An Evaluation of the use of Drillers' Logs in Lithologic Studies of the Ogallala Formation of the Southern High Plains of Texas

By C.A. Wilson, J.T. Smith, G.L. Thompson and W.M. Sandeen

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PROGRESS REPORT 1970-71

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C. A. Wilson, J. T. Smith, G. L. Thompson,
and W. M. Sandeen
U.S. Geological Survey

ABSTRACT

Logs made by water-well drillers were analyzed in conjunction with test-hole drilling and geophysical logging to evaluate usefulness of the driller's log in delineating areas that would be suitable for artificial recharge of the Ogallala Formation. This preliminary study indicates that lack of detailed and accurate information in many drillers' logs prevents their use as a reliable source of lithologic information. For many applications, such as evaluation of potential areas for artificial recharge, the value of more complete and more accurate information will be readily apparent as these applications become more widespread. More effort will be required in collecting lithologic information as part of the drilling operations.

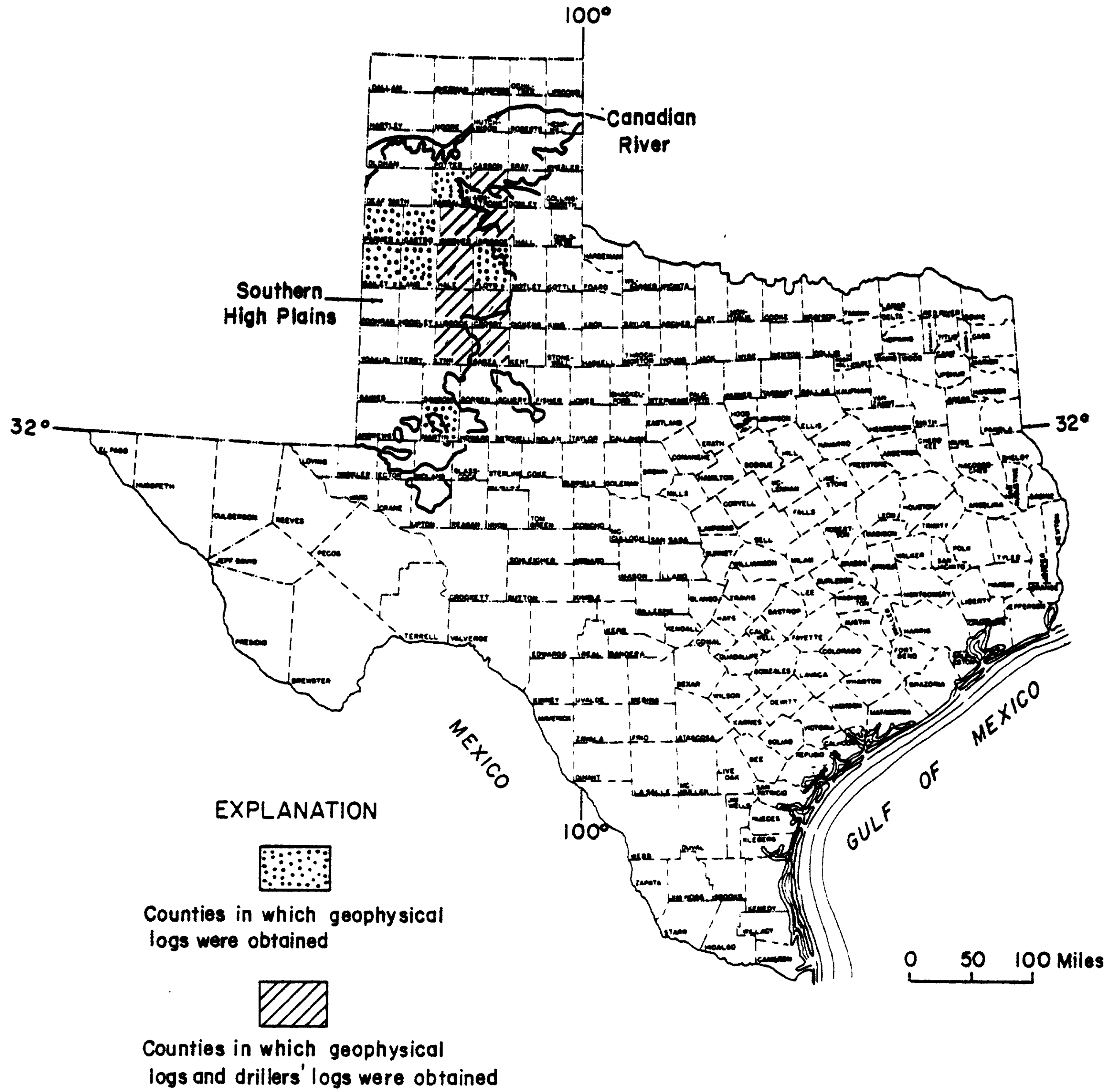

FIGURE 1.-Location of the study area and counties in which data were collected

Values given on drillers' logs such as water levels, are accurate; but information on quantitative values such as well yields and drawdowns, which were estimated or which are given as representative, may contain gross errors. Many well locations, especially those given on application forms for well permits or on well-data reports, are of questionable accuracy. A greater degree of accuracy in determining well-site elevations is now possible through the use of 7 1/2- and 15-minute Geological Survey topographic maps.

Table 1 shows the availability of drillers' logs in counties where the data were prepared for computer analysis. These logs were screened to eliminate those that: (1) Did not show the base of the Ogallala; (2) could not be located to an estimated accuracy of 1 mile on 7 1/2- or 15-minute topographic maps; or (3) did not have a continuous sequence of lithology. Locations for most of the logs selected for computer analysis are accurate to within 1/4 mile.

More logs were available in Lubbock County and in the northern one-fifth of Lynn County because these areas are within the boundaries of the High Plains Underground Water Conservation District No. 1. The District requires that a driller's log and well-construction data be filed upon completion of each well.

METHODS OF INVESTIGATION

Availability of Data

Drillers' logs of water wells are sources of extensive data on the lithology and structure of the Ogallala Formation of the Southern High Plains; in 1969, there were about 59,000 irrigation wells in the area. Most of the logs are in the files of the Texas Water Development Board, the High Plains Underground Water Conservation District No. 1, and the U.S. Geological Survey. Other, but less extensive data include well schedules, water-level measurements, drawdown-yield measurements, pumpage inventories, well-location maps, results of aquifer tests, and water-quality analyses. Very little of the data in the Geological Survey files have been gathered since 1958. Data in the files of the Texas Water Development Board date mostly from 1964 to 1971; the most recent material is the most abundant. Some geophysical logs may be available from oil-company files.

A limited amount of geologic data and water-quality analyses are available from the Geology Departments of Texas Tech and Texas A&M Universities. Some field data and ground-water depletion surveys are available from the files of consulting geologists and engineers who have worked in the area. Well-construction data are available from the records of water-well drilling contractors.

Table 1.--Availability of water-well drillers' logs in counties where data were prepared for computer analyses

County	Approximate number of irrigation wells 1/	Approximate number of drillers' logs available to the study	Number of logs available to sample population	Number of logs selected in sample sets and coded on formats
Armstrong	212	149	97	66
Briscoe	650	213	117	93
Crosby	2,082	267	139	128
Garza	60	39	39	27
Hale	4,400	1,334	672	326
Lubbock	6,200	2,664 2/	2,394 2/	786 2/
		2,470 3/	±2,100 3/	831 3/
Lynn	2,466	2,192	1,992	489
Swisher	4,600	811	452	275

1/ Texas Water Development Board, 1969.

2/ Northern one-half of Lubbock County (north of latitude 33°37'30").

3/ Southern one-half of Lubbock County.

Computer Analysis of Drillers' Logs and Other Hydrologic Data

The formats developed for coding drillers' logs and other geologic and hydrologic data are shown on figures 2a and 2b. The lithologic lexicon for the Ogallala Formation is given in table 2.

The procedures used in manual processing of drillers' logs for coding are illustrated by the systems flowchart shown on figure 3. The coded formats were mailed to the New Mexico District for conversion into punched cards for computer input.

A sample of the available logs were used for an initial evaluation of the usefulness of drillers' logs. Sample set No. 1 consists of one log per 2 1/2-minute quadrangle, and set No. 2 consists of two logs per 2 1/2-minute quadrangle, or 25 percent of all logs in the quadrangle, whichever is greater. Not all quadrangles, however, will have enough logs (minimum of three) for a complete sample selection.

The purpose of the second set was to compare the results based on the greater sampling with that obtained from the first set. If the results were not comparable, successive samplings would be tried to see if a suitable match was obtained.

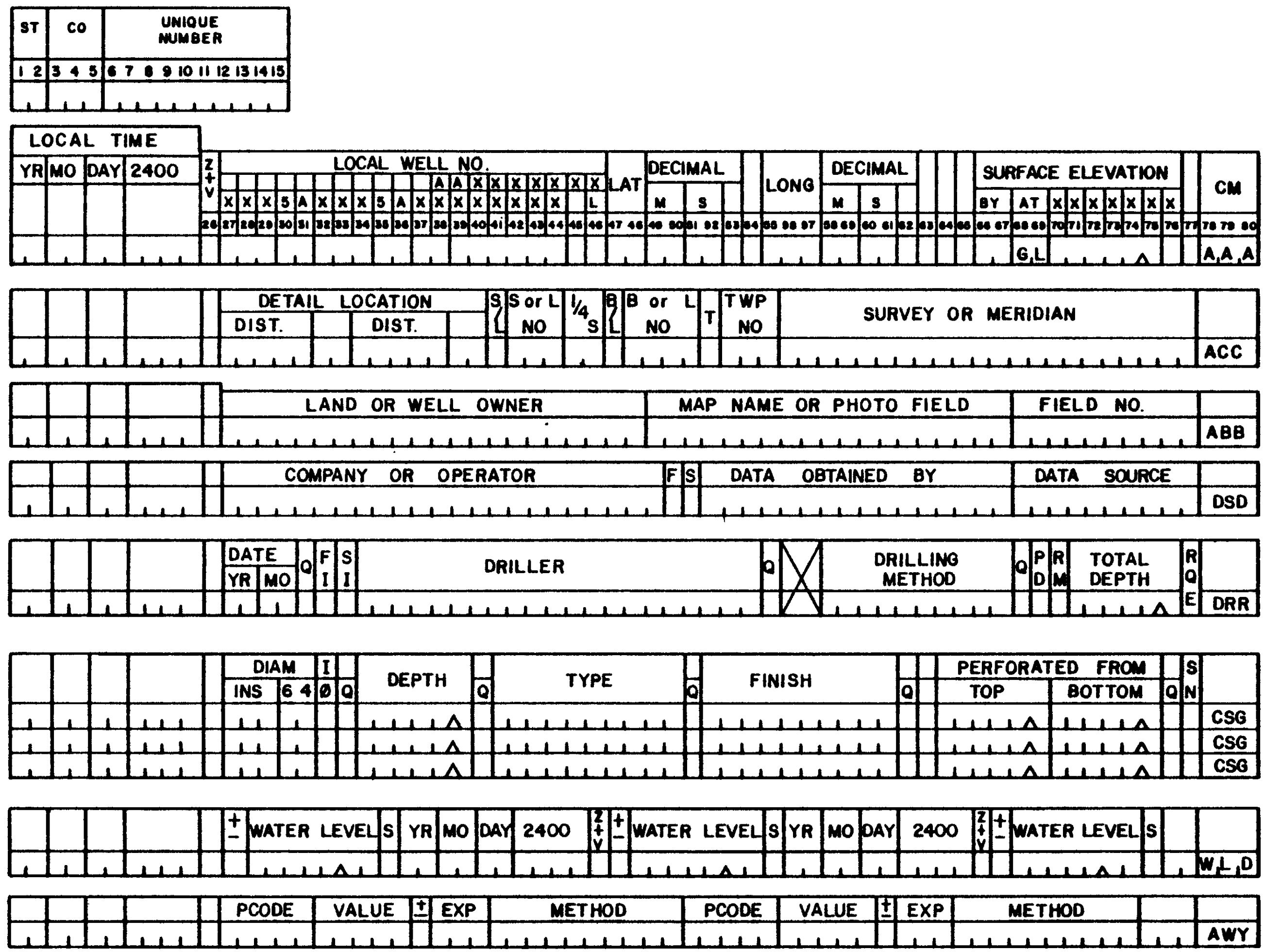

FIGURE 2A.-Coding format for computer analysis of drillers' logs, sheet I

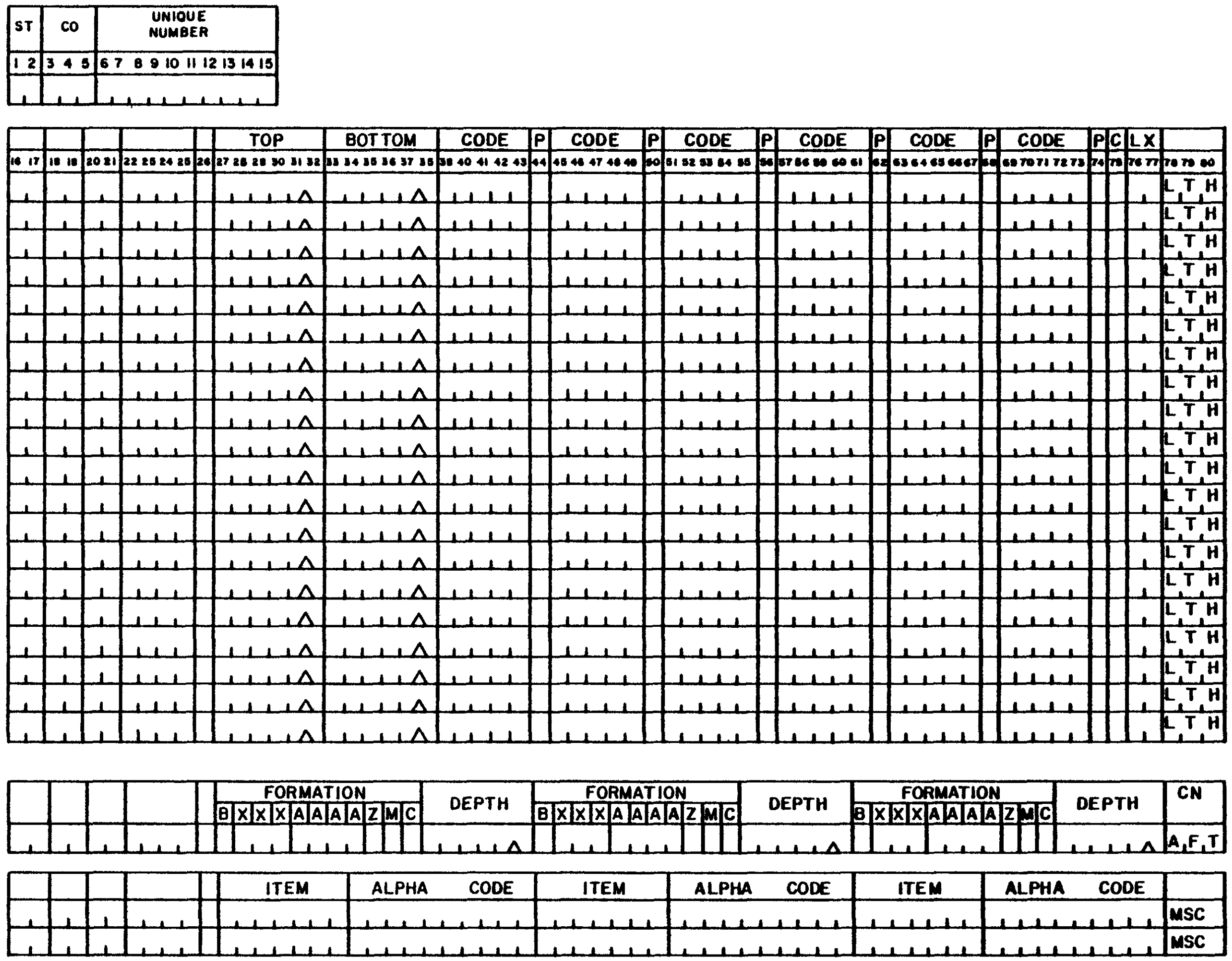

FIGURE 2B.-Coding format for computer analysis of drillers' logs, sheet 2

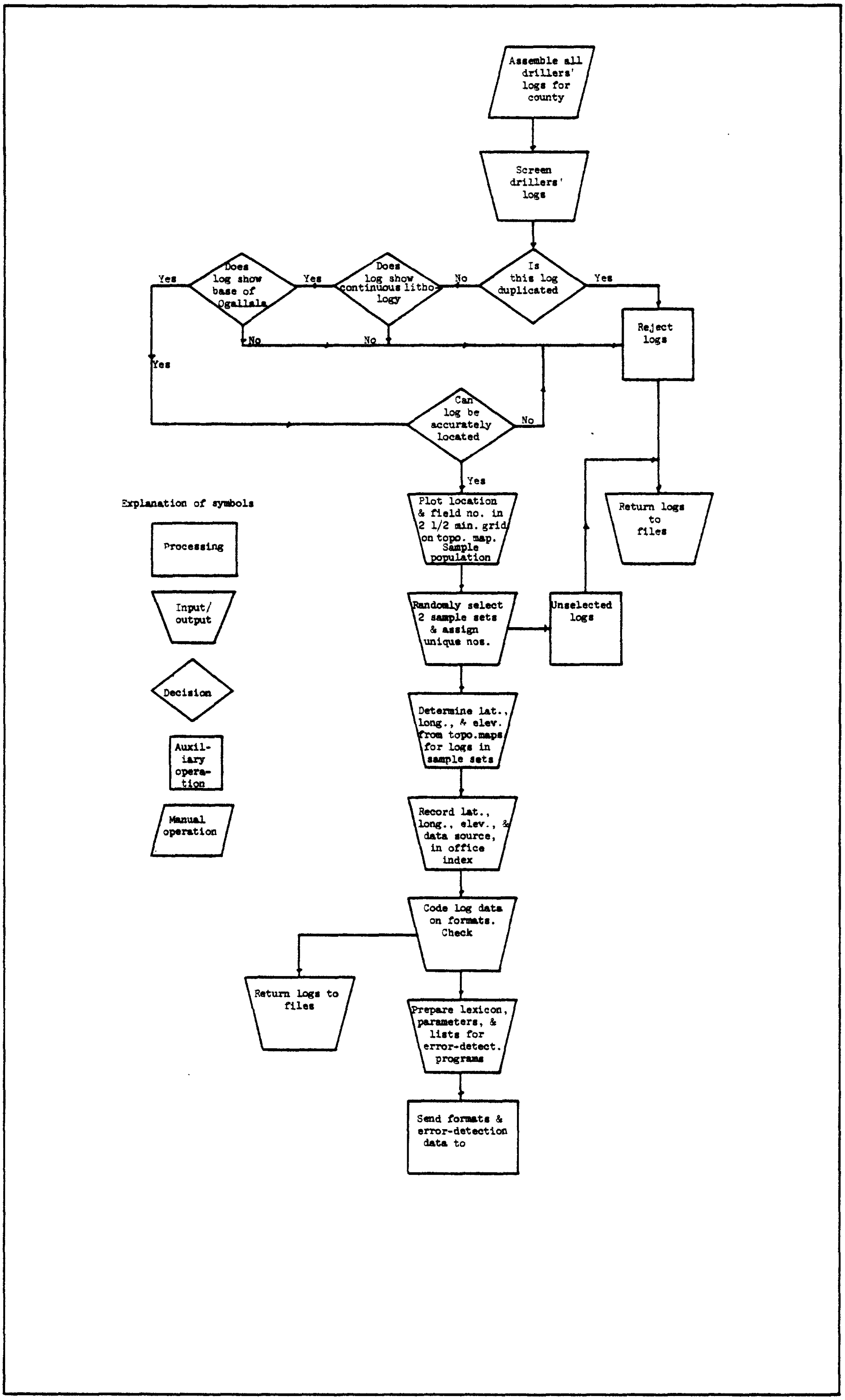

Figure 3. Flowchart for manual processing of drillers' logs

Table 2.--Lithologic lexicon of the Ogallala Formation

Rock type	Code	Rock-type modifier	Code	Color	Code	Cementation	Code	Miscellaneous	Code	Neutral	Code
Bentonite	BENT	Argillaceous	ARG	Black	BLK	Cemented	CMTD	Bearing	BRNG	Amount	AMT
Blue	BLU	Bed	BD	Blue	BL	Cement	CMT	Blocky	BLKY	And	+, AND
Boulder	BLDR	Bentonite	BENT	Bluish gray	BLGY	Crystallized	CRYLD	Breaks	BRKS	At	AT
Boulders	BLDRS	Calcareous	LIMY	Brown	BRN			Broken	BRKN	Balls	BALLS
Break	BRK	Caliche	CLCH	Buff	BUFF			Caves	CVS	Base	BASE
Caliche	CLCH	Cap	CP	Cream	CRM			Caving	CVG	Big	BIG
Caprock	CPRK	Caprock	CPRK	Dark	DK	Grain size	Code	Chips	CHIPS	Bits	BTS
Cavity	CAVT	Chalk	CHK	Gray	GY			Crumbly	CRMBY	Cleaty	CLTY
Chalk	CHK	Chalky	CHKY	Grayish white	GYWH	Coarse	C	Dough	DGH	Deep	DEEP
Clay	CLY	Clean	CLN	Green	GN	Coarse-grained	CGRD	Dry	DRY	Equal	=, EQUAL
Conglomerate	CGL	Crystalline	XLN	Greenish	GNISH	Fine	F	Firm	FIRM	Fair	FR
Dirt	DIRT	Dense	DNS	Light	LT	Fine-grained	FGRD	Fresh	FRESH	Few	FEW
Fullers earth	FLETH	Flint	FLNT	Multicolor	MLCØL	Medium	M	Heavy	HVY	Free	FREE
Gravel	GVL	Fossiliferous	FØSL	Orange	ØRNG	Medium-fine	MF	Heavier	HVR	Good	G
Gumbo	GMBØ	Glassy	GL	Pale blue	PLBL	Medium-coarse	MC	Joint	JØNT	In	IN
Hardpan	HDP	Granite	GRNT	Pink	PK	Small	SML	Jointed	JTD	Layer	LYR
Honeycomb	HNYCB	Gum	GUM	Red	RED			Ledge	LDG	Layers	LYRS
Lakebed	LKEBD	Gumbo	GMBØ	Reddish	RDSH			Ledges	LDGS	Little	LTL
Layers	LYRS	Gummy	GUMMY	Reddish brown	RBR			Lense	LENSE	Mixed	MXD
Ledge	LDG	Gypsum	GYP	Tan	TAN	Angularity	Code	Lenses	LNS	Not	NØT
Ledges	LDGS	Honeycomb	HNYCB	White	WH			Loose	LSE	Not reported	NREPT
Lime	LME	Lake	LAKE	Yellow	YEL	Sharper	SHRPR	Mostly	MSTLY	Of	ØF
Limerock	LMRK	Lime	LME	Yellowish	YWSH	Angular	ANG	Medium-loose	MLSE	Or	ØR
Limestone	LS	Limey	LMY					Pack	PCK	Real	REAL
Mixture	MXTRE	Loam	LOAM					Packed	PCKD	Scattered	SCAT
Muck	MUCK	Mica	MICA					Porous	PØRS	Slightly	SL
Mud	MD	Mired	MIRD			Hardness	Code	Powdery	PWDY	Small	SML
Packsand	PCKSD	Mixture	MXTRE					Seams	SEAMS	So	SØ
Pebble	PBL	Muddy	MDY			Hard	HD	Sheets	SHTS	Some	SØME
Red	REDD	Multicolor	MLCØL			Soft	SFT	Shell	SHEL	Thin	THN
Redbed	RDBD	Pea	PEA					Shelly	SHELY	To	TØ
Redbeds	RDBDS	Pebble	PEBBLE					Spots	SPS	Very	V
Riverbed	RVRBD	Quartz	QTZ					Sticky	STCKY	Weak	WEAK
Rock	RK	Quick	QCK					Streak	STR	With	WITH
Rocks	RKS	River	RVR					Streaks	STRS		
Quartz	QTZ	Rocky	RKY					Stringers	STRGS		
Sand	SD	Sand	SD					Strip	STRP		
Sandrock	SDRK	Sandy	SDY					Strips	STRPS		
Sandrocks	SDRKS	Shaly	SHY					Surface	SURF		
Sandstone	SS	Solid	SØLID					Tight	TT		
Shale	SH	Sugar	SGR					Tough	TGH		
Shell	SHEL	Water	WTR								
Shells	SHELS										
Silt	SLT										
Slag	SLAG										
Soapstone	SPSTN										
Stone	ST										
Soil	SØIL										
Streak(s)	STR(S)										
Subsoil	SSØIL										
Surface	SURF										
Topsoil	TSØIL										
Water	WTR										
White rock	WHRK										
Watersand	WTSD										

The general processing systems used by the New Mexico District are shown on figures 4, 5, and 6. After a series of error checks, updating, sorting, and merging, all coded data for each county are stored on magnetic tape. The computer output is obtained by using a program that lists the desired terms from the Ogallala lithologic lexicon (table 2) or terms used in the New Mexico District data file (OMNIANA). The requested information is retrieved from storage by the computer and can be converted into a variety of data output such as coordinate points, value plots, tables, graphs, or visual displays.

This study is primarily concerned with an output series of contour maps based on lithologic or structural data. Coordinate points, based on latitude and longtitude, are plotted by an off-line plotting device. The desired values are printed adjacent to the coordinate point, and these values may then be contoured by hand. The values could be contoured by machine if the computer were programmed for this operation.

Test-Hole Drilling

During fiscal year 1971, 58 test holes (total footage of 5,617 feet) were completed in 80 days of auger drilling in Briscoe, Hale, and Swisher Counties. The drilling unit, which was provided by the U.S. Geological Survey from Denver, Colorado, is equipped with 5-foot sections of a 5 3/4-inch diameter hollow-stem auger. The unit is also equipped with a split-spoon sampling device for taking undisturbed formation samples for laboratory analysis.

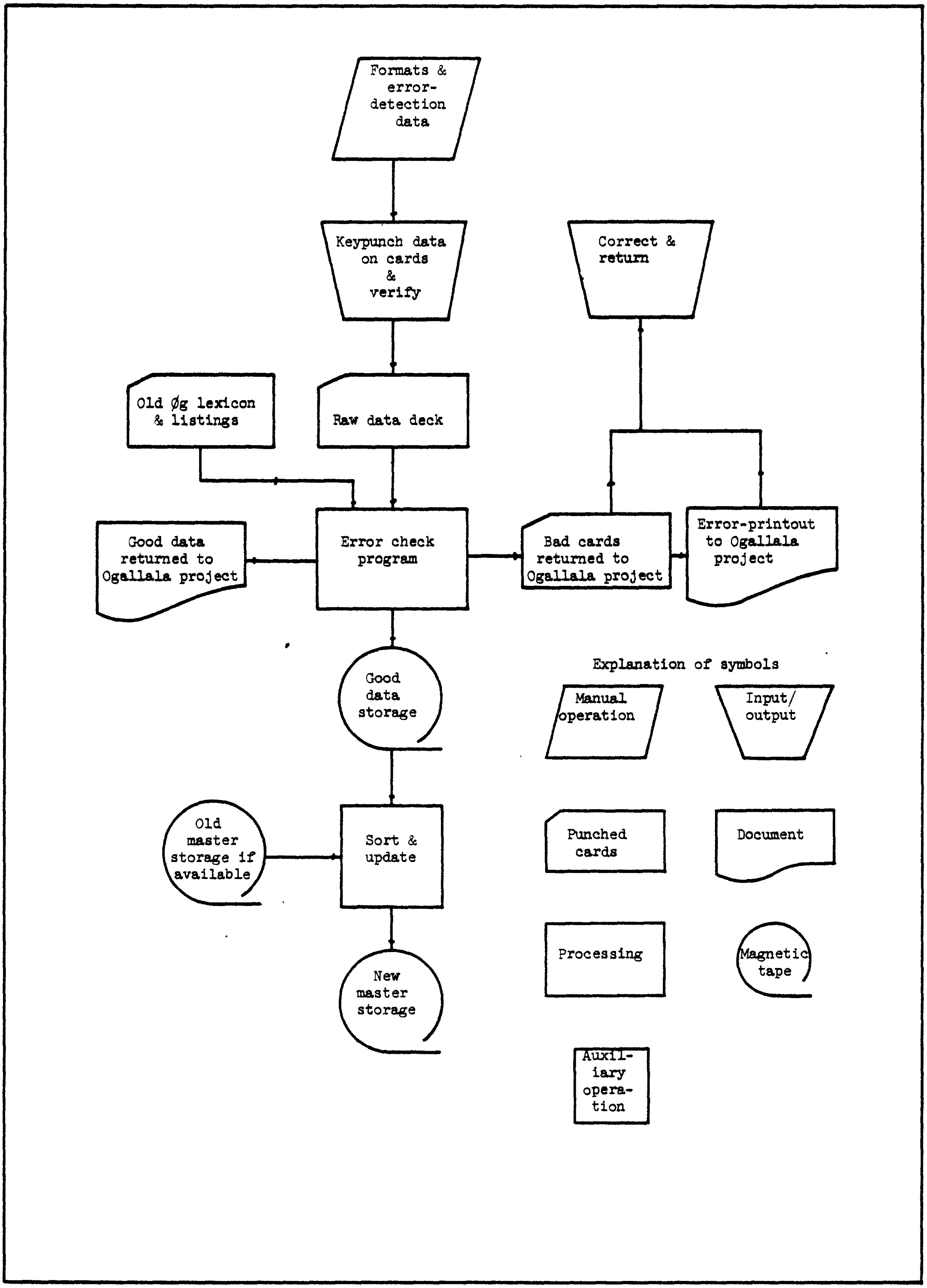

Figure 4. Systems flowchart for processing coded formats

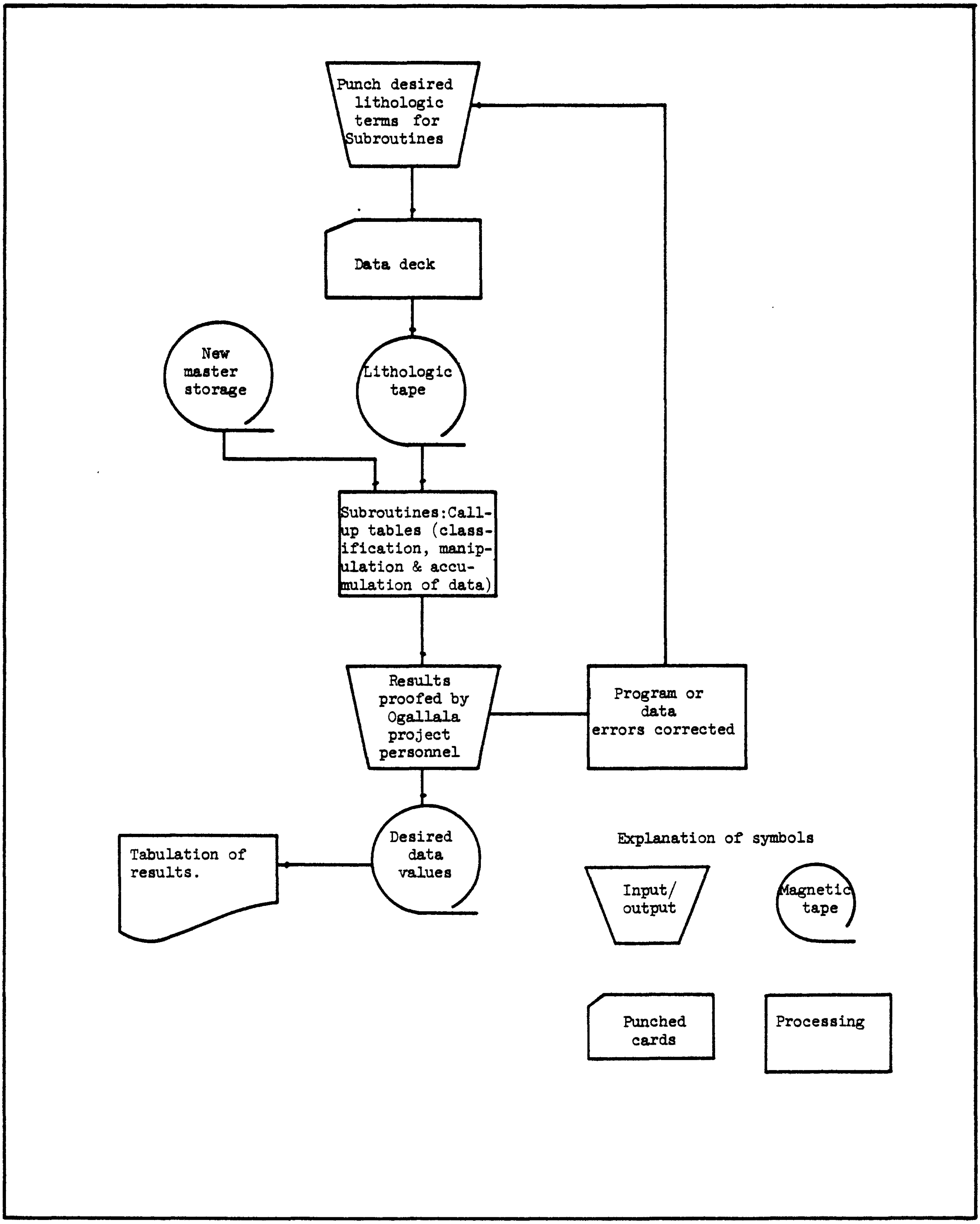

Figure 5. Systems flowchart for table-generating programs

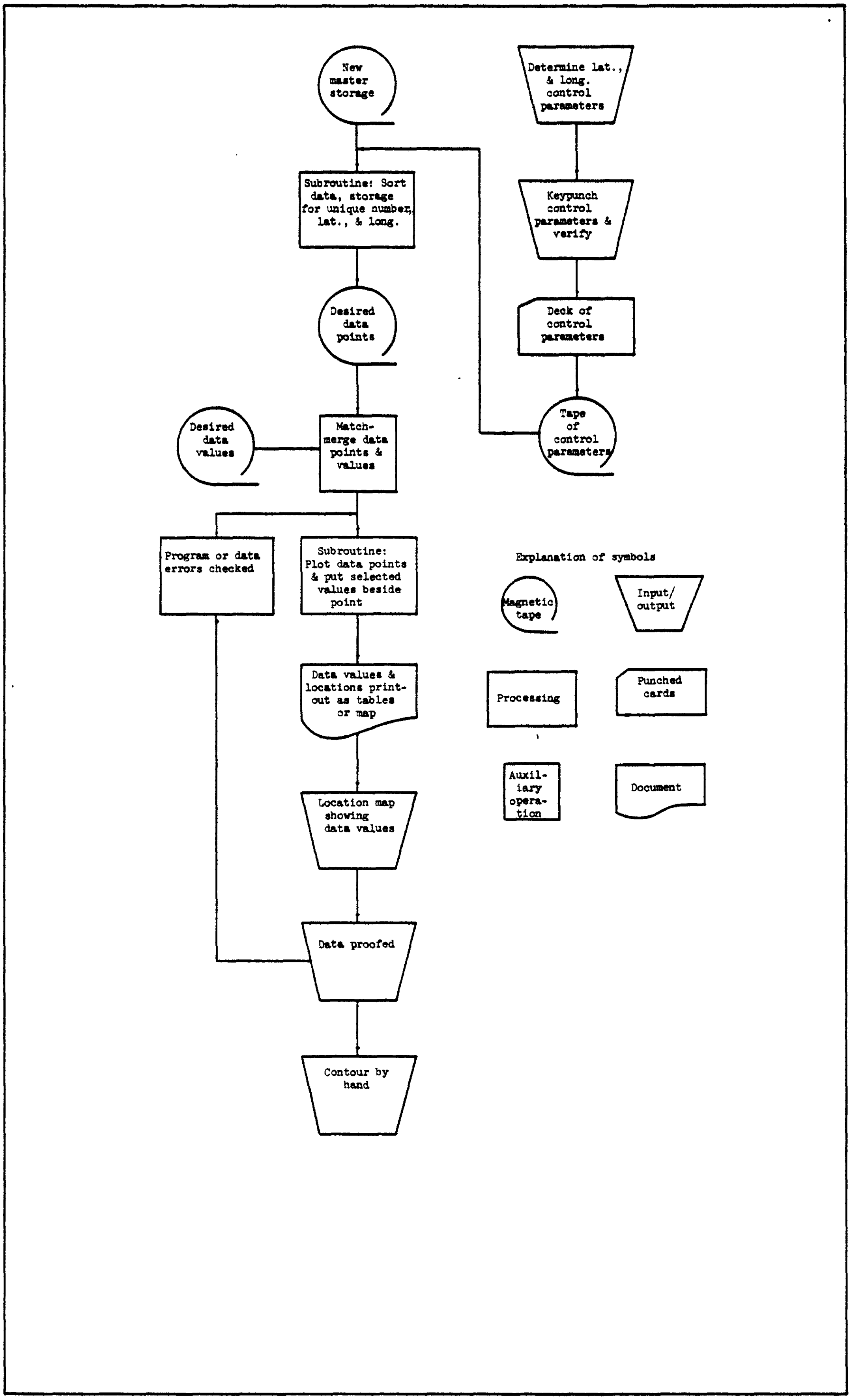

Figure 6. Systems flowchart for plotting data positions and values

Two test holes, one deep (100 to 150 feet) and one shallow (40 to 50 feet) were drilled at most sites. First the deeper hole was drilled, logged, and sampled at 5-foot intervals or at changes in lithology. After the hole was completed, a gamma-ray log was made through the hollow-stem auger, and then the auger was removed. Another gamma-ray log was made in the uncased hole. In addition, electrical and caliper logs were made at some sites, and some undisturbed samples were taken at the bottom of the holes. All of the data acquired by these operations were used to construct a lithologic log of the test hole.

The second, shallower hole was usually drilled about 10 feet or less from the first hole and was bottomed in a relatively impermeable layer of clay or silt. The desired depth was determined from analysis of the logs of the deeper hole, and an undisturbed sample was taken with the split-spoon sampler to determine the hydraulic conductivity.

Geophysical Logging

Geophysical well logs, including gamma-ray, electrical, caliper, and temperature, were used mainly to identify and to determine the boundaries of various lithologic units penetrated by the well. Some additional data on water quality, water temperature, and sediment consolidation can be obtained from the logs.

A total of 309 logs was made in 222 wells and test holes during fiscal years 1970 and 1971. Gamma-ray logs were made in all test holes and wells. Electrical logs were made in some uncased wells and other types of logs were made in a few selected wells and test holes. Table 3 gives the number and types of logs made in the various counties of the study area.

A comparison of the lithologic log and the gamma-ray log for test hole AK-11-12-8A is shown on figure 7. On completion of drilling a test hole, it is best to make a gamma-ray log through the hollow-stem auger or drill stem because caving of the hole may occur when the drilling tools are removed. A second gamma-ray log is made after the auger or drill stem is removed. Casing, auger, and drill stem all tend to subdue the response received by the logging instruments. The difference in the character of the gamma-ray log made through the hollow-stem auger and in the same hole after the auger was removed is shown on figure 8.

The effect of logging through the casing of a large-diameter well is shown by the gamma-ray log of well XT-11-20-5A (fig. 8), located about 800 feet east of well XT-11-20-5B. Logging below the water table increases the loss of response in addition to the loss caused by the casing. Gamma-ray logs made in gravel-packed or cemented wells are not accurate because the measured radioactivity is caused by both the sediments and the gravel pack or cement. Figure 9 shows a comparison of gamma-ray logs in well SP-24-32-8A made first in the open test hole and then after the well was reamed out, cased, gravel-packed, and cemented.

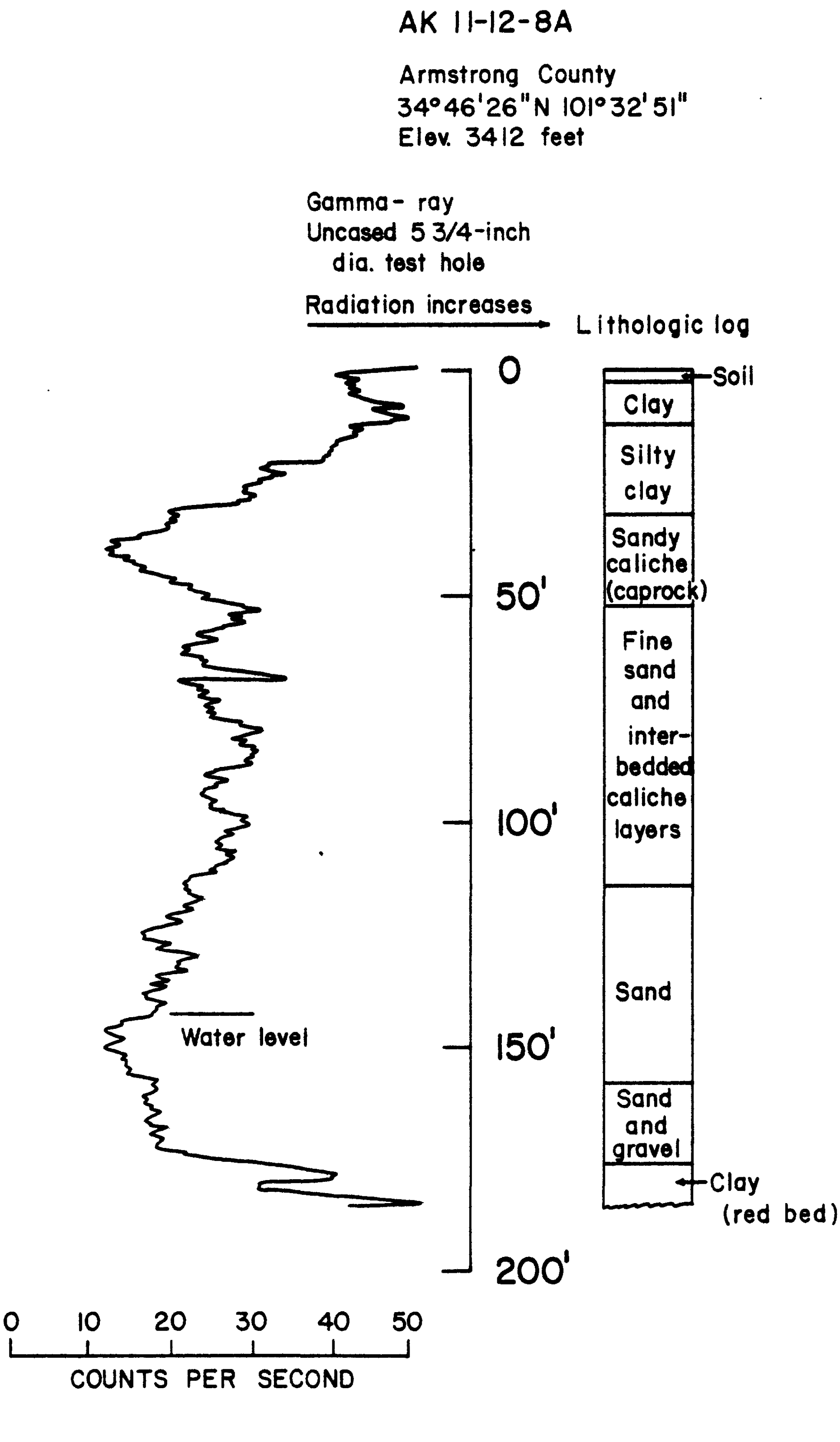

FIGURE 7.-Gamma-ray log and lithologic log of test-hole AK 11-12-8A in Armstrong County

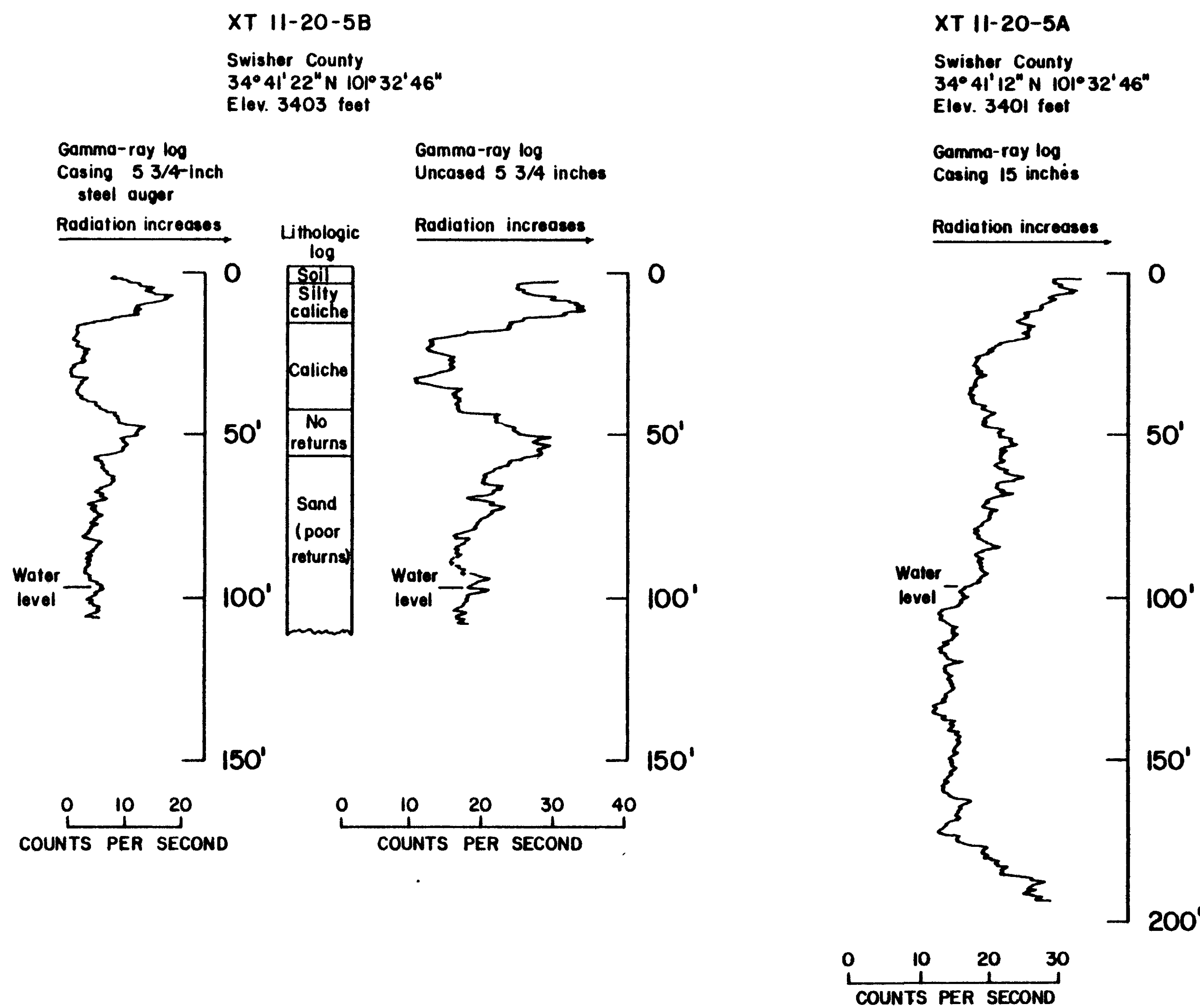

FIGURE 8.-Comparison of gamma-ray logs made through a hollow-stem auger, in the open hole, and in a nearby cased irrigation well.

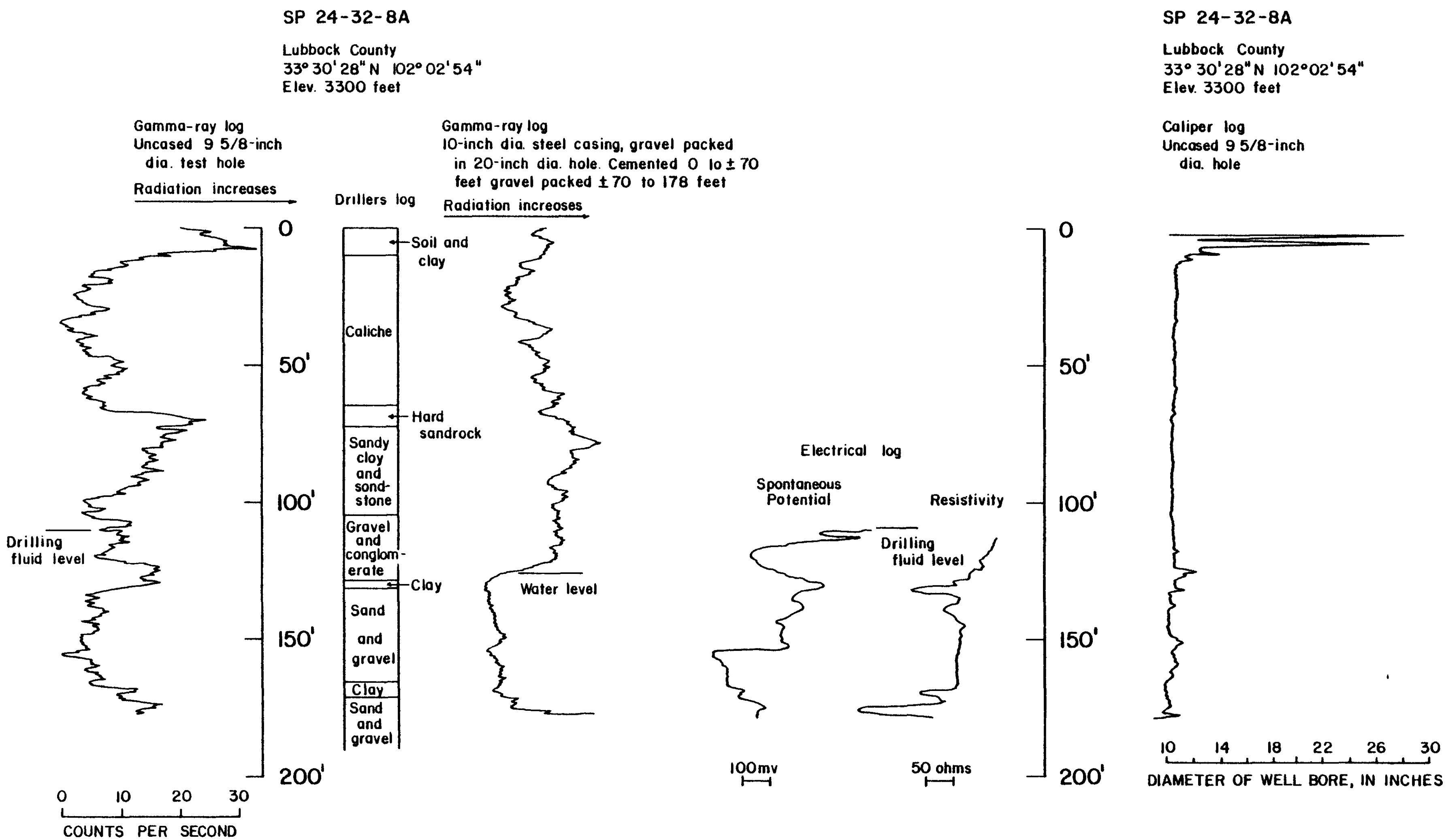

FIGURE 9.- Comparison of drillers' log and various geophysical logs made in well SP 24-32-8A in Lubbock County

Table 3.--Summary of geophysical logging of wells in the Ogallala Formation

County	Total number of wells logged	Type of geophysical log				
		Gamma-ray	Resistivity and spontaneous potential	Caliper	Temperature	Conductivity
Armstrong	21	24	2	-	-	-
Bailey	1	1	1	1	-	-
Briscoe	21	20	8	2	-	1
Castro	1	1	-	-	-	-
Crosby	10	13	-	-	-	-
Floyd	8	9	1	-	-	-
Garza	2	3	-	-	-	-
Hale	74	79	13	3	-	-
Lamb	3	3	-	-	-	-
Lubbock	24	28	7	3	9	4
Lynn	13	12	1	1	-	-
Martin	1	1	-	-	-	-
Parmer	2	2	-	-	-	-
Randall	2	2	-	-	-	-
Swisher	39	45	5	2	-	-
Total	222	243	38	12	9	5

Methods of Measuring Hydraulic Conductivity

The methods used in determining the hydraulic conductivity of the sediments were by laboratory analyses of core samples.

Core samples taken during the test-hole drilling program were analyzed by the U.S. Geological Survey in Denver, Colorado, or by the Texas Water Development Board. The core samples were analyzed for vertical hydraulic conductivity, porosity, specific yield, and grain-size distribution. Some samples from the deeper intervals were analyzed for horizontal hydraulic conductivity. In addition, 10 bag samples were repacked and analyzed for hydraulic conductivity, porosity, specific yield, and grain-size distribution.

The results of laboratory analyses of most of the samples are shown by the graphs on figures 10 and 11. The minimum vertical hydraulic conductivity of the samples was 5.8×10^{-5} ft/day (feet per day) or 2.05×10^{-8} cm/sec (centimeters per second) in test-hole 11-45-2B (Briscoe County) at a depth of 15 to 16 feet. Grain-size analysis for the sample in hole 11-45-2B shows that 45 percent of the sediment is of clay size or finer (less than 4 micrometers) and 75 percent is silt size or less (less than 0.0625 millimeter).

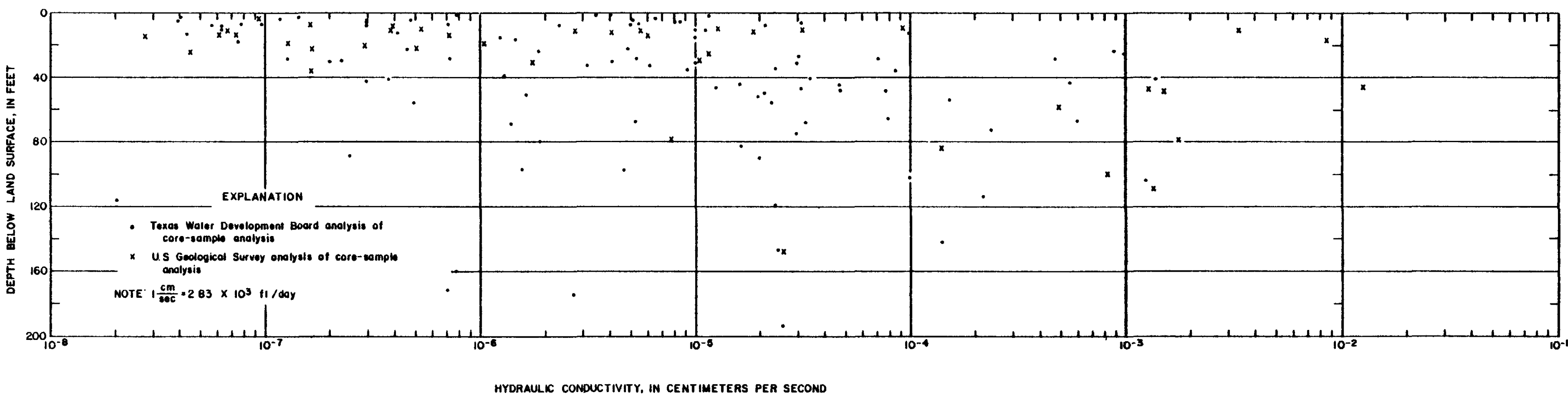

FIGURE 10.-Vertical hydraulic conductivity of care samples

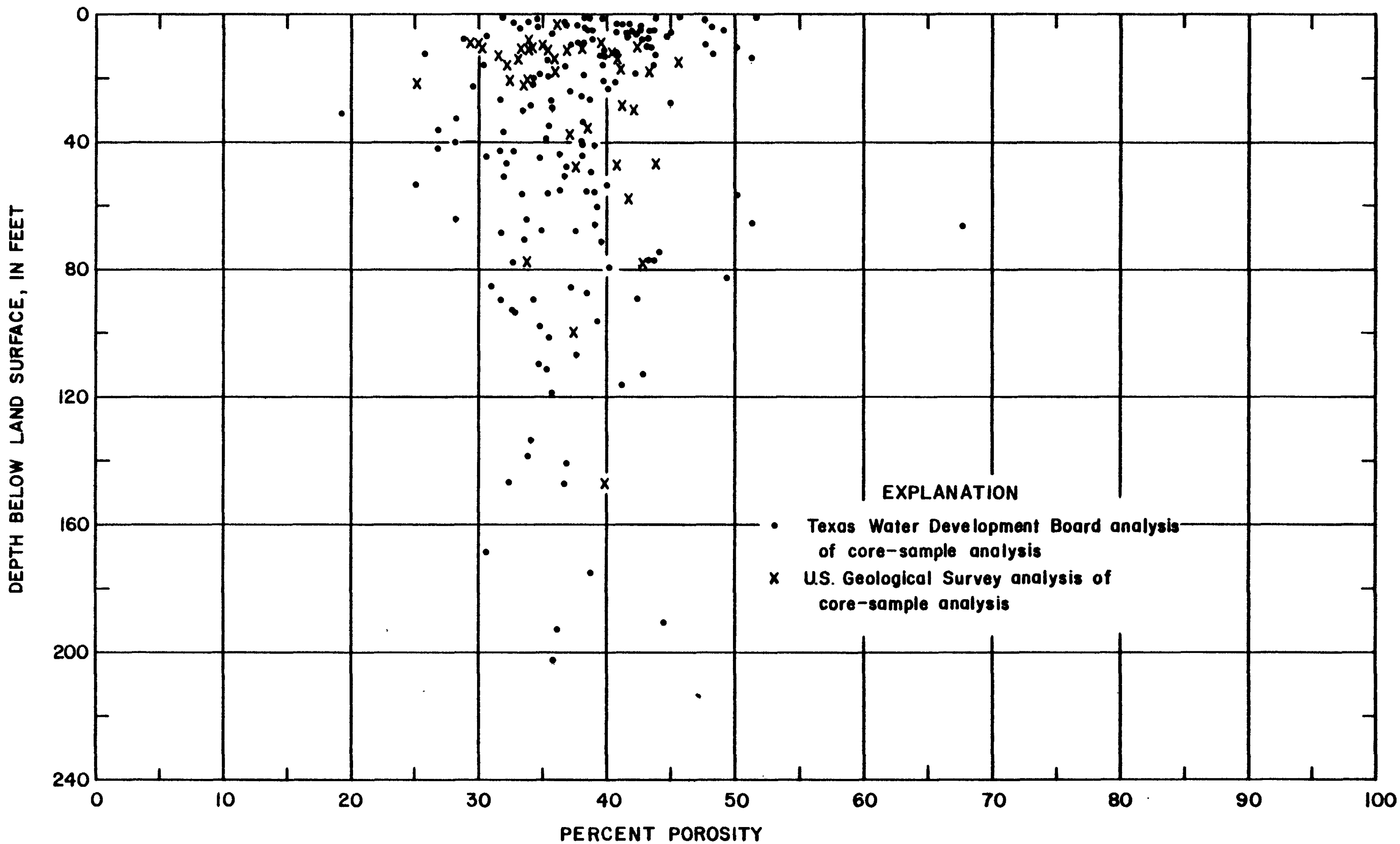

FIGURE 11.- Porosity of core samples

The maximum vertical hydraulic conductivity was 34.5 ft/day (1.22×10^{-2} cm/sec) in test-hole 11-60-2A (Hale County) at a depth of 47 to 47.5 feet. In the sample from test-hole 11-60-2A, about 20 percent of the material is of silt size or less, and 75 percent is smaller than fine sand (less than 0.25 millimeter). Grain-size percentages varied over a wide range, but the average was about 64 percent clay and silt. The porosities of the samples ranged from 25.1 to 45.5 percent.

RESULTS OF THE INVESTIGATION

Utility of Drillers' Logs

Many of the lithologic terms used on drillers' logs are vague or may have several different meanings. For example, some of the descriptions of rock types include such terms as "blue," "red," "break," "dirt," "lakebed," "ledge," "mixture," and "mud and rock" (table 2). Very often, an interval of the formation may be described as "clay, sand, and caliche" or "sand and rock layers."

The term "sand" means little on a driller's log because "sand" by definition, is a particle size, and much of the Ogallala Formation is composed of fine-grained sediments of low hydraulic conductivity. Few drillers use standard particle-size ranges (American Geological Institute, 1960 p. 253), so sediments described as "sand" may be very fine and practically impermeable or may be very coarse and highly permeable. The term "silt" is seldom used by the drillers, but a high percentage of the Ogallala Formation is composed of silt-size particles.

A series of commercial drillers' logs, the corresponding geophysical logs, and the interpretations of the geophysical logs are shown on figure 12.

Good correlation for both lithology and boundaries of the units is shown for logs AK-11-12-9A and KY-11-49-6A. Log XT-11-17-2A correlates well with the Geological Survey log of the samples collected at the well, but much less so with the commercial driller's log. Drillers' logs for wells XT-11-36-5A and JW-23-04-9A also cannot be correlated well with the geophysical logs.

The preparation of good lithologic logs of the Ogallala Formation is difficult because of the complex and rather variable lithology of the deposits. In general, the thicknesses and depths of the different rock types shown on drillers' logs are not closely comparable with those shown by geophysical logs. Differences, many of them amounting to several tens of feet, are attributed to difficulty in interpretation of depth of samples during drilling. Much of the difficulty stems from the fact that the drill commonly has reached a greater depth by the time material from a given depth reaches the surface. In consequence, the driller's logs commonly indicate a greater thickness of water-bearing sand or gravel than is shown on the geophysical log. Great care is needed in order to estimate more closely, from drilling characteristics (for example, difficulty of drilling), the depths at which significant changes in material occur.

(page 28 follows)

The completeness and accuracy of the additional information given on drillers' logs (such as location, well-construction data, static water level, yield, and drawdown) differs considerably from one log to another. The casing size, screened or slotted intervals and size, gravel-pack or straight-wall designations, pump description, and engine or motor size are incompletely described in many logs. Measurements or estimates of static water levels and pumping levels are commonly included, but in many logs, the time or date of measurement is not given. Yields estimated or based on the pump discharge-pipe diameter (a convenient method commonly used) are at best approximate, and may be greatly in error. The specific-capacity values calculated from the given discharge values are therefore approximations also.

In general, the commercial driller's log is more accurate for the intervals below the water table than for those above it. Greater accuracy below the water table probably reflects closer attention given to the drilling and logging procedures. The base of the Ogallala Formation is usually picked where the lithology changes from sand or sand and gravel to red clay or shale, blue clay or shale, or limestone.

As the usefulness of this information becomes more widely recognized, greater emphasis will be placed on the observation and recording of these data. It should be noted that the wells have usually been drilled to extract water for the least possible cost, and in practice there has been little demand for the accuracy and detail that can be obtained from careful construction of a lithologic log during drilling and from a complete summary of the test data.

Utility of Computer Analysis of Drillers' Logs

To determine the utility of computer analysis, data from drillers' logs of wells in Briscoe, Hale, and Swisher Counties were used as input. A sample of the initial computer printout showing a tabulation of the data is shown on figure 13.

After tabulation, the data can be manipulated by using different table-generating programs (figure 5). For example, the "total selected sands" routine is a program designed to examine all lithologic data on each log and to accumulate the thickness of permeable lithologic units such as sand and gravel.

Lithologic rock terms and modifiers used by drillers to indicate good permeability are: Medium-grained sand; medium sand; coarse-grained sand; coarse sand; medium-coarse sand; sand and gravel; gravel; medium-coarse gravel; medium gravel; fine gravel; coarse-grained gravel; river gravel; layers of gravel; small gravel; some gravel; big sand; big gravel; scattered boulders; loose boulders; and some boulders.

In general, the program is written so that the "total selected sands" include all intervals containing gravel, boulders, and sands coarser than medium. A page of computer output, showing the lithology of a log and the accumulated "total selected sands" for the entire log and for the total above the base of the Ogallala, is shown on figure 14.

Figure 13.--Computer printout giving tabulation of data from drillers' logs

General card data, columns 1-26: State, County, Ground water, Unique number, Date — Data — Card type

```
Card
number

 325   42045 G    29 677 2/27    G  228   230 CLY  ,RED  .                              OGLTH
 326   42045 G    29 677 2/27    G -  147                                               WLG
 327   42045 G    30 697 07      G                     342239 N1012637 REATMGL 3316    AAA
 328   42045 G    30 697 07      G J D NANCE             ROCK CREEK          11378NABE
 329   42045 G    30 697 07      G              S 44SWB  02    BEATY SCALE+FORWOOD    ACC
 330   42045 G    30 697 07      G 06550GLL F   225                                   AFT
 331   42045 G    30 697 07      G 69        LEDAVIS DRLG+PUMP     500TRSC FT  229 LORG
 332   42045 G    30 697 07      G   6       STEEL     GPPERFS                        CSG
 333   42045 G    30 697 07      G                                        TWDB        USG
 334   42045 G    30 697 07      G      0    5 TSOIL.                                 OGLTH
 335   42045 G    30 697 07      G      5   30 CLCH .AND   CLY   MXD  .               OGLTH
 336   42045 G    30 697 07      G     30   55 CLY  ,RED  .                           OGLTH
 337   42045 G    30 697 07      G     55   60 SD   .AND   CLY   MXD  .               OGLTH
 338   42045 G    30 697 07      G     60  174 SD   .SDRK .AND   RK   ,CLCH .         OGLTH
 339   42045 G    30 697 07      G    174  220 CLY  ,BRN  .AND   SDRK .               OGLTH
 340   42045 G    30 697 07      G    220  225 SD   .GVL  .AND   CLY   MXD  .         OGLTH
 341   42045 G    30 697 07      G    225  229 RDBD .                                 OGLTH
 342   42045 G    30 697 07      G -  144                                             WLG
 343   42045 G    31 677 07      G                     342324 N1012700 REATMGL 3309    AAA
 344   42045 G    31 677 07      G J-SUTTON              ROCK CREEK          11378KABE
 345   42045 G    31 677 07      G              S 44NWB  02    BEATY SCALE+FORWOOD    ACC
 346   42045 G    31 677 07      G 06550GLL F   223                                   AFT
 347   42045 G    31 677 07      G 67        LEDAVIS DRLG+PUMP     500TRSC FT  225 LORG
 348   42045 G    31 677 07      G                                        TWDB        USG
 349   42045 G    31 677 07      G      0    5 TSOIL.                                 OGLTH
 350   42045 G    31 677 07      G      5   30 CLCH .                                 OGLTH
 351   42045 G    31 677 07      G     30   50 CLY  ,RED  .AND   RK   ,CLCH .         OGLTH
 352   42045 G    31 677 07      G     50   56 CPRK .                                 OGLTH
 353   42045 G    31 677 07      G     56   70 SD   .AND   CLY   MXD  .               OGLTH
 354   42045 G    31 677 07      G     70  170 SD   .SDRK .AND   RK   ,CLCH .         OGLTH
 355   42045 G    31 677 07      G    170  206 CLY  .WITH  SDRK .AND  RK   ,CLCH .    OGLTH
 356   42045 G    31 677 07      G    206  223 GVL  .WITH  SOME  SD   .               OGLTH
 357   42045 G    31 677 07      G    223  225 RDBD .                                 OGLTH
 358   42045 G    32 467 3/28    G                     342050 N1012312 REATMGL 3267    AAA
 359   42045 G    32 467 3/28    G G E WALLACE          SILVERTON SH        166ABE
 360   42045 G    32 467 3/28    G              S 30NEB  02    BEATY SCALE+FORWOOD    ACC
 361   42045 G    32 467 3/28    G 36550GLL F   194                                   AFT
 362   42045 G    32 467 3/28    G 18     156 STEEL                                   CSG
 363   42045 G    32 467 3/28    G UGPMA  7007  0                                     AWY
 364   42045 G    32 467 3/28    G 4512        BOGLE + FLAKE DRLG CO500TRSC FT  200 LORG
 365   42045 G    32 467 3/28    G                                        TBE         USG
 366   42045 G    32 467 3/28    G      0    3 SURF .                                 OGLTH
 367   42045 G    32 467 3/28    G      3   28 CLY  .AND   CLCH .                     OGLTH
 368   42045 G    32 467 3/28    G     28   60 RK   ,BRKN .                           OGLTH
 369   42045 G    32 467 3/28    G     60   65 SD   ,WTR  .                           OGLTH
 370   42045 G    32 467 3/28    G     65   88 SR   .AND   RK   ,WH   .               OGLTH
 371   42045 G    32 467 3/28    G     88  147 SD   ,WTR  .                           OGLTH
 372   42045 G    32 467 3/28    G    147  168 SR   .AND   SD   .                     OGLTH
 373   42045 G    32 467 3/28    G    168  194 SD   ,BRKN .                           OGLTH
 374   42045 G    32 467 3/28    G    194  200 SH   .                                 OGLTH
 375   42045 G    32 467 3/28    G -  9721 400826     C-  1057 A                      WLG
 376   42045 G    34 65/11/      G                     342036 N1012311 REATMGL 3271    AAA
 377   42045 G    34 65/11/      G E DICKERSON          SILVERTON SH        11455AABE
 378   42045 G    34 65/11/      G              S 30NEB  02    BEATY SCALE+FORWOOD    ACC
 379   42045 G    34 65/11/      G 06550GLL F   240                                   AFT
 380   42045 G    34 65/11/      G 14     245           SWPERFS          150  245 CSG
 381   42045 G    34 65/11/      G 651101      ZIEGLER DRLG CO       500TRSC FT  245 LORG
 382   42045 G    34 65/11/      G                                        TWDB        USG
 383   42045 G    34 65/11/      G      0    2 TSOIL.                                 OGLTH
 384   42045 G    34 65/11/      G      2   18 CLY  ,YEL  .                           OGLTH
 385   42045 G    34 65/11/      G     18   35 CLY  .AND   SD   .                     OGLTH
 386   42045 G    34 65/11/      G     35   50 SDRK .                                 OGLTH
 387   42045 G    34 65/11/      G     50   65 CLY  .                                 OGLTH
 388   42045 G    34 65/11/      G     65   80 CPRK .                                 OGLTH
 389   42045 G    34 65/11/      G     80  100 SD   ,RED  .                           OGLTH
```

Data for log #30, Briscoe Co. (cards 327–342)

Data for log #31 (cards 343–357)

Data for log #32 (cards 358–375)

Card types:
- Master (AAA)
- Ownership data (ABE)
- Location (ACC)
- Drilling depths (AFT)
- Casing record (CSG)
- Yield (AWY)
- Driller and drilling data (LORG)
- Data source (USG)
- Intervals & lithology (OGLTH)
- Water levels (WLG)

Figure 14.--Computer printout for "total selected sands" routine

```
42045G00000000086805300000C                     343952 N1012629  EATMGL 3345   AAA
42045G00000000086805300000CE MCMURTRY EST          VIGO PARK                11216BABB
42045G00000000086805300000C               S 25  B  B3     BEATY SEALE+FORWOOD   ACC
42045G00000000086805300000CB6550GLL F    203                  P500TRSC DT   208 AFT
42045G00000000086805300000C 16       208                                        CSG
42045G00000000086805300000C6805   DAVIS DRLG + WELL SVC                 L  208  DRR
42045G00000000086805300000C                                           TWDB      DSD
42045G00000000086805300000C    0      5 TSOIL.                                OGLTH
42045G00000000086805300000C    5     25 CLCH .AND   SD    .                   OGLTH
42045G00000000086805300000C   32     43 SD   ,BRN  .                          OGLTH
42045G00000000086805300000C   43     85 CLCH .AND   RK    .                   OGLTH
42045G00000000086805300000C   85    125 SD   ,BRN  .                          OGLTH
42045G00000000086805300000C  125    145 SD   .AND   CLCH .                    OGLTH
42045G00000000086805300000C  145    160 SD   ,WH   .AND   CLY  .              OGLTH
42045G00000000086805300000C  160    170 SD   ,BRN  .                          OGLTH
42045G00000000086805300000C  170    203 WTR  .SD   .AND   GVL  .              OGLTH
42045G00000000086805300000C  203    208 CLY  ,RED  .                          OGLTH
42045G00000000086805300000C   25     32 SD   ,ORNG .AND   CLCH .              OGLTH

SUMMARY FOR UNIQUE NUMBER G000000008
TOTAL SELECTED SAND THICKNESS FOR THIS LOG      =      33.0
TOTAL SELECTED SAND THICKNESS TO OGALLALA BASE  =      33.0
```

The data selected and accumulated by the table-generating programs are best analyzed by plotting the values on a map. Figure 15 is a Calcom plot of the locations of drillers' logs in southeastern Hale County for sample sets 1 and 2. The locations, which are represented by squares, are plotted by latitude and longitude. The series of numbers to the left of the point designate the county and the well number. The well number used for this plot, which is a "unique number" (figs. 2a and 2b) assigned by the programmer is not related to the State well number. The numbers to the right show the land-surface elevation. The values given as "0.0" indicate the placement of other data that may be desired for that point. Latitude and longitude are shown next to the intersection symbols (+); however, not all values are shown on this sample of the Calcom plot.

This project was terminated before preparation of a computer program to combine the plotting program with the manipulating and accumulating programs, such as "total selected sands." If this had been done, values of "total selected sands" would be printed in place of one of the "0.0" shown on figure 15.

Other data that could be generated with the plotting routine include the altitude of the base of the Ogallala Formation and the total thickness of clay, silt, and other similar rock types that occur in the upper 40 and 100 feet of the Ogallala Formation (fig. 16).

(page 35 follows)

REFERENCE CITED

American Geological Institute, 1960, Glossary of geology and related sciences, with supplement: American Geol. Institute, Washington, D.C., 397 p.