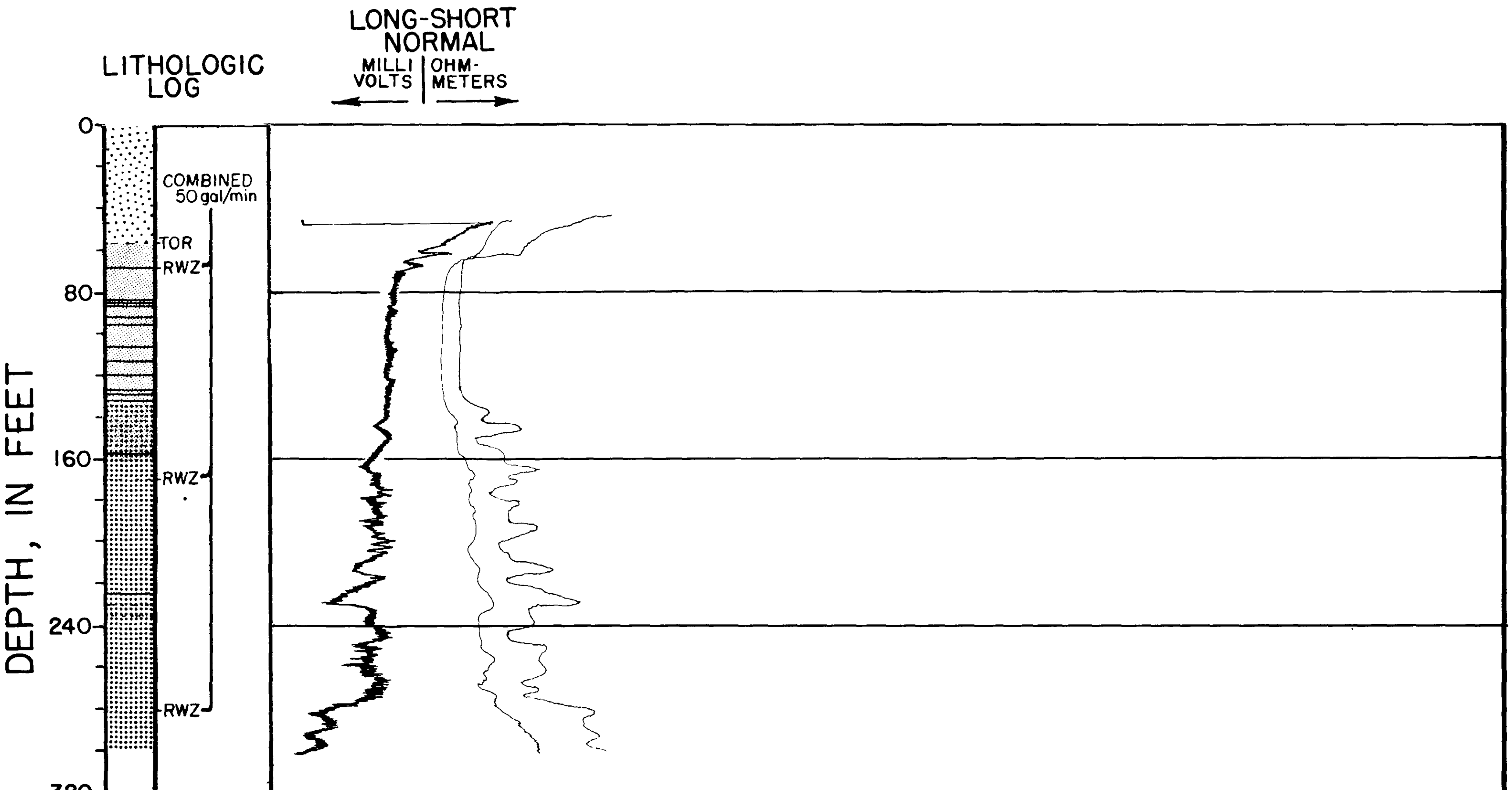


Figure 33.--Logs for well 11.

LOGS FOR WELL-11 (CONT.)



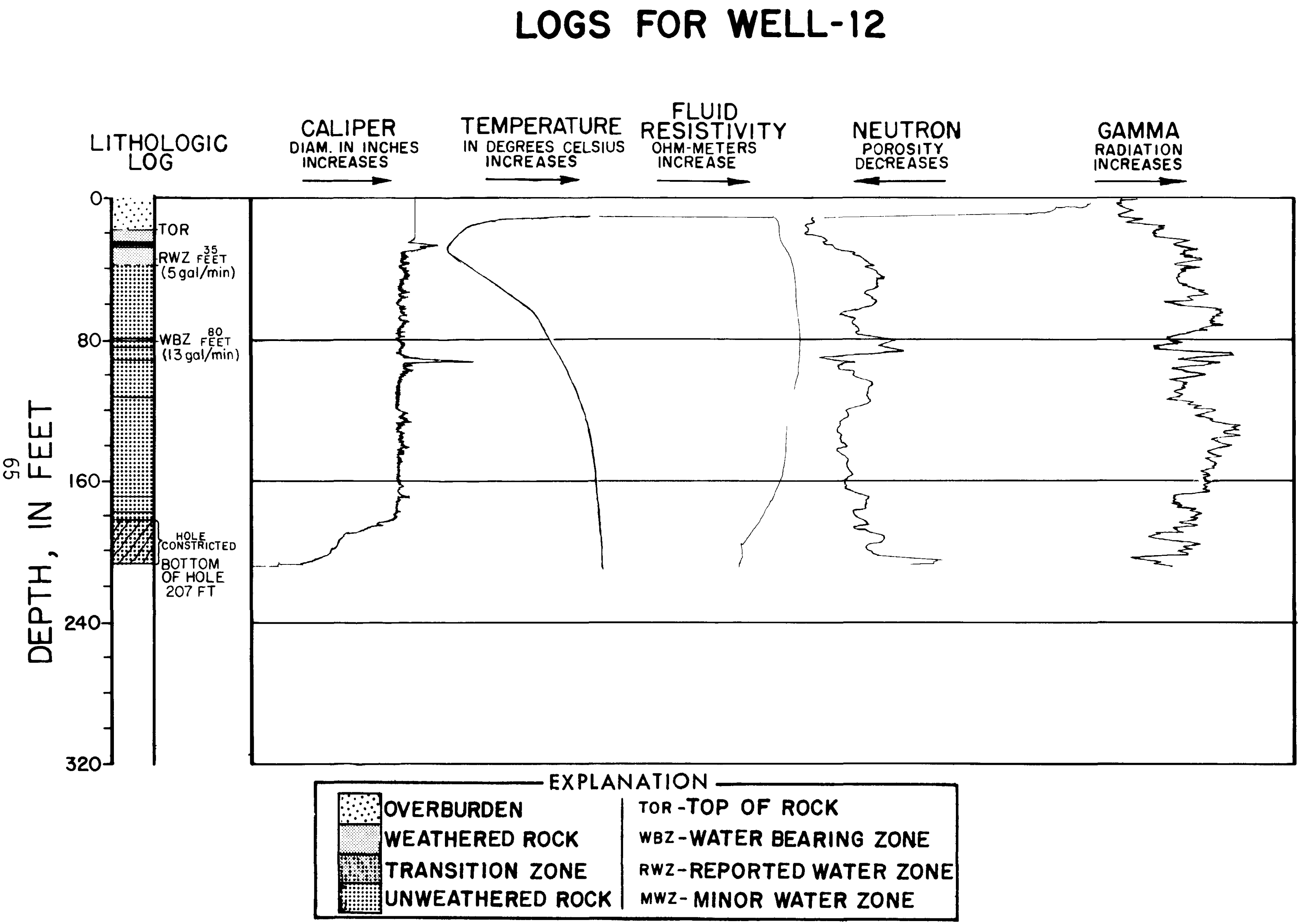
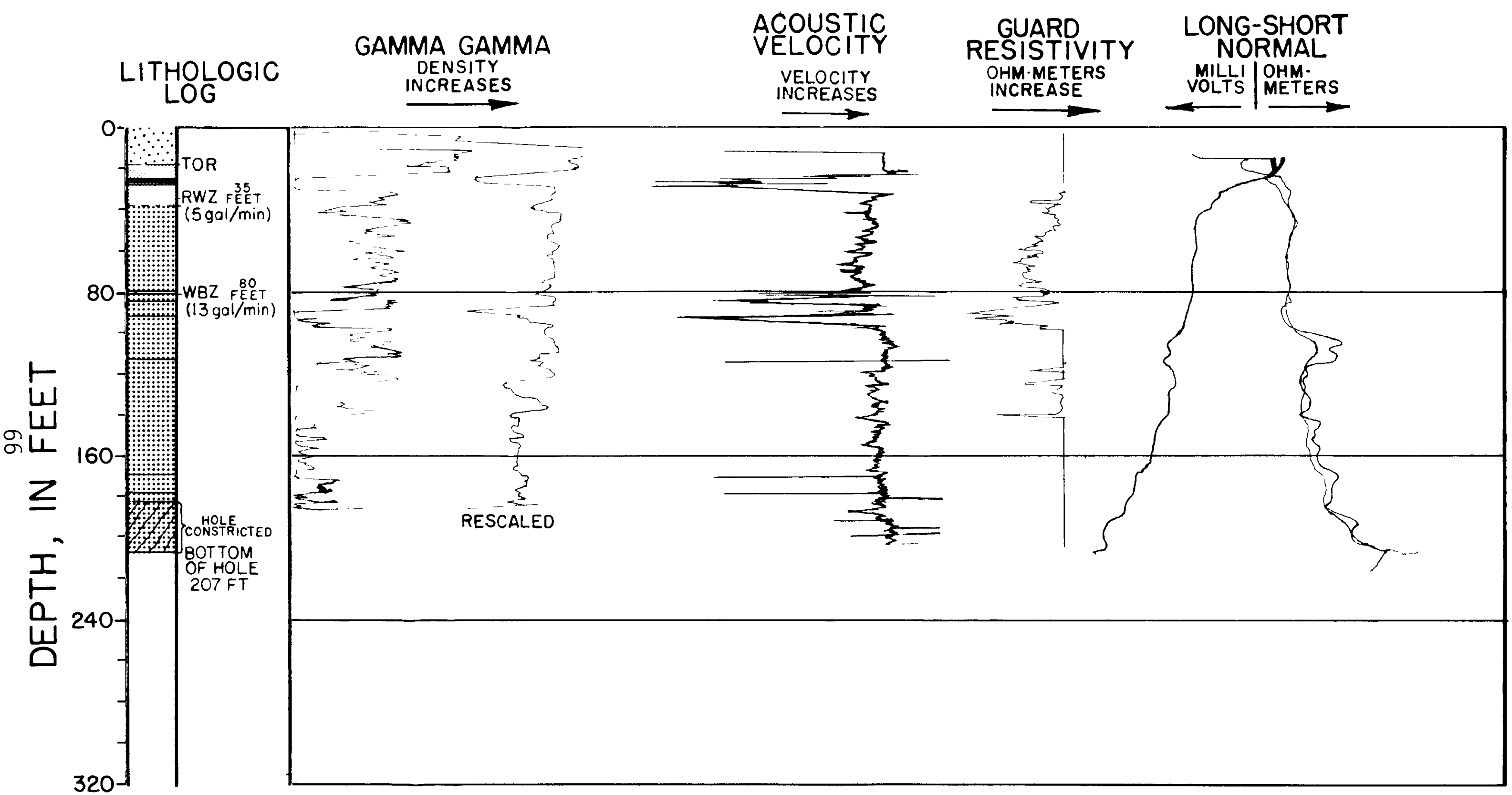


Figure 34.--Logs for well 12.

LOGS FOR WELL-12 (CONT.)



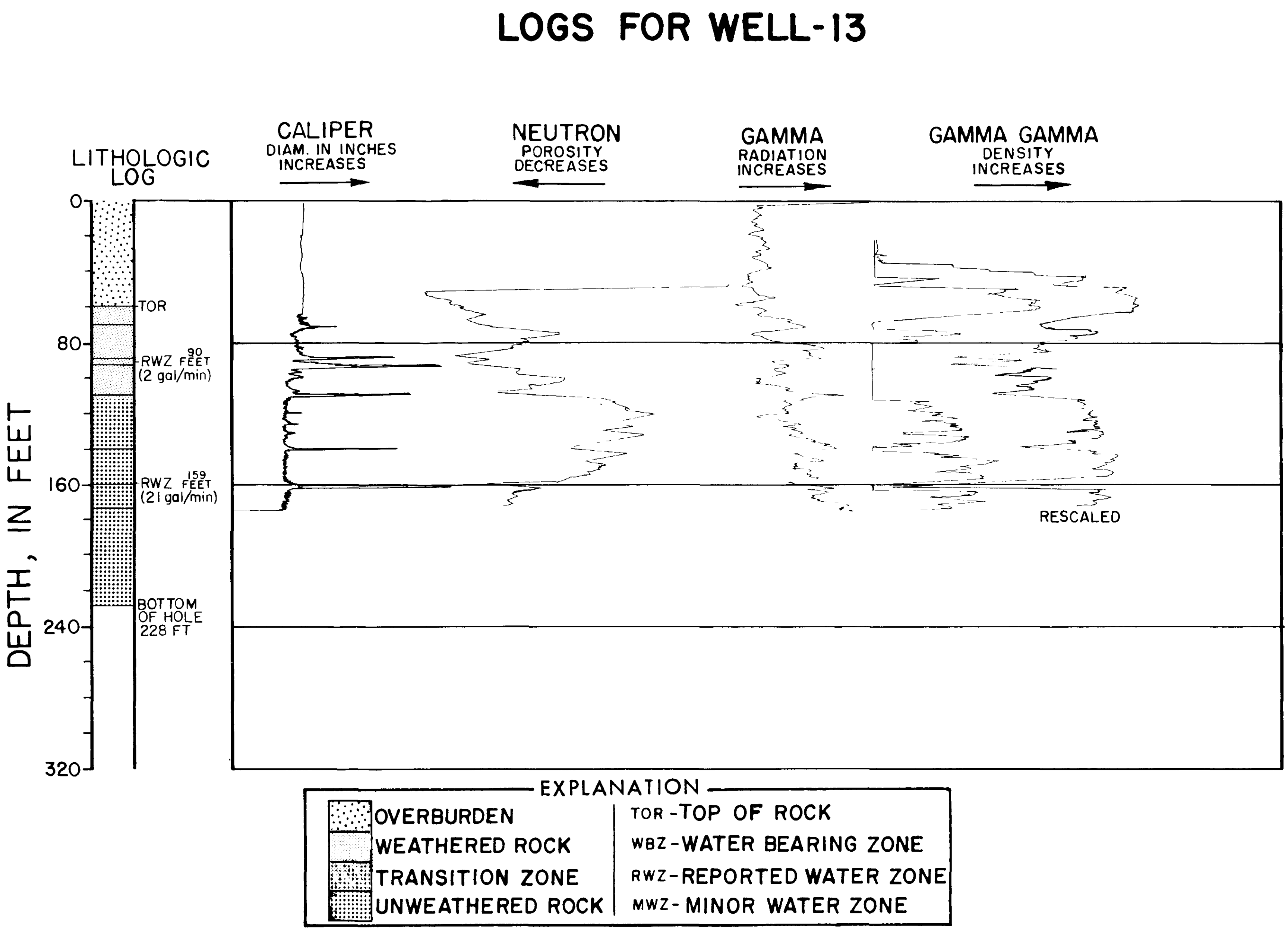


Figure 35.--Logs for well 13.

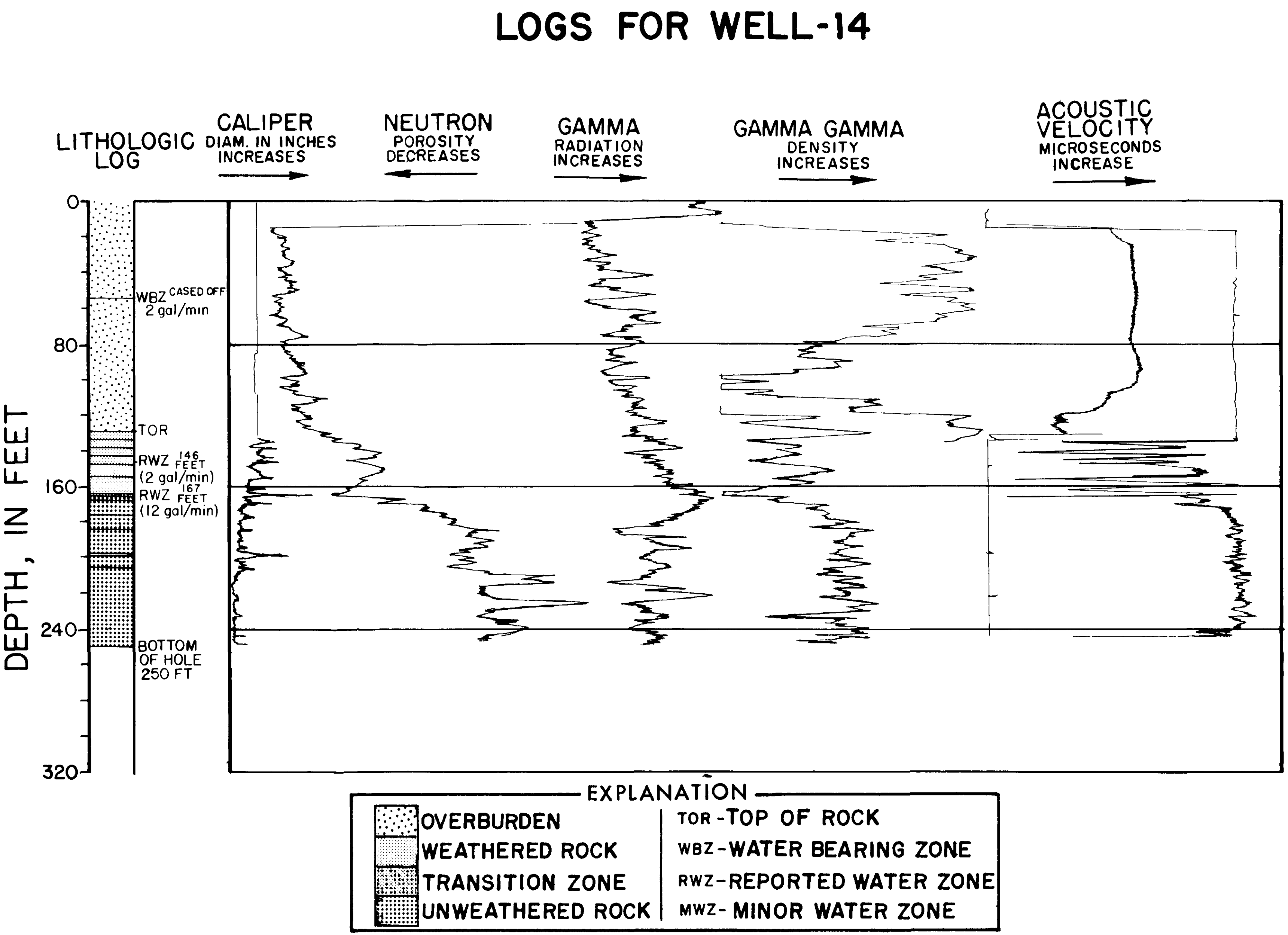


Figure 36.--Logs for well 14.

LOGS FOR WELL-15

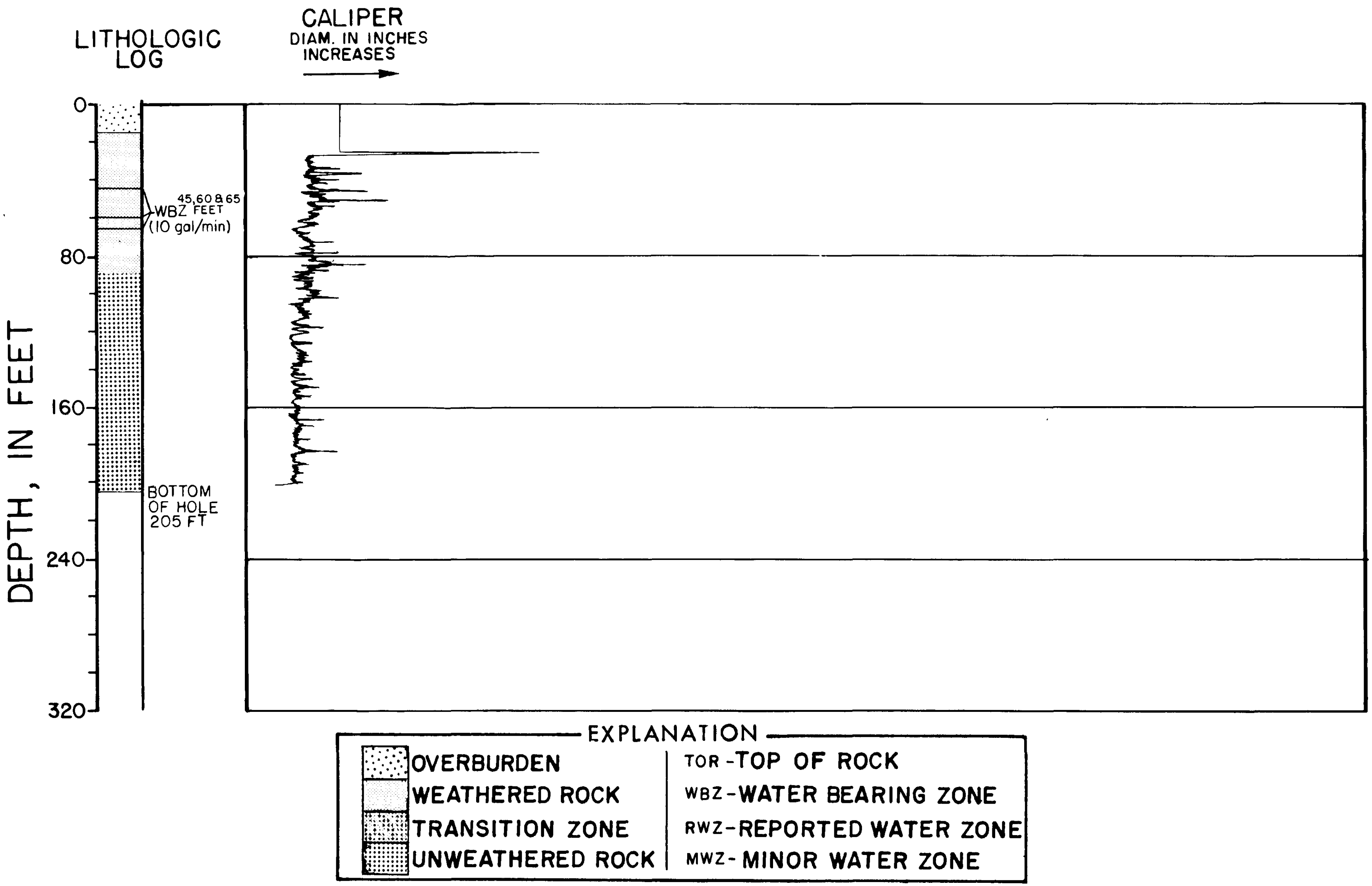


Figure 37.--Logs for well 15.

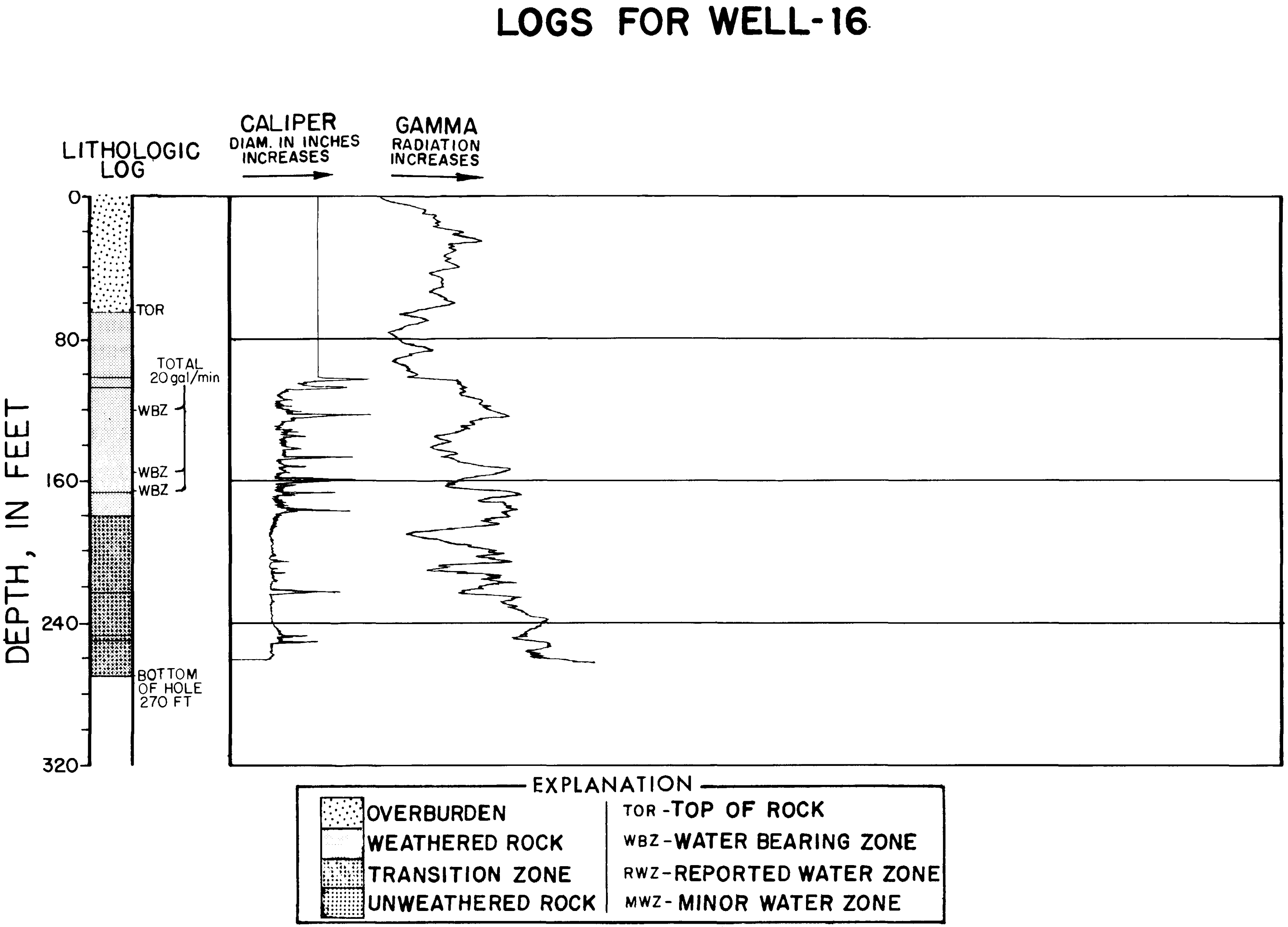


Figure 38.--Logs for well 16.

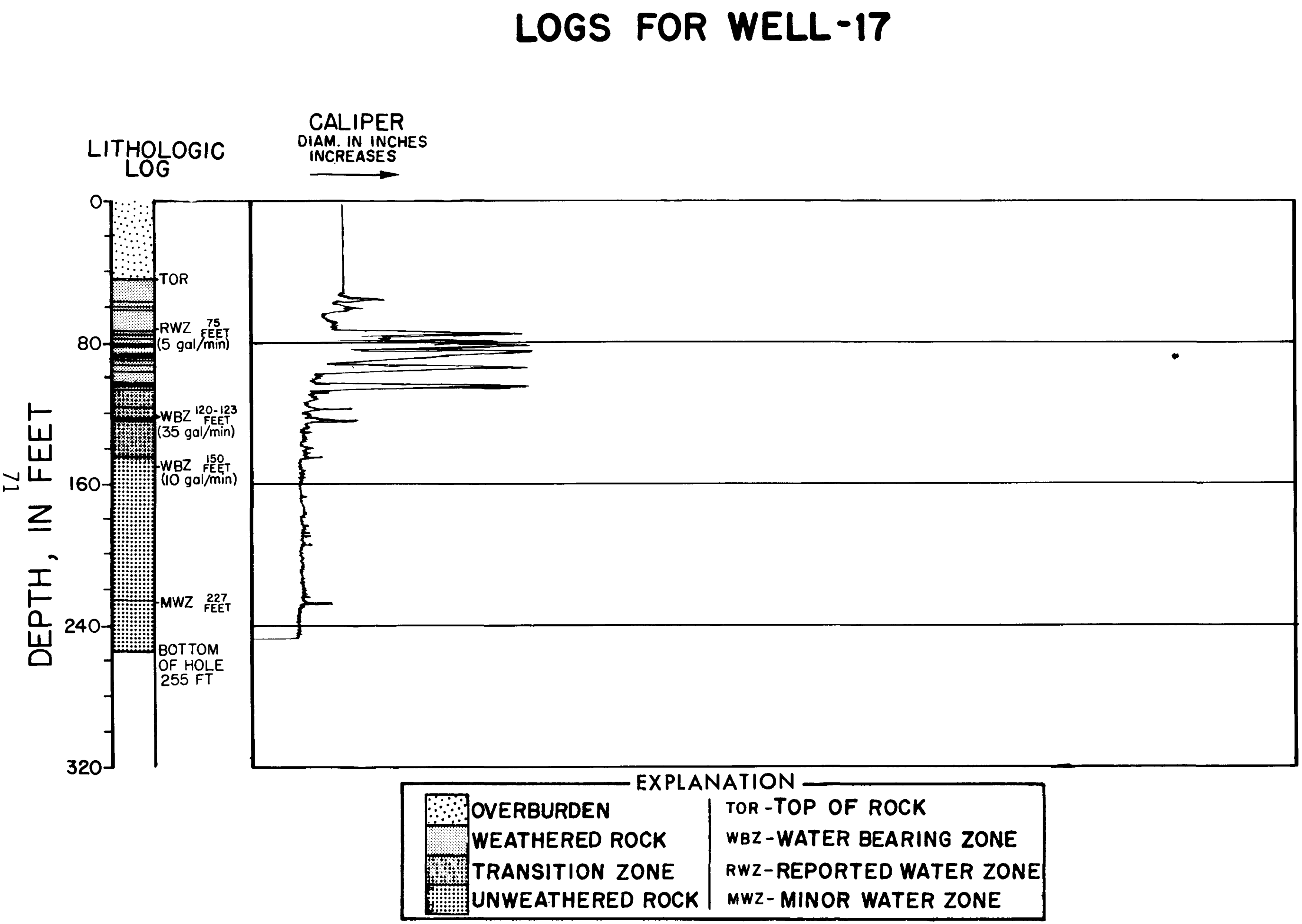


Figure 39.--Logs for well 17.

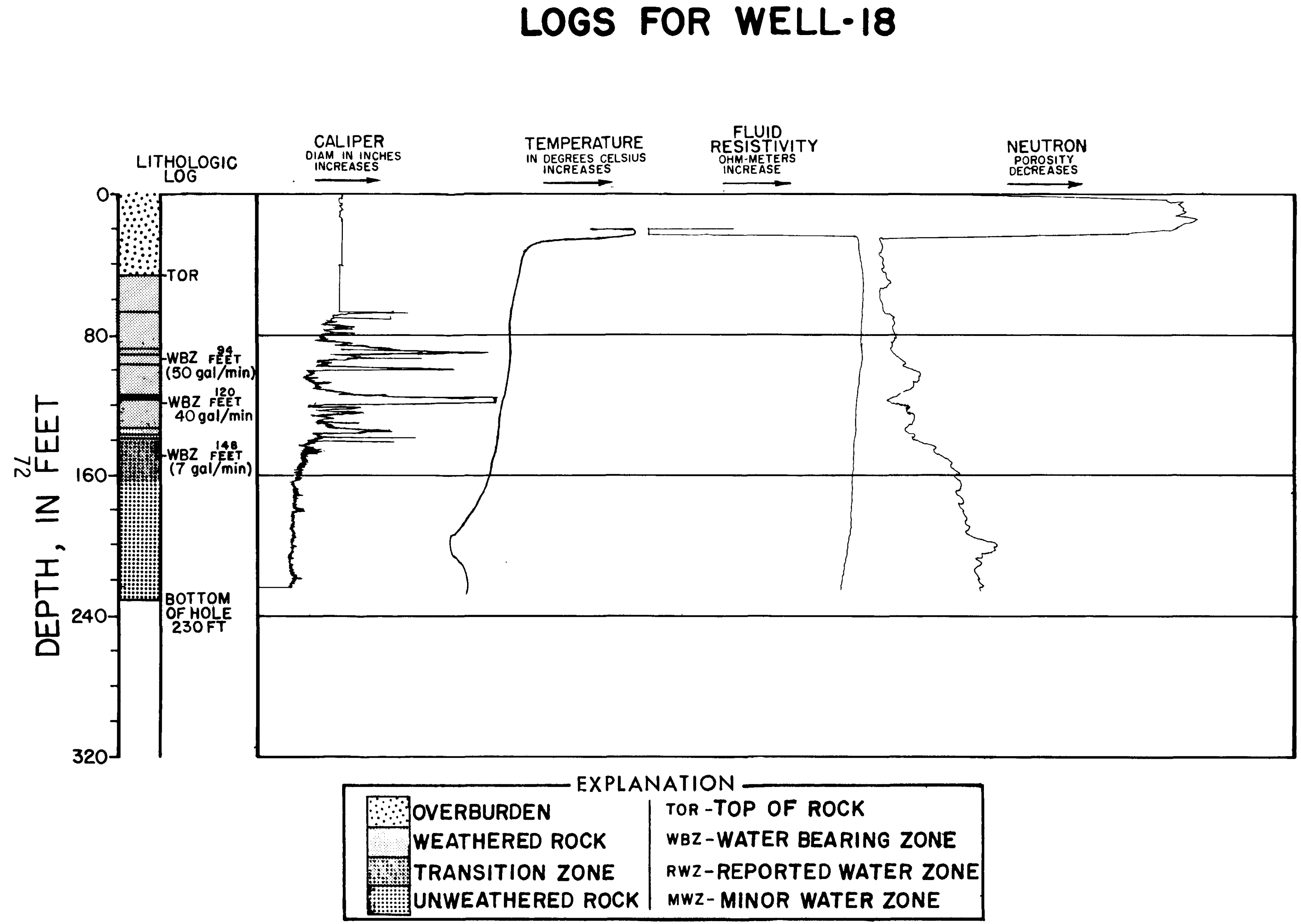
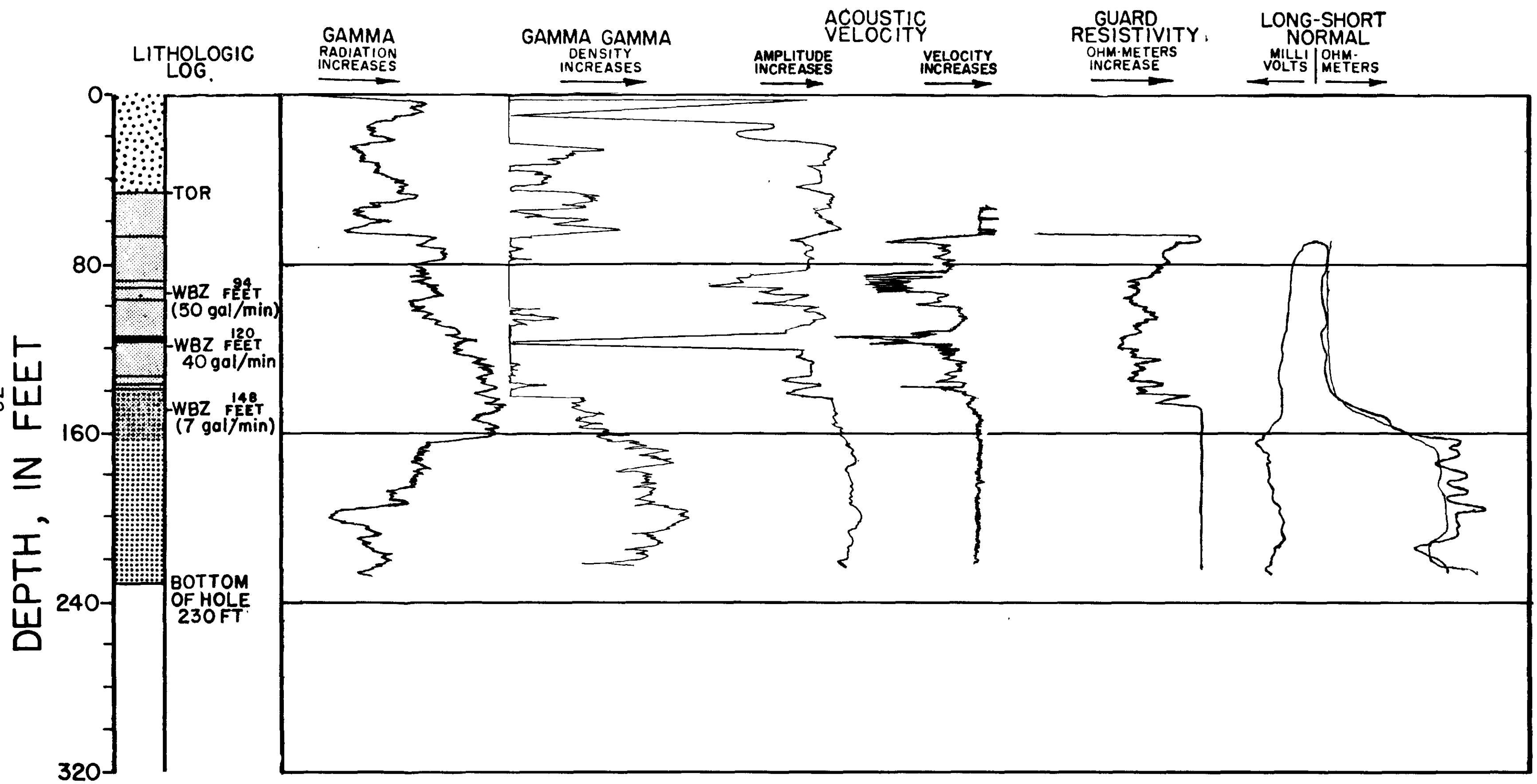


Figure 40.--Logs for well 18.

LOGS FOR WELL-18 (CONT)



LOGS FOR WELL-21

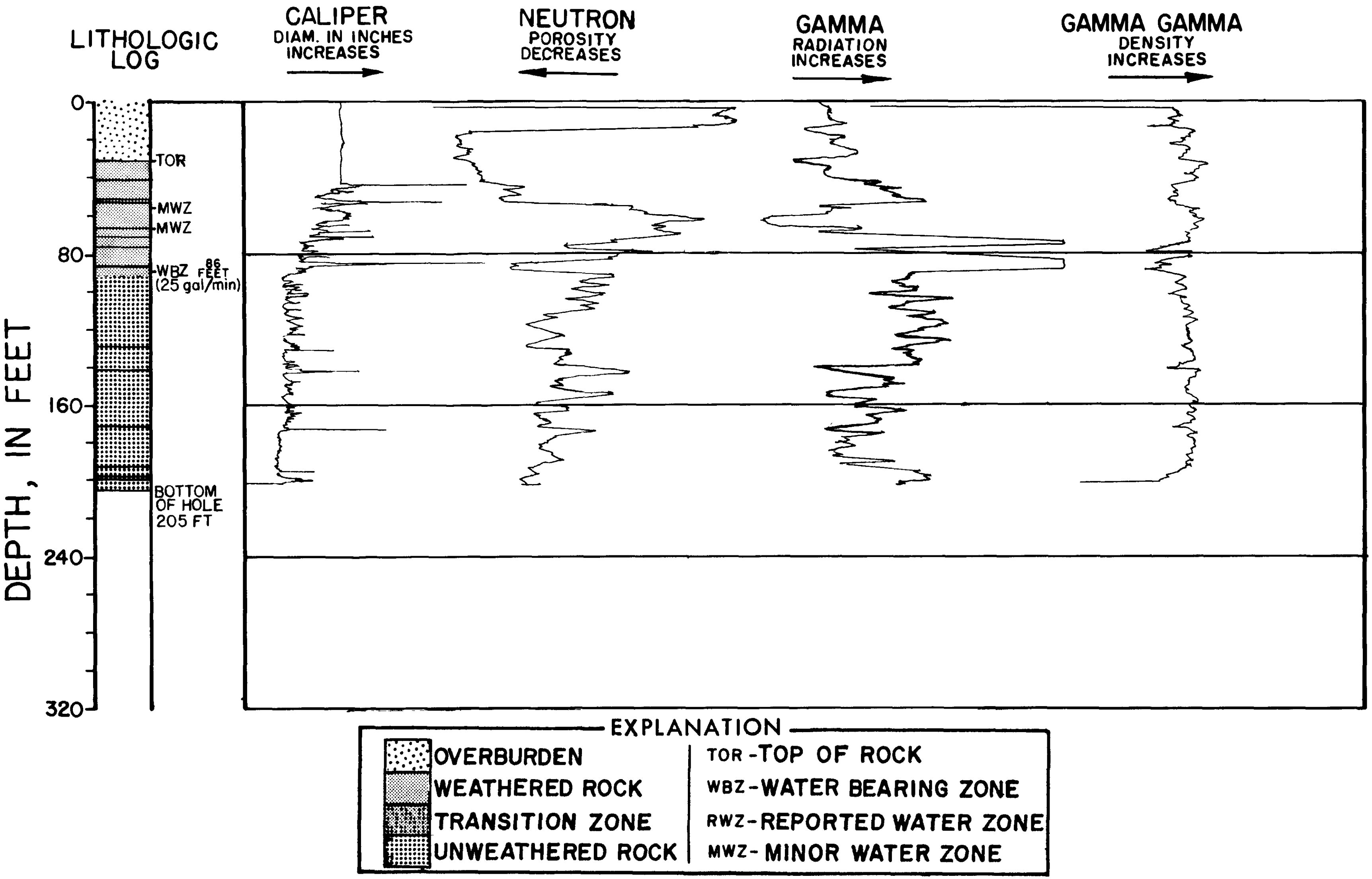


Figure 41.--Logs for well 21.

LOGS FOR WELL-22

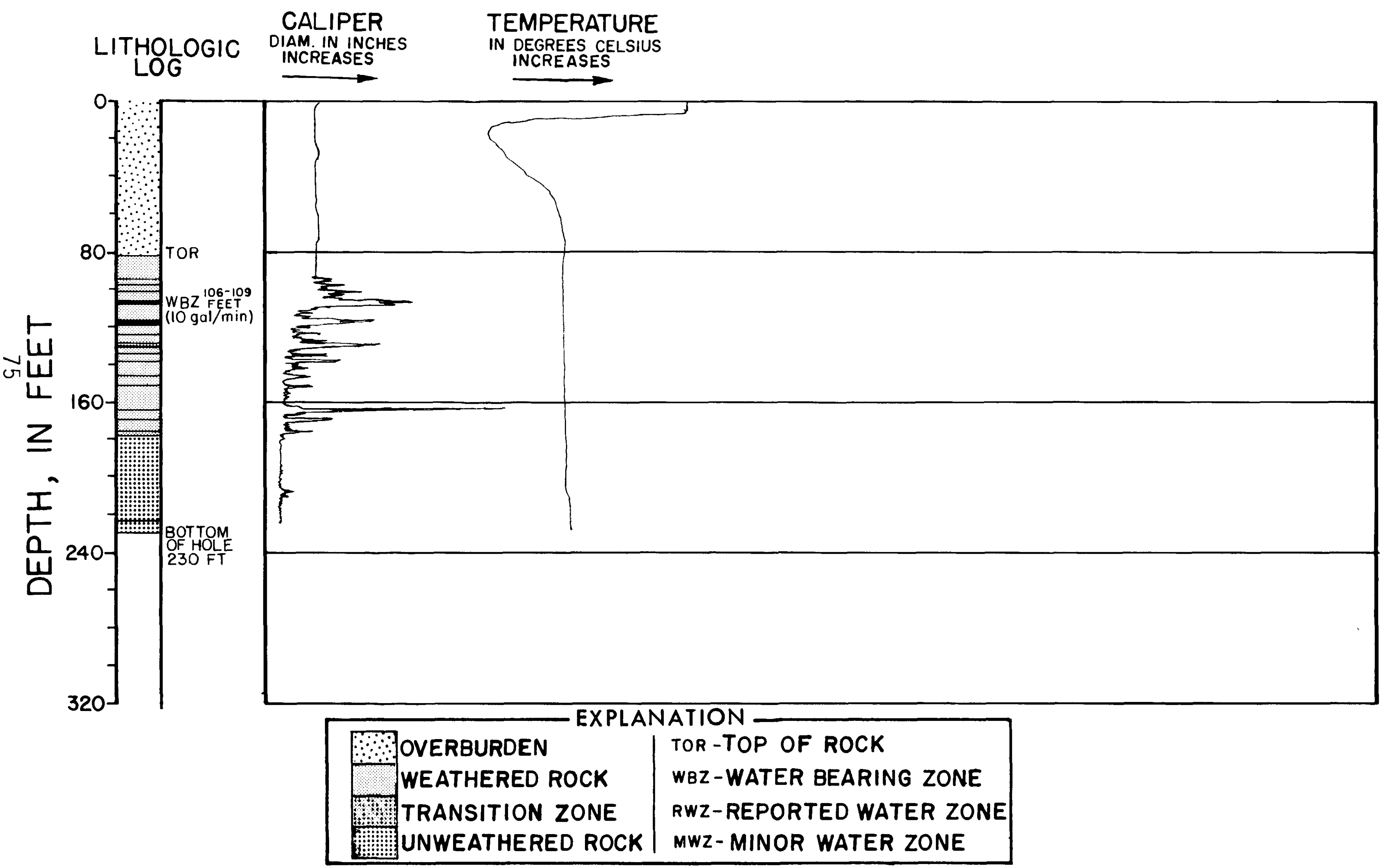


Figure 42.--Logs for well 22.

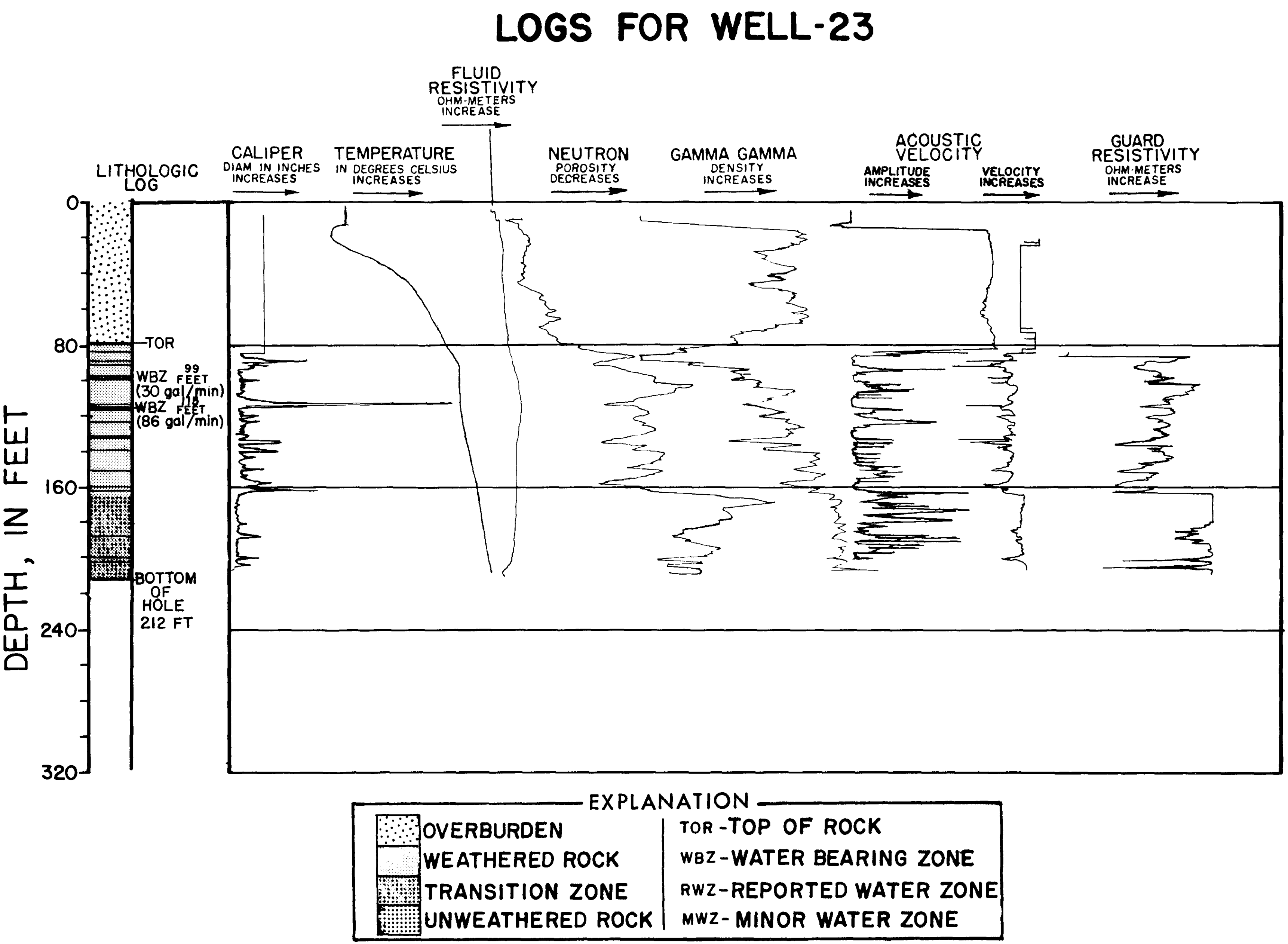
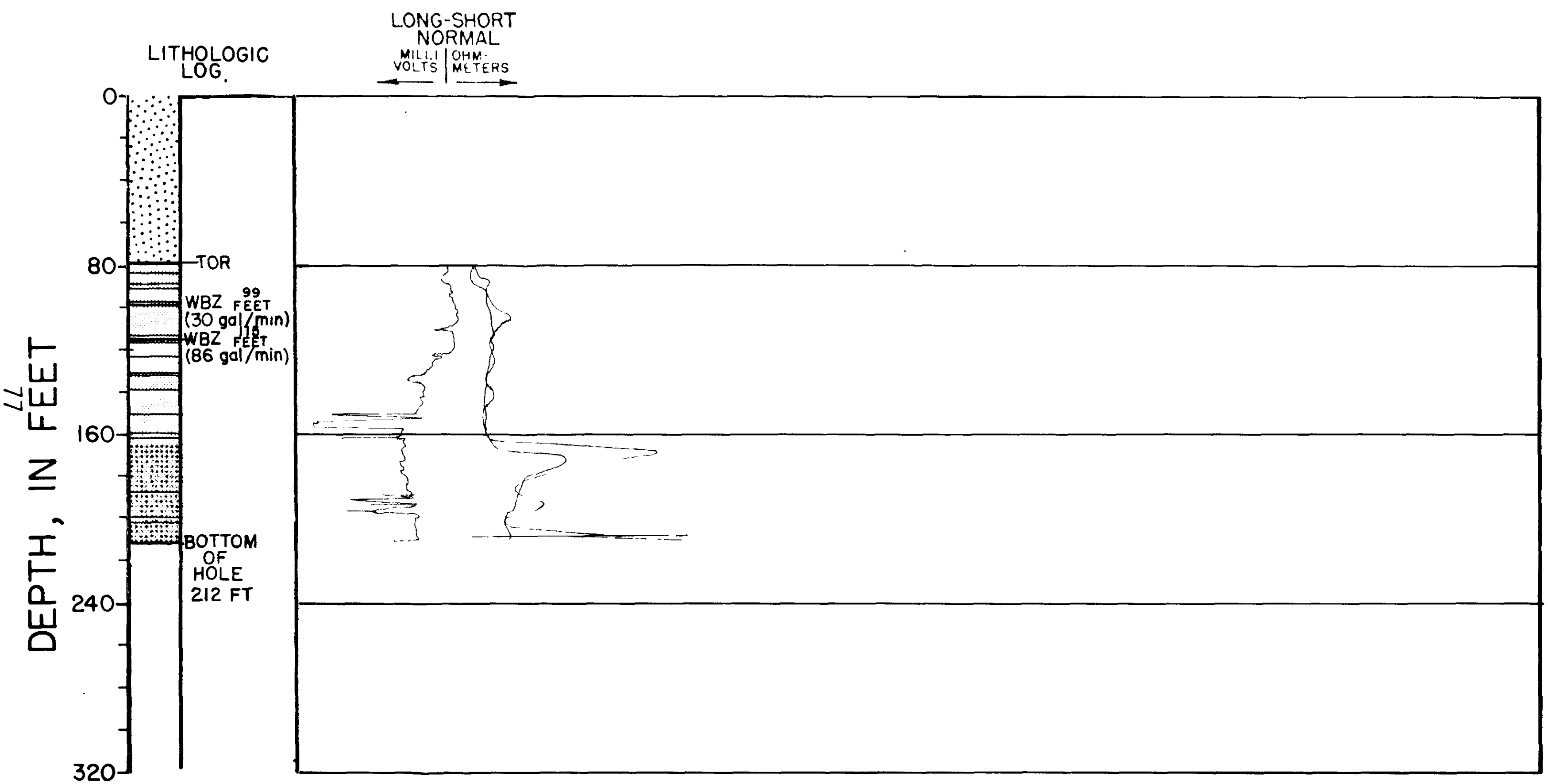


Figure 43.--Logs for well 23.

LOGS FOR WELL-23 (CONT)



LOGS FOR WELL-24

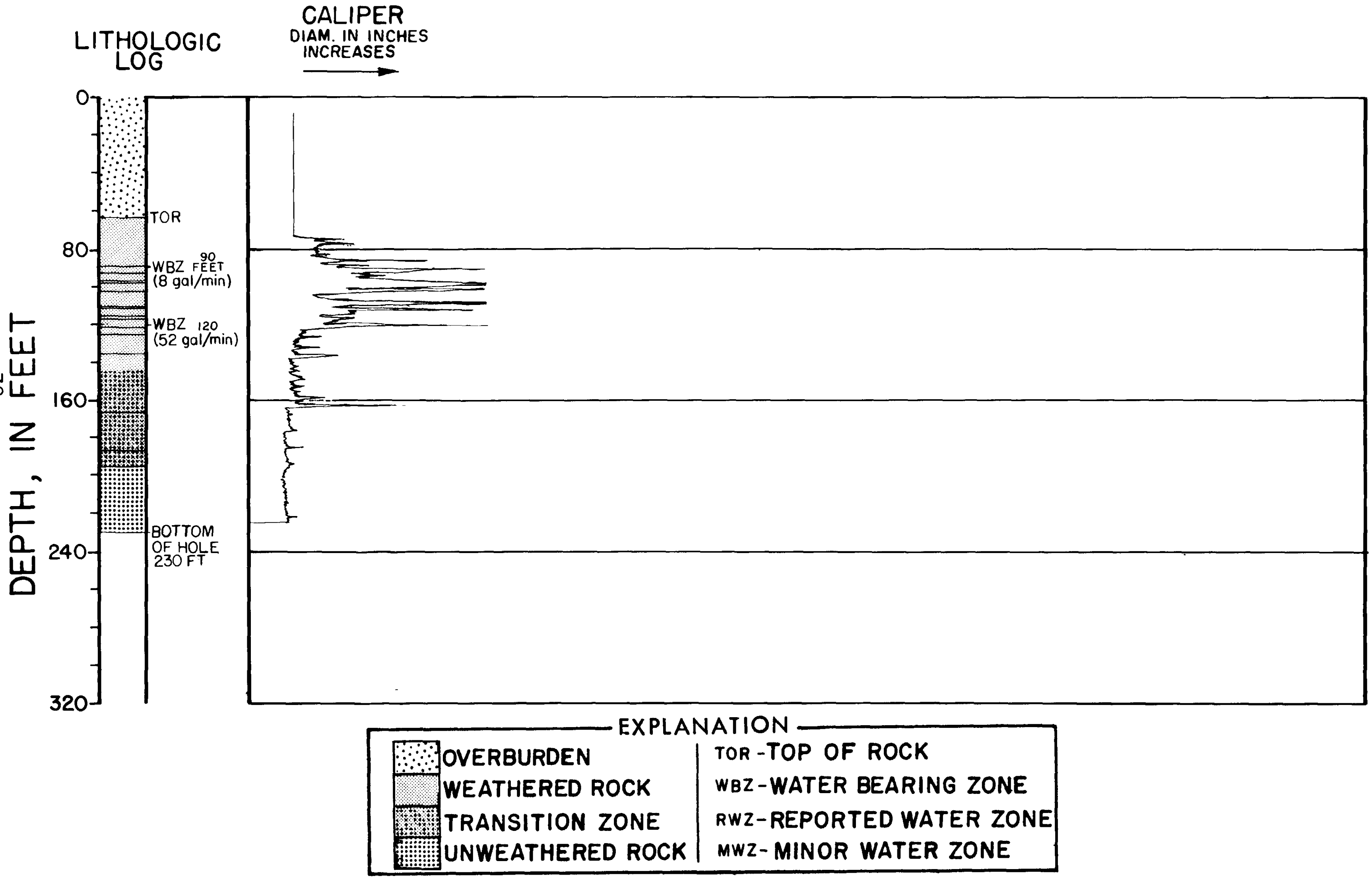


Figure 44.--Logs for well 24.

WELL LOGS FOR WELL-25

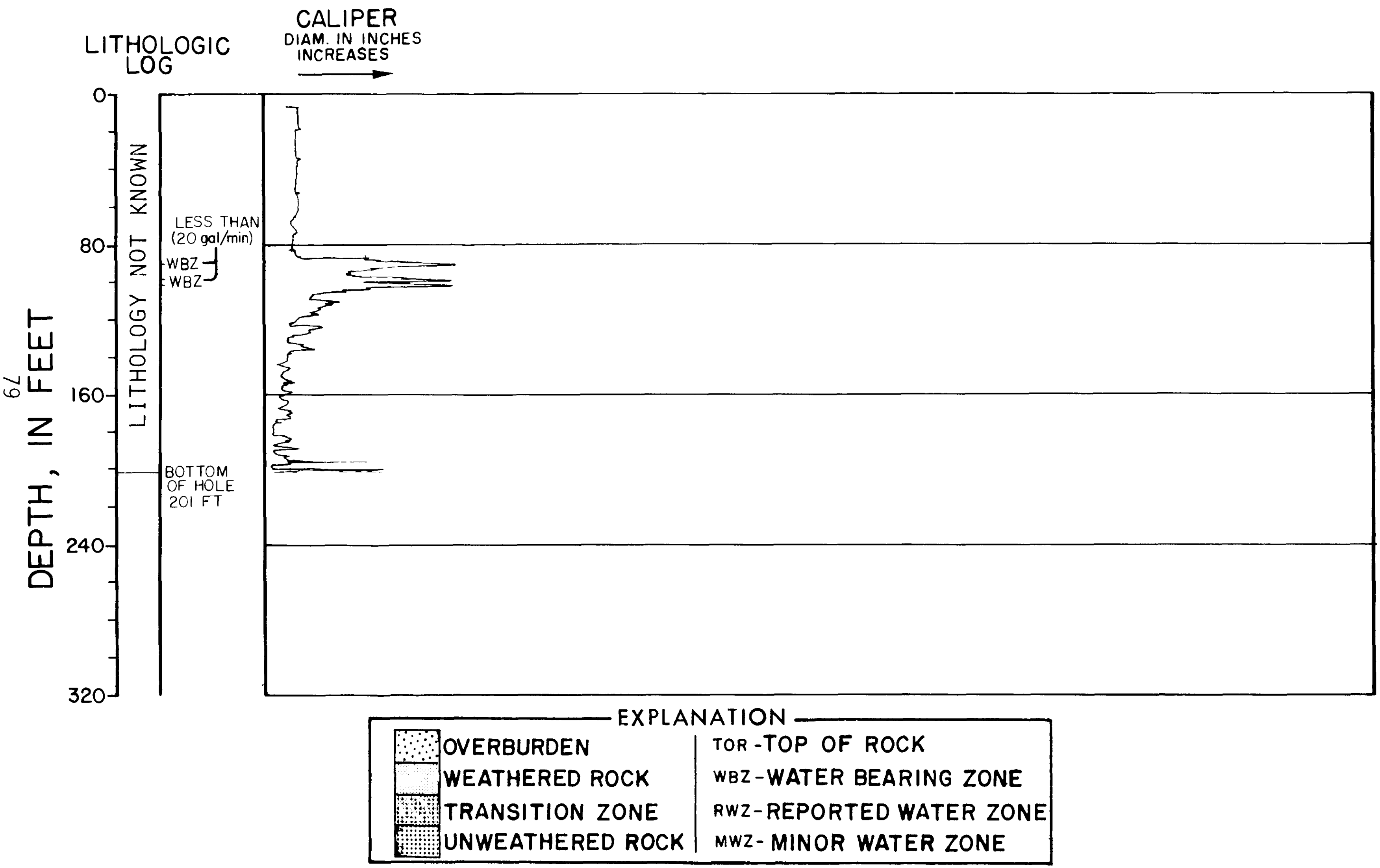


Figure 45.--Logs for well 25.