EFFECTS OF FRACTURING ON WELL YIELDS IN THE COALFIELD AREAS OF WISE AND DICKENSON COUNTIES, SOUTHWESTERN VIRGINIA

By Winfield G. Wright

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CONVERSION TABLE

Factors for converting inch-pound units to metric (International System) units are shown below:

Multiply Inch-pound Unit	By	To obtain Metric Unit
gallon per minute (gal/min)	0.6309	liter per second (L/s)
foot squared per day (ft^2/d)	0.0929	meter squared per day (m^2/d)
foot per day (ft/d)	0.3048	meter per day (m/d)
inch (in)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
temperature (°F)-32	0.5555	temperature (°C)

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EFFECTS OF FRACTURING ON WELL YIELDS IN THE COALFIELD AREAS OF WISE AND DICKENSON COUNTIES, SOUTHWESTERN VIRGINIA

By Winfield G. Wright

ABSTRACT

Fracturing associated with lineaments are the primary influence on yields from wells in the coalfields of southwestern Virginia. Graphical comparison of yields from wells shows that wells located in valleys with lineaments produce larger quantities of water than wells in valleys without lineaments. Aquifer tests on wells located in valleys with lineaments indicate that transmissivities are as high as 598 ft^2/d, mainly because of secondary porosities caused by fracturing.

Analysis of data collected from packer-injection tests in a test hole located on a ridge indicate relatively large hydraulic conductivities ranging from $2x10^{-2}$ to $1x10^{-1}$ feet per day in upper parts of the test hole, compared to conductivities ordinarily expected in unfractured rocks in the study area. Fracturing caused by stress relief contribute to these large values. Yields from wells located on lineaments are consistently higher than well yields from wells in unfractured rocks in the study area, but yields from wells randomly placed in areas suspected of having stress-relief fractures cannot be predicted.

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INTRODUCTION

The complex geologic structure of the coalfield region of southwestern Virginia affects rock permeability and, consequently, the capacity of the rocks to store and transmit water. Differences in permeability related to the differences in the number and size of fractures complicates the design of programs to monitor ground water near coal-mining operations. Conceptual models of the ground-water system are needed to explain the mechanisms controlling ground-water flow in the area.

Evaluation of the ground-water resources of Wise and Dickenson Counties is needed to meet the anticipated future demand for potable water. According to M. R. Dovel (Virginia State Water Control Board, written commun., 1983) the overall quality and quantity of ground water must be determined to prevent a restriction on future industrial development in the area. The need for ground water for industrial uses (particularly those associated with mining) and domestic uses will increase. Dovel states that it is necessary "to understand the ground-water conditions...so careful planning and management can be made." In addition, the quality of water in some aquifers of the study area is not suitable for most uses because of high concentrations of naturally occurring substances. Therefore, studies of the ground-water system are necessary to manage the ground-water resources of the area.

Several sources of hydrogeologic data in the coalfield region are available; these include wells used by the coal companies to monitor possible contamination of the aquifers above and below the mined coal seams and exploration holes (commonly three inches in diameter) drilled by coal companies.

Purpose and Scope

The purpose of this report is to describe the hydrogeologic effects of fracturing associated with lineaments on well yields in the coalfield areas of Wise and Dickenson Counties (figure 1). This description is developed from a comparison of geologic information, well yield data, and aquifer-test data obtained from coal companies operating in the area and from aquifer-test data collected by the U.S. Geological Survey as part of this study.

Methods of Investigation

Ground-water and geologic data used in this study were collected from four coal mining companies and a consulting firm. The Virginia Division of Mined Land Reclamation requires coal companies to establish a ground-water monitoring program, which has produced large quantities of subsurface hydrologic data. A general analysis of the hydrogeology of the coal bearing areas of Wise and Dickenson Counties was developed from a comparison of data from 56 wells to different geologic settings. Most of the wells are cased down to stable rock only; therefore, well yields and water levels represent an integration of all units in the saturated interval of the well. The saturated intervals and well yields, which are reported by drillers, are based on observation of the return flow from the well during air rotary drilling. The ranges of yields are shown in table 2 in the section "Effects of fracturing on well yields." Saturated interval, water bearing zone, and aquifer are used interchangeably in this report.

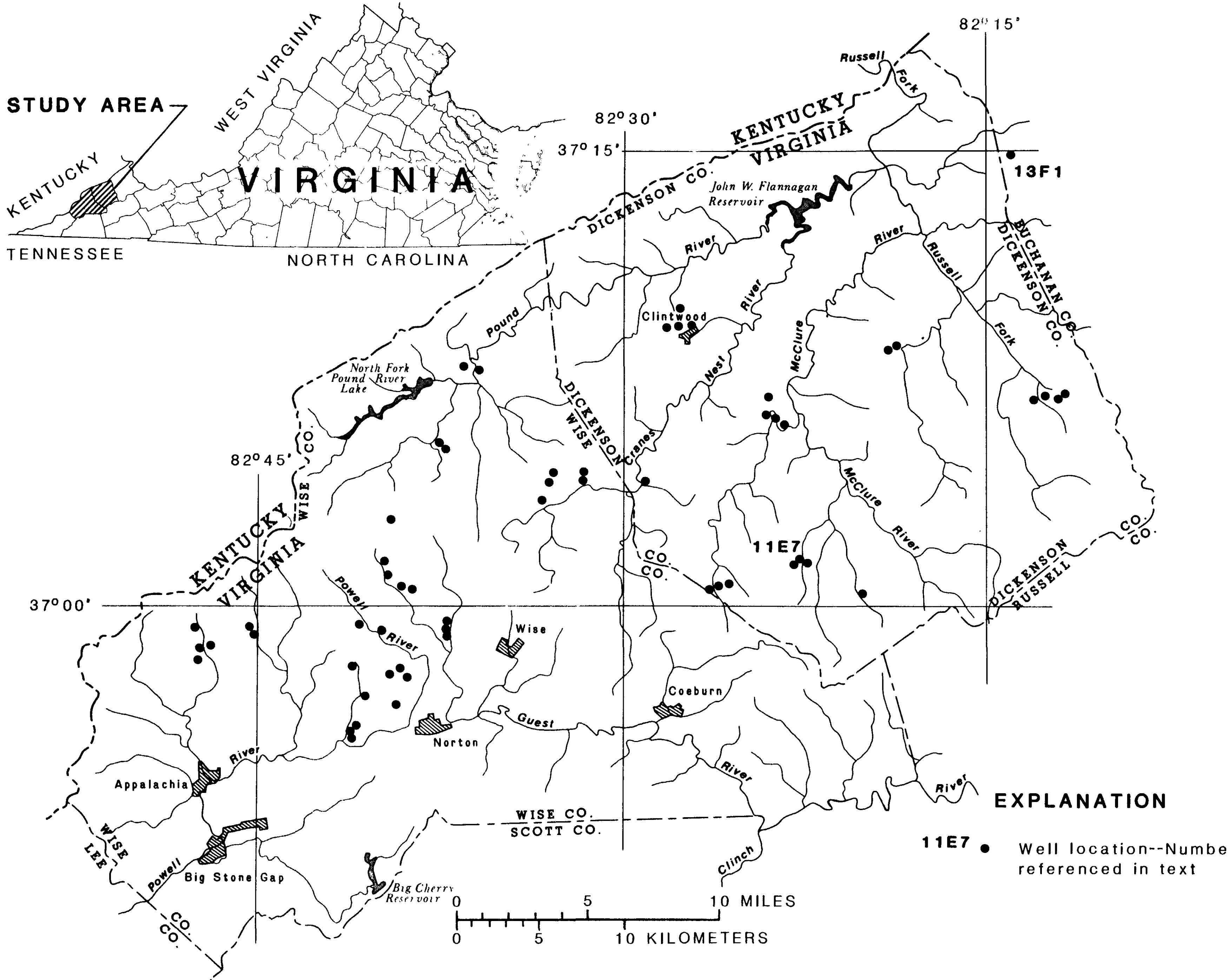


Figure 1.--Study area and location of monitoring wells.

Hydraulic conductivity and water-level elevations were determined for several rock units by use of specially designed packer-transducer test equipment. Water was injected into 15-foot intervals of a drill hole that had been isolated by packers. Hydraulic conductivity of the aquifer was calculated from injection pressure measurements. Successful tests were performed in five intervals from 50 to 420 feet below land surface.

Acknowledgments

Appreciation is extended to those companies providing employees of the U.S. Geological Survey access to their data files for ground-water and other related geologic information. Companies providing assistance were: Clinchfield Coal Company; Humphreys Enterprises; Mining Engineering Services, Inc.; Paramont Coal Company; and Westmoreland Coal Company. Particular recognition is accorded to the geologic division of Clinchfield Coal Company, through Daniel G. Manweiler, Geologist, for permission to perform hydraulic tests in one of their exploration drill holes.

PHYSICAL SETTING AND HYDROGEOLOGIC FRAMEWORK

The surface-drainage systems in the study area are influenced by geologic structure and fracture systems in the bedrock. Physical and chemical weathering of the rocks along fractures has left steeply downcut valleys as a topographic characteristic of the region. The ridges are, for the most part, capped by sandstones that resist erosion. The majority of the surface water in the area flows northeastward into the Russell Fork. The remainder flows south into the Powell and Guest Rivers. Altitudes range from 1,600 feet above sea level in the valley near Big Stone Gap to more than 3,800 feet on some of the ridges. The average precipitation in the study area is about 41 inches per year. Temperatures range from -15 to 100°F, with an average of about 54°F.

Strata investigated in this study are part of the Norton and Wise formations of Pennsylvanian age. These sedimentary rocks are composed of tightly cemented sandstone, siltstone, and coal beds of differing thicknesses. The lithologic and hydrogeologic characteristics are described in table 1. The depositional environment of the rocks is described by Miller (1974) as deltaic and alluvial complexes exhibiting intertongueing, lensing, and pinching out of the beds. Correlation among sandstones, siltstones, and coals is difficult (Campbell, in Eby, 1923, p. 73-77). Lithologic correlation is accomplished in the area using a few prominent sandstones and extensive coal seams (fig. 2). Soft micaceous sandstone is common and underclays occur beneath coal seams. Very little limestone has been found within the study area, but some of the sandstones possess carbonate cements (Rogers and Powell, 1983, p. 3).

Folds and faults in the area are related to the Pine Mountain thrust fault (fig. 3). Flexure-slip folding may have occurred in relation to the Powell Valley Anticline creating moderate anticlines and synclines throughout the study area. Rocks at the surface and at shallow depths dip 0.5 to 2° to the northwest and strike parallel to the trend of Pine Mountain at about N65°E. Major trends of systematic joints and fracture lineaments (N55°W and N5°E) are roughly normal and parallel to the axis of the Powell Valley Anticline (Millici and others, 1982, p. 51).

A lineament is an alinement of structural features, visible primarily on aerial photographs or remote-sensing-imagery mosaics, that is continuous for

Table 1.--Generalized geologic and hydrogeologic framework of Wise and Dickenson counties.

System	Series	Geologic Unit	Lithologic Characteristics[1]	Hydrogeologic Characteristics
Pennsylvanian	Lower and Middle Pennsylvanian	Harlan Sandstone	Uppermost Pennsylvanian Formation in Wise County - absent in Dickenson County. Basal unit consists of massive, locally conglomeritic sandstone ranging in thickness from 40 to 60 feet. Total thickness is about 880 feet.	Serves mainly as caprock for many high ridges in Wise County. May provide water from springs.
		Wise Formation	Consists of alternating layers of sandstones, shales, and coal beds, with sandstone accounting for approximately one-third of the total thickness. In western Wise County, it is approximately 2,300 feet thick, thinning slightly to the northeast to about 2,070 feet thick. Only the lower 750 feet are exposed in Dickenson County with most exposures occurring on upper parts of ridges.	In Wise County, water well yields are moderate with the sandstone beds in the southern part of the county providing the best yields. Drillers report a 60 to 70 percent success in drilling wells with yields adequate for domestic use. Highest yields are in valleys. Elevated iron content is common.
		Gladeville Sandstone	A fairly pure quartoze sandstone in places but varies to the north becoming more micaceous. Thickness varies from 90 to 130 feet.	Provides water for domestic and municipal use but yields are usually low.
		Norton Formation	Composed largely of shale and siltstone with some interbeds of sandstones and coal seams. The shales constitute approximately 75 percent of the total thickness and are slightly micaceous and commonly clayey. Total thickness of the formation ranges from 750 to 1,300 feet depending on the tongueing of the Bee Rock Sandstone Member of the underlying Lee Formation.	Well yields from the shales are moderate to low and the water is commonly irony and acidic. Highest yields are in valleys.

[1]Dovel, M.R., Virginia State Water Control Board, written commun., 1983.

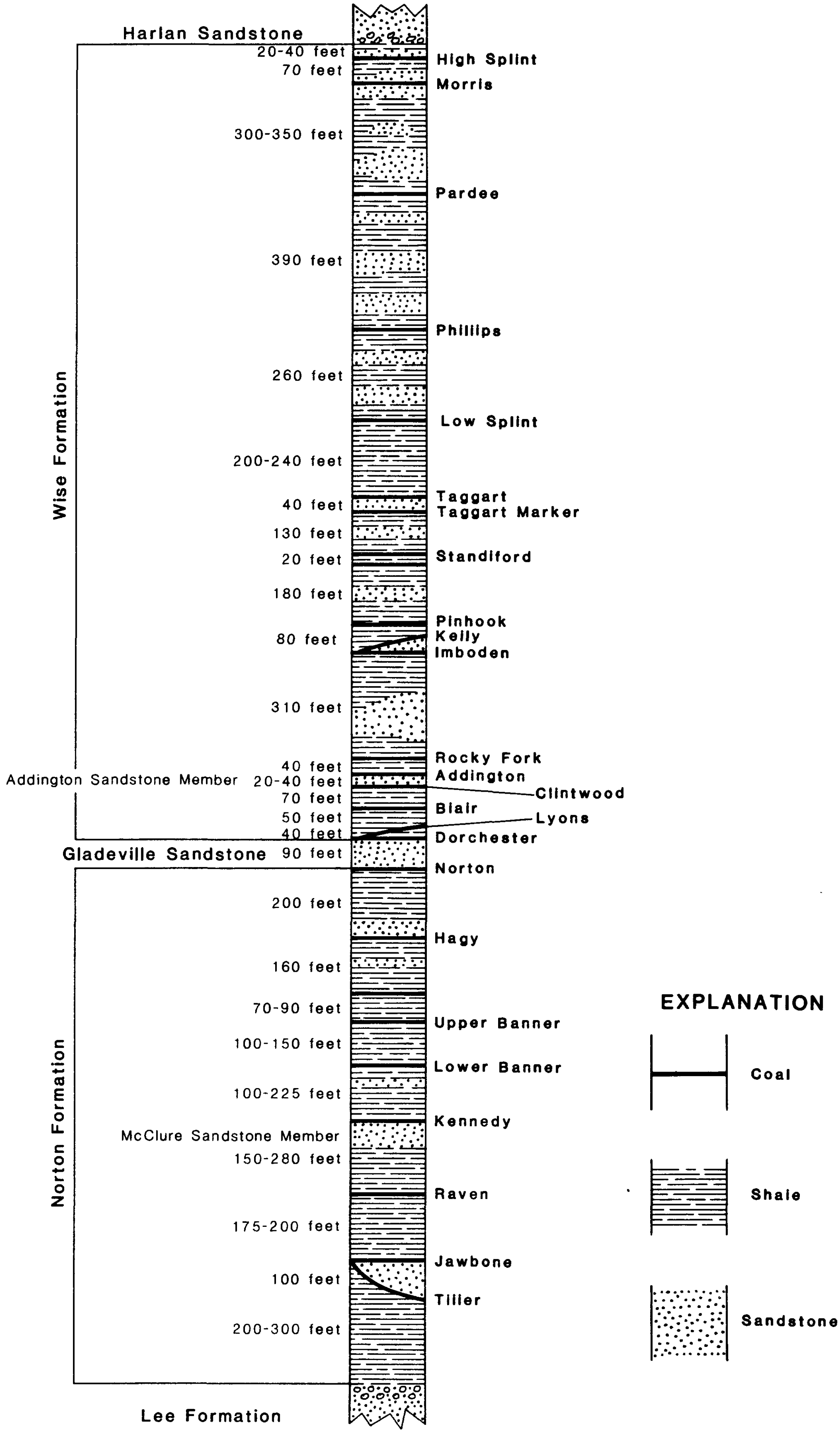
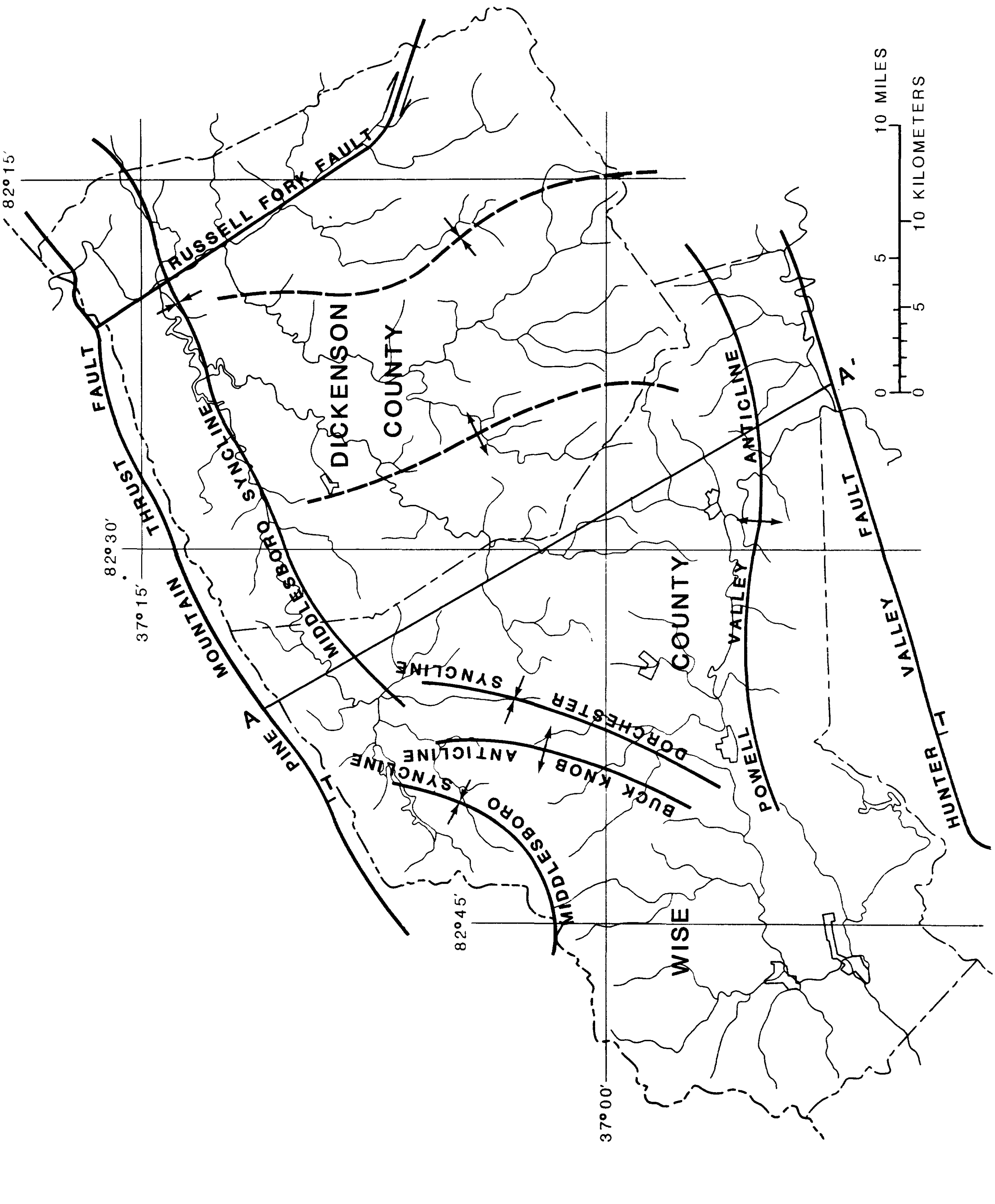
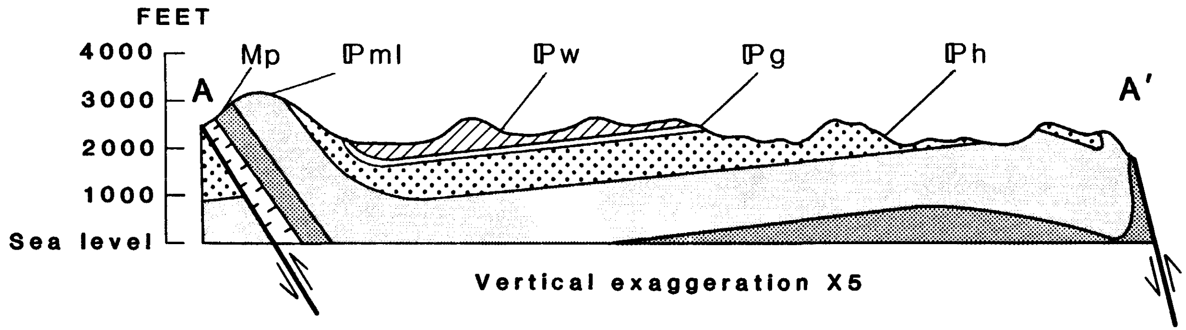


Figure 2.-- Generalized geologic column showing stratigraphic position of coal beds in Norton and Wise formations. (Reproduced from Eby, 1923.)



RUSSELL FORK FAULT
PINE MOUNTAIN THRUST FAULT
MIDDLESBORO SYNCLINE
DICKENSON COUNTY
WISE COUNTY
POWELL VALLEY ANTICLINE
HUNTER VALLEY FAULT
DORCHESTER SYNCLINE
BUCK KNOB ANTICLINE
MIDDLESBORO SYNCLINE
A
A'
82°15'
82°30'
82°45'
37°15'
37°00'
0 5 10 MILES
0 5 10 KILOMETERS



EXPLANATION

FAULT--Tick mark indicates direction of dip. T, upper plate. Arrows show relative horizontal movement

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

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

A A′ TRACE OF SECTION

GEOLOGIC UNIT

ℙw - Wise Formation

ℙg - Gladeville Sandstone

ℙh - Norton Formation

ℙml - Lee Formation

Mp - Pennington Group

Figure 3.--General structural features and geologic section of the study area. (Structural features from Miller, 1974; Geologic section modified from Giles, 1921.)

one or more miles (Lattman, 1958). Lineaments are believed to represent major zones of fracturing or small faults related to deep bedrock activity. Lineaments visible on Landsat imagery and on aerial photographs of southwestern Virginia have been delineated on 7½ minute topographic maps by the Virginia Division of Mineral Resources. A majority of the valleys in the study area are associated with lineaments.

The possible hydrologic effects of fracturing due to the relief of stresses in valleys have been described by Wyrick and Borchers (1981). The effective stress from overlying strata is released in valleys due to erosion causing fractures along the valley walls and under valley floors. Fractures in the study area may be a combination of lineament-related fracture zones and stress relief fractures. The openings in rocks produced by fractures are typically referred to as secondary porosity (or secondary permeability), whereas interstitial openings in the original rock material are known as primary porosity.

EFFECTS OF FRACTURING ON WELL YIELDS

In order to evaluate the effects of fracturing on well yields in the study area, values for well yields were compiled for areas with and without lineaments. Generalized ranges of well yields in both types of terrane are listed in table 2. Well yield values were standardized by dividing the yield by the thickness, in feet, of the saturated interval of the rock material. The resulting unit is yield per saturated thickness in gallons per minute per foot (gal/min/ft) and is referred to in this report as the unit yield. Also, for the purposes of this report, the saturated interval is considered the aquifer thickness.

Wells located on lineaments consistently demonstrate higher unit yields than wells not located on lineaments. This is shown in the cumulative frequency diagram in figure 4. The median (50th percentile) unit yield of wells located on lineaments is 0.18 gal/min/ft. The median value for wells not located on lineaments is 0.04 gal/min/ft.

The topographic setting also influences the unit yield of wells. Wells located on lineaments in valleys have higher unit yield than wells located on lineaments on hillsides. This is shown in the cumulative frequency diagram in figure 5. Some wells located on hillside lineaments, however, are completed below the land-surface elevation of adjacent valley bottoms and intersect fractures that are hydraulically connected to valley bottom fractures. These wells have unit yields comparable to those of valley wells.

Ten of the eleven wells in table 3 that have no measurable yields are not located near lineaments; this is further evidence that fractures associated with lineaments affect well yields in the area.

Unit yield does not differ significantly with rock type, indicating that the degree of fracturing, rather than rock type, is the major factor controlling well yields in the study area. Also, comparison of unit yields from wells on lineaments show that the type of rock that comprise the fractured aquifer is not a dominant factor contributing to well yields.

Table 2.--General ranges of yields from wells that penetrate the aquifers of Wise and Dickenson Counties.

Classification	Range of well yield, gal/min
very low	less than 0.5
low	0.5 - 2.0
moderate	2.0 - 5.0
moderate to high	5.0 - 12.0
high	more than 12.0

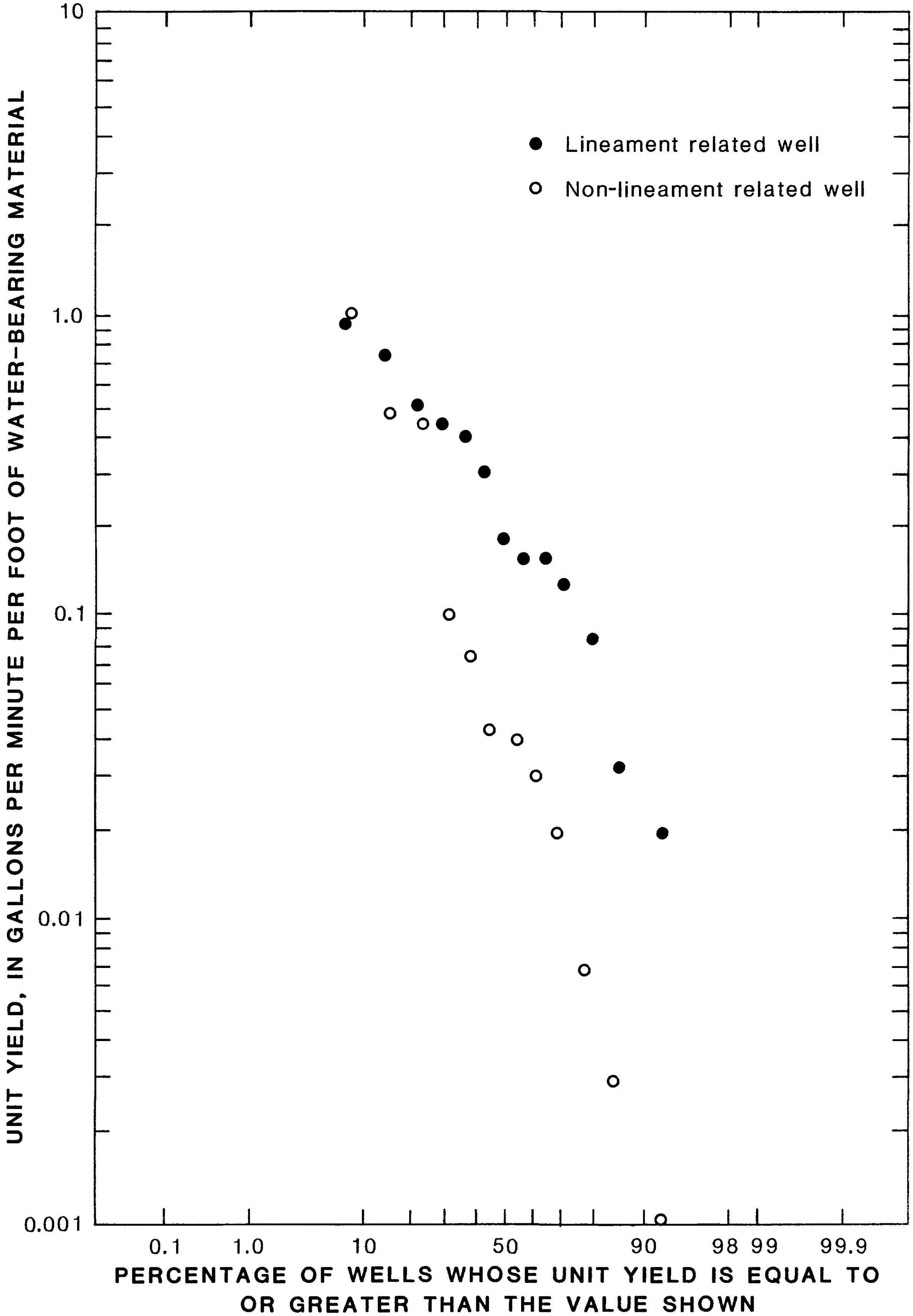


Figure 4.--Cumulative frequency of unit-yield values for wells in areas with and without lineaments.

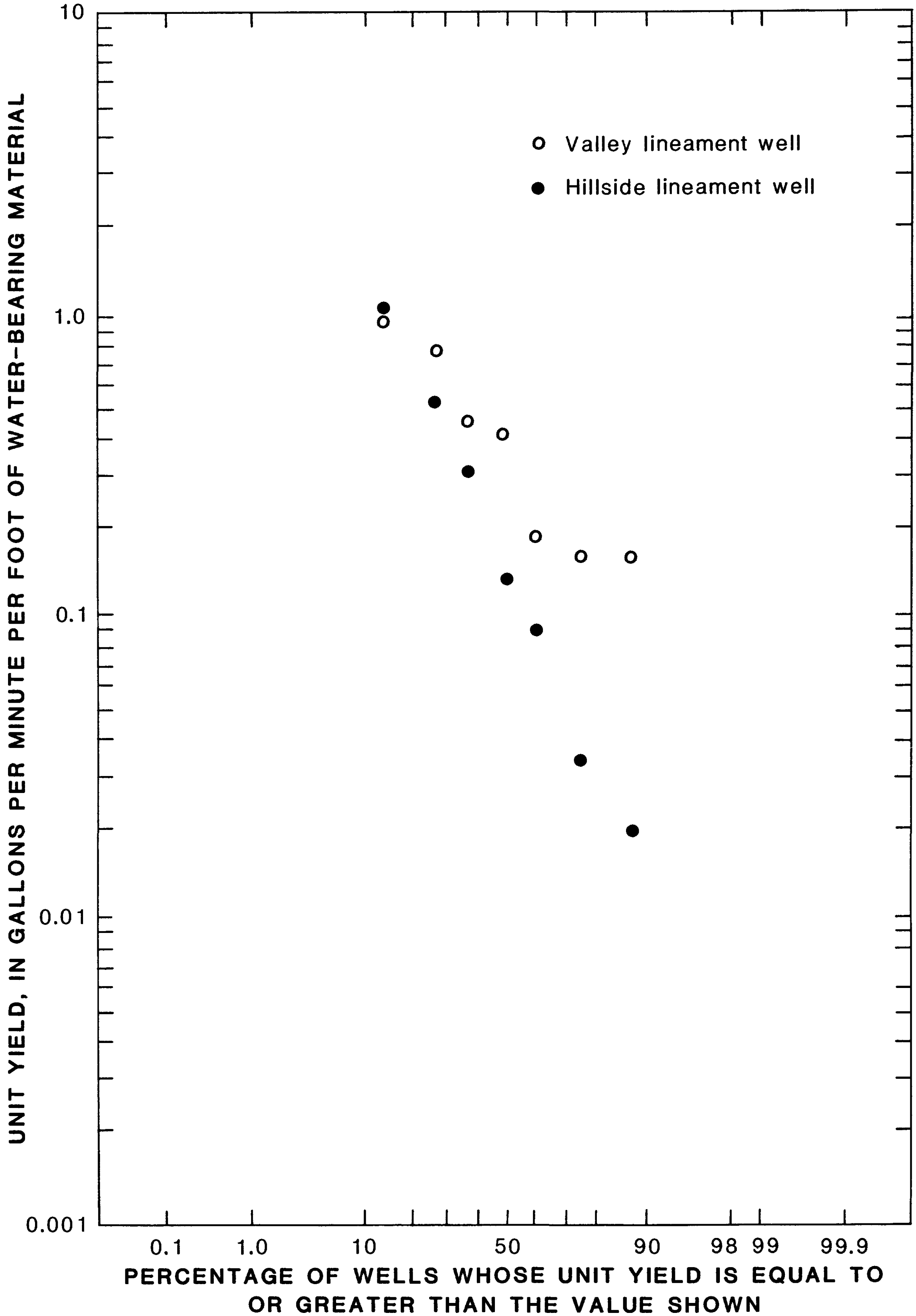


Figure 5.--Cumulative frequency of unit-yield values for wells in valleys and on hillsides that contain lineaments.

Table 3.--Records of monitoring wells located in Wise and Dickenson Counties, Virginia.

Geographic location: V, valley; H, hillside; R, ridge.
Depth of well: Depths are reported from drillers log.
Saturated interval: Water-producing zones are identified in drillers log from air rotary drilling and stated as interval of water-bearing rock from one point in well to another point.
Water-bearing material: SS, sandstone; Sh, shale; S-Sh, sandy shale; C, coal.
Well yield: Yields stated in gallons per minute are estimated from air blasting with air rotary drill rig or determined by pump test.
Remarks: L indicates the well is located in a lineament.

Identifier	Station Number	Geographic Location	Depth of well (feet)	Diameter of well (inches)	Saturated interval (feet)	Water-bearing material	Well yield (gal/min)	Depth to water (feet)	Casing depth (feet)	Altitude above mean sea level (feet)	Remarks
12F1	370824082191101	H	58	6	52 - 58	--	--	28	--	1,790	
12F2	370831082185901	H	100	6	21 - 25	--	--	52	--	1,750	
13E9	370653082124001	V	300	8	58 - 90	SS,Sh	30	37	52	1,688	L
13E10	370640082125101	V	35	4	--	--	--	30	23	2,000	L
12E4	370017082201201	H	260	6	120 - 180	Sh,S-Sh	60	120	50	1,969	
11E2	370546082232101	V	225	6	30 - 225	Sh,SS	86	30	52	1,499	L
11E3	370615082234901	H	250	6	100 - 200	SS	2	75	52	1,544	
11E4	370616082235601	H	323	6	85 - 323	SS	21	85	50	1,611	L
11E5	370651082241201	R	630	6	300 - 630	SS,Sh, S-sh,C	0.25	300	21	2,150	
13E11	370647082120101	H	305	6	28 - 305	SS,Sh, S-Sh	36	28	50	1,525	L
13E12	370651082115601	V	92	6	--	SS	75	31	40	1,480	L
10E4	370406082331001	R	40	6	21 - 22	SS,C	0.02	21	11	2,326	L
10E5	370426082314001	H	538	6	300 - 400	SS,C	4	176	51	1,902	
10E6	370420082314301	V	302	6	100 - 200	SS,Sh,C	16	140	52	1,718	L
10E7	370427082330201	R	162	--	60 - 65	--	0.03	--	10	2,319	
11E6	370126082223901	V	325	--	--	--	--	--	--	1,850	L
11E7	370129082224601	H	283	6	43 - 283	--	60	43	50	1,965	L
11E8	370123082230301	H	102	6	--	--	--	--	20	2,075	
11E9	370047082254601	V	550	--	0	--	0	--	--	2,100	
11E10	370030082262801	H	40	--	0	--	0	--	--	2,050	
11E11	370033082262501	H	520	--	0	--	0	--	--	2,090	
13F1	371449082141701	R	864	3	50 - 864	SS,Sh, S-Sh,C	--	351	20	2,160	
10F1	370757082363101	R	100	6	80 - 100	Sh	9	80	21	1,850	
10F2	370747082361001	V	80	6	60 - 80	Sh	2	80	31	1,600	
11F3	370916082282701	V	80	6	60 - 80	SS,Sh,C	1.5	22	20	1,840	

Table 3.--Records of monitoring wells located in Wise and Dickenson Counties, Virginia.--continued

Identifier	Station Number	Geographic Location	Depth of well (feet)	Diameter of well (inches)	Saturated interval (feet)	Water-bearing material	Well yield (gal/min)	Depth to water (feet)	Casing depth (feet)	Altitude above mean sea level (feet)	Remarks
11F4	370923082274201	H	42	--	20 - 42	SS,S-Sh	0.68	20	32	1,805	
11F5	370924082274501	H	70	--	50 - 70	SS,Sh	0.06	50	50	1,860	
11F6	370919082272001	H	100	6	0	--	0	--	18	1,860	
10E8	370329082333001	V	62	6	42 - 62	SS	15	19	34	1,810	L
9D6	365752082385701	H	125	4	--	SS,C	1	40	110	2,410	
9D7	365746082391101	H	128	4	103 - 128	SS,C	1.06	33	112	2,325	
9E1	370508082310301	V	38	--	--	--	7	26	24	1,700	L
9E2	370517082380001	H	41	--	0	--	0	--	34	1,775	
9D8	365928082403501	H	170	--	160 - 170	--	55	42	160	2,325	
9D9	365906082394701	H	90	4	80 - 90	SS,C	3	70	80	2,335	L
9D10	365807082405001	V	120	--	--	--	50	--	--	2,115	L
9D11	365707082402901	V	90	--	--	--	25	--	--	2,118	L
9D12	365559082404901	R	267	--	0	--	0	--	20	2,450	
9D13	365551082411001	R	127	--	96 - 127	--	5	96	106	2,209	
9D14	365536082410501	R	100	--	--	SS	0	94	80	2,100	
9D15	365646082390701	H	138	4	90 - 138	S-Sh,C, Sh	2	70	90	2,200	
9D16	365725082383401	V	150	4	--	C,SS,Sh	5	90	20	2,147	L
9E3	370134082400301	H	120	6	50 - 120	S-Sh,Sh	35	10	3	2,245	L
9E4	370130082400101	H	260	6	50 - 60 205 - 220	SS,Sh	12	60	42	2,305	
9E5	370255082394901	R	75	--	0	--	0	--	--	2,490	L
9E6	370056082395301	H	30	--	18 - 30	Sh	--	12	--	2,230	L
9E7	370029082385601	H	35	4	28 - 32	Sh	--	28	20	2,275	
9E8	370034082391401	H	50	4	20 - 41	SS,Sh	--	25	20	2,270	
10D17	365902082365801	V	32	--	10 - 32	Sh	4	12	30	2,155	L
10D18	365902082365601	V	75	--	50 - 75	Sh	4	15	73	2,155	L
10D19	365908082365801	V	75	--	70 - 75	SS	2	10	73	2,153	L
8D3	365917082450201	V	25	--	--	--	20	--	--	2,010	
8D4	365914082450101	V	9	--	--	--	10	--	--	2,000	
8D5	365834082463901	H	146	6	80 - 140	Sh,SS,C	2	82	16	2,320	L
8D6	365807082470701	H	175	6	16 - 167	SS	1	35	21	2,350	
8D7	365917082471201	V	21	6	9 - 21	--	25	9	--	2,180	
8D8	365830082470201	V	8	6	6 - 8	--	2	6	--	2,000	

Analysis by Well Testing

Data obtained during hydraulic tests of wells were used to determine values of selected aquifer properties (transmissivity and hydraulic conductivity) and can be useful for estimating well yields. Analysis and comparison of these properties from wells located in different topographic settings in a fractured area were used, in conjunction with geologic features (such as lineaments), to describe the relation of fracturing to well yields.

Aquifer Tests

Pumping-test data are available from selected ground-water monitoring wells used by the coal companies in the study area. The pumping tests were performed by the coal companies to determine production rates of wells; therefore only drawdowns from the pumping wells are available. The straight line approximation was used to estimate aquifer transmissivity from drawdown data observed in the pumping wells (Lohman, 1972, p. 23).

Analysis of data from a pumping test on well 11E7 (see fig. 1), which is in a valley with a lineament, indicated a transmissivity value of 215 ft^2/d. Analysis of aquifer-test data from other wells in the study area that are located on lineaments indicate transmissivities as high as 598 ft^2/d. Such large transmissivities for aquifers located in valleys with lineaments suggest the presence of secondary porosity (fractures) that contribute to large well yields.

Formation Testing with Multiple Packers

Packer-transducer equipment was designed and used in this study to determine properties of individual aquifers in small diameter, uncased test holes. The down-hole instrumentation used in the test hole (well number 13F1 in table 3) follows the design of Bagby and Webster (U.S. Geological Survey, written commun., 1983); and the configuration of the equipment is shown in figure 6. Tests are performed by lowering the instrumentation to the selected interval in the test hole and isolating the interval with the inflatable packers. During testing, a pressure transducer monitors the injection pressures between the packers. Transducers above and below the selected interval determine if leakage around the packers is occurring. Hydraulic conductivities of the selected intervals are estimated by performing "slug" injection tests (Cooper and others, 1967) and constant-head injection tests (U.S. Department of Interior, 1981, p. 259).

The results of the packer-injection tests performed in hole 13F1 are shown in table 4 and on figure 7. Fracturing probably is responsible for the relatively high hydraulic conductivities of 2×10^{-2} to 1×10^{-1} feet per day in the upper parts of the test hole, compared to those expected for cemented, unfractured sandstone and siltstone aquifers. The hydraulic conductivities decrease with depth, which possibly indicates that the fractures are not present at greater depths in the test hole or that the fractures become narrower with depth because of the weight of the overlying rock. Potentiometric surfaces of aquifers in the test hole range from 0 to 63 feet above the tops of the aquifers, and generally increase with depth because of the ground-water mound beneath the ridge.

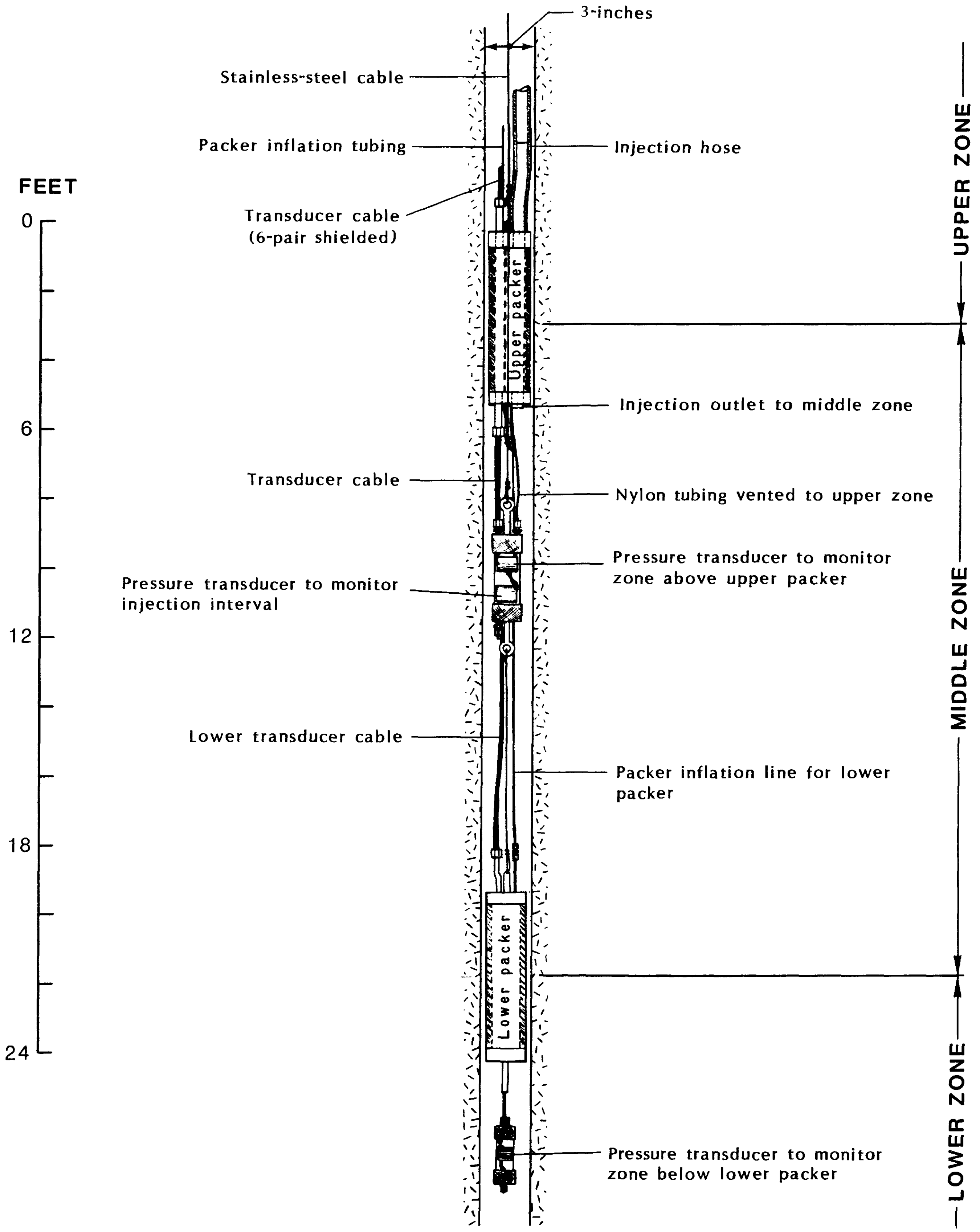


Figure 6.--Down-hole packer-transducer instrumentation.

Table 4.--Rock types, water-level altitudes, and hydraulic conductivities in test hole 13F1.

Depth of test interval, in feet below land surface[1]	Rock type[2]	Water level elevation		Hydraulic conductivity, in feet per day	Storage coefficient
		Feet above test interval	Feet above sea level		
50 - 65	Coarse grain sandstone, light gray with red streaks	3.0	2,112	2.1×10^{-2}	6.8×10^{-10}
80 - 95	Coarse grain sandstone, light gray with coal streaks	9.6	2,090	2.9×10^{-1}	—[3]
115 - 130	Medium grain sandstone, dark gray with silt streaks	22.0	2,067	6.1×10^{-1}	6.8×10^{-6}
150 - 165	Sandy shale with red streaks	18.7	2,029	1.1×10^{-1}	6.8×10^{-5}
405 - 420	Medium grain sandstone, light gray	63.4	1,818	7.4×10^{-3}	6.8×10^{-4}

[1]Land surface altitude 2,160 feet above sea level.
[2]Lithologic log reproduced by permission of Clinchfield Coal Company.
[3]Storage coefficient cannot be computed using constant-head test.

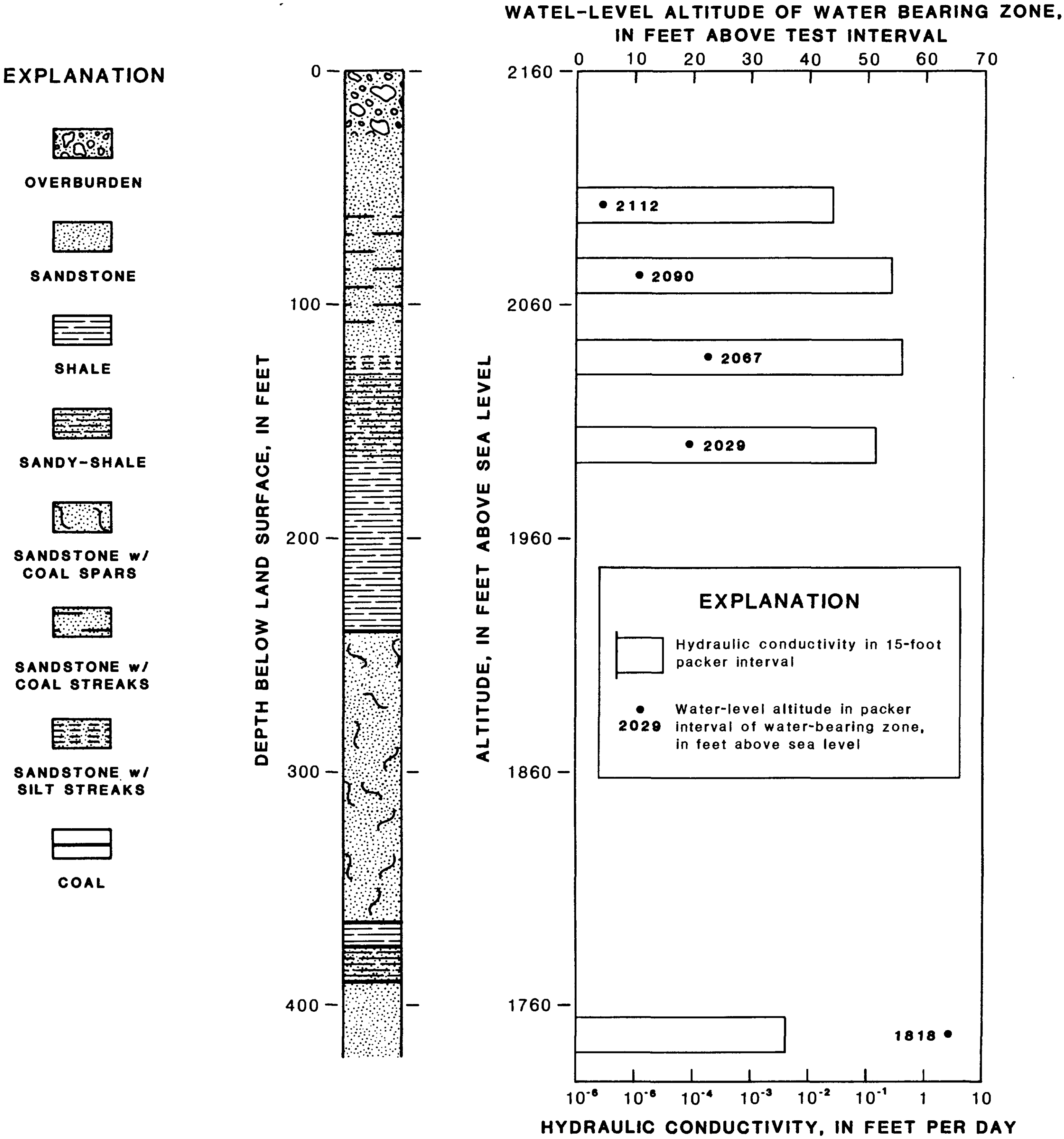


Figure 7.--Water-level altitudes and hydraulic conductivities of water-bearing zones in test hole 13F1. (Drill record by permission of Clinchfield Coal Company.)

Results of Analyses

Evaluation of results from pumping tests in wells located on lineaments shows that the fracturing associated with a lineament is a principal cause of secondary porosity and, therefore, to relatively large well yields. Yields from wells located on lineaments may differ areally but are consistently higher than yields from wells in unfractured rock in the study area.

Results from the packer tests indicate that the fracturing in the upper parts of ridges in the study area may be caused by stress relief. These fractures may occur along valley walls and in valley floors, but yields of wells placed randomly in areas suspected of having stress relief fractures cannot be reliably predicted. Deep beneath the ridges, fracturing from stress relief is minimal or absent; hence, very low well yields would be expected.

SUGGESTIONS FOR FURTHER STUDIES

The compilation of an area-wide data base of aquifer characteristics and ground-water quality is needed. The data base would be useful for preparing environmental assessments and for devising a ground-water monitoring program to evaluate the effects of reclamation on mined lands.

The ground-water resources of the study area need to be documented. The location and identification of potable ground-water supplies is necessary because many rural homes in Wise and Dickenson Counties presently use sources that are unsuitable for drinking water.

A more thorough evaluation of the influence of fractures on the ground-water system is needed in the southwestern Virginia coal region. Attempts to describe the length, depth, and connection of fracture systems will assist in developing a conceptual model on the relationship between shallow fractured aquifers and deep, regional ground-water systems. The determination of quantity of ground water stored in the fractured aquifers will assist in defining the ground-water resources. A study of aquifer recharge and ground-water movement in weathered and fractured rock systems will help develop a better understanding of the hydraulics of fractured aquifers.

SUMMARY AND CONCLUSIONS

The yields from wells located in the coalfields of southwestern Virginia are strongly influenced by fracturing. Graphical comparisons of unit yield show evidence that wells located on lineaments and in valleys with lineaments produce larger amounts of water than wells not located on lineaments nor in valleys. Pumping-test data from wells located on lineaments indicate large aquifer transmissivities. Fracturing created secondary porosities that contribute to large well yields.

Data from packer-injection tests in a well located on a ridge show relatively large hydraulic conductivities in the upper portions of the test hole compared to values ordinarily expected in unfractured rocks. Fracturing from stress relief contributes to these large values. Fracturing probably decreases with depth below the ridge as shown by hydraulic conductivities that decrease with depth in the test hole.

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