1081

"Field Study of Tight Gas Sands Reservoir Directional Characteristics"

FINAL REPORT

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ABSTRACT

Three shallow wells were drilled, cored and logged to provide additional information on the seismic picture of the GC-1 area developed by Dr. Dobecki of SANDIA (Dobecki, 1980).

The wells were drilled and cored without any appreciable problems. The orientation equipment used during the coring failed to provide data on a number of occasions, but fortunately none of these lapses were in the target areas identified by Dobecki.

The information from the various sources were in general agreement for some lenses, but the general scatter of results was somewhat disappointing.

	OUTCROP	ORIENTED CORE	LOGS	SEISMIC
GC-1A-A Lens	146°	146°	30°-195°	45°-135°
GC-1B-B Lens	133°	169°	153°-169°	30°- 90°
GC-1C-C Lens	144°	36°	164°-166°	30 - 90°
GC-1C-C Lens	144°	-	95°-147°	30°- 90°

The regional dip of 5° at an azimuth of 200° was removed from the logging calculations. This moved the average azimuth more than 90°, e.g. from 180° to 72°. However, the log calculations were very sensitive to the parameters used during the file compilation and computer analysis.

The site will be turned over to the State of Utah as a geological research area instead of plugging the wells and abandoning them. The wells will be filled with mud and locked, all the DOE and GRI reports and logs will be placed on file at the State Oil, Gas and Mining Department Offices in Salt Lake City, Utah.

We would strongly recommend that an additional 2-well program be initiated, with wells drilled within 50 feet of GRI GC 1B and 1C. The program would be in cooperation with the major logging companies (Dresser Atlas and Schlumberger) and with Christensen on the oriented coring. This program would include repeat logging of the new holes (with prototype

equipment, varying parameters and technique and with the core laid out at the well site for comparison). This procedure should continue until consistant and repeatable results are achieved. The resulting new quantitative dipmeter technique could then be evaluated by relogging the GRI GC 1B and 1C hole. These results could then be compared with the results obtained from the original directional data as well as with the results obtained from the nearby new wells GRI 2B and 2C.

I. INTRODUCTION

The process of modeling tight gas sand reservoirs is a complex one. Probably no single technique or type of investigation can yield all the information needed. Techniques that extract information from the reservoir produce non-unique representations or rely on small and non-representative sample sets. Outcrop and near surface studies have large sample sets available but are evaluating rock that is removed from the actual reservoir environment and may have been subjected to addtional leaching, jointing, etc., which have produced characteristics that are not typical of the reservoir. Thus, an investigation should attempt to extract information from the appropriate sources and to point out limitations of the study.

The purpose of this study was to evaluate the predictions of a 3D seismic investigation of channel definition in the Mesaverde Formation in the Uinta Basin of Utah. See Figure 1. Some peripheral aspects were comparing the directional measurements obtained with oriented core and high resolution dipmeter, comparing tracings of sedimentary structures from cores with the four trace patterns from the dipmeter logs, and comparing well derived directions with outcrop measurements and channel directions obtained from seismic studies.

Although some permeability measurements were made on the cores obtained from the GRI wells, it would be inappropriate to consider the values representative of the reservoirs. These values are of interest only to provide an insight into the relative permeabilities of the high and low detrital matrix (clayey) layers.

The site of the experiment was in the Book Cliffs area, Grand County, Utah. See Figure 1. These cliffs form the southern boundary of the Uinta Basin, an important Western Tight Gas Sand Province.

The field portion of this study was carried out between September, 1980, and May, 1981.

II. SUMMARY OF MULTI-WELL PROJECT

A. Scope of Work

The various tasks that together make up the C. K. Geo-Energy portion of the project are summarized as follows:

a. Survey drill sites for 3 core hole locations selected by Dr. Dobecki to test interpretation channel orientation.

b. Prepare drill pads, drill coreholes and obtain approximately 120 feet of oriented core from each well in the depth interval 350 to 650 feet subsurface. This interval contains the sands selected by Dr. Dobecki from the geophysical data.

c. Ream holes to a minimum diameter of 6 inches and log each hole with a high resolution dipmeter.

d. Measure orientation of structural elements evident in the sandstone portions of the oriented core and determine channel direction as indicated by core information.

e. Measure orientation of structural elements on the sandstone outcrops that occur in the 350 to 650 foot interval on the ridge east and west of the site.

B. Site Description

1. Location

The project site is located in Section 16, Township 17 South, Range 24 East, Grand County, Utah, on a south trending ridge that rises more than 1200 feet above the floor of the east fork of Westwater Creek, see Figure 2. A gravel road runs along East Canyon, and a dirt gas field road branching from the East Canyon road provides access to the site.

The three GRI wells were drilled approximately 200 feet west, 200 feet south and 450 feet southeast of the DOE GC-1 well. The locations of the five wells in the general area are tabulated below and also displayed on the large scale topographic map, Figure 3.

Well	Elevation	T.D.	Location
Trend Oil Co. Bryson #8	6672	1821	2000 FWL - 2000 FNL
DOE - Corehole GC-1	6672	1200	2034 FWL - 2037 FNL
GRI - Corehole GC-1A	6619	658	2105 FWL - 2478 FNL
GRI - Corehole GC-1B	6646	600	2034 FWL - 2237 FNL
GRI - Corehole GC-1C	6654	550	1830 FWL - 2060 FNL

The locations of the GC-1A, 1B, 1C wells were selected by Dr. Tom Dobecki - Sandia, so as to intersect three shallow sandstone lens locations that he interpreted from his seismic study (Dobecki, 1980). Figure 4 is a copy of Dr. Dobecki's sand lens map with the locations of the 1A, 1B and 1C coreholes plotted thereon.

The tops of the A, B, and C lenses correspond to the following depths in the DOE GC-1 well:

Lens	Depth	
	Feet Subsurface	Elevation
A	597	6075
B	482	6190
C	434	6238

Figure 5 is a portion of the log from the GC-1 well with Dobecki's A, B, and C lens top location plotted thereon. The A and B lenses do not have well developed sandstones present at the GC-1 location. This lack of A and B sandstone at the GC-1 location is also indicated by Dobecki's sand location map, Figure 4.

C. Geology of Well Site Area

A stratigraphic chart of the Upper Cretaceous rocks in the Book Cliffs area of interest is shown in Figure 6. The formation names used and lithologic facies encountered change to the east towards Colorado and to the west towards Price, Utah.

The following description fits the well site area only. The rock units of most interest are the Neslen, Farrer, and Tuscher Formations of the Mesaverde Group.

The Neslen consists of several facies, including coal, shale and fluvial sandstone. Coal seams up to 5 feet thick have been mined for local use. Some of the seams appear to be burned out and oxidized where they cropout. There are abundant fluvial channel sandstones interbedded with shale, especially in the upper part. Channel lengths and thicknesses vary considerably. Pinchout terminations are commonly found for the narrower channels. Parallel inclined and trough cross beds are common, and there are also massive beds in these sandstones. Sandstones weather a buff color, are commonly iron stained, and are very fine to medium grained.

The Farrer and Tuscher Formations previously had been undivided in the area. The Tuscher has a high sand/shale ratio, considerably higher than the Farrer, and consists mostly of fairly thick coalescing fluvial channel sandstones. Channels were not measured in the Tuscher, since it is stratigraphically above the well site.

The Farrer consists of fluvial channel sandstones enclosed in shales siltstones and very fine grain sandstones. The channels vary considerably in length and thickness. Parallel inclined and trough cross beds are common. Parallel planar beds, massive structure and hummocky cross stratification are also present. Sandstones weather buff to reddish brown, are iron stained, and are very fine to medium grained.

III. PROJECT RESULTS

A. Well Data

1. Core Hole Information

a. GC-1A

The GC-1A corehole was drilled in the center of Dobecki's A lens. The location was about 450 feet south-southeast of the GC-1 corehole (2105 feet from the west line - 2478 feet from the north line, Section 16, Township 17 South, Range 24 East, Grand County, Utah) and has a ground level elevation of 6619 feet above sea level. A 20 foot 9 5/8-inch surface hole was drilled and 17 feet of 7 inch casing was cemented in place. A 6 1/8-inch hole was air drilled to a subsurface depth of 424 feet.

The oriented coring was initiated at the drillers depth of 424 utilizing a 20' x 4 5/8" x 3" Christensen core barrel, a 5-inch Christensen "Chrispac" bit, the Sperry Sun/Christensen orienting package and foam for the coring fluid. Mr. Greg Taylor of the Christensen Denver Office was the core engineer. The summary of the drilling history is included in Appendix A.

The Sperry Sun/Christensen orienting package consists of a nonmagnetic drill collar and nonmagnetic subs to attach the drill collar to drill pipe and core barrel, a special core head with a rod lubricated through the head and attached to the camera located inside the nonmagnetic collar, and a special core shoe with three scribbers for marking the core as it moves up into the inner barrel. See Figure 7.

The camera assembly is set to take a picture every minute. The coring is halted every two feet for two minutes and the depth and time are recorded. After the camera assembly is recovered and the film developed, the orientation of the reference groove and the hole drift direction and angle can be calculated. The information thus obtained for the GC-1A corehole is presented in Table 1.

The 6^{o} target that was used to record information from 440 to 498 feet in this hole proved to be nonmagnetic. Hence, this interval has resurveyed and the core orientation was calculated using the hole drift azimuth as the reference angle instead of magnetic north. Since the hole drift angle was only 1^{o}, the accuracy of these measurements is probably about ± 20 degrees.

The only other orientation problem encountered in this well was a partial bearing failure during the last day of coring that resulted in periodic inner barrel rotation. This resulted in short pieces of core with occasional spin-offs or signs of rotation between core fragments.

The coring was initiated at 424 feet subsurface in a sandstone interval, and was terminated at 652.2 feet subsurface in a sandstone interval. Approximately 56% of the core was sandstone.

A core description is presented as Table 2, and a core log is included as Figure 8. Three principle sandy sections were noted in this well:

Sandstone Section	424' - 440'
Sandstone Section	454' - 496'
Sandstone Section	545' - 604'

Photographs of a number of boxes of core are presented as Figure 9A-E. These figures show the general condition of the core and some of the small scale sedimentary structures from the three sandy intervals enumerated above. Figure 9A displays core from 424 to 439 feet in the upper interval. Figures 9B and 9C display the core from 448 to 479 feet in the middle interval and Figure 9D and 9E displays a core section from 548 to 580 feet in the lower interval. (The aluminum cans in the boxes are used for packing to prevent the core from sliding around and breaking during handling. The cans are the right diameter, are light and can be easily compressed to a convenient length, yet are sturdy enough so that they do not readily compress further.)

The core recovery was reasonably good, averaging more than 95% for the entire cored interval. The core frequently was removed from the core barrel in pieces longer than the 2 foot length of the core boxes, (usually in the sandstone intervals). These pieces were carefully broken into the correct lengths using a hydraulic core splitter. Occasionally the core jammed in the inner barrel while cutting shale sections. The jammed core was pumped from the barrel using a pump-out plug and an adapter that allowed the inner barrel assembly to be attached to the biplex foam injection pump on the rig. The core was slowly extruded from the barrel using fluid pumped behind the plug at pressures up to 600 psi.

b. CG-1B

The GC-1B corehole was drilled to penetrate Dobecki's B lens and was located about 200 feet south of GC-1. (2237 feet from the north line - 2034 feet from the west line, Section 16, Township 17 South, Range 24 east, Grand County, Utah). A 9 5/8-inch hole 16 feet deep was drilled and 15 feet of 7½-inch casing was cemented in place. A 6 1/8-inch hole was then air drilled to 400 feet subsurface and the coring operation was initiated. A 15'x 4 5/8" x 3" Christensen corebarrel with a

5-inch Christensen "Chrispac" bit, and the Sperry Sun/Christensen orienting package was used to foam core the hole to about 600 feet subsurface. At this time the hole was reamed out to 6 1/8-inch and filled with mud in preparation for the logging operations. A brief drilling history summary is included in Appendix A.

The orienting equipment was replaced after each half days run, to minimize the amount of information loss in the event of a failure. Only one run was lost (544-559 feet) and that loss was caused by a camera malfunction. Both cameras frequently shot double exposures, which complicated the interpretation, but still yielded valid orientation results. The orientation information is summarized in Table 3.

The core was removed from the core barrel after each run, fitted together on a tray or on a couple of pieces of drill pipe taped together, and described. The core description is summarized in Table 4 and a corelog is presented as Figure 10. After the core was marked with a double line on the reference groove cut by the special orienting shoe (Red on the right looking up the core and blue or black on the left), it was photographed and boxed. Photographs of several of the boxes from the principal sand sections encountered in this well (418-453 feet and 420-511 feet) are presented as Figures 11A-D. Figures 11A and B show core and the inclined bedding of small scale sedimentary structures from the upper sandy interval, and Figures 11C and D show similar features from cores in the lower sandy interval.

Photographs were also taken of each core prior to boxing. Figure 12 shows two typical sections from one of the resulting photos. The photos of the core in trays and in boxes are retained as part of the well files for each of the three coreholes.

Approximately 41% of the core cut in the GC-1B well was sandstone. Core recovery was good, about 97%, as was the percentage of core with orientation information, about 93%. No lost circulation or major lost mud problems occurred in this corehole.

c. GC-1C

The GC-1C corehole was drilled approximately 200 feet west of the GC-1 location. The location was selected so as to penetrate Dobecki's "C" lens,

Figure 4. The surface elevation is 6654 feet above sea level and the geographic location is 1830 feet from the west line and 2060 feet from the north line of Section 16, Township 17 South, Range 24 East, Grand County, Utah.

A 9 5/8-inch diameter surface hole was drilled and 11 feet of 7-inch surface pipe was set. A 6 1/8-inch diameter hole was air drilled to 350 feet and an attempt was made to secure oriented core from 350 to 550 feet subsurface. The previously described Sperry Sun/Christensen orienting package was used along with the 5-inch diameter Chrispac corebit. Mr. Greg Taylor and an engineering trainee were the Christensen representatives on site.

A number of equipment malfunctions occurred during the coring operations on this well. These problems resulted in the loss of orienting record in the interval 350 to 359, 465 to 481 and 490 to 527 feet subsurface. Fortunately, none of the failures occurred in the principal target area of 410-460 feet subsurface. With the exception of the first information loss interval when the inner barrel assembly came loose, the problems were all Sperry Sun camera malfunctions.

The available orienting information from this well is summarized in Table 5. The core description is summarized in Table 6, and a corelog is presented as Figure 13.

Sandstone intervals were encountered in this well at 369-394, 418-455 and 469-513 feet subsurface. The 86 feet of sandstone recovered in the core represented about 43% of the core.

Core recovery was good, about 98%, but orientation was lost on about 30% of the total core and on a slightly higher fraction of the sandstone, about 32%.

The hole was reamed to 6 1/8-inch diameter from 350-552 feet subsurface and filled with mud. Mud loss was minor during this operation. A screwed cap was used to seal the mud filled hole and the drilling operations were terminated on this hole. A summary drilling history is included in Appendix A.

Photographs of several of the core boxes from the sandy intervals are presented as Figures 14A and 14B. Figure 14A shows sandstone structures in the interval 436 to 452 feet subsurface (Dobecki's "C" lenses) and Figure 14B are photos of core from the interval 468 to 506 feet subsurface.

d. Directional Information from Cores

After the wells were cored, the core was brought to Las Vegas for processing. The core from each well was handled separately. The sandy sections of core were unboxed and assembled in 12-foot core trays.

The act of stopping and starting rotation at the same depth for the two minute orienting picture taking interval frequently leaves a characteristic horizontal "pause" groove on the core. These grooves were located and the azimuth of the red orienting groove was noted at its intersection with the pause groove. The core was then carefully evaluated to ascertain whether the orientation could be extrapolated between pause grooves. Occasionally a piece of core would have been found between pause grooves with smooth ends. If there was any appreciable azimuthal difference in the reference groove orientations above and below these "floaters", a rotation was assumed to have taken place at the floater location and they were assumed to be without orientation. If the orientation of the reference groove at the pause grooves above and below the floater was approximately the same, then the orientation was assumed to be the same throughout the interval, including the floater.

After noting the reference groove azimuth for each of the oriented pieces of core, they were removed from the tray and the dip direction and dip angle calculated for each small scale sedimentary structure using a core goniometer. See Figure 15. The goniometer procedure is summarized in Appendix B.

The goniometer results were tabulated for each of the sands in the three wells where Sperry Sun/Christensen orientation was available. The sandstones were given a designation that corresponds to Dobecki's sand lens pick in GC-1 where an A-B-C pick was made. The nomenclature and depths of the sandstones in each of the coreholes follows:

Well	Upper Sandstone		Middle Sandstone		Lower Sandstone	
	Nom.	Depth (ft)	Nom.	Depth (ft)	Nom	Depth (ft)
GC-1A	C	424-440*	B	454-496	A	544-594
GC-1B	C	418-453	B	470-511	**	**
GC-1C	α	369-394	C	418-455	**	**

* Coring was initiated below top of lens.
** No orientation data from some or all of this sand lens.

These goniometer measurements were then summarized for each sandstone unit and the information needed to plot dip direction roses and dip angle cummulative curves was calculated. The seven tables summarizing the data are numbered 7A through 7G.

Each of the measurements was considered a unit vector, and the X and Y component was determined. The sum of the X and Y components for each sandstone unit was then obtained and used to calculate the vector sum direction, θ. The relationship used to calculate a vector sum with a positive ΣX and a negative ΣY (the most common situation) is:

$$\theta = 180^{\circ} - \tan^{-1} \frac{\Sigma X}{\Sigma Y}$$

where:

θ = vector sum azimuth
ΣX = sum of individual unit vector X components
ΣY = sum of individual unit vector Y components

The directivity was calculated by dividing the magnitude of the vector sum by the number of unit vectors:

$$D = \sqrt{(\Sigma X)^2 + (\Sigma Y)^2} / \eta$$

where:

D = Directivity
ΣX = Sum of individual unit vector X components
ΣY = Sum of individual unit vector Y components
η = Total number of unit vectors in lens

The values for the various parameters used in the calculations, as well as the resulting θ and D values are presented in Table 8.

The vector sum for all of the measurements has a southeast trend, θ, of 129°, and a directivity, D, of 0.18. Five of the individual lenses trended southeast and two trended northeast.

The dip direction roses are presented as Figures 16A and 16B and the cumulative dip angle curves are presented as Figures 17A through C. The regional dip was not removed from these results prior to plotting, since they were not removed from the log calculations.

Graphic overlays were also made from each of sandstone lenses with core orientation data. These overlays were constructed by cutting strips of 4 mil thick transparent plastic so that their width was equal to the core circumference. One edge of the plastic was tightly wrapped around the core and secured with a strip of invisible transparent tape. The small scale sedimentary features visible on the outside of the core were traced onto the plastic with a black magic marker. The depths were marked on the core, the plastic cover slit vertically down the reference grooves and the pieces taped together end to end to form a strip with a length equal to the length of the sandstone interval and a width equal to the circumference of the core.* If these strips are reduced to the size of the four arm traces of the high resolution dipmeter, they can be compared directly with the structural features displayed on the log. A full size portion from one of the strip overlays is presented as Figure 18.

2. Well Logging Information

a. GC-1A

The GC-1A well was logged by Dresser Atlas on April 21, 1981. The well had encountered lost circulation problems during drilling and these were never completly overcome. Drilling was completed

* This technique was suggested by Dr. Roy Nurmi, Schlumberger Research, Richfield, Conn.

on this well on 3/31/81. At this time it was left filled with mud with a screwed cap in place.

The mud level after it had been filled to the surface dropped continuously in this well. In order to provide a hole full of mud during the logging operation we requested the drilling contractor, Himes Drilling, Grand Junction, to provide a mud pit that would surround the hole and help keep the mud level near the surface. After reviewing the problem, they came up with a good design and fabricated it in their shop prior to the logging operations. A sketch of their design is included as Figure 19. Mud from the mud pump is directed into compartment A where water, mud additives and lost circulation material can be mixed in to retain favorable mud volume and mud characteristics. The mud flows over the baffles through compartment B then through the baffle into C where it is picked up by the mud pump intake and circulated back to A. If the mud level drops in the balance compartment that surrounds the well head, it tends to be balanced by input from A/B/C. Conversly, displaced mud can fill balance chamber than flow into A/B/C. Excessive displaced mud overflows to the earthen mud pit. This fabricated mud pit fits under the rig. Figure 20 shows two photographs of the GC-1A logging operation, with the mud pit in place.

A rig was moved on the hole on 4/20/81 and started to circulate to bottom. The mud level was found below 400 feet subsurface and tight spots were found from 460 to 658 feet subsurface. This required rereaming this interval. After cleaning out the well to total depth, TD, the hole was circulated for about 45 minutes and then the drilling string was laid down in preparation for logging.

The GC-1A logs are on file with the State of Utah Oil, Gas and Mining Division and copies are also filed at the CER Tight Gas Library, in Las Vegas, Nevada.

b. GC-1B

The GC-1B corehole was first logged by Schlumberger on 12/12/80, immediately after completion of the drilling. No problems were encountered during the operation. The logs and the computer output containing the dipmeter calculations are on file with the State of Utah and the CER Library. The well was filled with mud and capped after the Schlumberger logging operation.

A rig was moved over the well on this location on 4/22/81 and a string was started to the bottom with a 6 1/8-inch bit in preparation for conditioning the mud for a second logging operation. A bridge was encountered at about 200 feet subsurface that required drilling. The drilling was so slow that the driller felt that he may have left the existing well bore and was drilling a new hole. This situation persisted until 460 feet was reached. From this point on, the string was easily lowered to the TD of 600 feet subsurface and thus was obviously back in the existing hole. The well was circulated for about 45 minutes, at which time the drill string was laid down and the hole topped off with mud.

The well was logged by Dresser Atlas on 4/22/81. The sonde hung up on a bridge at about 285 feet subsurface during the second logging run. The hole was entered with a 6 1/8-inch bit on a drill string with no drill collars, and the bridge was knocked loose. The string was run to the bottom and the hole was circulated. After the string was laid down the logging was continued without further problems. There was very little mud loss during the operations.

c. GC-1C

The GC-1C corehole was logged by Dresser Atlas on 4/23/81. Drilling had been completed on this hole on 12/4/80. The hole had been filled with mud and capped at completion of drilling.

A rig was moved on location on 4/23/81 and the hole was re-entered and the mud was conditioned by running a 6 1/8-inch bit to the bottom on the drill string and circulating the mud for about 45 minutes prior to logging. The mud level was encountered initially at about 200 feet. After filling and conditioning the hole, the mud level remained stationary or fell very slowly. The logging operation was carried out without any problems.

The logs and computer output from the GC-1C well are on file with the state of Utah and at the CER Library in Las Vegas, Nevada.

d. Directional Data from Logs

The target zone picked by Dr. Dobecki for the GC-1A well was designated the A lens, the target for the GC-1B well the B lens, the target for the GC-1C well the C lens and an additional important lens encountered in the GC-1C well the α lens. The correlation of these lenses and the numbered lenses (F1-F8) previously identified in the GC-1 well are shown in Figure 21.

The technique used to calculate the vector sum azimuth, θ, and Directivity, D, is as follows:

1. The interval to be evaluated is defined for the particular log and run by correlation with the corelog.

2. Each measurement in the sandstone lens interval is weighed by the grade or degree of correlation and the X and Y components are calculated:

$$X_i = g_i \sin \theta_i$$

$$Y_i = g_i \cos \theta_i$$

where:

X_i = the X component of measurement i

Y_i = the Y component of measurement i

g_i = the grade of measurement i

θ_i = the azimuth of measurement i.

3. The vector sum azimuth is the angle whose tangent is the sum of the X components divided by the sum of the Y components:

$$\theta = \tan^{-1} \Sigma X_i / \Sigma Y_i$$

where:

θ = vector sum azimuth

ΣX_i = sum of X components

ΣY_i = sum of Y components

4. The directivity, D, is the magnitude of the vector sum divided by the sum of the grades

$$D = \frac{\sqrt{(\Sigma X_i)^2 + (\Sigma Y_i)^2}}{\Sigma g_i}$$

The information from these calculations for the various logs and wells is summarized in Table 9.

There is a good deal of variation in calculated vector azimuth θ. The difference might be the result of different θ azimuth directions when a zone is compared from well to well. Sandstones may occur at the same interval in two different wells but they may be different lenses. The A interval, for example, certainly has a very different appearance in the GC-1, GC-1A, and GC-1B wells. An evaluation of the accuracy of the "θ" azimuth from log information may be obtained when repeat logging runs or runs by different companies in the same well are compared. One technique that can be used is to compare the average θ azimuth for a number of sands from two logs in the same well. Table 10 is a comparison of results from the Farrer interval in GC-1. The 178 vs. 189 values are not too far apart.

If we consider a statistic, β, to be the difference between the calculated θ azimuth in each lens, then we can evaluate the average β and the standard deviation of β. Selecting the same GC-1 Schlumberger-Dresser Atlas logs for the Farrer interval, we find the difference varies between 1 and 74° with a mean or average difference between calculated azimuths of about 38°, and the standard deviation of about 26°*.

Thus, about 1/3 of the time, one would expect a difference of greater than ± 26° from the average or mean, i.e. 2/3 of the time the difference will be between 12° and 64°, 1/6 of the time between 64° and 180°. This assumes our sample is representative of the "between company variations" in the calculations of the θ azimuth.

An estimate of the run to run variation can be extracted in a similar manner from the Dresser Atlas repeat runs on GC-1C. The mean or average difference

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* Standard deviation, α, was calculated using small sample distribution techniques (Hoel, 1954)

is about 10^{o} and the standard deviation is about 7^{o}. Hence, 2/3 of the time the mean or average value if multiple runs were made would be within ± 7^{o} of the measured value. Occasionally a real glitch occurs, e.g. the structural dip removal program malfunctioned toward the bottom of the GC-1C-3 program and a 100^{o} difference occurred between calculated θ azimuths for the B3 interval. The trace patterns for the two logs correlate, see Figure 22, and the values without regional dip removal are close, 240 and 224, thus, the large difference is probably a computer malfunction.

B. Outcrop Data

1. Introduction

The ridge used for the multiwell experiment contains surface exposures of the Tuscher, Farrer and Neslen units, see Surface Geologic Map - Plate I. During the earlier DOE sponsored portion of this experiment, 215 sandstone lens outcrops, with a thickness of greater than 5 feet were identified, see Outcrop Location Map, Plate II. About 10% of these lenses were selected and subject to a detailed analysis of small scale sedimentary structures (Knutson and Hodges, 1981) The average vector sum direction, θ, for these lenses trends northeast. Additional outcrop measurements were deemed necessary and the results of this additional work is reported in the following section of this report.

2. Outcrop Characterization

The interval of interest in the GRI minimulti well is in the Farrer and corresponds to about 400 to 650 feet in the GC-1 well. Since the top of the Farrer is at about 158 and the bottom about 758 feet subsurface in this well, the interval of interest is from about 0.2 to 0.6 of the distance from the bottom to the top of the Farrer Formation. Outcrops identified in Knutson's DOE report in this interval were tabulated and a representative number of these units were selected for small scale sedimentary structure geometric analysis. The outcrop pattern for beds counted in the band are shown in Plate II.

The measurement technique consists of determining the thickness, dip angle and dip direction of planer small scale sedimentary features, the thickness, width and axial projection direction of trough type sedimentary structures and the thickness, and current direction of ripple marked beds, (Knutson and Boardman, 1978). Each of the small scale sedimentary structures is considered to be a vector defining current direction at time of deposition. The vector sum at any one reach of stream deposit defines the paleocurrent direction and this direction correlates with the long axis of the channel sandstones, (Knutson and Boardman, 1979). The results of calculations of vector sum direction, θ, and directivity, D, for the measured sandstone outcrops is presented in Table 11. The average vector sum direction, θ, for all the data is east-southeast at 103°.

The height distribution for the measured beds is summarized in Figure 23. The median height for the measured beds is about 0.5 feet. The dip angle information is summarized in Figure 24. The median dip angle is about 15 degrees.

The extrapolation of the outcrop trends back into the ridge is graphically presented on Plates III A, B, C, D. In these plates the .2 to .6 band is broken into four increments .2-.3, .3-.4, .4-.5, and .5-.6 *

The channel sandstones seem to have low sinuosity meanders Hence, the extrapolated channel boundries were enlarged $\pm 15^{\circ}$ to take this sinousity into account.

This type of extrapolation results in predicting 8 sandstones in the 0.2 - 0.6 interval in the minimultiwell area. The information on these sandstones is summarized in Table 12. To allow for possible errors in interpretation of the stratigraphic position a band $\pm$ .05 was added to the interval of interest, hence the lowest stratigraphic location considered was 0.15 and the highest was 0.65 above the base of the Farrer.

C. Comparison of Information Obtained from Core, Outcrop and Logs.

1. "A" Lens

The geophysical picture of the "A" lens shows it only intersecting the GC-1A well and trending west at that location. However, the location is on a meander and the trend at GC-1A could be between southeast to northeast. Analysis of the A lens oriented core from the GC-1A well yields a 146° southeast orientation. The 84/202 outcrop is extrapolated into the GC-1A well and has a calculated azimuth of 146°. The dipmeter logs yield calculated azimuths between 30 and 195°. Thus, the four techniques are in general agreement -

* The fractions represent the relative distance above the base of the Farrer, e.g. 0.5 is the mid-point in the interval.

GC-1A WELL -A LENS			
Outcrop	Oriented Core	Logs	Seismic
146°	146°	30° - 195°	45°-135°

The outcrop 84/202 is much thinner than the A lens in the GC-1A well, but it has the same azimuth as the oriented core.

Sandstone is also present at the A lens stratigraphic position in the GC-1 and GC-1B wells. The appearance of GC1 and GC1B Lens A is appreciably different from the GC-1A- Lens A. A comparison of the Dresser Atlas dipmeter azimuths from the three wells follows:

GC-1A	GC-1	GC-1B
A 544'-584' - 195°	A-1 572'-588 - 97°	A-1 570'-577' - 226°
	A-2 600'-618'-193	A-2 592'-600 - --

The A-2 interval in GC-1 has an azimuth similar to that GC-1A the other readings are variable. The bulk of the "A" interval dip azimuths in the area have a southern trend, hence wouldn't show up in the outcrop.

2. "B" Lens

The seismic picture of the B lens shows it intersecting only the GC-1B well and having a east to northeast trend. All of the wells drilled in the GC-1 area have a double sand in this interval. A comparison of the calculated azimuths from the various techniques in the GC-1B well follows -

GC-1B WELL - B LENS			
Outcrop	Oriented Core	Logs	Seismic
133°	169°	153°-169°	30°-90°

The outcrop, oriented core and logs yield a southeast trend which is about 90° off the seismic interpretation.

The double sandstones in this interval in the other well with oriented data, GC-1A, has a southeastern trend, 142°.

The logs display a varied azimuthal spectra, but basically with a southern trend.

	GC-1	GC-1A	GC-1C
Schlumberger	180°	-	-
Dresser Atlas	236°	167°/189°	153°-169°

The outcrop bed, 70/201, that extrapolates into the GC-1 area has a height of 14 feet. This height correlates with the 13, 14, 16, and 18 foot heights of the equivalent bed encountered in the GC-1 area by the 4 research wells.

3. "C" Lens

The seismic picture of the C lens shows it intersecting the GC-1 and GC-1C wells and trending from northeast to east, about 30 to 90 degrees. A sandstone was encountered in this interval in all four GC-1 area wells. A comparison of the calculated azimuths from the various techniques for the C sand in the GC-1C well follows:

GC-1C WELL - C LENS

Outcrop	Oriented Core	Logs	Seismic
144°	36°	164°-166°	30°-90°

In this case the oriented core and seismic interpretaion is northeast and the logs and outcrop are southeast.

The outcrop sandstone lens height corresponds to the 22,23,24,26 foot height of the sandstones in the GC-1 area wells.

The comparison of the calculated dip azimuth from the logs of the four wells in the GC-1 area follows:

	GC-1	GC-1A	GC-1B	GC-1C
Dresser Atlas	147°	175°	65°	164°-166°

Three of the azimuths are to the southeast and one trend is to the northeast.

4. α Lens

An additional well defined sandstone unit was found above the three sandstones figured by Dobecki.

The directional azimuths calculated from the different information sources for the α lens follows:

α LENS AZIMUTHS

Well	Outcrop	Oriented Core	Logs	
			Schlumberger	Dresser Atlas
GC-1	60°/98°	-	118°	15°
GC-1B	60°/98°	-	-	113°
GC-1C	60°/98°	42°	-	116°/126°

The azimuths are generally in the east to northeast direction.

The height of the sandstone outcrop and the α lens height in GC-1, GC-1B and GC-1C wells correspond reasonably well.

In general, the great variability in the azimuths calculated from the logs handicaps the correlations. A representative from one of the logging companies said that they had developed their technology on the basis of calculations that seem reasonable, and not with any great amount of solid back-up data. He expressed the opinion that the GRI/DOE area representated an unique opportunity to set up a more rigorous and quantitative basis for the dipmeter log interpretation. The district manager for the other major logging company expressed similar sentiments.

5. Qualitative Evaluation GD-1B Logs

Schlumberger provides a qualitative evaluation of dip logs. Their technique is to place the multiple runs (from an interval using the same calculation parameters - 1'x¼'x40°) and perform a qualitative analysis by using the points that seem common to all logs.

This technique was applied to the 426 - 506 foot interval in the GC-1B well. Three sandstone units were selected and the results are compared to the oriented core and seismic channel orientation intrepretations:

	Outcrop	Oriented Core	Schlumberger
B1	-		90
B2	133°	169°	180
C	144°	36°	180

The Schlumberger interpretation definitely divides the B interval into two distinct units with their trends about 90° apart. The C interval correlations were not good in this well hence the north-south trend is not too apparent.

The complete Schulmberger analysis is attached as Appendix C.

D. Comparison of Azimuths with Regional Structure Removed

One major problem with the direct interpretation of the seismic information was the fact that the seismic horizontal slices were indeed horizontal and the beds were dipping at an angle to a horizontal datum. Hence, the seismic output cut across the lenses at an angle.

It is also apparent that the south-southwest "regional" structure is providing a bias in an azimuth of approximately 200° to all the measurements except these made on the outcrops.

The dipmeter logs provided the most comprehensive coverage for the GC-1 area, and a decision was made to evaluate the effects on the θ azimuth correlations if the regional dip is removed.

Both Schlumberger and Dresser Atlas agreed to cooperate in this venture on a non cost to GRI basis (and as computer time and programmers were available). Logs on GC-1, 1A, 1B and 1C were recomputed by D/A and GC-1 was recomputed by Schlumberger.

In order to provide a more consistant overall comparison, the unit vector mode was used in the θ azimuth calculations (the grade weights used by the two companies are somewhat different). The comparisons are summarized in a number of tables. Table 13A is the "regional dip removed" D/A GC-1 zone by zone summary and Table 13B is the original calculation summary. Table 14A and 14B are the Schlumberger GC-1 zone by zone summary and Table 13B is the original calculation summary. Tables14A and 14B are the Schlumberger GC-1 zone by zone summary with regional dip removed and Table 14C is the original calculation summary. The regional dip removal moved the average azimuth θ for all the zones from 178° to 62° for the D/A calculations and from 189° to 32°/62° for the Schlumberger logs (the two values are the result of using different parameter sets in two different computer analysis runs on the same basic data).

A similar comparison can be made of the other logging calculations, Tables 15 through 17. The average angles are summarized in Table 18. The average azimuth for all the comparable logs before removal of regional dip has a southerly trend, 180°. After the dip was removed the average trend was northeast 70°, which is consistant with the general trend of the seismic evaluation.

IV CONCLUSIONS AND RECOMMENDATIONS

The correlation between paleocurrent direction determination (and associated lens elongation) from the various techniques were poorer than expected, and the internal consistancy of dipmeter results was unexpectedly low. Since the dipmeter represents the technique that can be most expeditiously applied to paleocurrent direction determination, a major effort to improve the dipmeter technology would seem appropriate.

The GC-1 area represents a unique opportunity to upgrade some of the tools useful in tight gas sand as well as general gas sand exploitation.

Representatives of both of the major logging companies have requested that the site be made available for subsequent logging evaluation studies and have expressed their appreciation for the opportunity to some quantitative work in the dipmeter evaluation area. We have made arrangements with the Utah State Oil Gas and Mining Division, the Utah State Land Division and the Utah State Geological Survey to turn the area back to the state as a state research area. The state agreed to be the control agency and if the logging companies wish to reenter the wells (which have been left filled with mud and with locked caps - instead of plugged and abandoned) they can secure the keys from the state, do their research logging, clean up the site and return the keys to the state.

An available site will be helpful to the logging companies, but will probably not provide the stimulas necessary for a dipmeter development program that would be completed in the near term. The major companies are very busy meeting current "routine" commitments, and even small non-routine projects (such as the removal of the structural dip) require a lot of follow up and pushing.

We would strongly recommend that an additional 2-well program be initiated with wells drilled within 50 feet of GRI GC 1B and 1C. The program would be in cooperation with the major logging companies (Dresser Atlas and Schlumberger) and with Christensen on the oriented coring. This program would include repeat logging of the new holes (with prototype equipment, varying parameters and technique and with the core laid out at the well site for comparison). This procedure should continue until consistant and repeatable results are achieved. The resulting new quantitative dipmeter technique could then be evaluated by relogging the GRI GC 1B and 1C hole. These results could then be compared with the results obtained from the original directional data as well as with the results obtained from the nearby new wells of GRI 2B and 2C.

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TABLE 1-1

GC-1A Corehole Directional Data

Depth (ft subsurface)	Hole Drift Angle (degree)	Hole Drift Azimuth (degree)	Orientation Groove Azimuth (degree)
426	1°	357	119
428	1°	6	125
430	1°	13	287
432	1°	1	294
434	1°	9	303
436	1°	9	368
438	1°	16	17
440	1°	0	22
442	1°	3	351
444	1°	3	341
446	1°	1	77
448	1°	22	321
450	1°	358	90
452	1°	1	101
454	1°	2	118
456	1°	10	143
458	1°	355	138
459.5	1°	3	141
461.5	1°	2	205
463.5	1°	6	249
465.5	1°		
467.5	1°	11	288
469.5	1°	357	57
471.5	1°		
473.5	1°	22	346
475.5	1°	28	2
477.5	1°	20	70
479.5	1°	26	50
481.5	1°	18	314
483.5	1°	356	297

TABLE 1-2

GC-1A Corehole Directional Data

Depth (ft subsurface)	Hole Drift Angle (degree)	Hole Drift Azimuth (degree)	Orientation Groove Azimuth (degree)
485.5	1°	358	302
487.5	1°	357	313
489.5	1°	9	141
491.5	1°	19	151
493.5	1°	29	13
495.5	1°	7	13
497.5	1°	19	13
500	1°	7	342
502	1°	357	334
504	1°	356	340
506	1°	10	15
508	1°	21	73
510	1°	11	47
512	1°	24	157
514	1°	17	116
516	1°	13	
518	1°	22	91
520	1°	25	160
522	1°	35	175
524	1°	356	342
526	1°	13	74
528	1°	16	61
530	1°	0	358
532	1°	37	179
534	1°	21	71
536	1°	359	353
538.75	3/4	1	272
541	1	27	150
543	1¼	29	
544.5	1¼	17	137

TABLE 1-3

GC-1A Corehole Directional Data

Depth (ft subsurface)	Hole Drift Angle (degree)	Hole Drift Azimuth (degree)	Orientation Groove Azimuth (degree)
547	3/4	23	199
549	3/4	27	239
551	1¼	44	124
553	1	32	179
555	1	34	184
557	1	40	204
559	1	2	292
561	1¼	36	150
563	1	25	133
564.5	1	39	159
566.5	1¼	28	214
568.5	1	17	219
570.5	1	19	222
572.5	1	17	331
574.5	1	17	333
576.5	1¼	12	11
577.5	1	17	14
579.5	1	22	296
581.5	1	17	124
583.5	1½	17	135
585.5	1	17	136
587.5	1	23	144
589.5	1	27	168
591.5	1	19	357
593.5	1	28	294
595.5	1	24	139
596	1	18	319
598	1	23	165
601	3/4	26	257
603	1	13	344

TABLE 1-4

GC-1A Corehole Directional Data

Depth (ft subsurface)	Hole Drift Angle (degree)	Hole Drift Azimuth (degree)	Orientation Groove Azimuth (degree)
605	1	16	125
607	1	21	193
609	1	24	99
611	1	20	334
613	1	16	83
615	1	15	25
616.5	1	25	129
618.5	1	20	96
620.5	1	15	253
622.5	1	29	206
624.5	1		301
626.5	1	19	140
628.5	1	20	72
630.5	1	29	107
632.5	3/4	17	323
634.5	1	25	203
636.5	1	22	123
638.5	1	25	137
640.5	1	32	182
642.5	1	16	54
644.5	1	15	217
646.5	3/4	26	233
648.5	3/4	21	341
650.5	1	16	358
652.5	1	37	161

CORE HOLE

DOE GC-1A

TABLE 2

Depth	Lithol	Description	Depth	Lithol	Description
24		gy. med. gr ss w/sctd	461		
25		thin sh strks	62		
26			3		
26			4		
28			5		
29			6		
30			7		
31			8		.25' coal
32			9		
33			470		
34			1		c. gr A bottom
35			2		
36			3		gy mudstone w/gr-gr
37			4		slt blobs
38			5		gy-gr mudstone
39			6		gy mudstone
40		dk. gy sh w/carb	7		d. gy mudstn w/ small carb stks
41		stks gy slty mudstone	8		
42			9		
43		gy sh w/mud &	480		gy. md-gr. ss w/sh &
44		slty blobs	1		carb stks
45		dk gy mottled slty	2		
6		mudstone gy slty mudstone	3		
7		w/carb stks	4		
8		gy-green slty mudstone	5		
9		dk gy sh	6		
450		gy slty mudstone	7		
1		gy green slt	8		
2		blk sh gy mottled slt	9		
3			490		
4		gy ss w/sctrd sh stks	1		
5		and zone w/carb	2		
6		cement	3		
7			4		coal
8			5		blk mud stone w/
9			6		carb frags
0			7		gy mtld slt, mud,

Sample intervals (left): A1 (424–431), A2 (431–439), A3 (440–447), A4 (447–455), A5 (455–459); #1, #2, #1.

Sample intervals (right): A6, A7, A8, A9, A10; #3, #4.

Depth	Lithol	Description	Depth	Lithol	Description
498		intbd slt - fgr . ss	535		
99		gy fgr ss w/slt & sh stks	6		
500		dk gy mudstone	7		dk mdst intbd w/
1		blk organic sh w carb stks	8		blk sh
2		gy fgr ss w/slt lyrs	9		gy mdst
3			540		
4		intbd d gy mudstone & gy slt	1		blk mdstn
5		blk mudstone	2		
6		gy intbd mudstone &	3		dkgy mdstn w/carb stks
7		slt	4		fgr gy ss
8		dk gy mudst gy slt	5		gy mdstn.
		blk mudstones w/carb stks			
9		gy mudst w/ slt lyrs	6		gy f-m gr ss
510		d.gy mdst	7		w/ sh stks
1		intbd gy ss & slt/sh	8		some carb cmt nr
2		d.gy. sh	9		top
3		v.d.gy mdst w/carb stks	550		
4			1		
5		gy slt grading down into gy slty ss	2		clay infrafm cgl
6			3		
7			4		
8		blk sh	5		
9			6		
520			7		
1		intbd gy fgr ss & blk sh stks	8		
2		blk sh	9		
3		rdk gy mudstone	560		bottom core
4		w/ dk-gy mdstn blobs	1		
5			2		Washed Over 2' of Pieces
6			3		
7		gy slty mdst grading	4		
8		down into slt then	5		
9		fgr ss w/ sh stks	6		
530			7		
1		dk gy mdst	8		
2		dk gy mdst w gy	9		
3		slt blobs & stks	570		
4			1		

A10 A11 A12 A13 A14 A15 A16 A17 A18 5 6 7 8 9

Depth	Lithol	Description
572		
3		
4		Bottom of Core
5		
6		ss w/ many sh stks
7		
8		gy m.gr. ss w/occ
9		sh stks
580		
1		
2		
3		intbd contorted ss
4		& sh.
5		
6		gy m gr ss w/
7		sh stks
8		
9		
590		
1		
2		Bottom of Core
3		dk gr mdst
4		w/corb stks
5		
6		gy f gr ss w/sh stks
7		dk gy mdstn int bd gr gj ss sh
8		lt. gy mlst w/ blk 598.7
9		sh stks gy mdstn
600		gy m-f gr ss w/
1		sh stks
2		
3		
4		
5		gy mdstn w/ ss blobs
6		gy grn mudstn
7		
8		intbd ss & sh

Core run markers: 9, 10, 11, 12; 30

Depth	Lithol	Description
609		dk gy mdstn
610		gy grn mudstn w/ slt stks; bottom core
1		
2		
3		
4		
5		gy slty mdstn
616.5 6		
7		D.br mdst w/carb stks
8		intbd gy-br mstn & stt
9		intbd l.gy ss & gy mdstn
620		f - m.gr gy ss w/ ubndt d.gy sh stks
1		& lyrs
2		
3		
4		gy mdstn
5		
6		intbd gy & d gy mdstone
7		gy f gr ss
8		d br mdstn w/gy mdstn stks & blobs
9		gy slty mdstn
630		intbd gy mdstn &
1		l.gy slty mdstn
632.5 2		gy & dgy intbd
3		mdstn
4		
5		
6		f.gr, gy ss w/
7		sh stks & mdstn bds
8		d gy mdstn
9		d.br mdstn w/
640		coal & carb.
1		stks
2		gy slty mdstn
3		dgy mdstn w/carb frags
4		d br gy mdstn w/
5		slt & vf ss blobs

Core run markers: 12, 13, 14

COREHOLE
DOE GC-1A

Depth	Lithol	Description	Depth	Lithol	Description
646					
7					
8		mixture of contorted 14			
9		gy.ss & slt & d gy.mud -			
650		stone - ss content increases			
1		towards bottom			
652.2					
2					
3					
4					
5					
6					
7					
8					
9					
660					

TABLE 3-1

GC-1B Corehole Directional Data

Depth (ft subsurface)	Hole Drift Angle (degree)	Hole Drift Azimuth (degree)	Orientation Groove Azimuth (degree)
402	2	247	43
404	2	292	151
406	1	147	162
408	2	281	177
410	2	289	186
412	1	212	65
414	1	263	129
417	½	226	13
419	¼	225	29
421	½	249	230
423	½	244	245
425	½	239	262
427.7	½	239	80
430	½	230	90
432	½	226	95
434.7	½	229	103
436.7	½	233	125
438.7	½	239	120
442.7	½		195
444.7	½		195
446.7	½	239	193
448.7	¼	242	203
450.7	½	235	208
452.7	½	237	247
454.7	½	230	20
457.7	½	243	281
459.7	½	227	40
461.7	½	218	50
463.7	½	210	57
465.7	½	225	68

TABLE 3-2

GC-1B Corehole Directional Data

Depth (ft subsurface)	Hole Drift Angle (degree)	Hole Drift Azimuth (degree)	Orientation Groove Azimuth (degree)
467.7	½	226	77
469.7	½	243	114
472.7	½	223	108
475.7	½	217	235
477.7	½	215	264
479.7	½	229	268
481.7	½	232	293
483.7	½	235	301
487.7	½	237	245
489.7	½	232	325
491.7	½	217	345
493.7	½	241	285
495.7	½	261	309
497.7	½	239	44
499.2	½	232	54
501.2	½	223	10
503.2	½	228	315
505.2	½	225	318
507.2	½	223	333
509.2	½	241	345
511.2	½	223	353
513.2	½	217	24
514	½	248	212
516	½	213	81
518	½	227	321
520	½	222	323
522	½	237	332
524	½	242	343
526	½	242	117
528	½	232	142

TABLE 3-3

GC-1B Corehole Directional Data

Depth (ft subsurface)	Hole Drift Angle (degree)	Hole Drift Azimuth (degree)	Orientation Groove Azimuth (degree)
531	½	234	225
533	½	236	250
535	½	239	25
537	½	241	15
539	½	241	320
541	½	244	357
543	½	240	115
561	½	234	144
562	½	236	285
564	½	229	311
566	½	244	328
568	½	232	320
571	½	251	292
573	½	234	315
574	½	232	290
575	½	243	148
577	½	237	166
579	½	233	182
581	½	230	72
583	½	237	125
586	½	255	163
588	½	237	175
590	½	255	265
592	½	256	252
594	½	224	260
596	½	243	331
598	½	226	33

CORE HOLE
DOE GC-1B

Depth	Lithol	Description
400		gy vf ss w/ blk sh stks
1	SS	
2		
3		blk sh
4		
5		gy vf gr ss w/ blk
6		sh stks
7		int bd gy sh & blks & slt
8		int bd gy slt & dgy
9		sh w/ some
410		vf gr ss
1		
2		
3		
4		
5		
6		
7		
8		lgy v f gr ss w/ sh stks
9		gy f gr ss w/ sh stks
420		
1		
2		l gy v f gr ss w/ sh stks
3		gy f gr ss w/ carb stks
4		
5		gy slt
6		gy intbd slt & clystn
7		gy f gr slty ss
8		
9		
430		gy m gr ss w/ rr
1		cly blobs
2		
3		
4		
5		
6		

Depth	Lithol	Description
437		
8		
9		
440		
1		
2		
3		
4		
5		
6		
7		
8		
9		
450		
1		
2		
3		
4		blk grading down to dgy sh
5		
6		lgy sh w/ carb stks
7		broken blk sh
8		
9		gy slt w/ sh stks
460		
1		blk sh
2		
3		blk sh w/ slt stks
4		blk sh
5		slty blk sh
6		
7		d gy sh
8		slty blk sh
9		blk sh
470		
1		interbd slt sh & v f
2		gr ss w/ ss fraction
3		increasing toward bottom

B1 B2 B3 B4 B5 C1 C2 C3 B6 B7 B8 B9 C4 C5 C6

o.ok 12/8/80 o.ok 12/19/80 o.ok

Depth	Lithol	Description
474		
5		
6		gy mgr ss w/ sh
7		stks
8		
9		
480		
1		
2		
3		
4		
5		
6		
7		blk sh
8		gy mudstone
9		
90		
1		
2		
3		intbd gy mudstone & ss
4		
5		d gy mudstone
6		
7		gy ss w/ rr sh stks
8		
9 (499.2)		
500		
1		
2		
3		
4		
5		
6		
7		
8		
9		
510		

Depth	Lithol	Description
511		gy mudstone
2		
3		
4		gy slt w/ carb
5		stks
6		d gy claystone
7		l gy slty claystone
8		w/ rr ss stks
9		
520		
1		
2		d gy to blk claystone
3		w/ carb frags
4		
5		
6		
7		
8		
9		
530		blk slty clyst
1		intbd gy ss slt clyst
2		blk slty clyst
3		gy slty ss
4		lt gy clyst
5		blk clyst
6		gy clyst
7		blk clyst
8		gy slty claystone
9		d gy slty claystone
540		
1		cly slt
2		gy clyst
3		
4		
5		
6		gy mgr ss w/
7		sh stks

B10 B11 B12 B13 B14 B15 B16 B17 B18 B19

C6 C7 C8 C9 C10

12/9/80 0 OK

12/10/80 0 OK

0 OK

COREHOLE
DOE GC-1B

Depth	Lithol	Description
548		
49		
550		
1		
2		
3		
4		gy slty clyst w/
5		ss lyrs
6		
7		tan clyst
8	X	
9		d gy clyst
560		gy
1		blk
2		v f to mgr ss (gy
3		color) w/ sh stks
4		
5		
6		] gy clyst
7		
8	X	barrel - jammed
9		
570		intbd gy vf ss, slt w/
1		sh stks
2		
3		gy f-m gr ss w/
4		
5		occ sh &/or carb
6		stks
7		gy slt clyst
8		intbd gy ss, slt, sh stks
9		gy clyst w/ occ slt/ss
580		blobs & stks
1		d gy clyst w/ rare
2		slt/ss blobs
3	X	
4		gy clyst
		blk & gy intbd clyst

Margin annotations (left column): 12/10/80 NV.O; 12/10/80 0 OK; B19; B20; B21; C11; C12; C13

Depth	Lithol	Description
585		gy vf gr ss w/ slty &
6		sh lyrs
7		
8		
9		d gy slty clyst
590		
1		v f gr gy ss w/ carb
2		streaks
3		
4		gy f-m gr ss w/
5		acc carb stks
6		
7		
8	X	
9		
600		
1		
2		
3		
4		
5		
6		
7		
8		
9		
610		

Margin annotations (right column): 12/11/80 0 OK; C14

TABLE 5-1

GC-1C Corehole Directional Data

Depth (ft subsurface)	Hole Drift Angle (degree)	Hole Drift Azimuth (degree)	Orientation Groove Azimuth (degree)
361	1½	3	112
363	2	355	117
365	2	365	344
367	2	364	336
368	2	344	175
370	1	351	94
372	1	345	94
374	3/4	355	325
376	1	348	71
378	1	355	74
380	1	352	79
382.5	1	345	88
384.5	3/4	358	36
386.5	1	350	207
388.5	1	2	218
391	1	352	222
393	1	359	276
395	1	347	70
398	1	351	89
400	1	357	78
402	1	350	187
404	1	348	104
406	1	344	91
408	1	349	133
410	1 1/4	352	197
412	1	358	10
414	1	349	85
416	1 1/4	352	285
418	1	359	155
420	1	354	161

TABLE 5-2

GC-1C Corehole Directional Data

Depth (ft subsurface)	Hole Drift Angle (degree)	Hole Drift Azimuth (degree)	Orientation Groove Azimuth (degree)
422	1	355	168
424	1	2	175
426	1	3	2
428	1	300	69
430	1	346	74
432	2	345	43
432.5	2	347	39
434	2	215	99
436	2	291	
438	2	230	80
439	2	212	96
441	2	335	53
443	2	344	48
445	2	344	48
447	2	338	169
449	2	340	172
451	2	332	171
454.5	1	15	34
456.3	3	48	20
459	2	15	17
461	2	337	80
463	2	327	97
465	2	334	75
467	2.5	337	52
484.5	1	349	30
486.5	1¼	350	68
488.5	2¼	351	98
529.5	1	2	144
531.5	1¼	3	152
533.5	1¼	2	14
535.5	1¼	3	91

TABLE 5-3

GC-1C Corehole Directional Data

Depth (ft subsurface)	Hole Drift Angle (degree)	Hole Drift Azimuth (degree)	Orientation Groove Azimuth (degree)
537.5	1¼	1	99
539.5	1¼	4	93
541.5	1¼	359	152
543.5	1¼	0	158
545.5	1¼	0	170
547.5	1¼	358	183
549.5	1¼	2	189
551	1¼	3	198

CORE HOLE
DOE GC-1C

Depth	Lithol	Description
350		blk, sh
1		broken
2		
3		
4		blk to gy
5		slt & sh w/
6		carb stks
7		gy sh
8		gy slt sh
9		gy sh w/ slt
360		stks
1		
2		blk sh
3		gy slt w/
4		carb stks
5		gy sh
6		
7		blk sh
8		gy intrbd sh & slt
9		gy v f gr ss w/
370		sh stks
1		
2		
3		
4		intbd dgy slt & sh w/ ss blobs
5		gy f gr ss w/
6		abndt sh stks
7		
8		
9		
380		
1		

Depth	Lithol	Description
382		cont
3		cont
4		
5		gy m f gr ss
6		w/ occ th
7		sh stks
8		
9		
390		
1		
2		
3		
4		dk gy sh
5		
6		gy sh w/ slt blbs
7		
8		gy sh w/ occ carb stks
9		
400		
1		gy slt
2		m gr gy ss
3		gy sh
4		blk slt & sh
5		I gy ss
6		
7		gy slt blk sh
8		
9		gy intbd sh ss & slt
410		
1		
2		gy slt & sh w/
3		carb stks

NO O. O.OK O.OK 11/26/80 O.OK

B1 B2 B3 B4 B5 B6 B7 B8 C1 C2 C3 C4 C5

Depth	Lithol	Description	Depth	Lithol	Description
414		gy sh w/ carb stks	446		
5			7		
6		lt gy slt w/ sh stks	8		
7		~~l gy ss w/ sh stks~~	9		
8			450		
9		intbd slt & sh d gy	1		
420		l gy ss w/ sh stks	2		gy, m-f gr ss
1			3		few dk sh streaks
2		gy slt w/ carb stks	4		
3			5		
4		mottled gy slt & sh	6		dk gy sh
5			7		
6		gy sh grades into gy slt	8		mudst w/dk gy sh frags
7			9		slty dk gy sh
8			460		slightly shaly gy
9		intbd gy slt vf gr ss & sh	1		siltstone, occasion v f sand grains
430			2		
1			3		
2		gy m-vf gr ss w/ th sh stks	4		dk gy shaly sltst
3			5		
4			6		gy slty v f gr ss w/ many dk sh streak
5			7		
6			8		gy slty, v f med gr ss
7			9		few dk shaly streaks
8			470		
9		cont	1		
440			2		
1			3		gy slty v f m gr ss w/ common shaly streaks & contorted mottled beds
2			4		
3			5		
4			6		
5			7		

Margin annotations: O.OK; O.OK; 12/1/80 O.OK; NO.O; box/core markers B9, B10, B11, B12, B13, B14, B15, B16, B17, C6, C7, C8, C9, C10.

COREHOLE
DOE GC-1C

Depth	Lithol	Description	Samples
478			
79		dk gy slty shale	C10
480			B17
1			
2			
3		gy slty v f m r ss	
4			B18 2/27/80 NO.0
5		gy slay sltst.	
6		gy sh	C11
7		gy shly sltst.	
8		dk gy shw/ blobs	
9			
490		gy shly slty v f f gr s s	
1		gy shaly sltst. (broken)	
2			
3			
4		gy slty sh.	
5		gy sandy sltst.	B19
6		no recovery	
7		+ crumbly	
8		slty, v f-f gr s s	
9		m g d y gy bands	
500		minor sh. bands	
1		some distorted beds	
2			
3			B20 C12 2/28/80 0.0K
4			
5			
6			
7			
8			
9			B21
510			

Depth	Lithol	Description	Samples
511			B21 C12
2		no recovery slty v f-f gr s s	
3			
4		dk gy slty sh.	
5			
6		dk carb. sh.	B22
7		w/ sm. coaly bands	
8		med. gy shaly	C13
9		sltst, minor s s	
520		minor carbon	
1		frags, some	
2		irreg. beds	
3			B23
4			
5			
6			
7		slty med gry	
8		shw/ few carb frags	
9		dk gy sh w/	
530		carb frags gy slty v f gr s s	
1		gy shly sltst	B24
2		dk gy carb	
3		sh.	
4		med gy shly	C14
5		sltst, v f	
6		sd grains - few	B25
7			
8		crumbly sh	
9		gy sltstone, v f	
540		sd g carb frags dk carb. shly	
1		sltst gy v f-f gr	B26 C15
2		s s, silty	
3		w/ thin dk shaly bands	

Depth	Lithol	Description	Depth	Lithol	Description
544		cont B26			
5					
6					
7		gy sltst. C15			
8		w/ some v f sand grains			
9		some irregular banding B27			
550					
1					

0.0K

Table 7A. Directional Data from Oriented Core
Well GC-1A
Lens A

Depth'	Ref Groove Az.°	Dip Dir. Az.°	Dip Angle°
544.22	137	37	20
.28	"	"	"
545.32	137	37	18
546.59	199	332	22
547.04	199	350	25
.11	"	"	"
548.15	199	84	12
.40	"	98	"
.63	"	84	"
549.29	239	354	12
551.05	124	257	12
.10	"	"	"
552.32	124	53	10
.33	"	"	"
.41	"	"	"
553.23	179	250	18
554.69	179	108	20
555.07	184	338	20
.34	"	114	18
.88	"	190	25
.90	"	232	8
556.10	184	185	10
.13	"	"	"
.68	"	160	18
.97	"	175	"
557.10	204	205	10
.22	"	148	18
.28	"	"	"
.35	"	125	20
.45	"	134	"
.50	"	"	"
.55	"	125	"
.92	"	38	15
558.27	204	38	15
.36	"	"	"
.60	"	75	12
.70	"	"	14
.81	"	"	12
559.30	292	201	12
.35	"	"	"
.41	"	"	"
.65	"	290	"
.90	"	267	"
560.15	292	290	12
.20	292	290	12
.61	"	55	15
.67	"	112	13
.78	"	"	"
561.04	150	4	10
.08	"	"	"
.15	"	315	12
.18	"	"	"
.23	"	"	"
.40	"	"	"
562.91	150	130	10
563.10	133	70	13
564.66	133	128	8
.95	"	44	"
565.15	159	70	15
.27	"	"	"
566.26	214	348	10
.28	"	"	"
.32	"	"	"
.39	"	12	"
.43	"	"	"
.78	"	160	20
.79	"	"	10
567.24	214	295	6
.35	"	190	14
.68	"	165	9
.75	"	"	"
.81	"	"	"
568.29	219	147	9
.35	"	"	"
.50	"	180	21
.58	"	"	"
.68	"	"	"
.70	"	"	"
.73	"	"	"
.83	"	"	"
.91	"	"	"
.98	"	"	"
569.51	219	220	12
.55	"	"	"
.60	"	187	10
.68	"	"	"
.91	"	"	"
570.10	222	220	8

Table 7A. Directional Data from Oriented Core
Well GC-1A
Lens A

Depth'	Ref Groove Az.°	Dip Dir. Az.°	Dip Angle°	Depth'	Ref Groove Az.°	Dip Dir. Az.°	Dip Angle°
.20	222	170	12	578.	14	50	12
.40	"	140	13	580.11	296	230	10
.55	"	190	10	.15	"	"	"
.65	"	"	15	.22	"	"	12
.73	"	160	4	.57	"	293	"
.85	"	"	"	582.50	124	127	12
571.30	222	160	10	.66	"	188	10
.43	"	103	"	584.21	135	75	6
.63	"	295	13	.99	"	128	15
.67	"	"	"	585.11	136	105	15
.77	"	220	9	.30	"	220	22
.80	"	"	"	.32	"	225	10
572.27	331	10	15	.46	"	205	8
.40	"	33	10	.50	"	"	"
.77	"	211	6	.55	"	190	"
.91	"	210	5	.65	"	163	17
.99	"	241	8	.68	136	180	15
573.81	331	277	10	.71	"	"	"
.97	"	284	8	.81	"	73	10
574.06	333	5	10	586.07	136	73	10
.37	"	90	7	.11	"	"	"
.45	"	205	10	.13	"	"	"
.48	"	"	"	.18	"	"	"
.60	"	"	12	.31	"	242	22
.58	"	223	10	587.70	144	225	6
.75	"	320	13	588.04	144	40	10
.80	"	237	10	.06	"	"	"
575.10	333	205	10	590.65	168	225	17
.12	"	"	"	591.36	357	155	16
.50	"	143	"	392.23	357	101	16
.51	"	"	"	.76	"	"	"
576.38	11	48	12	.53	"	70	14
.42	"	77	"	.60	"	"	"
.47	"	"	"	.61	"	93	12
.63	"	9	10	.67	"	"	"
.86	"	15	15	.80	"	74	9
.95	"	70	"	.82	"	"	"
577.20	11	65	15	.83	"	"	"
.30	"	80	12	.98	"	101	15
.38	"	95	"	593.18	294	297	10
.55	"	102	16	.20	"	"	"
.74	"	58	10	.75	"	175	12
.79	"	"	"	.78	"	"	"
.89	"	20	6	.80	"	"	"
.91	"	"	10	.90	"	"	"
.99	"	32	"	.91	"	"	"

Table 7A. Directional Data from Oriented Data
Well GC-1A
Lens A

Depth'	Ref Groove Az.°	Dip Dir. Az.°	Dip Angle°
594.17	294	163	10
.22	"	"	"
.24	"	38	"
.45	"	225	15
.51	"	110	10

Table 7B. Directional Data From Oriented Core
Well GC-1A
Lens B

Depth'	Ref Groove Az.°	Dip Dir. Az.°	Dip Angle°	Depth'	Ref Groove Az.°	Dip Dir. Az.°	Dip Angle°
456.93	143	337	14	468.17	288	140	12
.98	"	"	"	.19	"	"	"
457.11	143	231	8	469.18	57	12	28
.13	"	"	"	470.23	57	172	13
.15	"	"	"	479.65	50	337	18
.72	"	91	12	.73	"	320	"
.84	"	93	10	481.15	50	148	15
.90	"	"	"	.18	"	163	12
.92	"	"	"	.24	"	178	"
458.05	138	20	18	.27	"	184	"
.11	"	"	"	485.01	302	5	9
.20	"	"	"	.10	"	"	"
459.71	138	340	14	.15	"	"	"
460.15	205	138	20	.26	"	"	"
.25	"	"	"	.37	"	"	"
.27	"	"	"	.45	"	"	"
.31	"	"	"	.60	"	79	"
.34	"	"	"	.63	"	"	"
461.89	205	185	3	.67	"	"	"
462.38	205	70	8	.74	"	"	"
.40	"	"	"	.85	"	"	"
.80	"	132	10	.88	"	"	"
.85	"	"	"	486.20	302	93	10
.90	"	"	"	.23	"	"	"
463.62	249	53	10	.80	"	116	15
.68	"	28	6	.82	"	"	"
.70	"	"	"	.87	"	"	"
464.36	249	291	11	.90	"	"	"
.38	"	"	"	487.01	313	217	7
.58	"	300	20	.03	"	"	"
466.42	249	141	15	.10	"	"	"
.48	"	139	18	.17	"	"	"
.52	"	138	22	.50	"	"	"
.66	"	95	19	.60	"	"	"
.68	"	"	"	.63	"	"	"
.88	"	145	18	488.17	313	252	20
.90	"	"	"	.25	"	"	"
.91	"	"	"	.27	"	"	"
467.13	288	192	14	.38	"	"	"
.17	"	"	"	.73	"	"	"
.23	"	106	14	.84	"	"	"
.46	"	"	15	489.38	141	125	20
.58	"	76	12	.42	"	"	"
.67	"	"	13	.45	"	"	"
.73	"	62	10	.49	"	"	"

Table 7B. Direction Data From Oriented Core
Well GC-1A
Lens B

Depth'	Ref Groove Az.°	Dip Dir. Az.°	Dip Angle°
.85	141	125	20
493.95	158	135	12
494.10	158	157	7
.16	"	"	"
.38	"	"	"
.64	"	"	"
.68	"	"	"
.70	"	"	"
.77	"	"	"
.80	"	155	4
.82	"	"	"
.85	"	"	"
.89	"	"	"
.93	"	"	"
.95	"	"	"
.99	"	"	"
495.16	169	160	10
.60	"	245	15
.63	"	"	"
.87	"	"	"
.93	"	"	"

Table 7C. Directional Data From Oriented Core
Well GC-1A
Lens C

Depth'	Ref Groove Az.°	Dip Dir. Az.°	Dip Angle°
428.60	125	254	14
.70	"	"	"
429.08	"	45	11
.10	"	"	"
.11	"	"	"
430.30	287	35	18
431.15	"	336	4
.20	"	"	"
.30	"	"	"
.32	"	282	6
.38	"	4	"
.43	"	98	22
.80	"	342	10
432.60	294	174	17
.73	"	157	15
.80	"	"	"
434.11	303	124	12
.65	"	138	14
435.11	"	184	15
436.38	8	355	11
.40	"	"	"
.48	"	"	"
.52	"	248	12
.74	"	175	23
.78	"	"	"
.85	"	"	"
437.32	"	229	13
.40	"	"	"
.80	"	145	"
.83	"	"	"
438.35	17	190	12
.39	"	"	"
.40	"	"	"

Table 7D. Directional Data From Oriented Core
Well GC-1B
Lens B

Depth'	Ref Groove Az.°	Dip Dir. Az.°	Dip Angle°	Depth'	Ref Groove Az.°	Dip Dir. Az.°	Dip Angle°
471.05	108	272	8	477.39	284	160	10
.26	"	"	"	.75	"	80	11
.47	"	268	6	.78	"	"	"
.60	"	258	8	.81	"	"	"
.71	"	"	"	.82	"	"	"
.99	"	180	18	478.75	284	358	9
472.10	108	170	15	.80	"	"	"
.75	"	168	"	.85	"	"	"
.84	"	324	22	479.06	288	358	9
473.05	108	262	15	.14	"	"	"
.11	"	"	"	.23	"	"	10
.19	"	126	14	.25	"	"	"
.23	"	"	"	.41	"	14	"
.27	"	"	12	.42	"	"	"
473.30	108	122	16	.52	"	356	19
.32	"	"	"	.55	"	"	"
.62	"	158	18	.60	"	348	"
.79	"	"	14	.65	"	"	"
.90	"	128	"	480.60	288	99	14
.92	"	"	"	.67	"	84	"
.98	"	"	16	.81	"	"	"
474.05	235	178	22	481.10	293	96	11
.10	"	174	"	.20	"	75	"
.11	"	"	20	.30	"	"	"
.20	"	168	22	.56	"	105	10
.21	"	"	"	.62	"	"	"
.22	"	192	15	.65	"	"	"
.52	"	189	"	.70	"	"	"
.55	"	"	"	.89	"	"	6
.62	"	"	"	.91	"	"	"
.65	"	"	"	482.32	293	177	16
.83	"	190	14	.53	"	"	"
.98	"	"	"	.59	"	"	"
475.32	235	226	20	.64	"	"	"
.34	"	"	"	483.12	301	87	12
.70	"	178	22	.40	"	94	9
.75	"	234	38	.42	"	"	"
.77	"	"	"	.52	"	100	10
.96	"	226	20	.62	"	175	12
476.05	235	162	12	.67	"	"	"
.10	"	"	"	.80	"	"	"
.16	"	160	19	484.30	301	105	18
.20	"	"	"	485.54	301	213	28
.80	"	"	"	486.	301	–	–
.97	"	68	11	487.30	245	250	13
.98	"	"	"	.32	"	"	"

Table 7D. Directional Data From Oriented Core
Well GC-1B
Lens B

Depth'	Ref Groove Az.°	Dip Dir. Az.°	Dip ∠ Angle°
493.95	285	109	18
494.15	285	93	10
497.08	44	56	15
.10	"	"	"
.15	"	"	"
.16	"	84	28
498.77	44	195	11
499.10	54	163	8
.11	"	"	"
.37	"	170	"
.38	"	"	"
.89	"	290	"
.90	"	"	"
500.29	54	287	10
.40	"	"	"
.80	"	324	8
.94	"	310	13
501.28	10	198	13
.30	"	"	"
.34	"	197	22
.68	"	283	18
.70	"	"	"
.72	"	"	"
.74	"	"	"
.80	"	305	"
.83	"	"	"
.91	"	"	"
502.19	10	300	18
.30	"	"	"
.35	"	"	"
.37	"	"	"
.45	"	315	20
.52	"	300	15
.90	"	176	9
.99	"	164	12
503.01	315	165	12
.10	"	"	"
.20	"	"	"
.32	"	"	"
.55	"	212	"
.61	"	"	"
504.81	315	201	13
.83	"	"	"
.85	"	"	"
.87	"	"	"
.92	"	"	"
505.11	318	92	10
.13	"	"	"
.14	"	"	"
.19	"	"	"
.49	"	76	9
.52	"	"	"
.88	"	358	8
.90	"	"	10
506.12	318	347	8
.30	"	263	12
.50	"	"	"
.53	"	"	"
507.00	333	–	–
508.03	333	120	11
.06	"	"	"
.16	"	"	"
.18	"	"	"
.20	"	115	10
.24	"	"	"
.43	"	"	"
.64	"	75	12
.68	"	87	10
509.20	345	344	11
.30	"	"	"
.52	"	130	10
.53	"	"	"
510.35	345	224	10
.56	"	293	12
511.22	353	180	12
.30	"	"	"

Table 7E. Directional Data From Oriented Core
Well GC-1B
Lens C

Depth'	Ref Groove Az.°	Dip Dir. Az.°	Dip Angle°
418.15	13	234	8
.21	"	"	"
.24	"	"	"
.30	"	"	"
.55	"	46	15
.62	"	157	8
.70	"	"	10
.82	"	123	"
.96	"	-	0
419.13	29	237	8
.30	"	196	4
.62	"	102	3
.70	"	246	12
.72	"	"	"
.83	"	240	2
.96	"	242	10
.99	"	"	"
420.05	29	177	8
.10	"	"	"
.42	"	98	10
.46	"	"	"
.50	"	"	12
.52	"	"	"
.59	"	92	10
.64	"	"	"
.72	"	96	12
.77	"	"	"
421.27	230	92	2
.37	"	109	23
.50	"	168	8
.52	"	"	"
.55	"	170	12
.78	"	217	14
.80	"	"	"
422.25	230	163	8
.30	"	"	"
.36	"	113	10
.70	"	124	6
.72	"	126	"
.74	"	"	8
.80	"	92	"
.82	"	"	"
423.30	245	147	18
.34	"	"	"
.41	245	147	18
.58	"	168	20
.62	"	"	"
424.15	245	144	8
.30	"	188	15
.42	"	180	18
.46	"	"	"
.50	"	174	22
.55	"	176	24
.56	"	"	"
429.38	90	6	18
.42	"	"	"
.58	"	10	15
.72	"	256	8
.78	"	"	15
.85	"	"	"
430.15	90	44	25
.24	"	332	10
.40	"	12	"
.46	"	"	"
.85	"	21	"
431.27	95	331	11
.32	"	"	"
.36	"	"	"
.83	"	295	14
.85	"	"	"
432.24	95	25	12
433.00	95	-	-
434.20	103	198	12
.41	"	265	"
.71	"	"	10
435.00	103	-	-
436.17	140	174	7
.62	"	188	12
.80	"	"	14
437.21	140	285	24
.70	"	275	10
.78	"	"	"
438.15	135	265	10
.28	"	"	14
439.55	135	264	26
.61	"	"	"
.65	"	"	22
.74	"	"	"

Table 7E. Directional Data From Oriented Core
Well GC-1B
Lens C

Depth'	Ref Groove Az.°	Dip Dir. Az.°	Dip Angle°
441.42	135	257	23
.55	"	217	24
.57	"	"	"
.64	"	234	20
.70	"	"	"
.86	"	235	"
.90	"	"	"
442.22	195	194	20
.24	"	"	"
.32	"	"	5
.58	"	"	"
.90	"	"	22
444.21	195	82	36
.25	"	"	"
.71	"	"	0
445.18	195	82	32
.25	"	"	30
.90	"	80	"
.94	"	"	"
446.21	193	90	30
.41	"	194	5
.43	"	"	"
.50	"	"	"
.66	"	"	0
447.15	193	184	22
.20	"	"	"
.40	"	325	12
.47	"	"	"
.56	"	288	10
.58	"	"	"
.65	"	268	22
.80	"	132	12
.85	"	"	"
448.08	203	133	14
.45	"	68	12
.50	"	"	"
.55	"	"	"
.70	"	138	10
.75	"	"	"
.83	"	"	"
449.22	203	42	10
.37	"	"	"
.50	"	90	"
.60	"	"	"
.92	"	196	"
.98	203	196	10
450.18	208	216	10
.48	"	358	12
.82	"	8	9
.86	"	"	"
451.40	208	148	14
.45	"	"	"
.47	"	"	"
.78	"	163	9
.80	"	"	"
452.55	247	264	4
.75	"	65	3
.99	"	–	–
453.97	247	325	2
.99	"	"	"

Table 7F. Directional Data From Oriented Core
Well GC-1C
Lens C

Depth'	Ref Groove Az.°	Dip Dir. Az.°	Dip Angle°	Depth'	Ref Groove Az.°	Dip Dir. Az.°	Dip Angle°
431.40	74	90	10	.59	96	84	11
.45	"	"	12	.65	"	97	15
.50	"	"	"	.67	"	"	"
.55	"	"	"	.84	"	100	"
.59	"	"	"	.88	"	"	"
.60	"	"	"	.94	"	"	16
.62	"	"	"	441.11	53	51	21
.65	"	"	"	.32	"	44	18
.69	"	"	10	.36	"	"	"
432.20	43	4	7	.41	"	"	"
.31	"	"	"	.48	"	"	"
.43	"	46	9	.95	"	"	14
.65	"	323	18	.99	"	"	"
433.11	39	281	12	442.10	53	45	12
.19	"	"	"	.13	"	"	"
.30	"	344	11	.17	"	"	8
.57	"	277	"	.19	"	"	"
.64	"	"	"	.22	"	53	12
.69	"	"	"	.30	"	"	"
.78	"	"	13	.34	"	"	8
434.04	99	42	11	443.10	53	350	10
.27	"	22	"	.15	"	"	8
.43	"	356	18	.18	"	"	"
.56	"	"	14	.27	"	330	10
.62	"	353	"	.53	"	318	11
.65	"	3	15	444.07	48	110	21
435.23	99	217	12	.11	"	"	"
.68	"	332	10	.17	"	"	"
436.19	99	265	15	.20	"	"	"
.22	"	105	"	.39	"	295	19
.50	"	355	11	.42	"	305	15
.58	"	"	"	.52	"	314	17
.68	"	340	14	.62	"	50	24
437.80	99	113	14	.68	"	"	"
.99	"	"	"	.82	"	"	"
438.08	80	113	14	.92	"	1	14
439.11	96	237	14	.94	"	"	"
.50	"	89	11	445.00	48	358	10
.58	"	"	"	.10	"	"	"
.90	"	44	9	.21	"	45	20
440.03	96	44	9	.39	"	"	"
.10	"	"	"	.49	"	48	"
.15	"	55	8	.89	"	77	30
.17	"	"	"				

Table 7F. Directional Data From Oriented Core
Well GC-1C
Lens C

Depth'	Ref Groove Az.°	Dip Dir. Az.°	Dip Angle°	Depth'	Ref Groove Az.°	Dip Dir. Az.°	Dip Angle°
.91	48	318	20	454.21	34	60	26
.92	"	77	30	.22	"	"	"
.94	"	318	20	.28	"	"	"
.99	"	244	30	.30	"	"	"
446.50	48	50	15	.38	"	68	"
.52	"	"	"	.58	"	276	8
447.16	169	164	15	.60	"	"	"
.32	"	168	"	.61	"	"	"
.42	"	"	14	.63	"	"	"
.68	"	105	12	.88	"	35	6
.80	"	110	"	.91	"	"	"
.82	"	"	"	455.08	34	287	8
448.85	169	163	15	.09	"	"	"
.87	"	"	"	.38	"	283	"
.89	"	"	"	.41	"	"	"
.93	"	"	"	.42	"	"	"
.96	"	"	"	.47	"	"	9
.98	"	"	"	.51	"	"	"
.99	"	"	"	.58	"	270	10
449.02	172	167	15	.61	"	"	"
.04	"	"	"				
.33	"	75	11				
.37	"	"	"				
.96	"	"	13				
450.10	172	75	10				
.11	"	"	"				
.13	"	"	"				
.20	"	"	"				
.90	"	266	12				
.91	"	110	8				
451.69	171	121	13				
452.21	171	88	14				
.59	"	50	15				
.68	"	"	"				
.71	"	75	12				
.83	"	40	22				
.84	"	"	"				
.86	"	"	"				
.89	"	"	"				
453.27	171	358	22				
.40	"	"	"				
.70	"	223	16				
.79	"	"	"				
.89	"	195	13				

Table 7G. Directional Data From Oriented Core
Well GC-1C
Lens α

Depth'	Ref Groove Az.°	Dip Dir. Az.°	Dip Angle°	Depth'	Ref Groove Az.°	Dip Dir. Az.°	Dip Angle°
369.50	175	174	12	.71	71	70	10
.70	"	204	14	.79	"	"	"
.78	"	"	18	.83	"	100	12
.93	"	99	10	.99	"	"	"
370.72	94	251	22	378.21	74	110	10
.80	"	262	6	.39	"	"	11
.92	"	242	26	.40	"	"	"
371.15	94	297	22	.44	"	90	"
.21	"	336	"	.50	"	"	12
.32	"	"	14	.61	"	75	17
.50	"	350	10	.73	"	111	15
.61	"	215	11	.78	"	122	17
.63	"	240	"	.93	"	90	10
.81	"	158	14	.98	"	"	"
.90	"	"	"	379.31	74	89	11
.93	"	"	10	.45	"	"	"
372.20	94	92	15	.50	"	"	"
.46	"	324	12	.53	"	"	"
.57	"	14	10	.54	"	"	"
.61	"	"	"	.61	"	72	15
.65	"	343	12	.69	"	"	16
.77	"	89	10	.75	"	75	17
.85	"	21	"	.79	"	"	"
.93	"	"	"	.80	"	"	"
373.08	94	23	10	379.88	74	75	16
.18	"	2	8	.90	"	152	14
.27	"	24	18	.92	"	"	"
.30	"	13	12	380.10	79	75	17
.50	"	345	18	.15	"	"	"
.54	"	"	"	.16	"	"	"
.63	"	"	"	381.10	79	30	6
.77	"	"	20	.15	"	160	7
.87	"	"	"	.30	"	90	6
374.00	325	-	-	.37	"	"	"
375.00	325	-	-	.40	"	"	"
376.03	71	70	12	.61	"	73	12
.47	"	"	"	382.08	88	91	6
.68	"	45	10	.10	"	"	"
.99	"	55	8	.29	"	351	9
377.08	71	58	13	.30	"	"	"
.13	"	"	"	.31	"	"	"
.20	"	77	14	.49	"	140	8
.30	"	111	16	.60	"	"	"
.47	"	124	18	.62	"	90	10

Table 7G. Directional Data from Oriented Core
Well GC-1C
Lens α

Depth'	Ref Groove Az.°	Dip Dir. Az.°	Dip Angle°
.74	88	90	10
.76	"	"	"
383.32	88	358	22
.73	"	333	18
.78	"	"	"
.80	"	"	"
.95	"	218	14
384.05	36	336	15
.11	"	"	"
.18	"	"	"
.23	"	"	"
.27	"	"	"
.34	"	"	"
.47	"	"	"
.50	"	"	"
.88	"	232	14
384.90	36	273	11
.96	"	"	"
.99	"	"	"
385.03	36	285	15
.08	"	"	"
.10	"	"	"
.13	"	"	"
.20	"	"	"
.30	"	287	"
.40	"	"	"
386.22	207	21	13
.58	"	10	12
.71	"	"	13
.82	"	"	12
.96	"	"	"
387.18	207	218	16
.20	"	"	"
.30	"	"	"
.31	"	"	"
.34	"	"	"
.37	"	"	"
.40	"	"	10
.55	"	214	22
.58	"	"	"
.65	"	300	15
.74	"	"	12
.80	"	"	"
388.10	218	220	15
.25	218	220	15
.38	"	"	"
389.09	218	98	12
.30	"	"	14
.90	"	132	10
.99	"	138	"
390.28	218	35	11
.61	"	134	10
391.38	222	209	12
392.04	222	85	8
.20	"	38	"
.58	"	"	"
.72	"	25	10
.78	"	"	"
.92	"	100	"
393.05	276	165	10
.16	"	"	"
.39	"	150	6
.80	"	"	"
.98	"	77	8
394.05	276	77	8
.34	"	242	22

TABLE 8. Θ and D values and Input Parameters From Oriented Core Analysis in Wells GC-1A, GC-1B, and GC-1C.

	GC-1A Lens A	GC-1A Lens B	GC-1A Lens C	GC-1B Lens B	GC-1B Lens C	GC-1C Lens C	GC-1C Lens α	TOTAL
Σx	16.2	22.1	1.5	4.2	0.3	31.8	19.5	95.9
Σy	-19.7	-28.8	-16.5	-21.8	-31.4	23.5	17.4	-77.3
η	100	100	100	100	100	100	100	700
Θ	146	142	175	169	179	36	42	129°
D	0.26	0.36	0.17	0.22	0.31	0.40	0.26	0.18

TABLE 9. Comparison of Individual Zone θ and D Values.

Logs	α/F2 θ	α/F2 D	Cα/F3A θ	Cα/F3A D	C/F3B θ	C/F3B D	B1 θ	B1 D	B2/F4 θ	B2/F4 D	B3/F5A θ	B3/F5A D	A1/F5B θ	A1/F5B D	A2/F6 θ	A2/F6 D
(S) Schlumberger GC-1 1'x4"x30°	118	.48	229	.88	275	.41			180	.30	169	.70	163	.56	202	.82
Schlumberger w/o Regional Dip 1'x4"x30°	75	.77	334	.61	273	.14			101	.34	121	.58	57	.54	187	.54
Schlumberger w/o Regional Dip 6"x2"x30°	36	.31	320	.41	327	.17			82	.26	140	.42	88	.50	166	.50
(D/A) Dresser Atlas GC-1 1'x4"x40°	15	.39	82	.47	147	.32			236	.40	184	.30	97	.25	193	.47
Dresser Atlas GC-1 1'x4"x40° w/o Regional Dip	18	.51	194	.46	127	.08			42	.47	77	.32	283	.31	200	.46
(D/A) Dresser Atlas GC-1A 1'x4"x40°					175	.53	201	.59	167	.40						
Dresser Atlas GC-1A 1'x4"x40° w/o Regional Dip					29	.49	63	.25	72	.18						
(S) Schlumberger GC-1B 1'x4"x40° File 1			138	.63	50	.41	137	.32	56	.61						
Schlumberger GC-1B 1'x4"x40° File 2			163	.61	78	.52	177	.66	83	.66						
Schlumberger GC-1B 1'x4"x40° File 3			123	.62	41	.15	154	.40	29	.47						
Schlumberger GC-1B 1'x4"x40° File 4			123	.61	311	.40	77	.30	17	.34						
(D/A) Dresser Atlas GC-1B 1'x4"x40° File 1	113	.77	80	.13	65	.10	189	.77	167	.80	316	.27	226	.97		
Dresser Atlas GC-1B 1'x4"x40° File 1 w/o Regional Dip	85	.76	9	.75	4	.27	166	.46	140	.62	2	.60	240	.97		
(D/A) Dresser Atlas GC-1C 1'x4"x40° File 1	116	.52			164	.66	169	.85	160	.52	240	.65				
Dresser Atlas GC-1C 1'x4"x40° File 3	126	.31			166	.75	153	.72	165	.46	224	.46				
Dresser Atlas GC-1C 1'x4"x40° File 1 w/o Regional Dip	73	.51			133	.48	155	.68	127	.26	283	.32				
Dresser Atlas GC-1C 1'x4"x40° File 3 w/o Regional Dip	64	.43			144	.60	141	.62	139	.17	23	.17				

TABLE 10. Calculated Azimuth of Lenses in GC-1.

Lens	Dresser Atlas	Schlumberger
F-1	152	194
F-2	192	118
F-3	119	147
F-4	236	180
F-5	168	105
F-6	193	202
F-7	242	277
F-8	72	73
AVERAGE	178°	189°

TABLE 11. Paleocurrent Orientation of Fluvial Channel Sandstones From Outcrop Data

Channel Number	Sample Size	Paleocurrent Azimuth θ	Paleocurrent Directivity d
6	15	88	.69
7	15	24	.56
10	145	83	.63
41	104	146	.70
45	49	151	.47
46	25	26	.46
47	45	32	.35
48	43	121	.58
71	80	93	.56
91	81	130	.35
148	8	304	.62
149	19	48	.91
157	80	83	.62
162	38	350	.42
164	22	119	.63
170	47	3	.56
171	80	10	.66
172	36	353	.55
174	84	100	.75
175	83	91	.74
177	32	85	.31
178	80	184	.36
191/43	78	133	.49
193/240	163	201	.27
200	84	106	.69
201	82	133	.77
202/84	85	305	.72
300	80	357	.71
301	32	142	.53
304	68	13	.69
305	80	282	.31
306	80	357	.39
307	58	80	.14
308	30	145	.68

TABLE 11. Continued

Channel Number	Sample Size	Paleocurrent Azimuth θ	Paleocurrent Directivity d
310	81	144	.66
311	80	331	.38
312	80	322	.20
313	80	41	.08
315	24	295	.33
316	7	169	.37
317	80	98	.31
321	80	177	.79
6 through 202	(West Side)	68	.21
300 through 321	(East Side)	99	.37

TABLE 12. Predicted Sandstones in 0.2-0.61 Farrer Interval From Outcrop Analysis.

Sandstone	Interval	Thickness	Azimuth
10AB	.63	20	98
10C	.63	26	60
312	.58	24	144
70/201	.43	14	133
84/202	.32	7	146
307	.25	14	80
47	.25	6	32
317	.02	14	98

TABLE 13A. Calculated Directions of Farrer Sandstone From Dresser Atlas Logs (with Regional Dip Removed) 1'x4"x40° Well GC-1

Sandstone Unit Depths	Number of Measurements	Vector Sum Azimuth	Directivity
1- 278-302	62	171	.39
2- 384-404	71	18	.51
3a- 432-441	22	194	.46
3b- 445-466	31	127	.08
4- 509-523	45	42	.47
5a- 552-570	54	77	.32
5b- 576-590	13	283	.31
6- 603-619	31	200	.46
7a- 651-667	13	168	.20
7b- 671-688	21	335	.40
8- 740-756	30	295	.24
ALL LENSES	393	62	.07

TABLE 13B. Calculated Directions of Farrer Sandstone From Dresser Atlas Logs (with Regional Dip) 1'x4"x40°
Well GC-1

Sandstone Unit and Depths	Number of Measurements	Vector Sum Azimuth	Directivity
#1 - 278-302	88	152	0.2
#2 - 384-404	62	193	0.07
#3a- 432-441	32	82	0.47
#3b- 445-466	50	147	0.32
#4 - 509-523	28	236	0.4
#5a- 552-570	65	184	0.3
#5b- 576-590	23	97	0.25
#6 - 603-619	32	193	0.47
#7a- 651-667	30	161	0.39
#7b- 671-688	36	276	0.53
#8 - 740-756	37	72	0.05
ALL LENSES	483	178	0.17

TABLE 14A. Calculated Directions of Farrer Sandstones From Schlumberger Logs (with Regional Dip Removed) 1'x4"x40° Well GC-1

Sandstone Unit Depths	Number of Measurements	Vector Sum Azimuth	Directivity
1- 282-306	45	101°	.16
2- 388-408	31	75°	.77
3A-435-445	27	334°	.61
3B-449-470	43	273°	.14
4- 511-525	29	101°	.34
5A-556-574	36	121°	.58
6- 607-623	34	187°	.54
7A-655-671	37	10°	.36
7B-675-692	33	344°	.50
8- 734-738	12	30°	.79
ALL LENSES	414	32°	.21

TABLE 14B. Calculated Directions of Farrer Sandstones From Schlumberger Logs (with Regional Dip Removed) 6'x2'x30° Well GC-1

Sandstone Unit Depths	Number of Measurements	Vector Sum Azimuth	Directivity
1- 282-306	77	58	.07
2- 388-408	51	36	.31
3A-435-445	36	320	.41
3B-449-470	66	327	.17
4- 511-525	49	82	.26
5A-556-574	62	140	.42
5B-580-594	53	88	.50
6- 607-623	55	166	.50
7A-655-671	55	25	.14
7B-675-692	46	15	.36
8- 734-738	16	36	. 8
ALL LENSES	643	62°	.13

TABLE 14C. Calculated Directions of Farrer Sandstones From Schlumberger Logs (with Regional Dip) 1'x4"x30° Well GC-1

Sandstone Unit Depths	Number of Measurements	Vector Sum Azimuth	Directivity
#1 - 282-306	47	194°	0.48
#2 - 388-408	36	118°	0.48
#3A 435-445 B 449-470	24 42	229° 275°	.88 .41
#4 - 511-525	13	180°	0.30
#5A 556-574 B 580-594	35 35	163° 169°	.55 .70
#6 - 607-623	32	202°	0.82
#7A 655-671 B 675-692	57	277°	0.30
#8 747-756	15	73°	0.67
ALL LENSES	340	189°	0.28

TABLE 15A. Calculated Directions of Farrer Sandstones From Dresser Atlas Logs (with Regional Dip) 1'x4"x40° GC-1A

Sandstone Unit Depths	Number of Measurements	Vector Sum Azimuth	Directivity
C- 418-445	36	175	.53
B1-460-479	35	201	.59
B2-486-504	29	167	.40
A- 552-592	57	195	.64
AA-594-602	8	196	.89
AB-629-639	29	205	.93
TOTAL	194	209°	

TABLE 15B. Calculated Directions of Farrer Sandstones From Dresser Atlas Logs (with Regional Dip Removed) 1'x4"x40° GC-1A

Sandstone Unit Depths	Number of Measurements	Vector of Azimuth	Directivity
C- 418-445	36	29	.49
B1-460-479	35	63	.25
B2-486-504	29	72	.18
A- 552-592	57	30	.36
AA-594-602	8	200	.73
AB-629-639	29	221	.29
TOTAL	194	42°	

TABLE 16A. Calculated Directions of Farrer Sandstones From Dresser Atlas Logs (with Regional Dip) 1'x4"x40° GC-1B

Sandstone Unit Depths	Number of Measurements	Vector Sum Azimuth	Directivity
α- 393-408	19	114	.77
Cα-438-444	17	80	.13
C- 448-472	15	65	.10
B1-491-504	32	189	.77
B2-514-528	14	167	.80
B3-564-571	14	316	.27
A1-587-594	15	226	.97
TOTAL	126	166°	

TABLE 16B. Calculated Directions of Farrer Sandstones From Dresser Atlas Logs (with Regional Dip Removed) 1'x4"x40° GC-1B

Sandstone Unit Depths	Number of Measurements	Vector Sum Azimuth	Directivity
α- 393-408	19	85	.76
Cα-438-444	17	9	.75
C- 448-474	15	4	.27
B1-491-504	32	166	.46
B2-514-528	14	140	.62
B3-564-571	14	2	.60
A1-587-594	15	240	.97
TOTAL	126	96°	

TABLE 17A. Calculated Directions of Farrer Sandstones From Dresser Atlas Logs (with Regional Dip) 1'x4"x40° GC-1C

Sandstone Units Depths	Number of Measurements	Vector Sum Azimuth	Directivity
α- 368-390	68	117	.52
C- 429-454	57	165	.66
B1-465-472	9	169	.85
B2-496-517	62	160	.52
B3-540-548	21	234	.68
TOTAL	217	158°	

TABLE 17B. Calculated Directions of Farrer Sandstones From Dresser Atlas Logs (with Regional Dip) 1'x4"x40° (File 3)

Sandstone Unit Depths	Number of Measurements	Vector Sum Azimuth	Directivity
α- 368-390	70	127	.31
C- 429-454	56	166	.75
B1-465-472	14	153	.72
B2-496-517	66	165	.46
B3-540-548	21	224	.43
TOTAL	227	163°	

TABLE 17C. Calculated Directions of Farrer Sandstones From Dresser Atlas Logs (with Regional Dip Removed) 1'x4"x40° GC-1C (File 1)

Sandstone Unit Depth	Number of Measurements	Vector Sum Azimuth	Directivity
α- 368-390	68	74	.51
C- 429-454	57	133	.48
B1-465-472	9	155	.68
B2-496-517	62	127	.29
B3-540-548	23	283	.32
TOTAL	219	115	

TABLE 17D. Calculated Directions of Farrer Sandstones From Dresser Atlas Logs (with Regional Dip Removed) 1'x4"x40° (File 3)

Sandstone Unit Depth	Number of Measurements	Vector Sum Azimuths	Directivity
α- 368-390	68	64	.44
C- 429-454	56	144	.60
B1-465-472	15	141	.62
B2-496-517	65	139	.17
B3-540-548	21	24	.17
TOTAL	225	60°	

TABLE 18. Summary of Average Azimuths With And Without Regional Dip Removed GC-1 Area.

	GC-1	GC-1A	GC-1B	GC-1C
With Dip				
Schlumberger	178°			
Dresser Atlas 1.	189°	209°	166°	158°
3.				163°
AVERAGE	184°	209°	166°	160°
Dip Removed				
Schlumberger	62°			
Dresser Atlas 1.	62°	42°	96°	115°
3.	32°			60°
AVERAGE	52°	42°	96°	88°

WITH DIP-AVERAGE = 180°

DIP REMOVED-AVERAGE = 70°

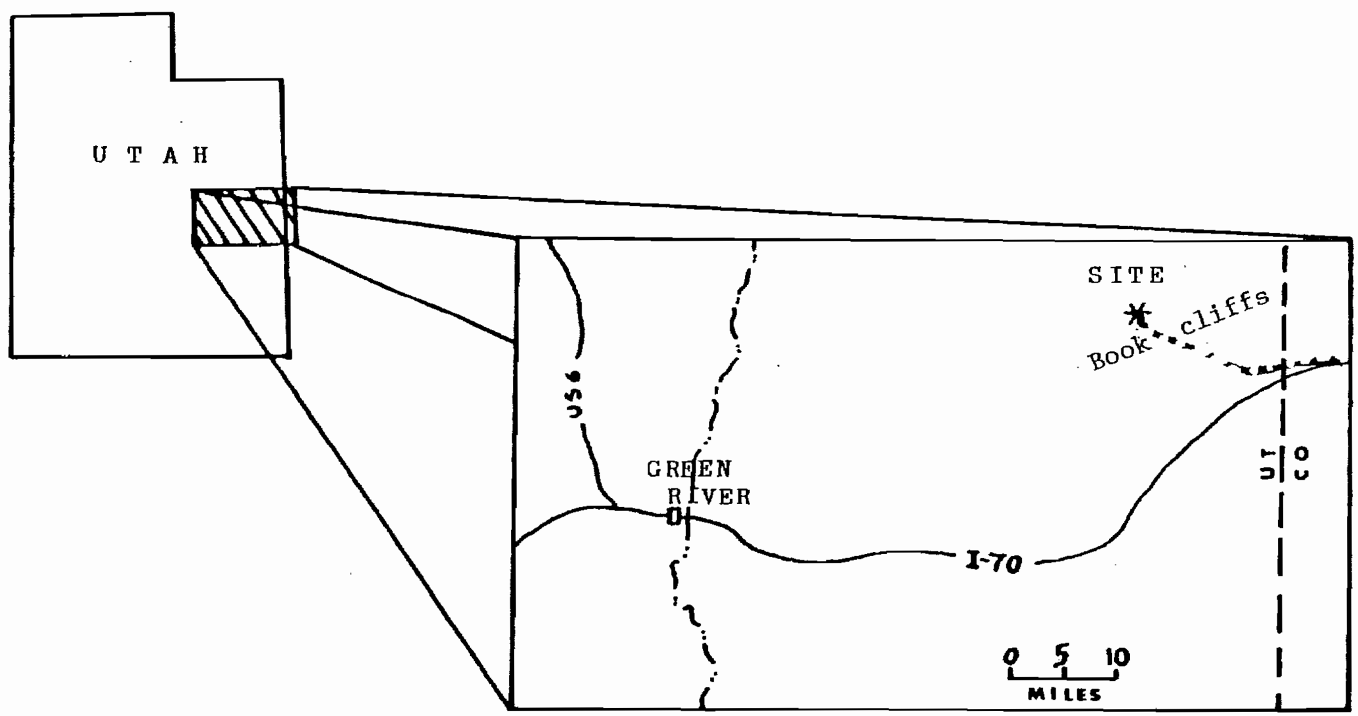


FIGURE 1. Location of 4 cored wells and study site in the Bookcliffs, Sec. 16, T.17S., R.24E., Grand County, Utah.

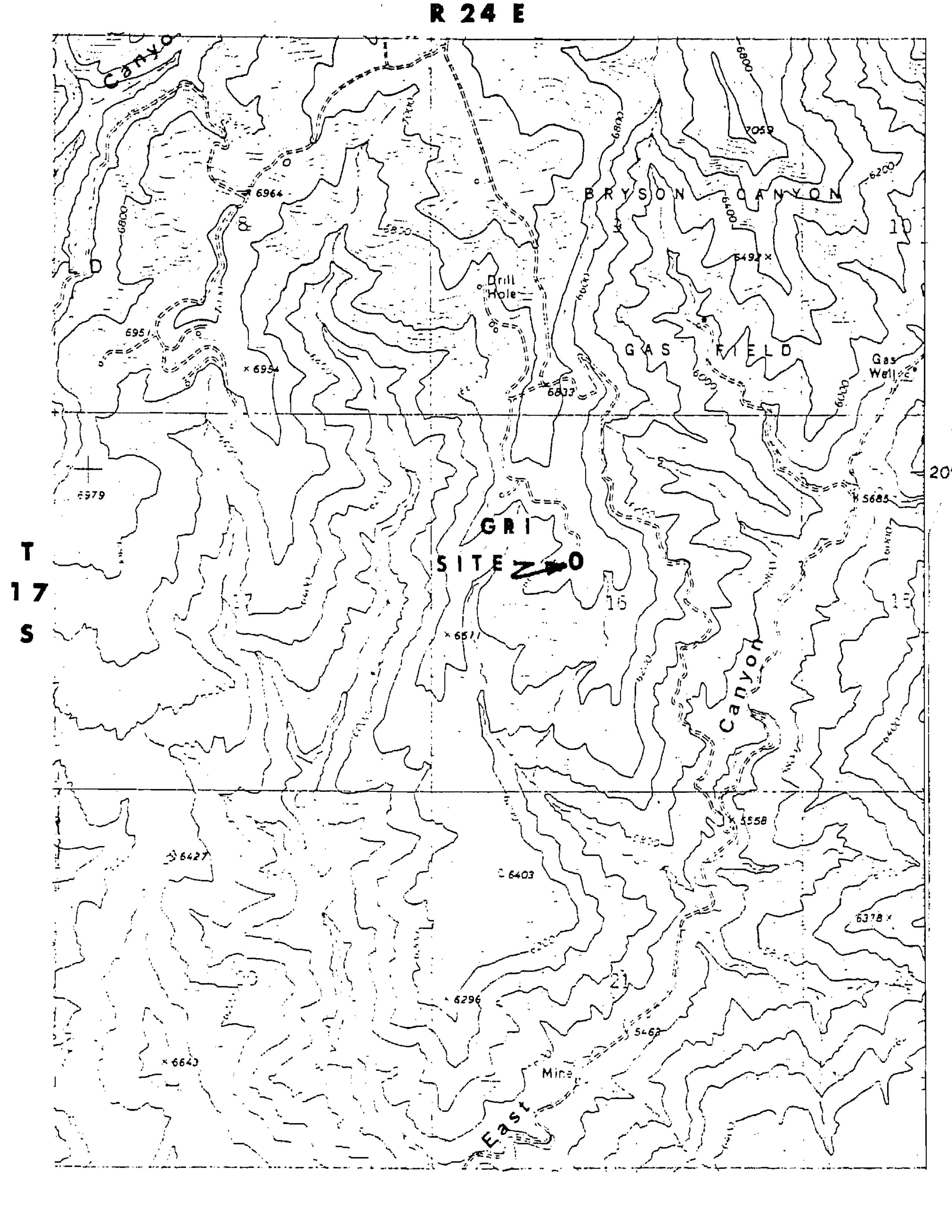


FIGURE 2. Location of GRI site on 1" - 2000' USGS Topographic map.

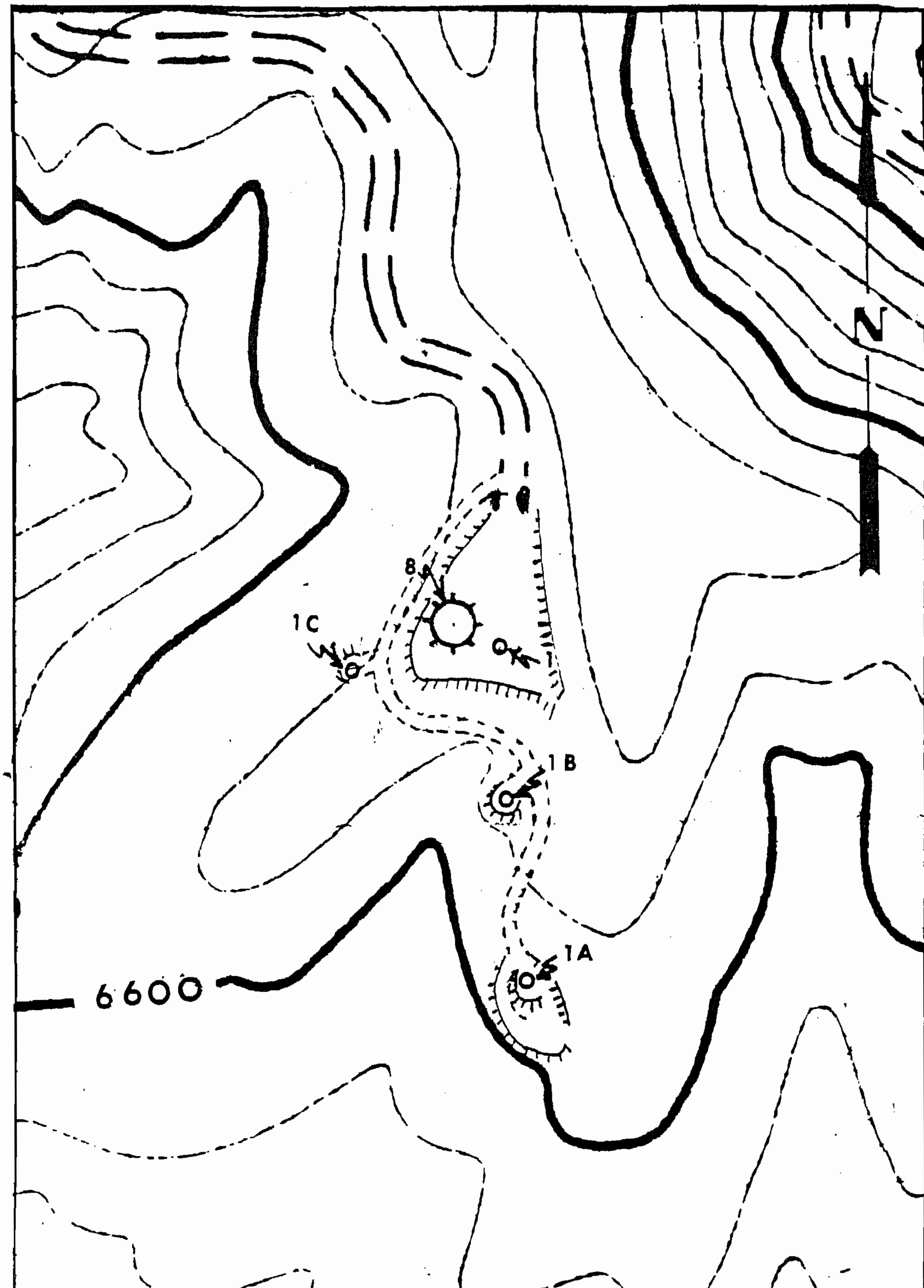


FIGURE 3. Location of GC-1A, 1B, and 1C with respect to DOE GC-1 and Trend No. 8. (Scale 1" = 200', Contour Interval 40')

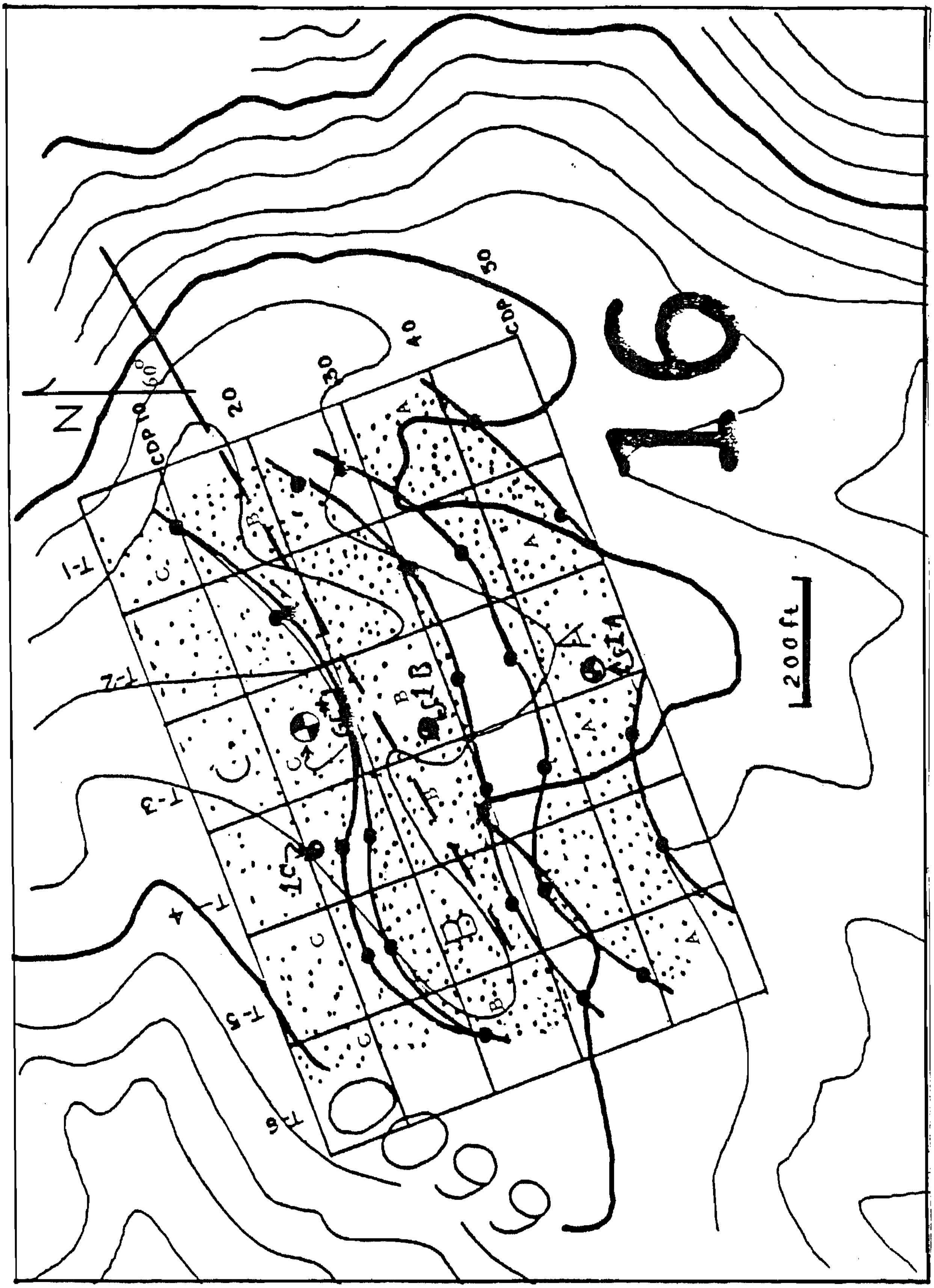


FIGURE 4. Map projection of channels "A", "B", and "C" as determined from traverses 1-6 seismic data. The three units are at different depths. The locations of the GC-1A, 1B, 1C coreholes are indicated by large solid circles (Dobecki, 1980).

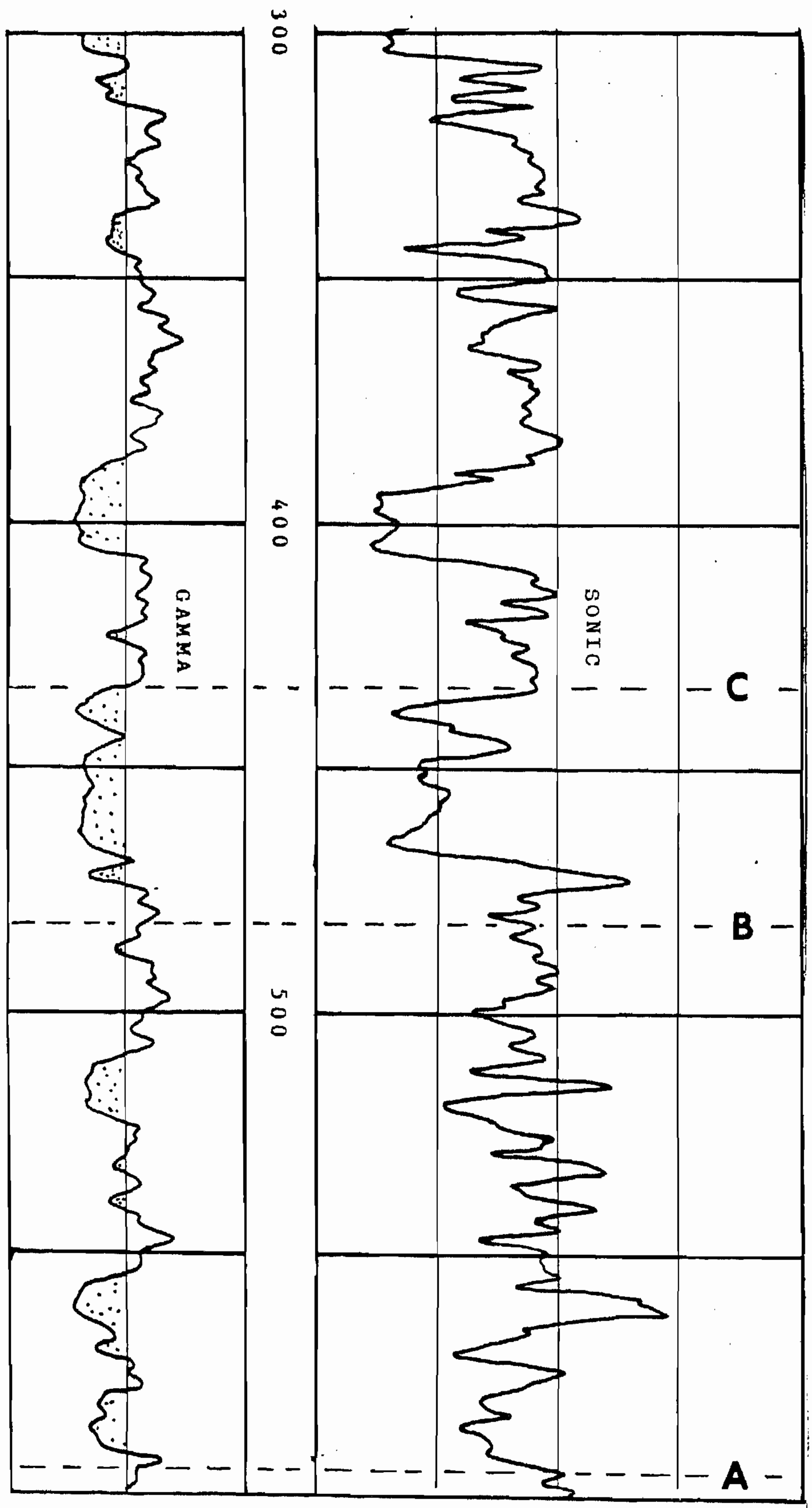
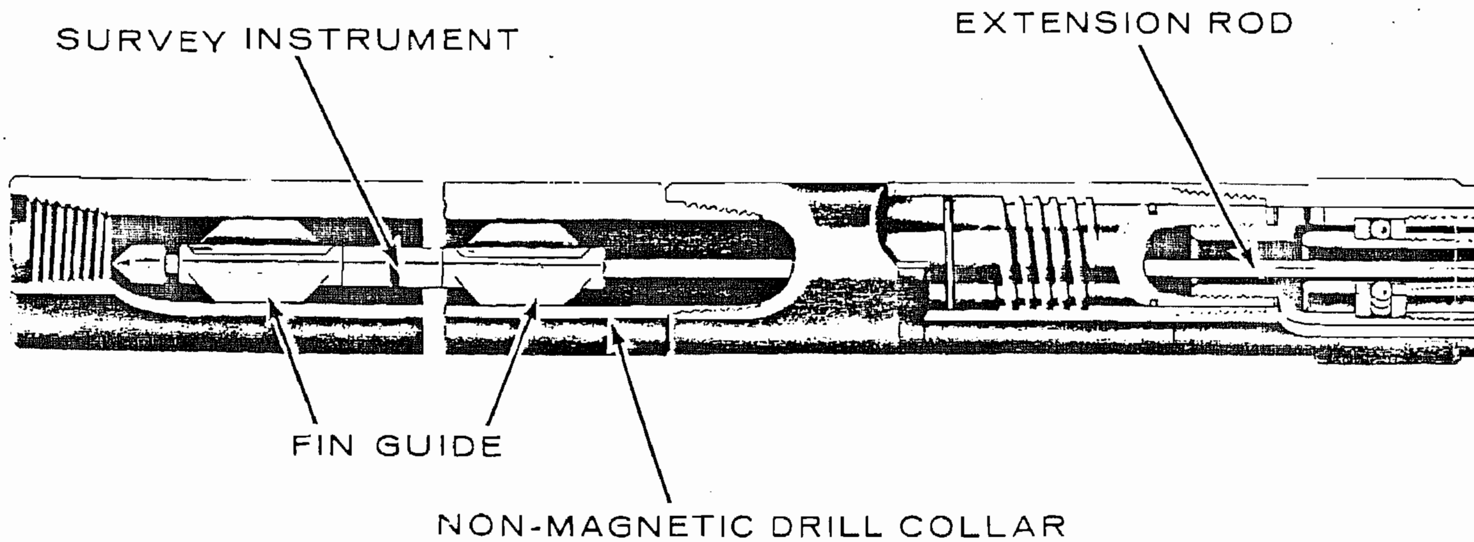


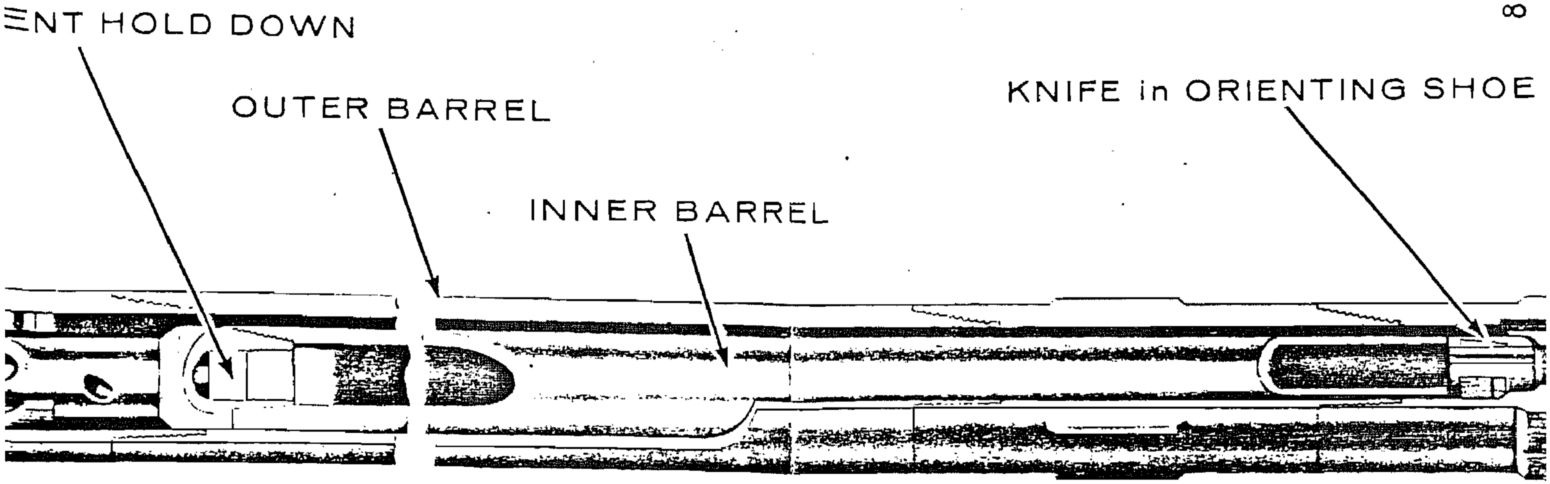
FIGURE 5. Segment of BHC sonic log and natural gamma log for corehole GC-1. Tops of lenses A, B, and C are indicated by dashed lines. Only lens C sandstone is present at this location.

AGE		ROCK UNIT	DESCRIPTION
LOWER TERTIARY		WASATCH FM.	alluvial s.s., sltst., clyst.
UPPER CRETACEOUS	MESAVERDE GP.	TUSCHER FM.	nonmarine fluvial s.s. interbedded with shale
		FARRER FM.	mudst., sltst., with lenses of alluvial s.s.
		NESLEN FM.	nonmarine coal and interbedded s.s. and shale
		SEGO S.S.	shallow marine s.s.
		MANCOS SH.- BUCK TONGUE	marine shale
		CASTLEGATE S.S.	shallow marine s.s.
		MANCOS SH.	marine shale

FIGURE 6. Stratigraphic Chart, Sec.16, T.17 S., R.24 E., Bookcliffs Area, Grand County, Utah.

INSTRUM


SURVEY INSTRUMENT
EXTENSION ROD
FIN GUIDE
NON-MAGNETIC DRILL COLLAR



CHRISTENSEN-HÜGEL ORIENTING BARREL

CORE ORIENTING BARREL
(SCHEMATIC)

Figure 7

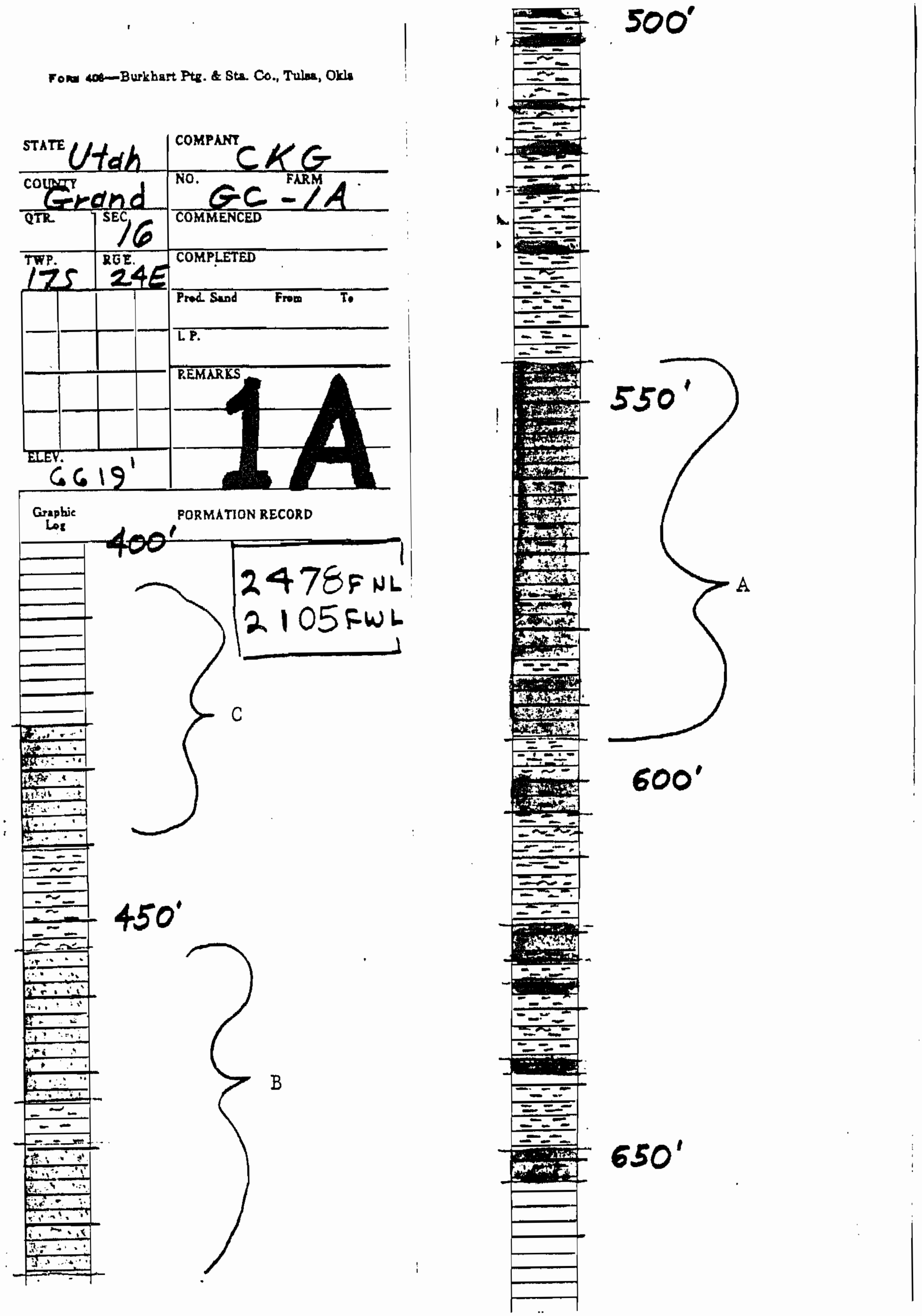
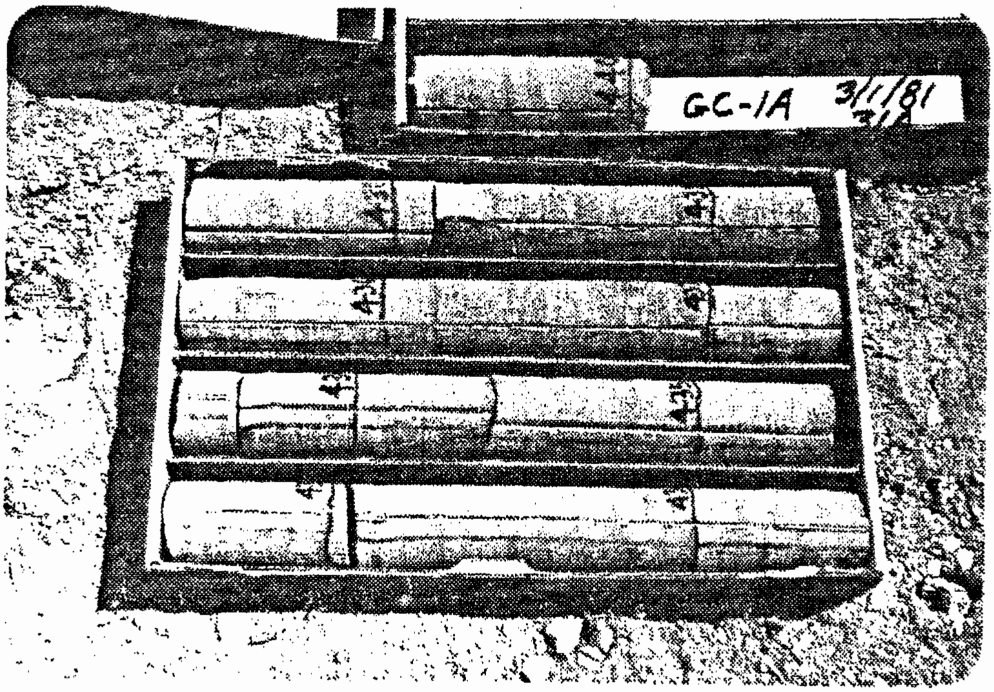


FIGURE 8. Log of GC-1A corehole



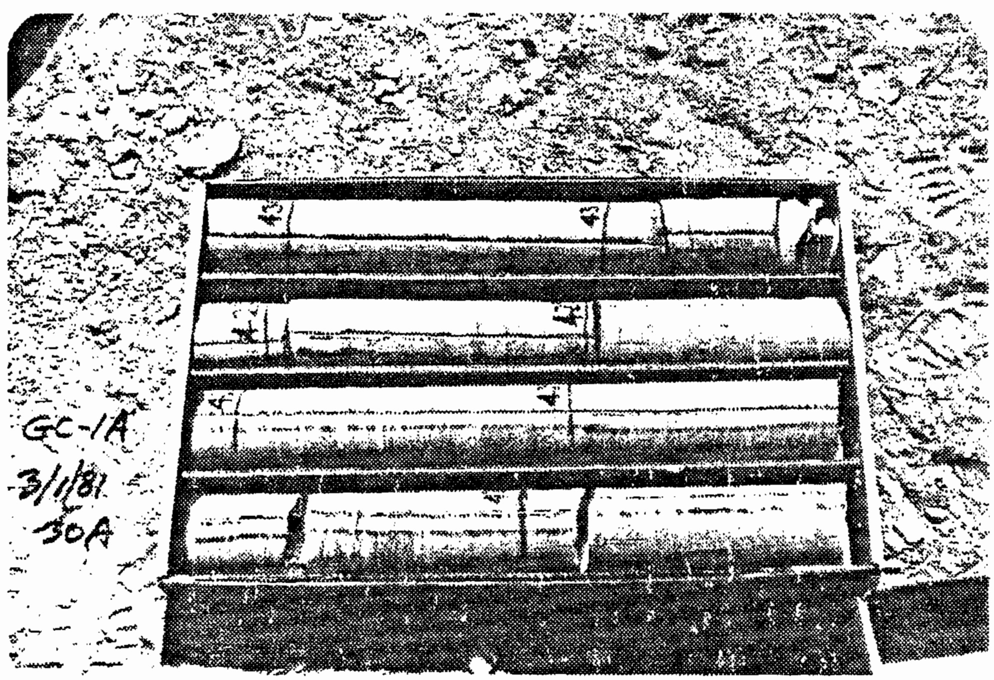
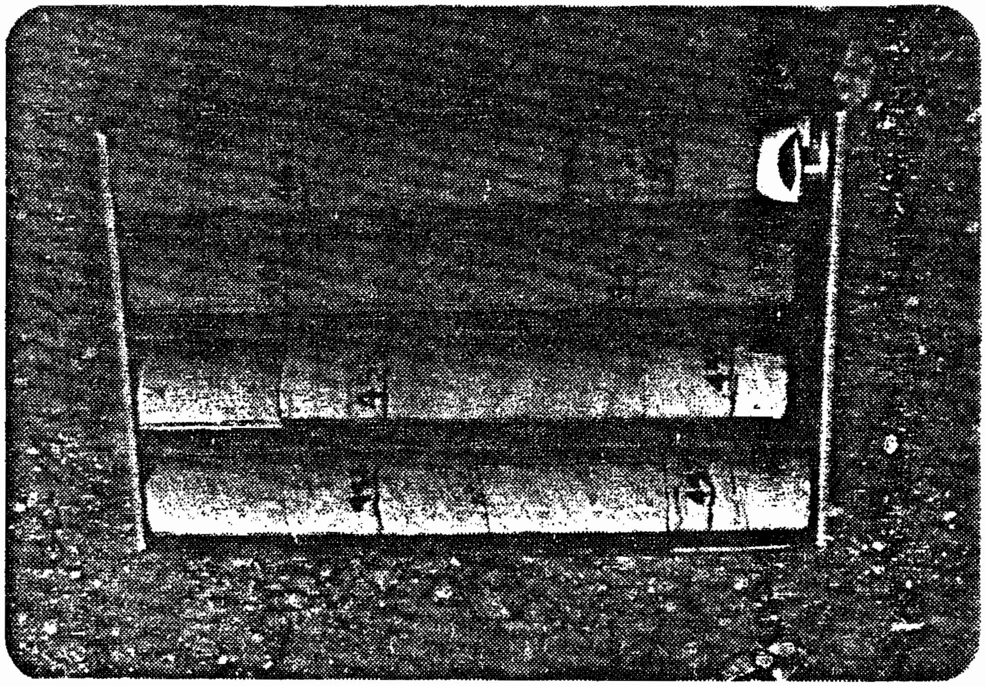


FIGURE 9A. Photographs of boxes of core from sandstone intervals in GC-1A.



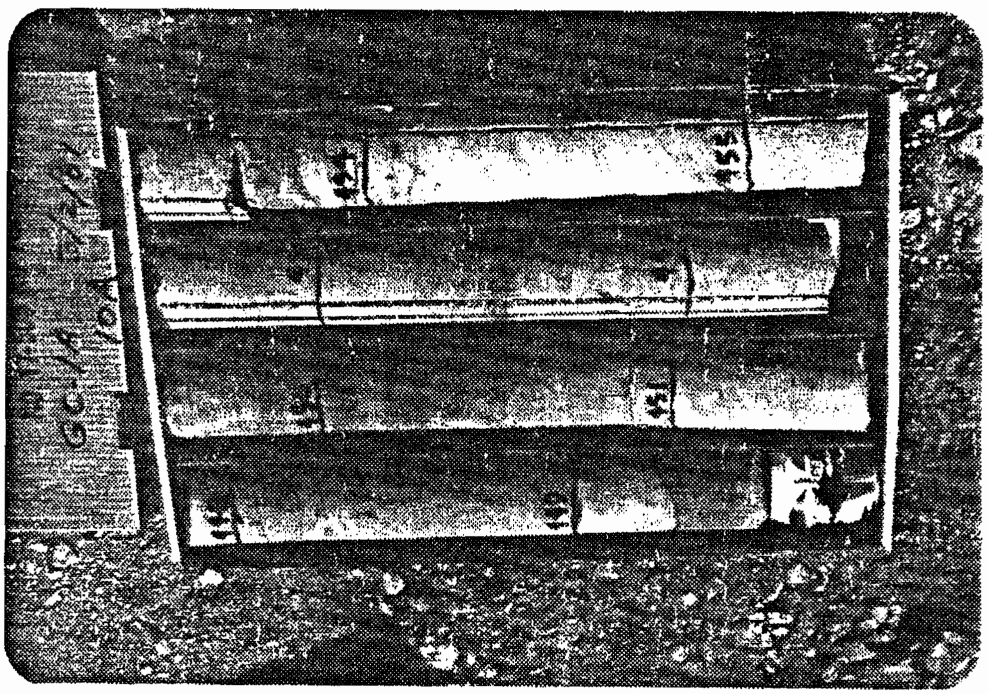
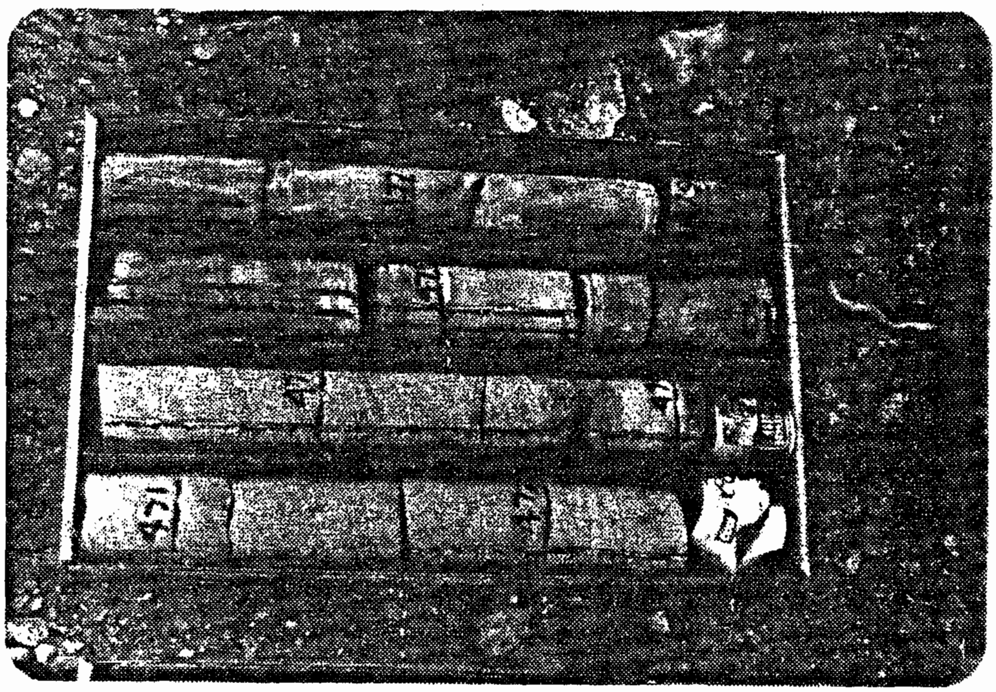


FIGURE 9B. Photographs of boxes of core from sandstone intervals in GC-1A.



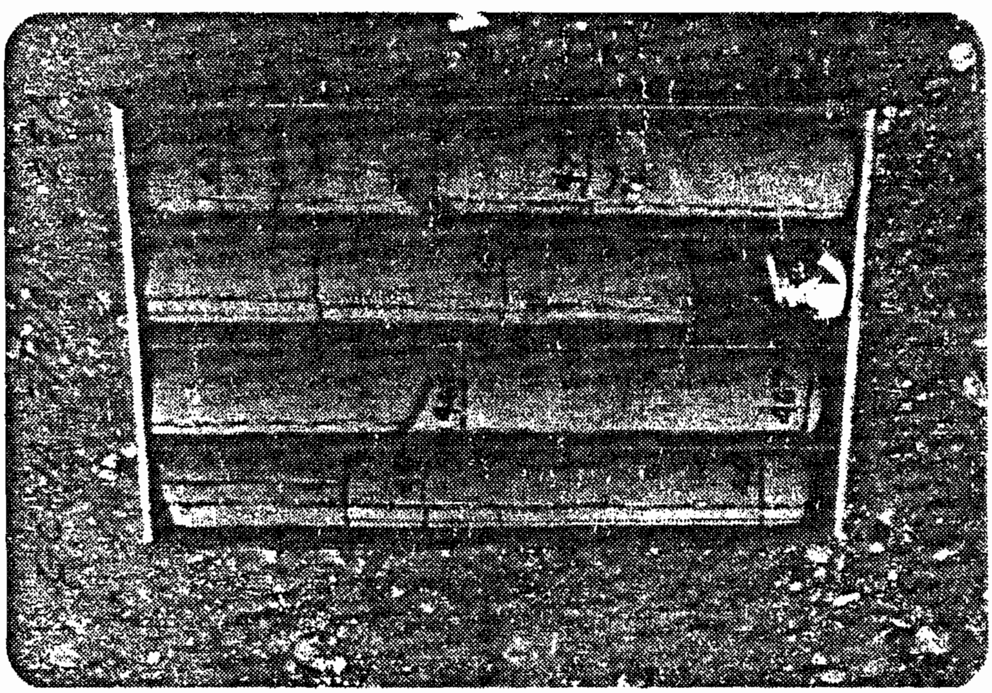


Figure 9C. Photographs of boxes of core from sandstone intervals in GC-1A.

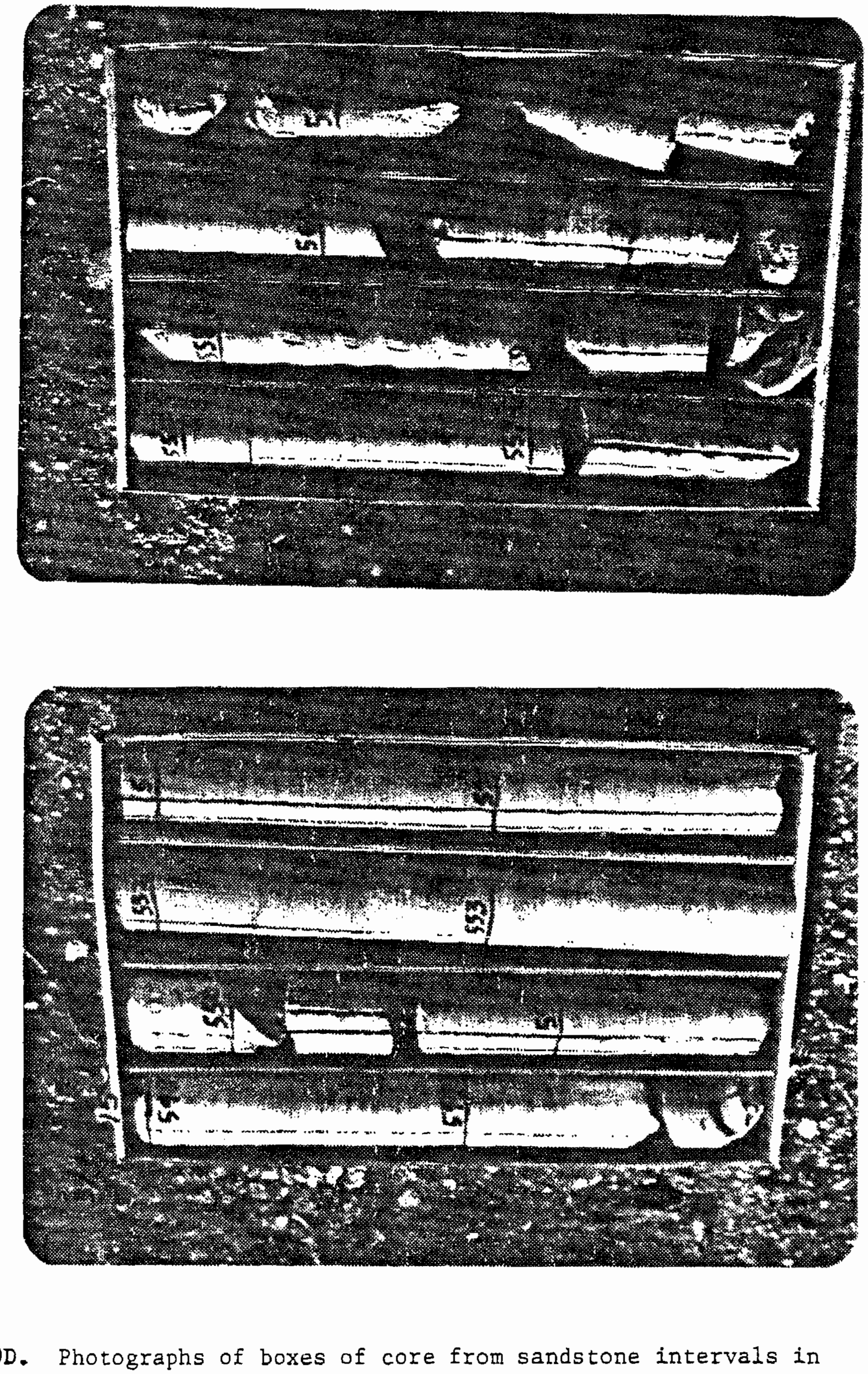


Figure 9D. Photographs of boxes of core from sandstone intervals in GC-1A.

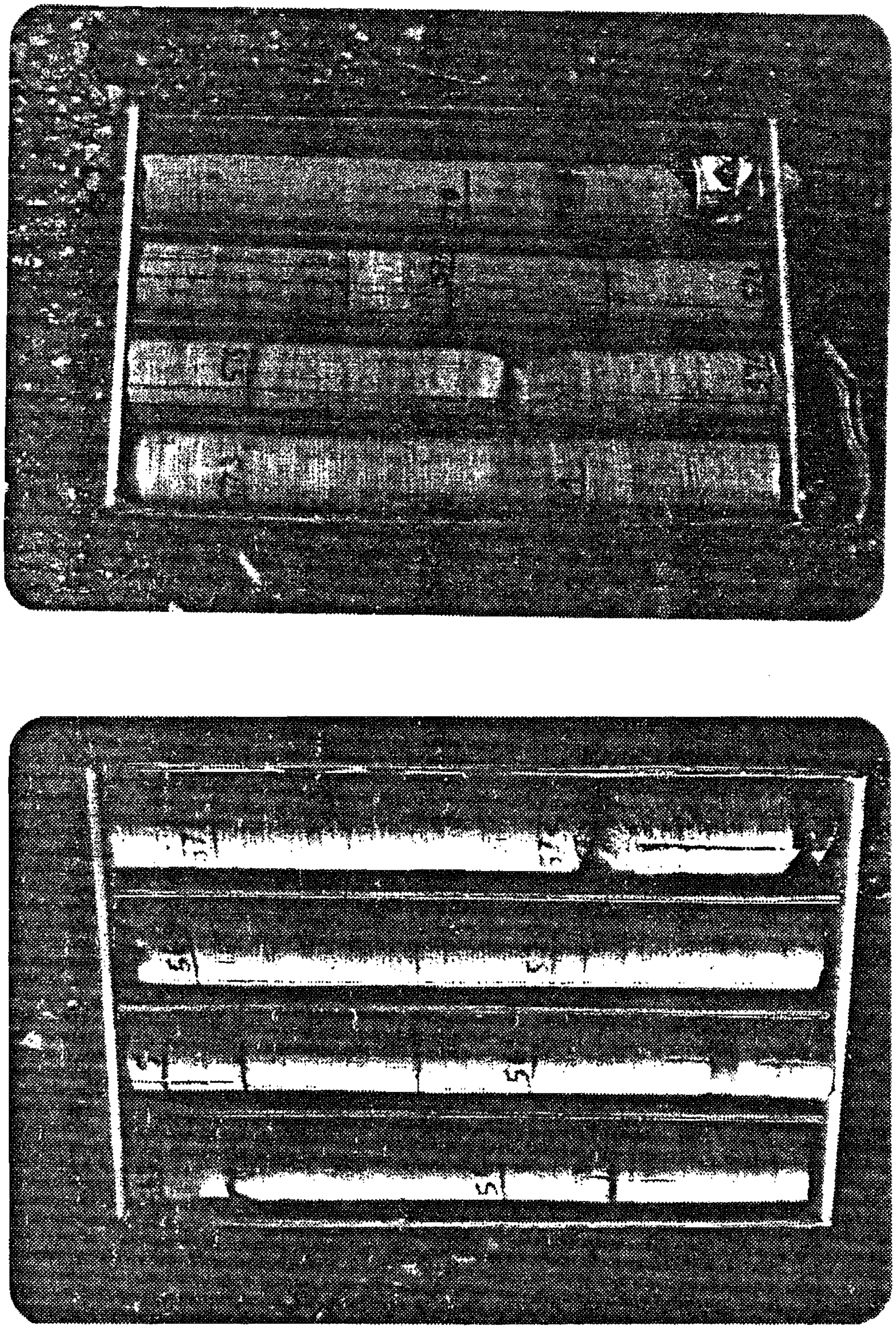


Figure 9E. Photographs of boxes of core from sandstone intervals in GC-1A.

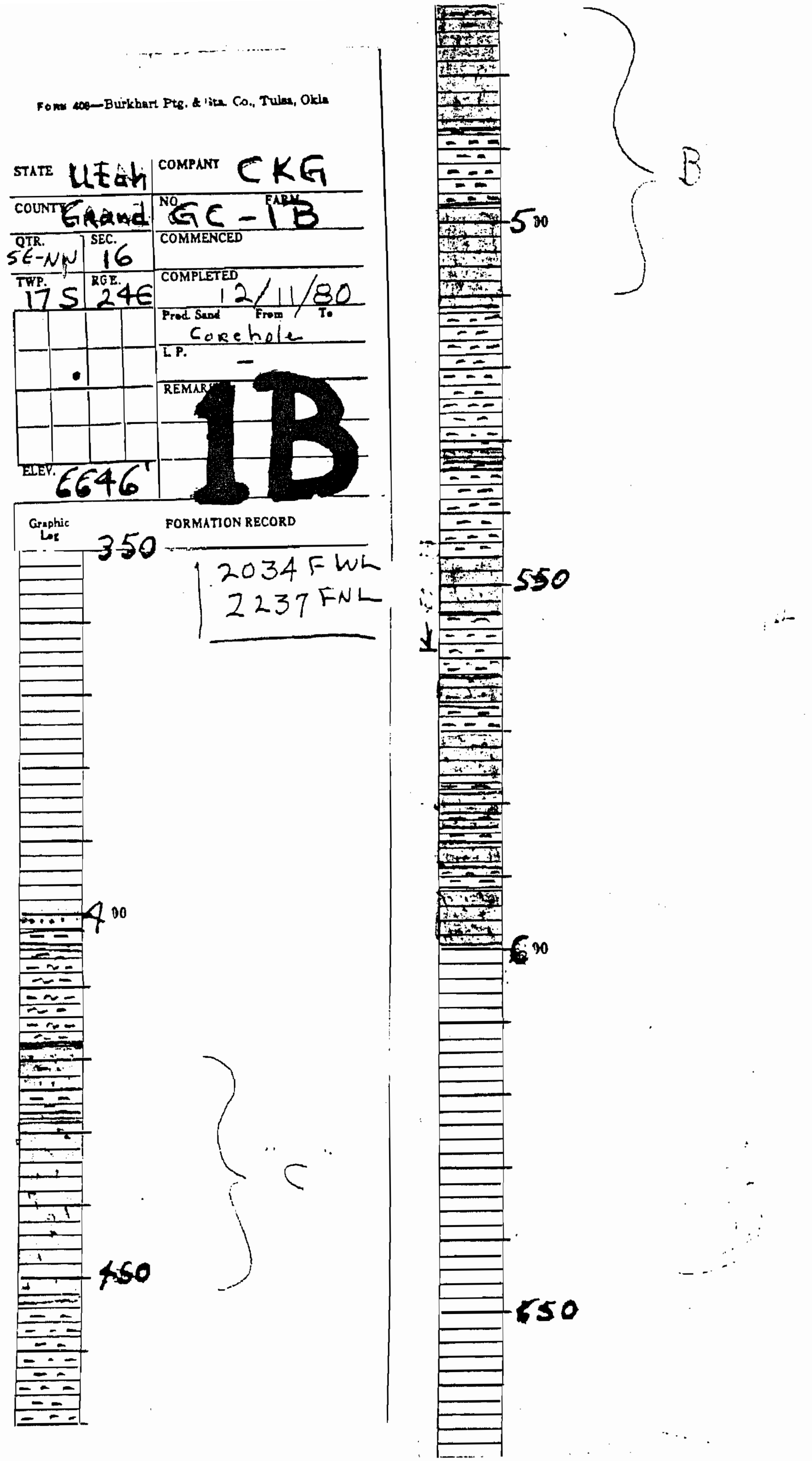


Figure 10. Corelog from GC-1B corehole.

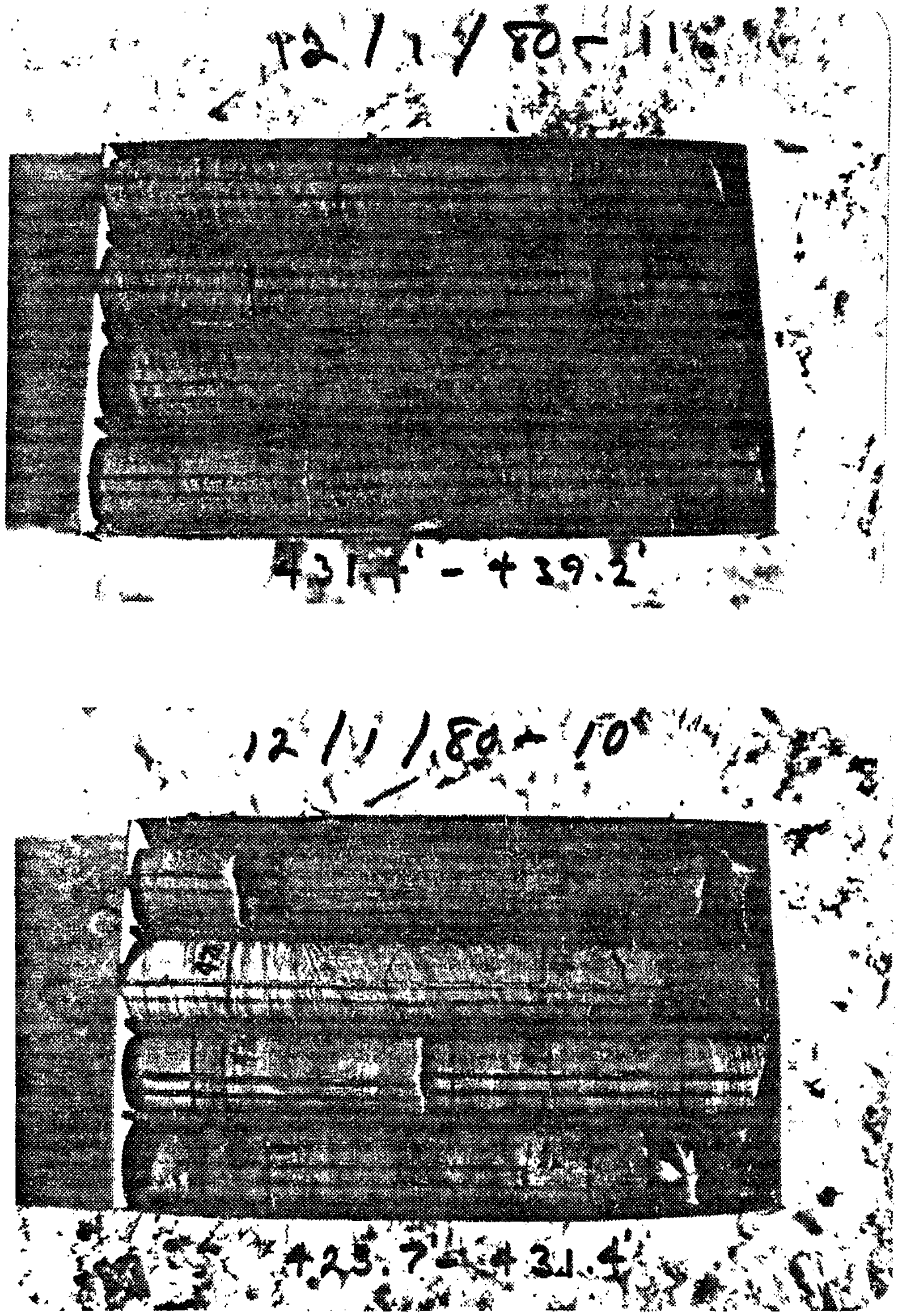


Figure 11A. Photograph of core of sandy intervals from GC-1B

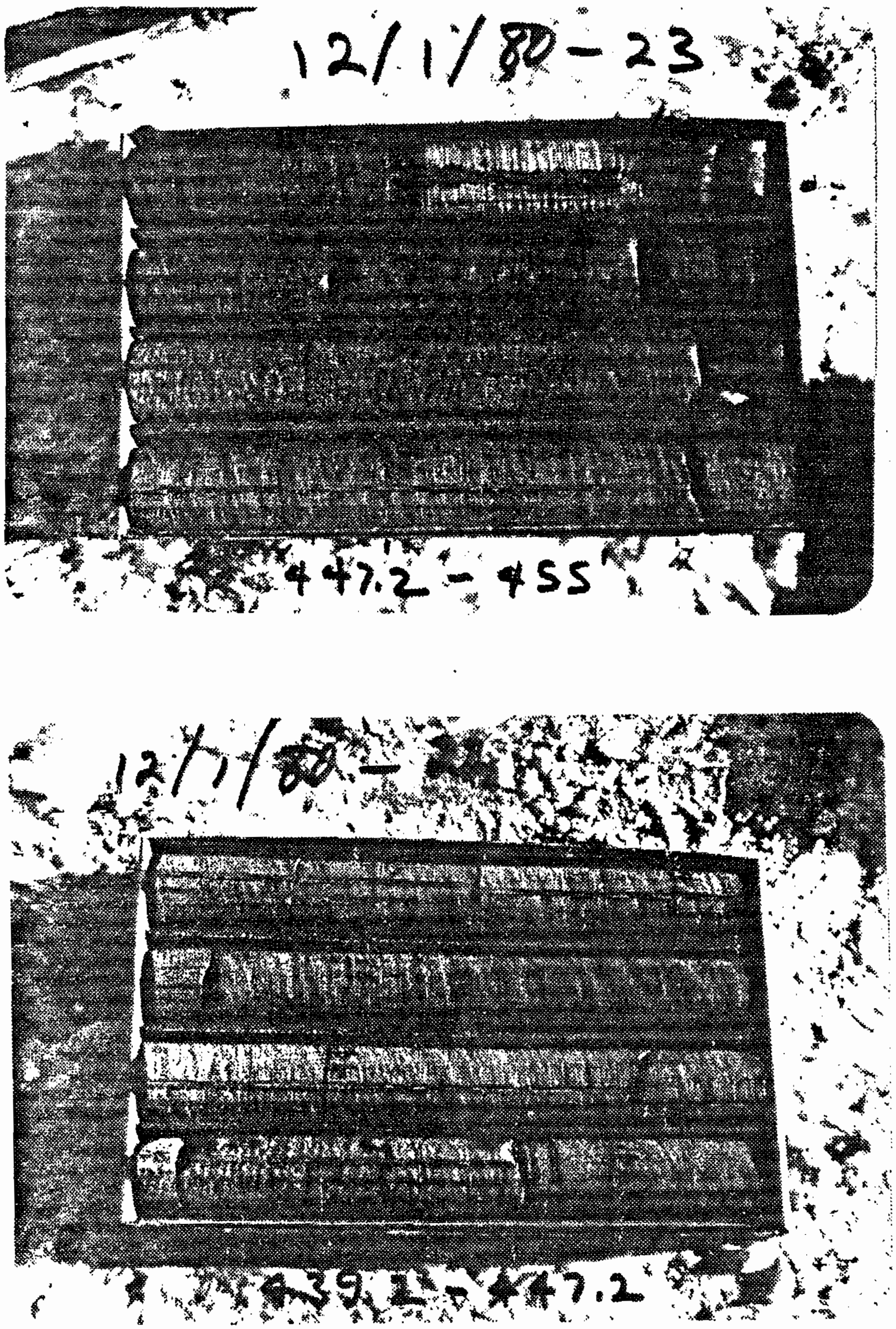


Figure 11B. Photograph of core of sandy intervals from GC-1B

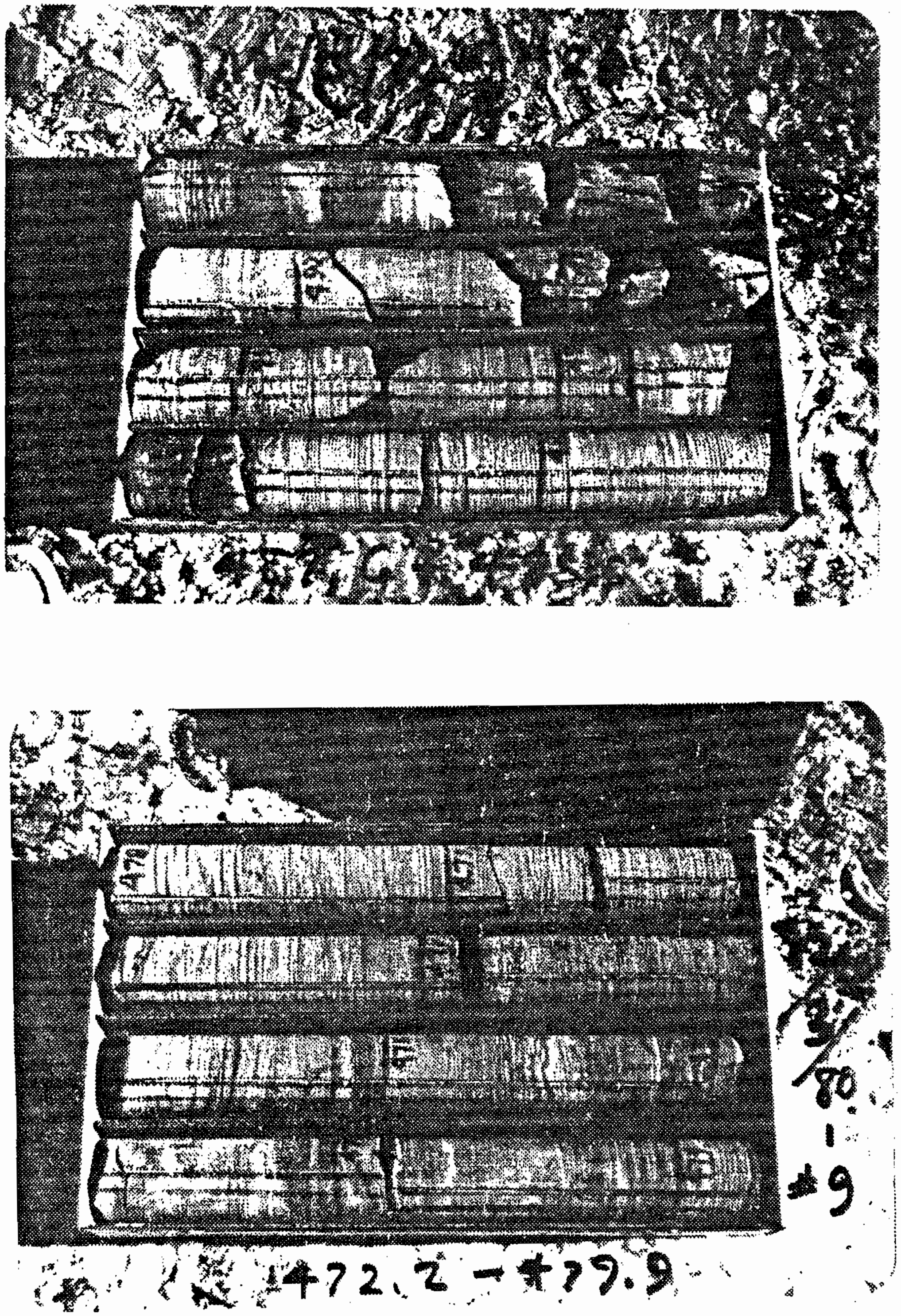


Figure 11C. Photograph of core of sandy intervals from GC-1B.

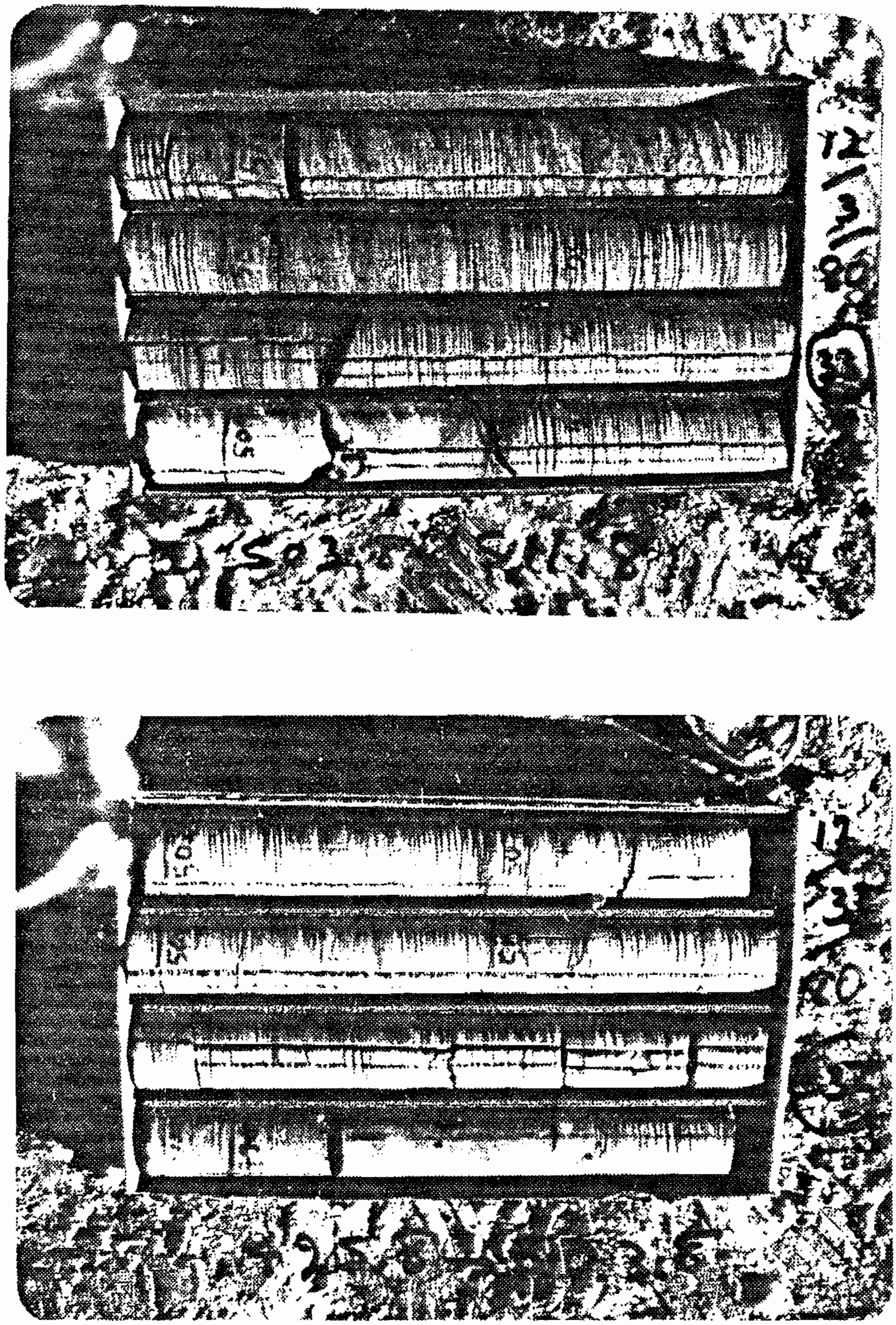


Figure 11D. Photograph of core of sandy intervals from GC-1B.

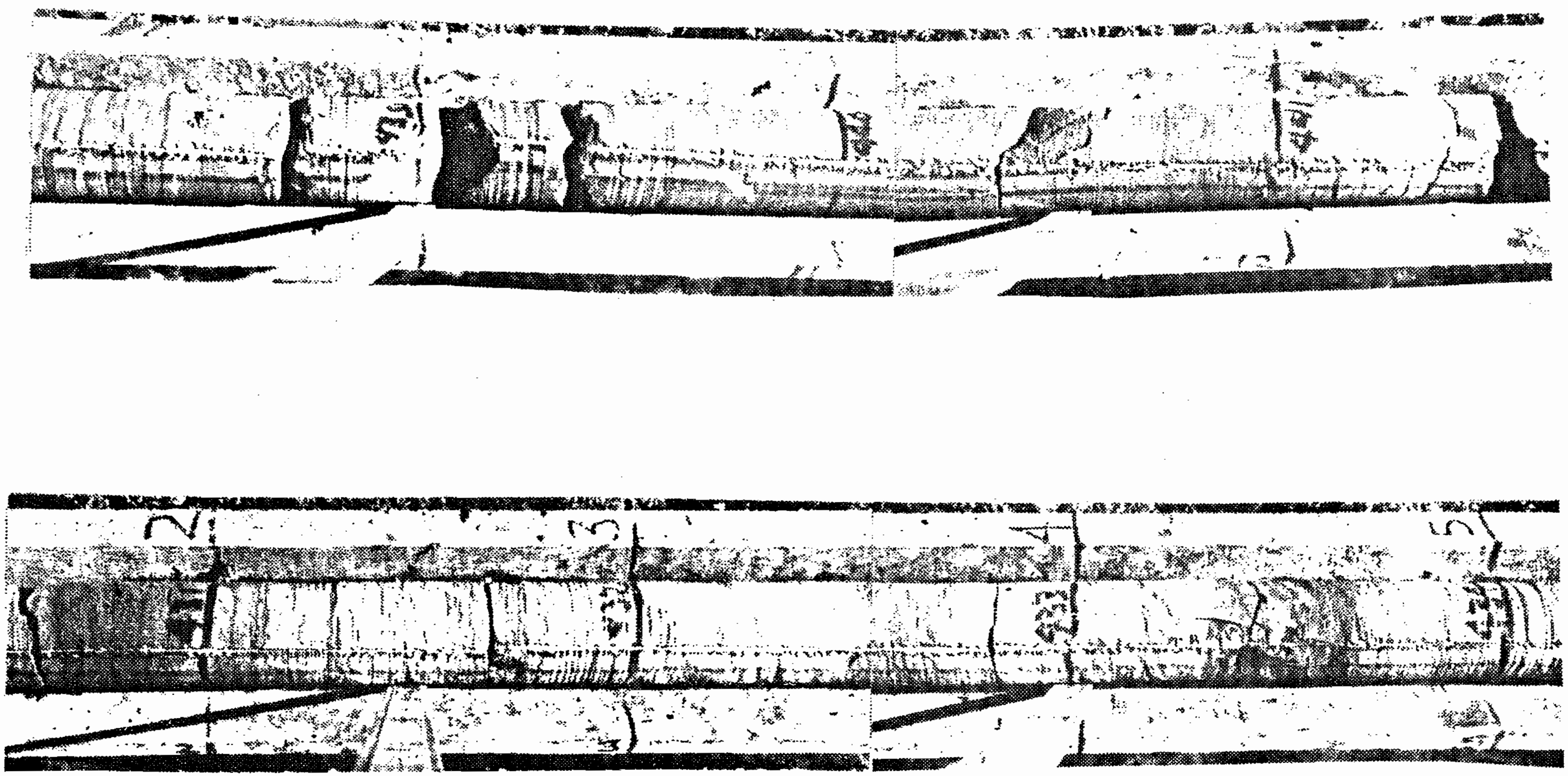


Figure 12. Photostrips from upper sandy portion of corehole GC-1B.

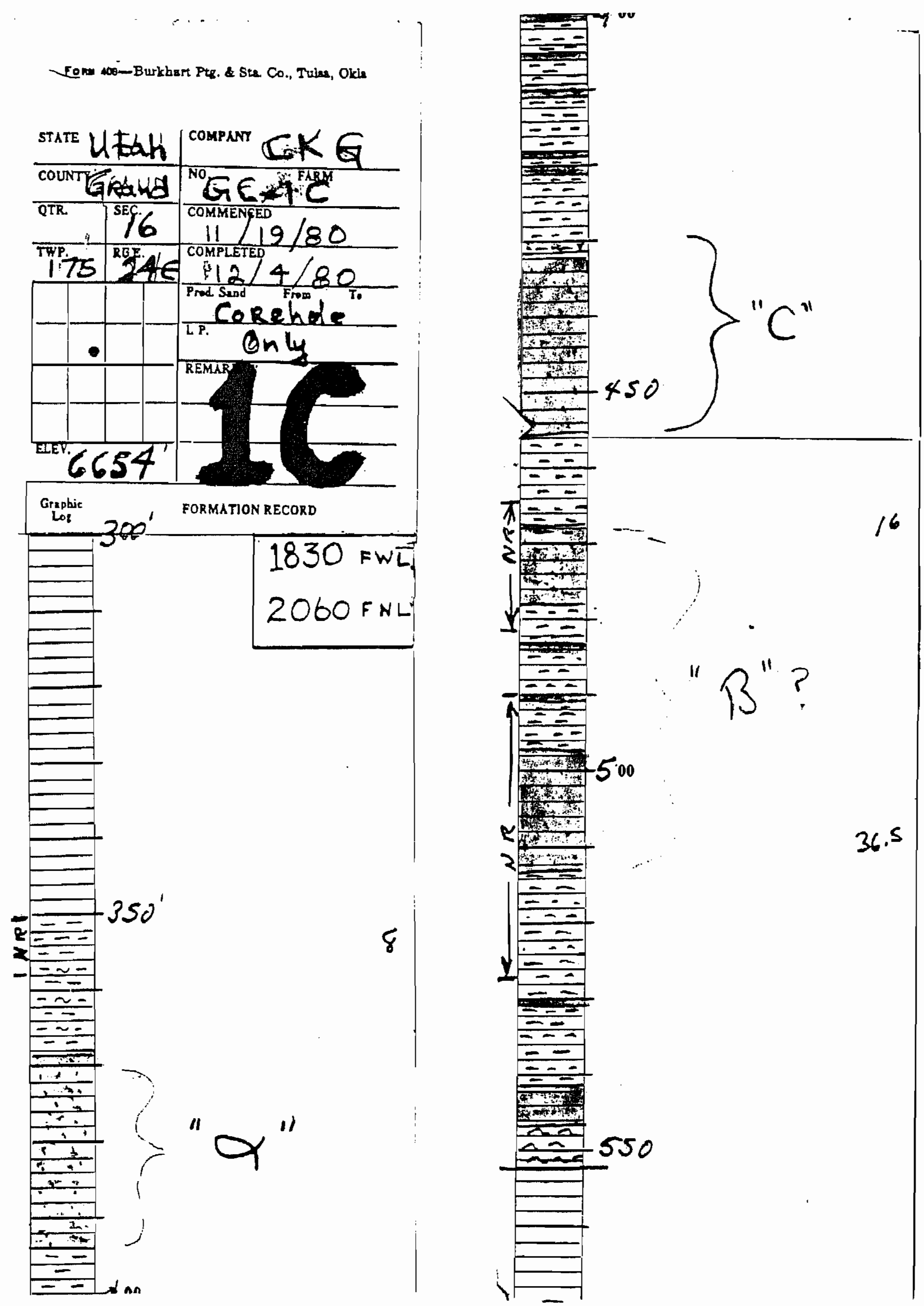
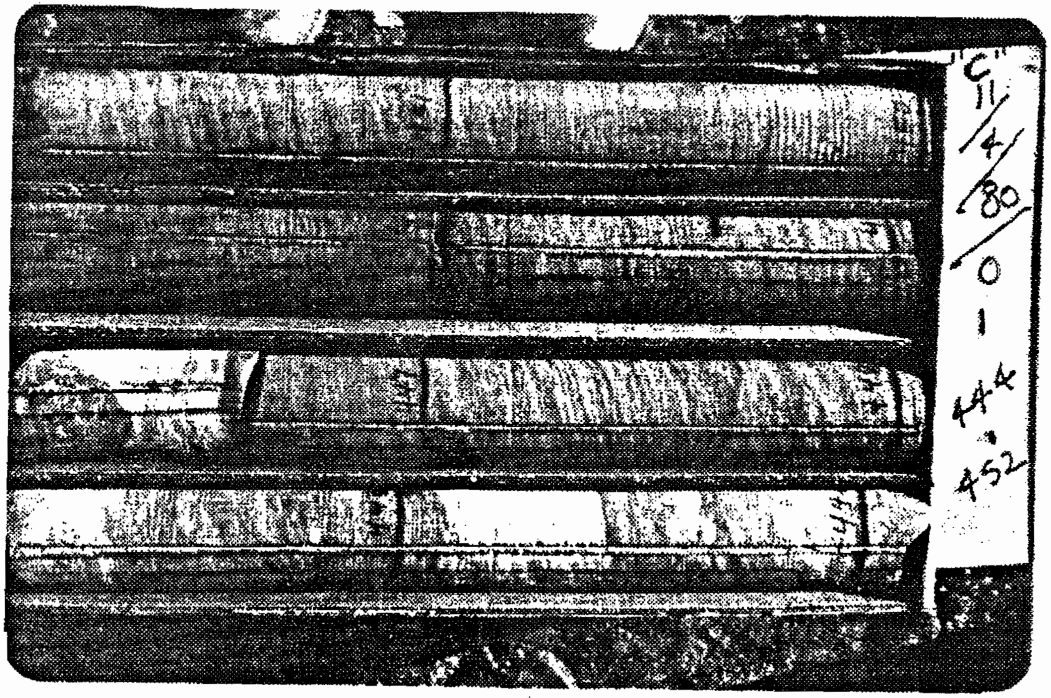


Figure 13. GC-1C - Corelog.



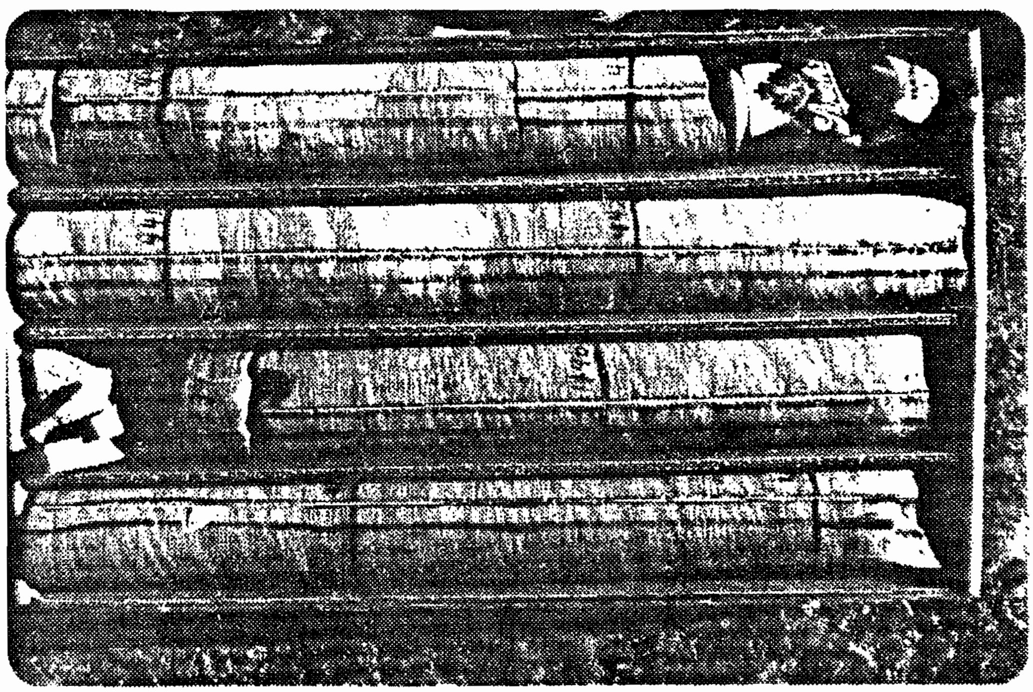
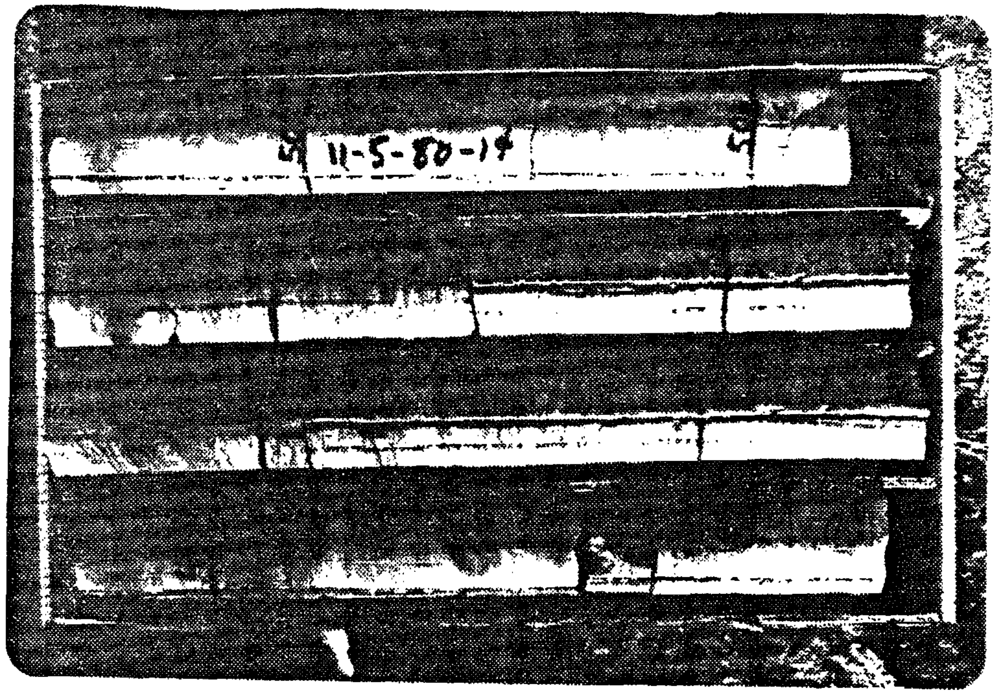


Figure 14A. Photos of core from sandy intervals of corehole - GC-1C.

Figure 13. GC-1C - Corelog



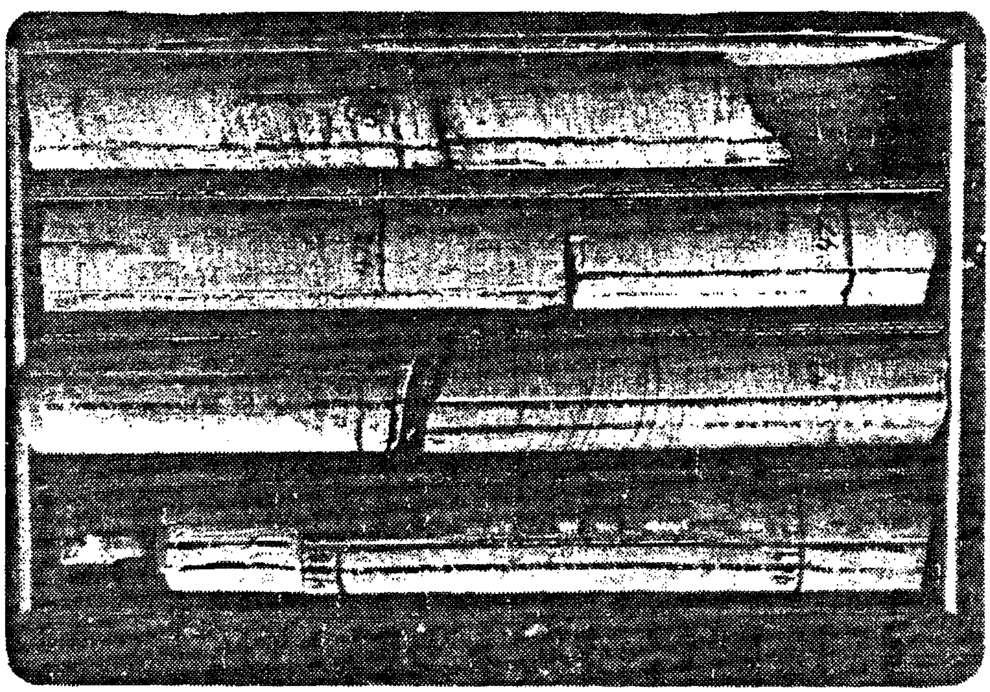


Figure 14B. Photos of core from sandy intervals of corehole - GC-1C.

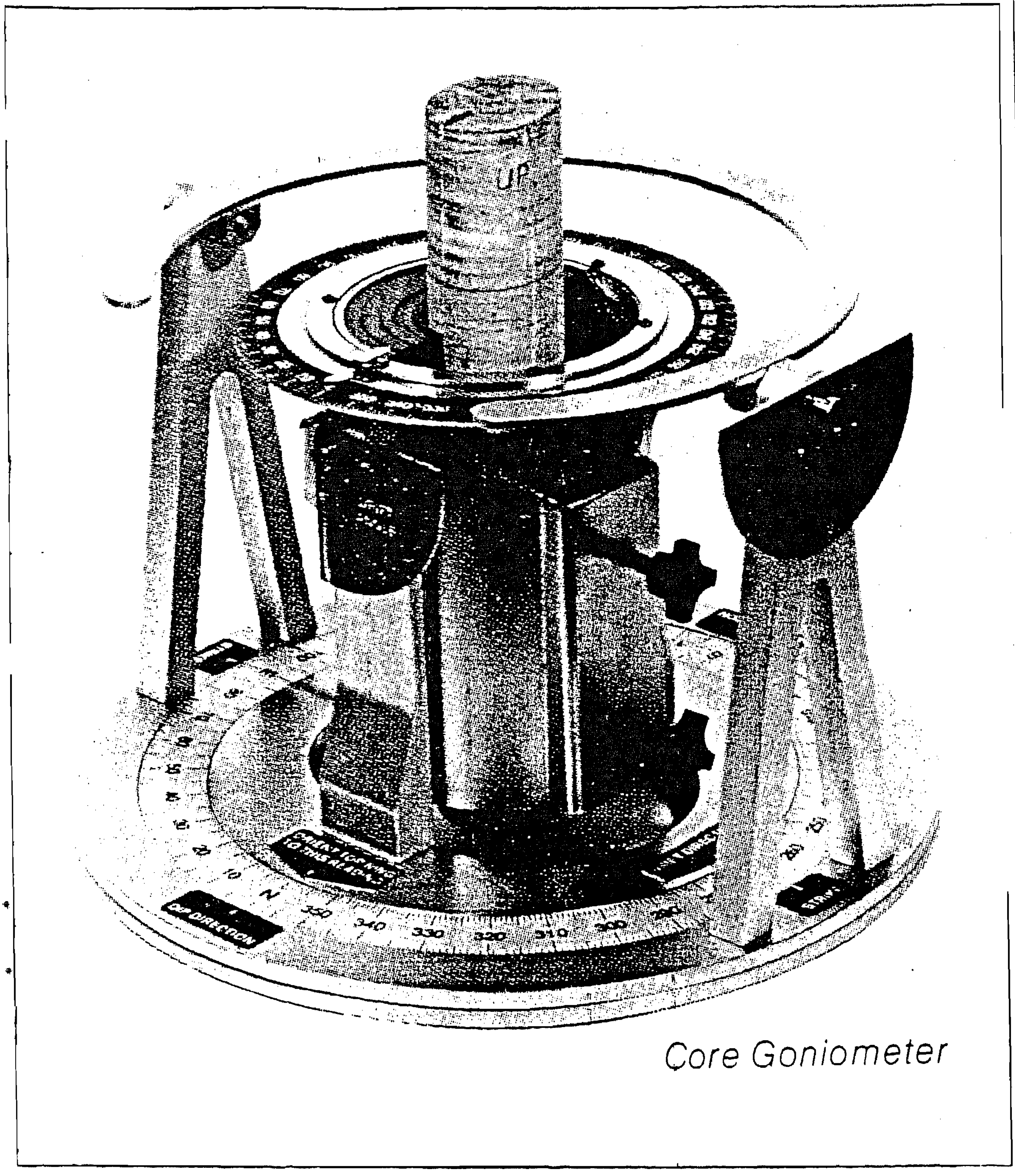


FIGURE 15. Photo of piece of core in goniometer.

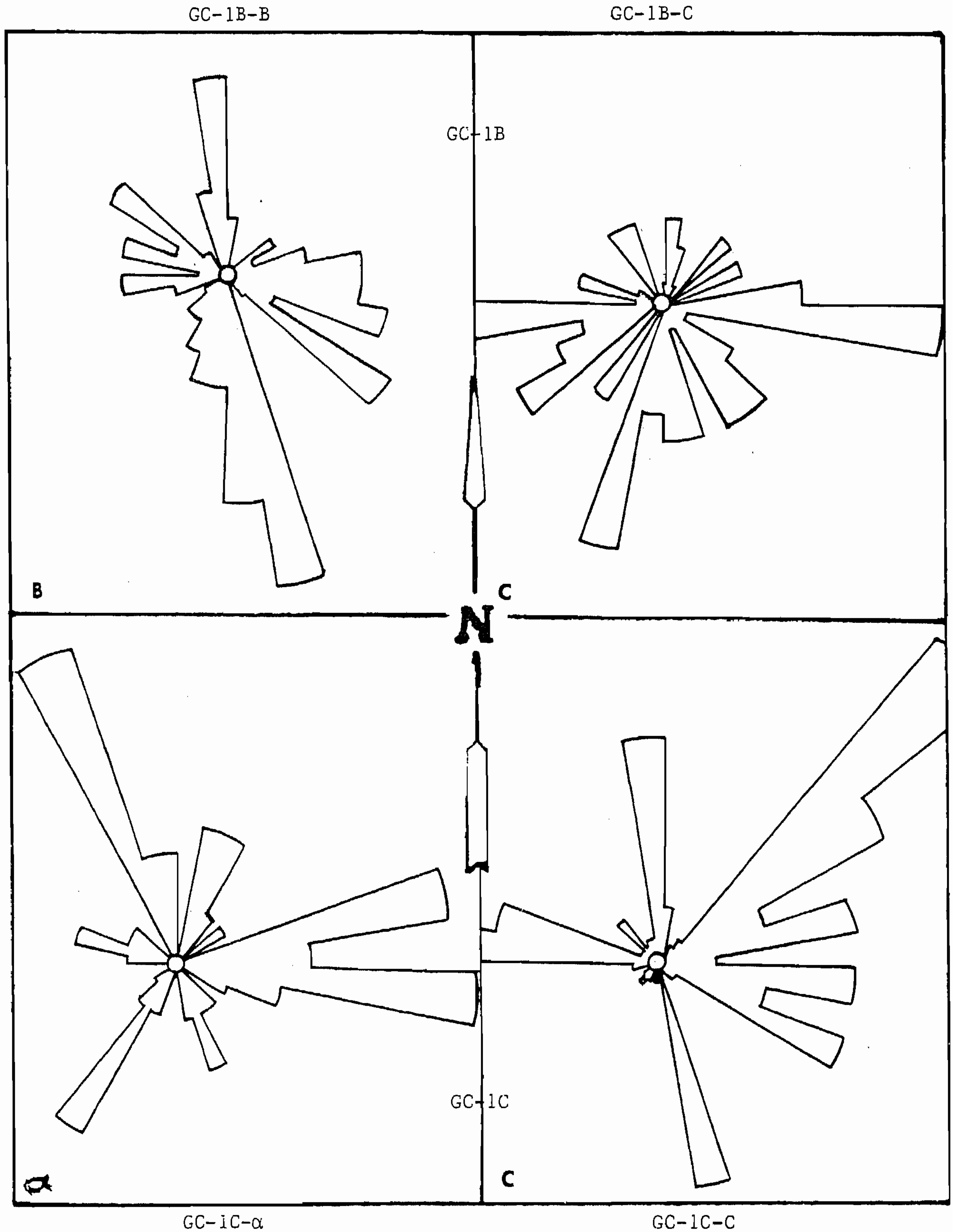


FIGURE 16A. Directional Roses from Oriented Core Measurements Wells GRI-GC-1B Lenses Band C and GRI-GC-1C Lenses C and α.

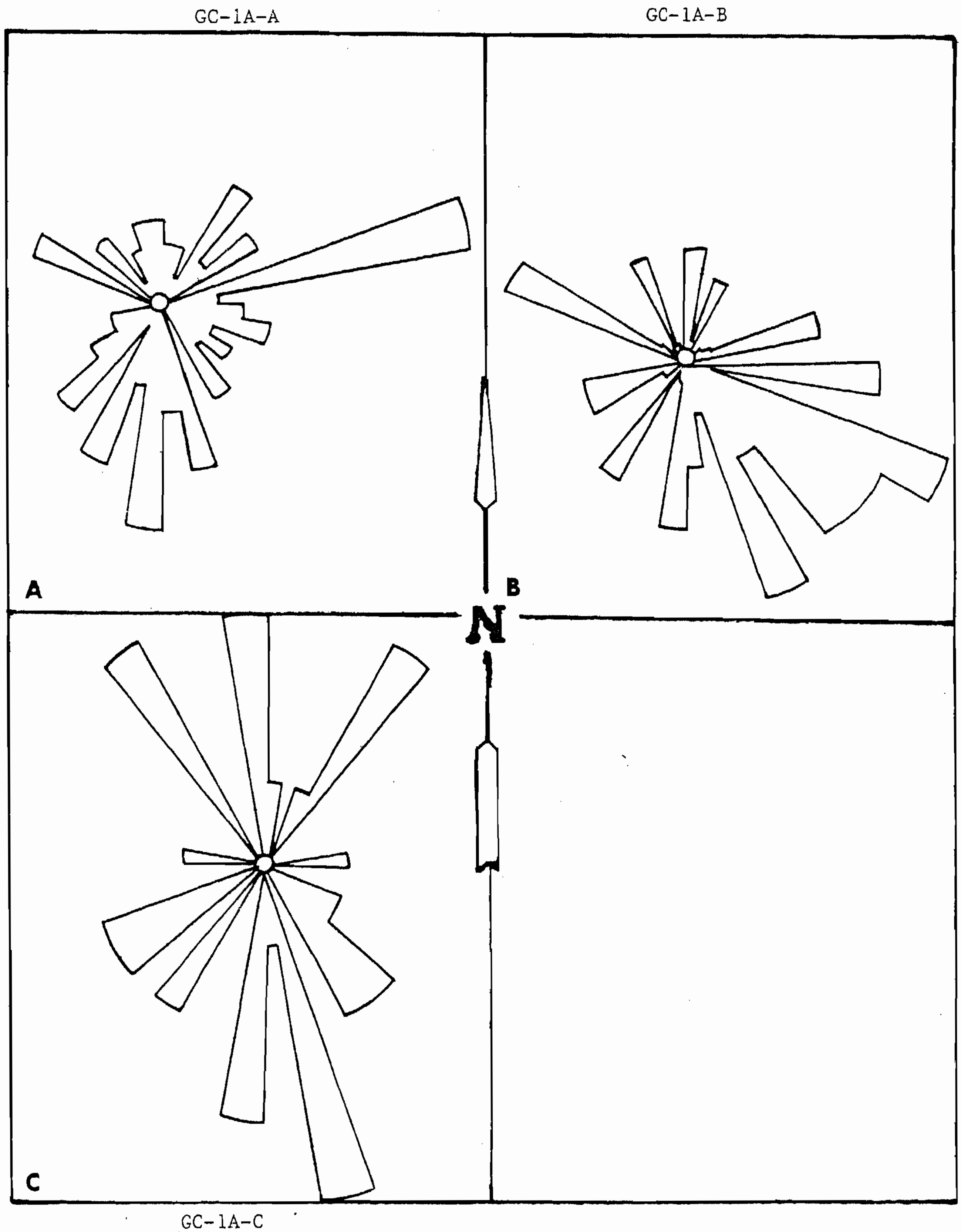


FIGURE 16B. Directional Roses for Oriented Core Measurements Well GRI-GC-1A, Lenses A, B and C.

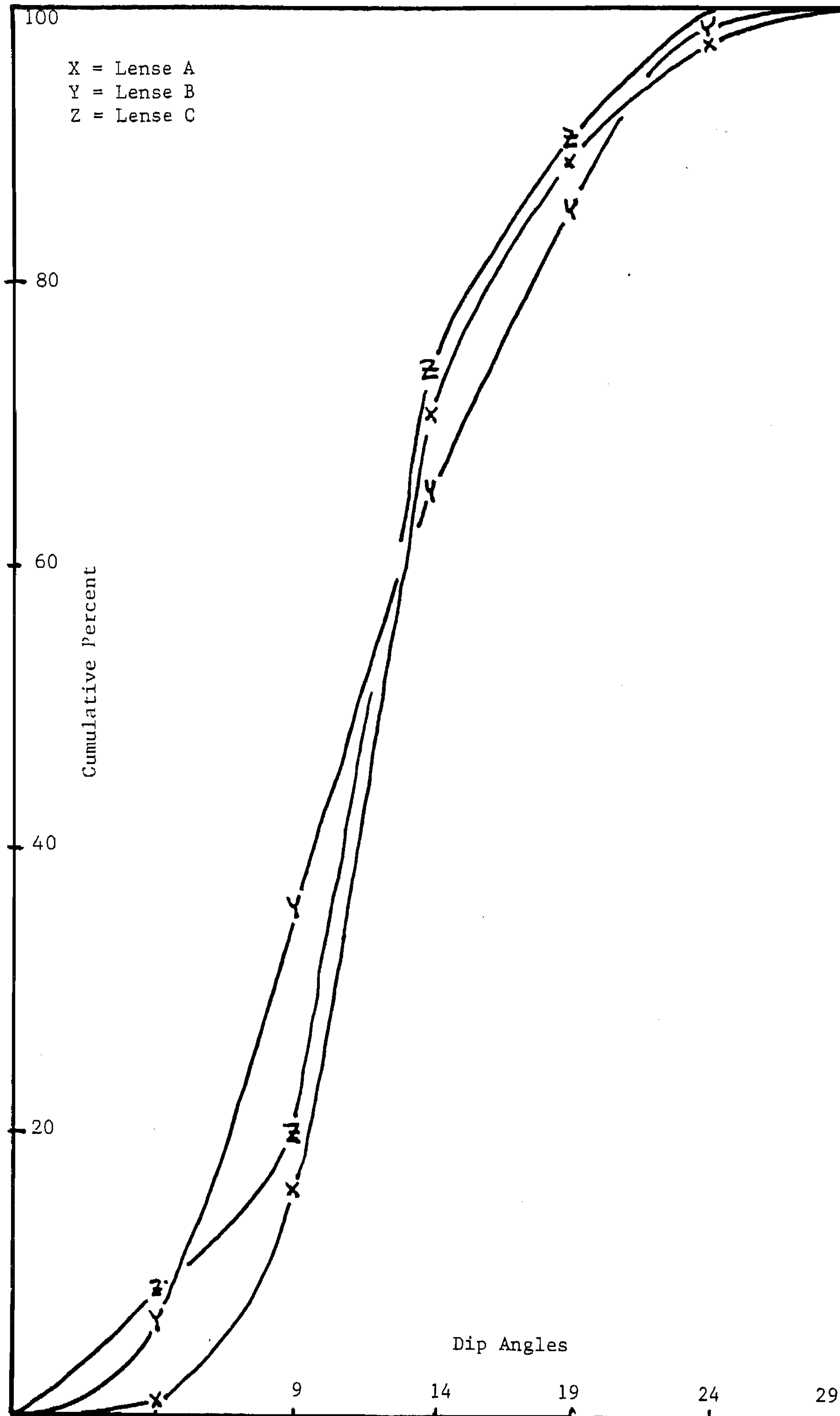


FIGURE 17A. Small Scale Sedimentary Structure Dip Angle Cumulative Distribution Curve Well GC-1A - Oriented Core Analysis.

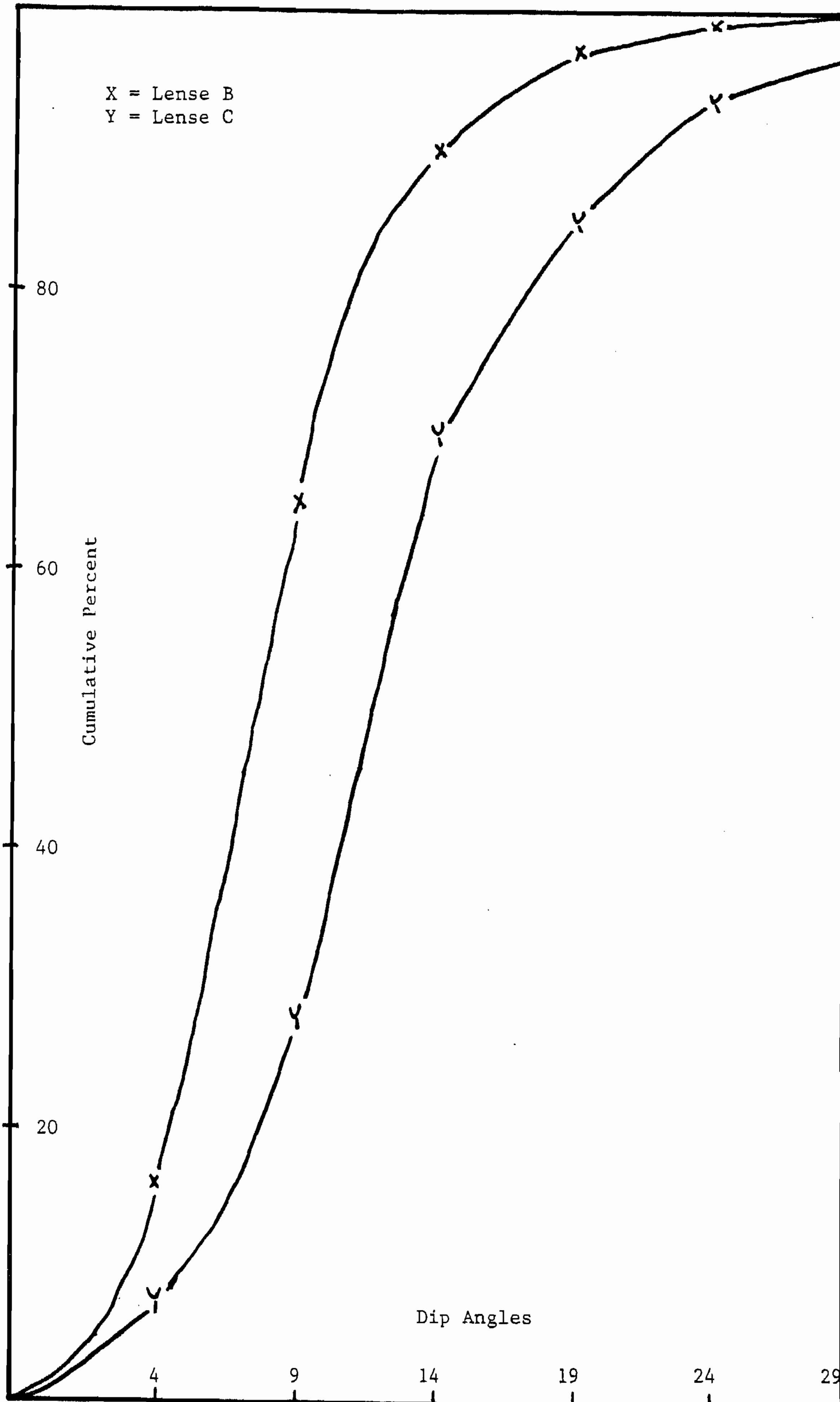


FIGURE 17B. Small Scale Sedimentary Structure Dip Angle Cumulative Distribution Curve Well GC-1B - Oriented Core Analysis.

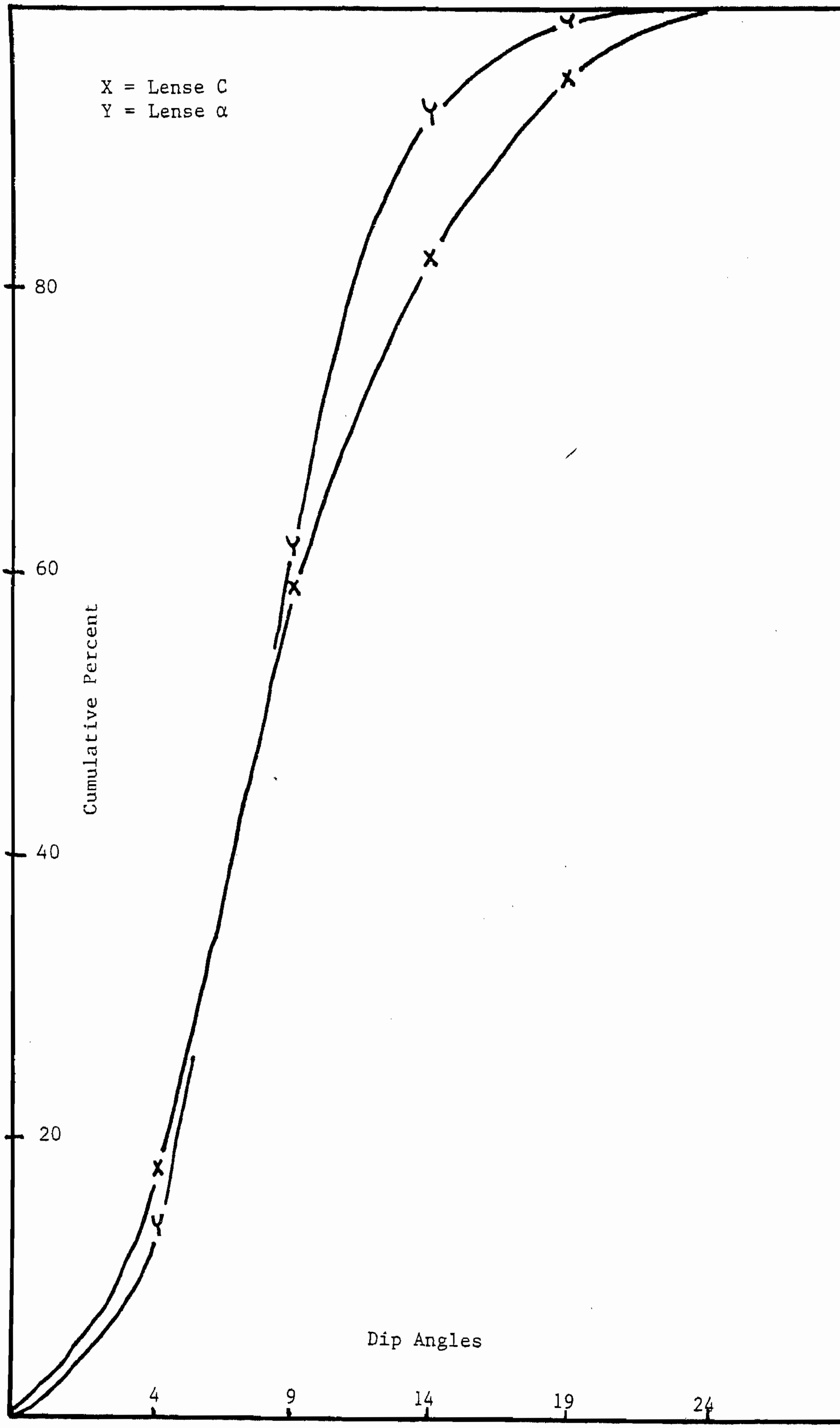


FIGURE 17C. Small Scale Sedimentary Structure Dip Angle Cumulative Distribution Curve Well GC-1C - Oriented Core Analysis.

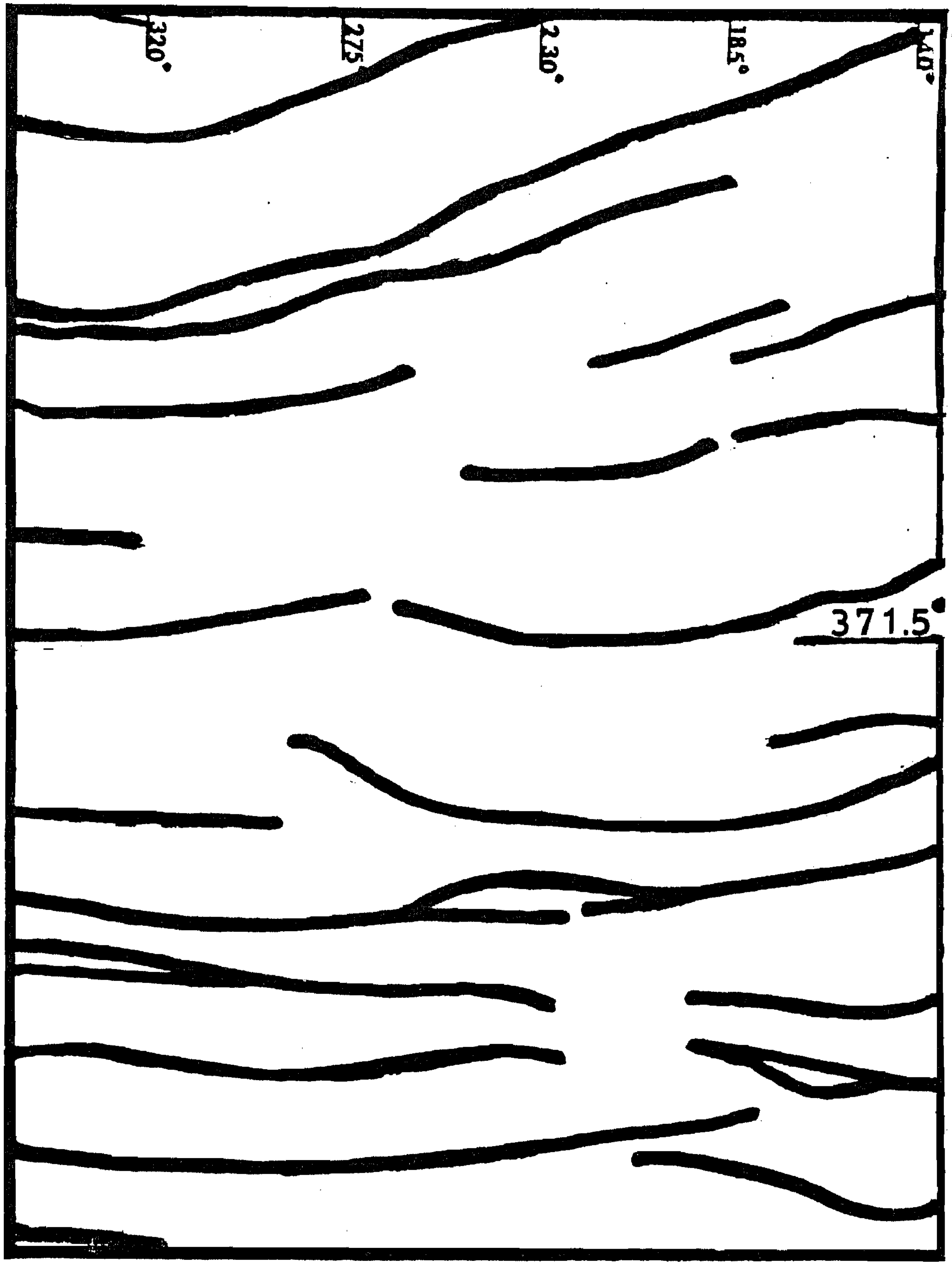


Figure 18. Portion of Plastic Overlay from Sandstone Lens C in Core Hole GC-1.

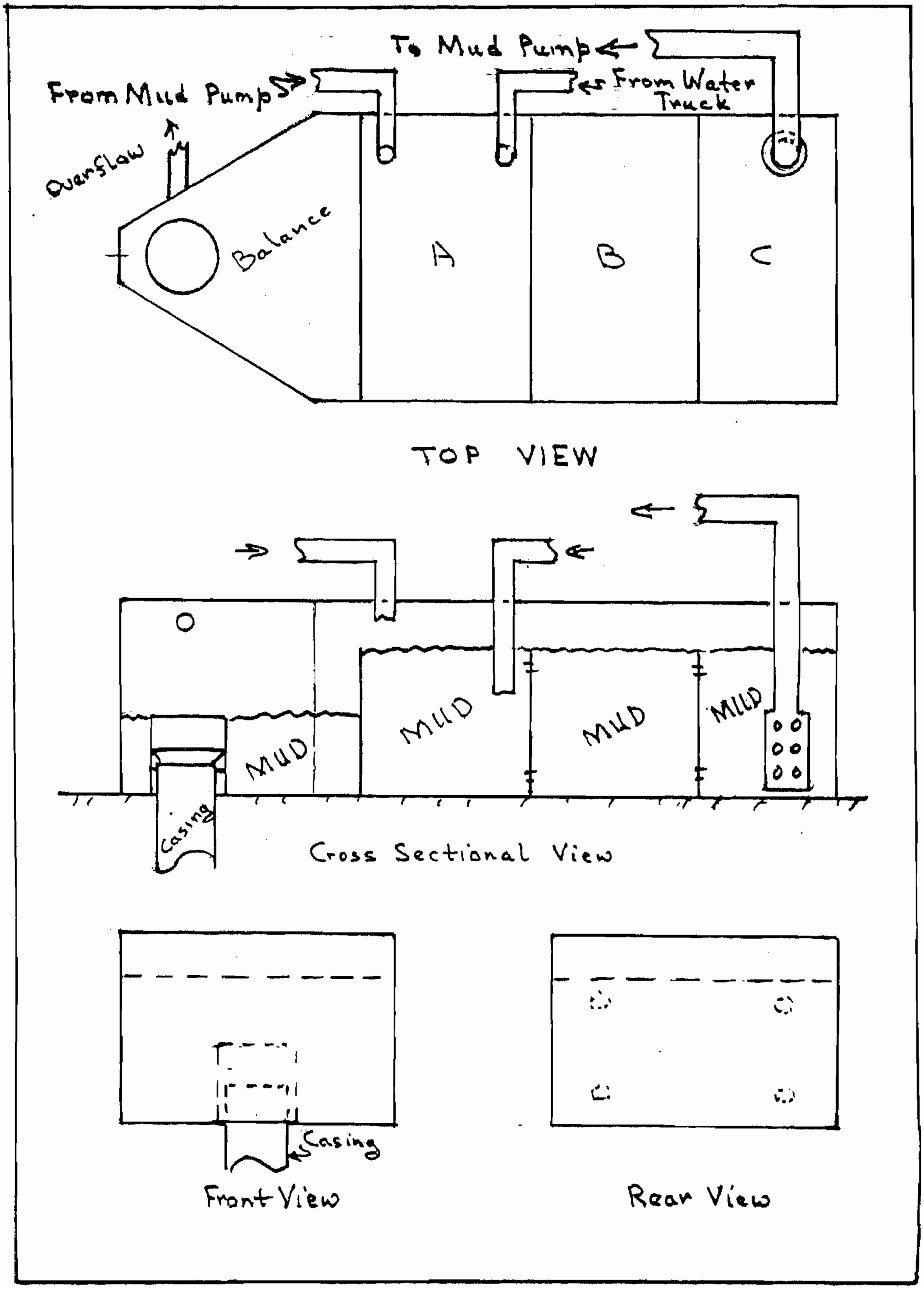


FIGURE 19. Schematic Drawing of Mud Pit.

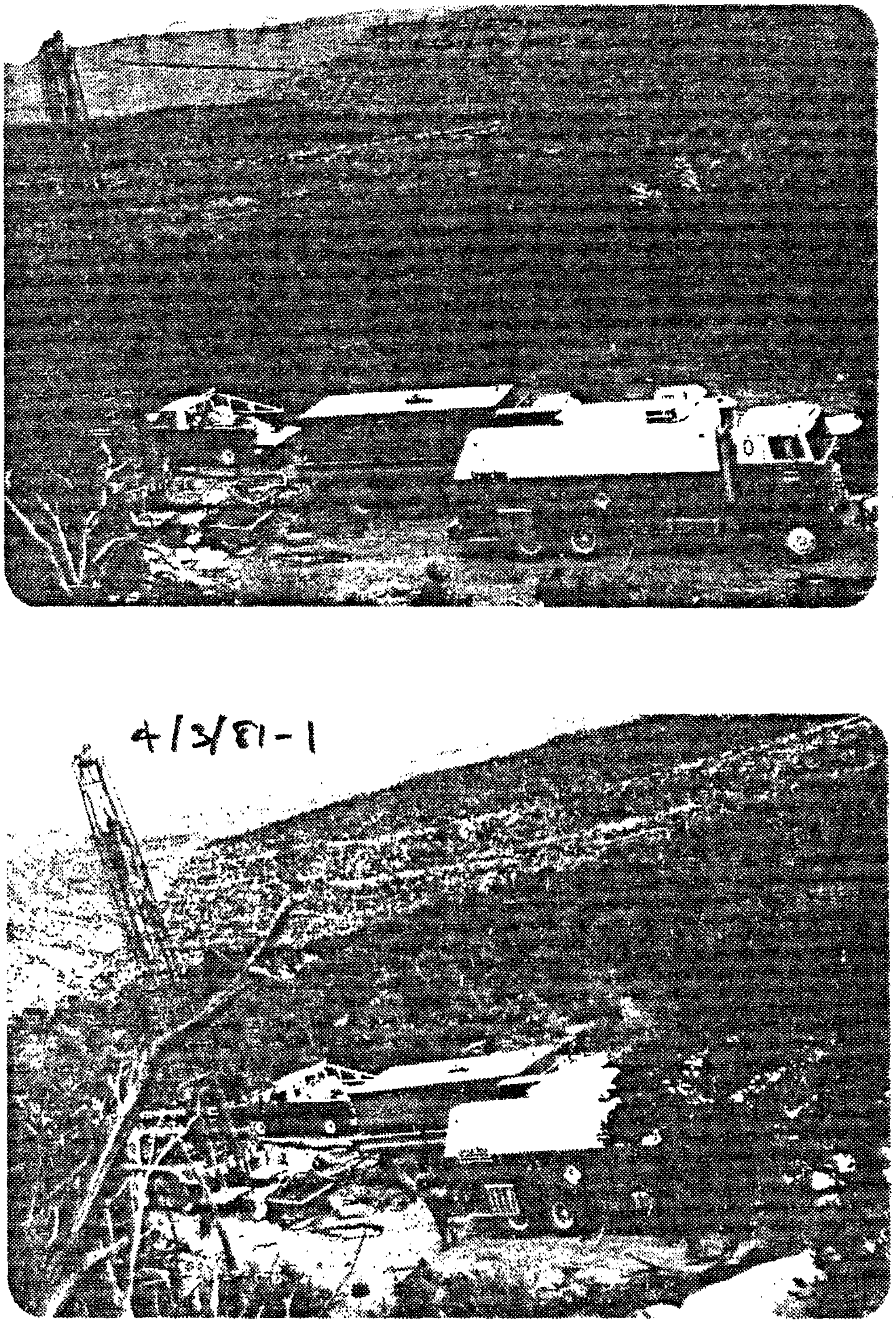


FIGURE 20. Photographs of GC-1A Logging Operation.

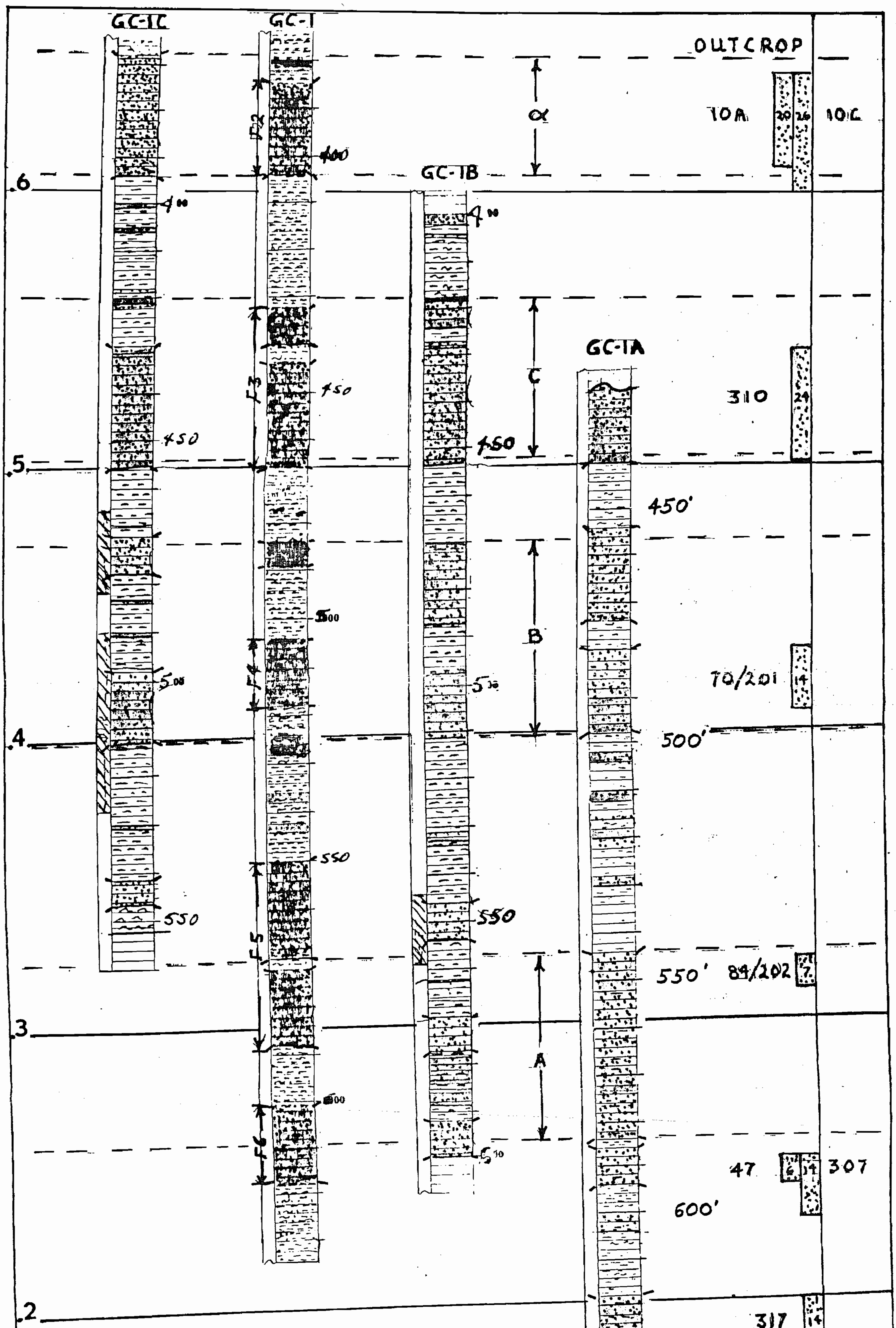


FIGURE 21. Comparison of Sandstone Intervals in GC-1, 1A, 1B, 1C and Predicted Occurances From Outcrop Data. Crosshatched Intervals Represent Lost Core Orientation Data.

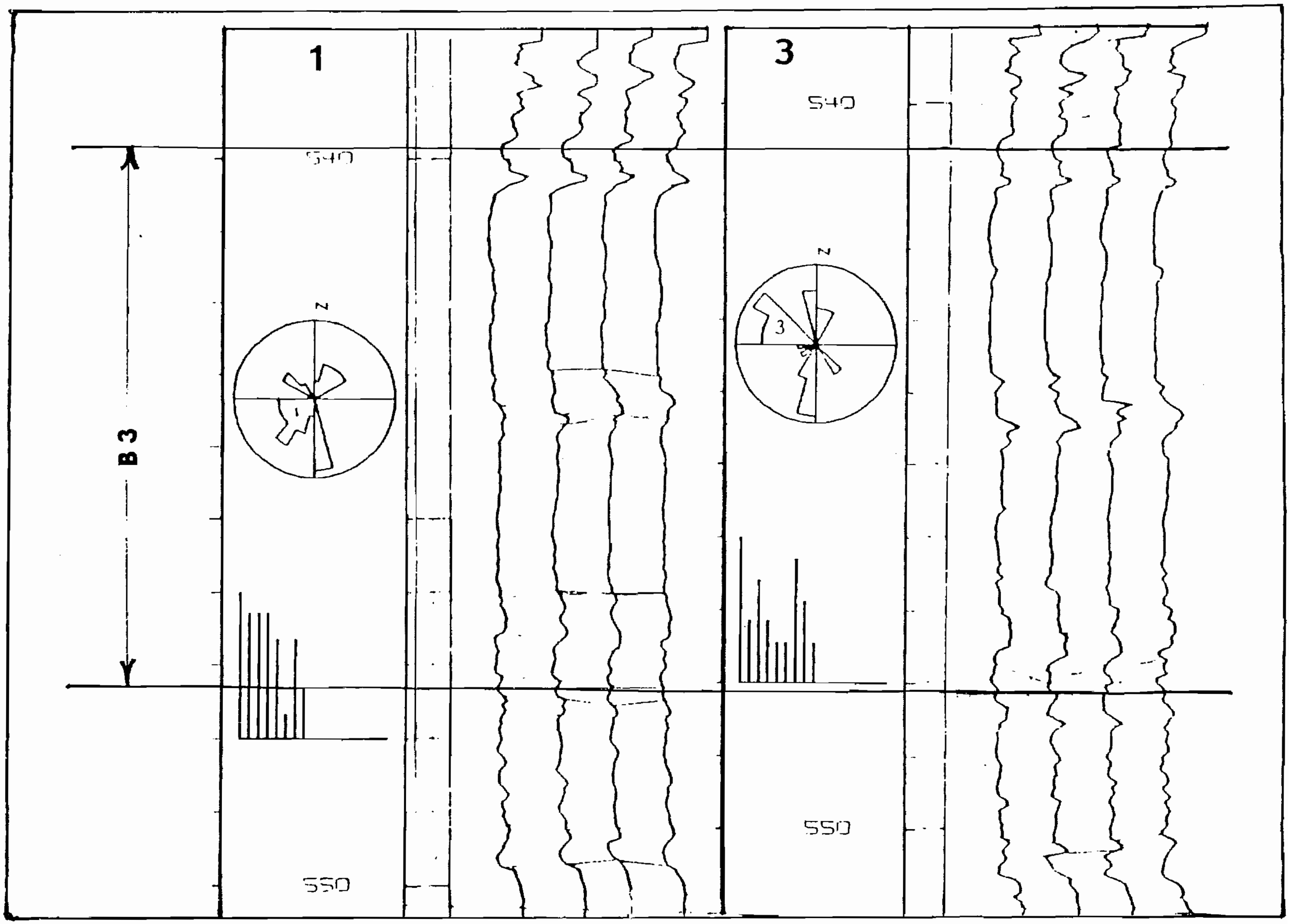


FIGURE 22. B3 Interval in GC-1C Showing Correlation For Runs 1 and 3.

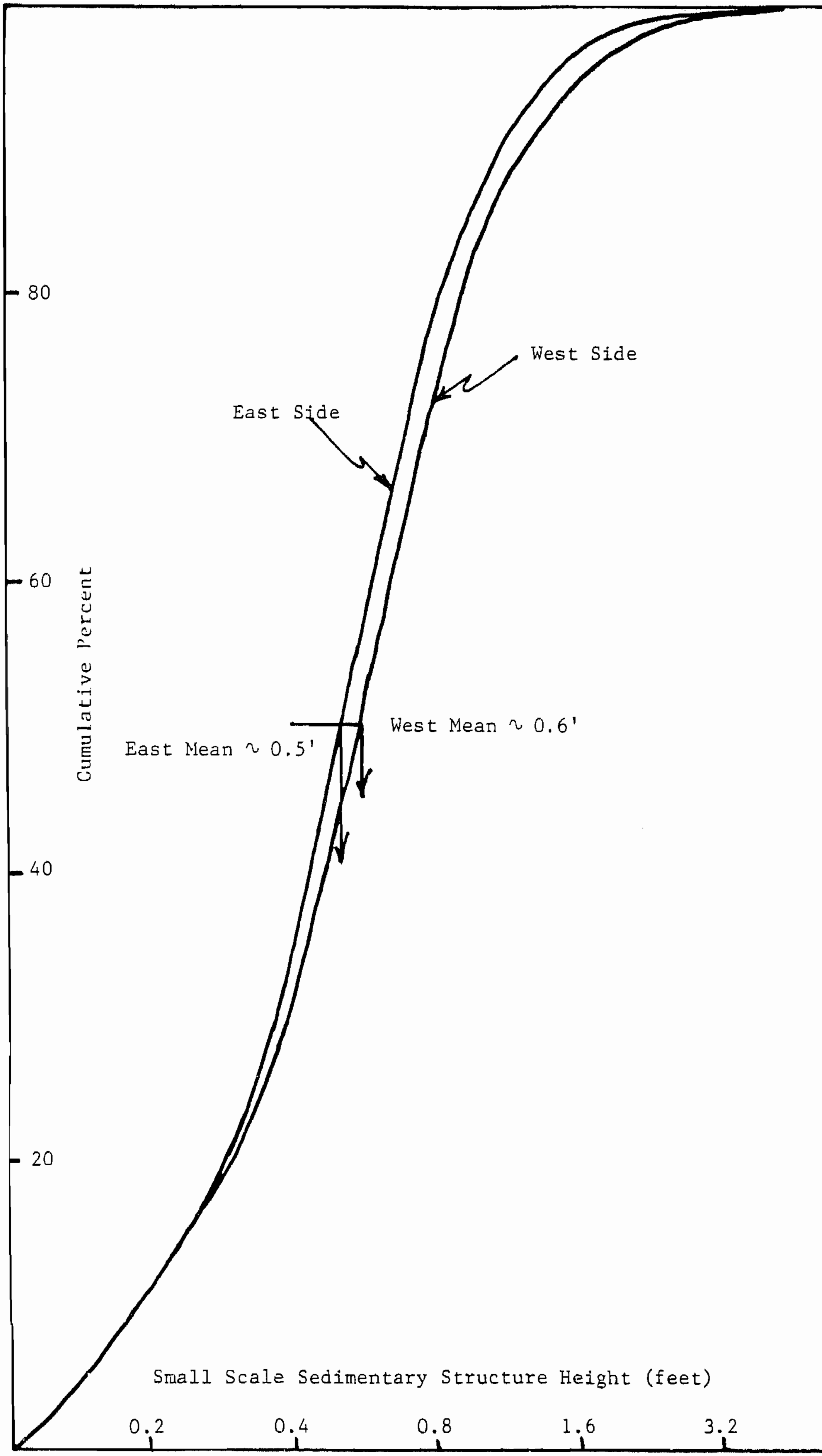


FIGURE 23. Cumulative Height Curve for Small Scale Sedimentary Structures in Farrer Interval (0.2 - 0.6 above base)

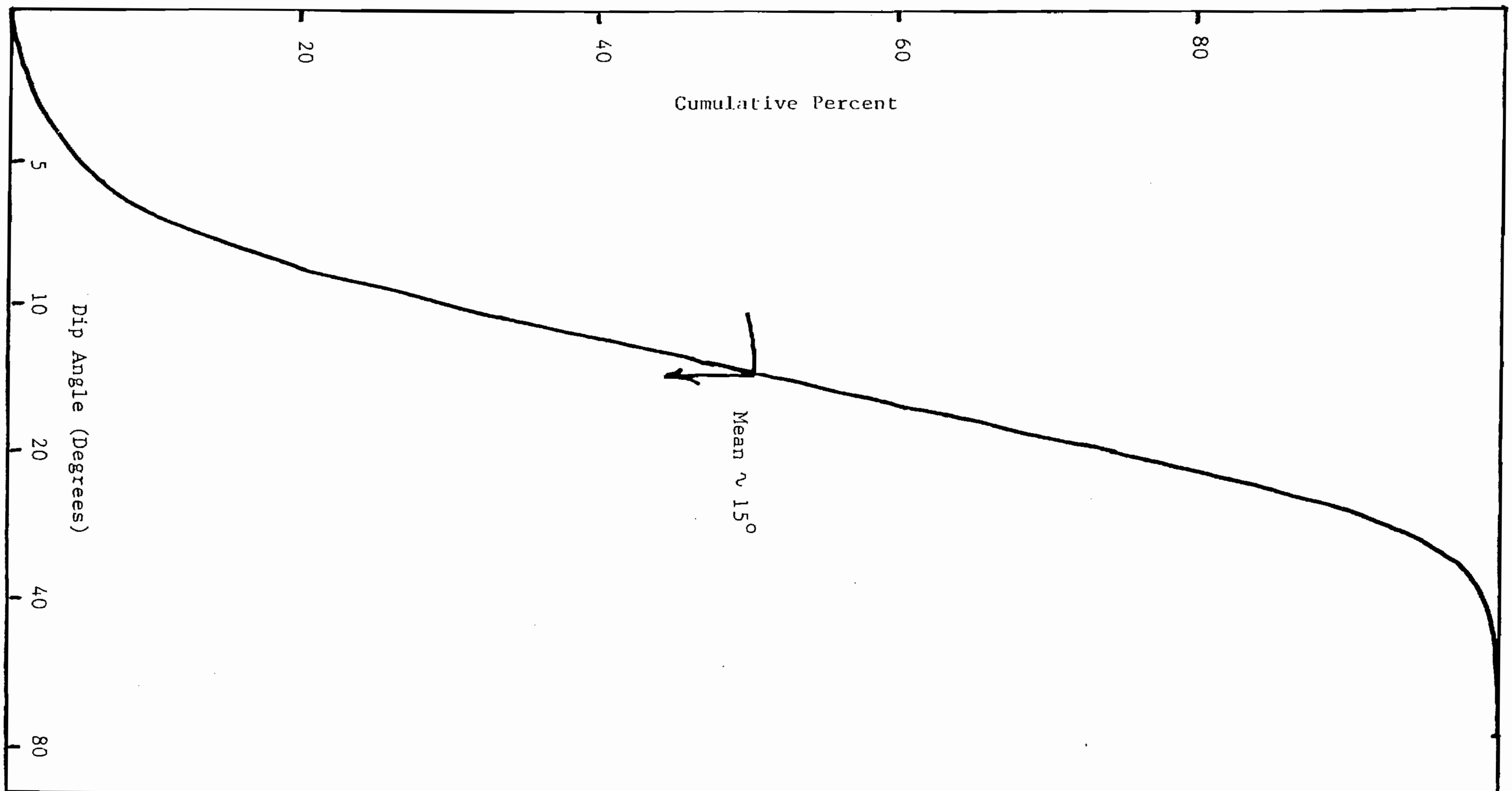
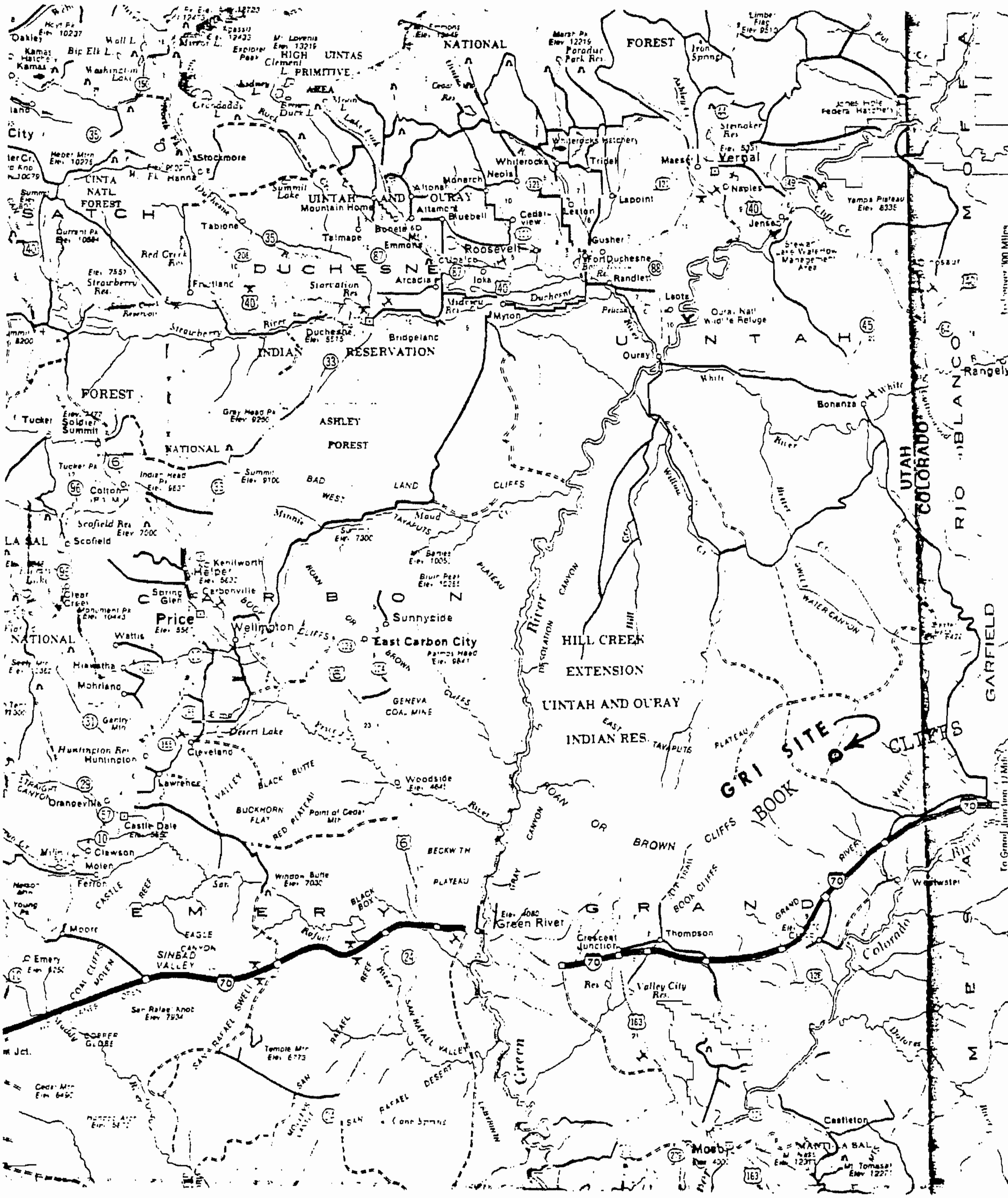


FIGURE 24. Cumulative Dip Angle Curve for Farrer Outcrop Data (Interval ∿ 0.2 – 0.6 Above Base of Formation)



Location Map for Wells Described in Appendix A.

APPENDIX A

APPENDIX A

GC-1A COREHOLE

WELL DRILLING SUMMARY

3/23/81	Rig up site, air drill, 20 feet of 8 5/8 in. surface hole, set 17 ft. of 7 in. casing, air drill 6 1/8 in. hole to 125 ft., cement 7 in. casing and let cement set up overnight. TD 125 ft.
3/24/81	Air drill 6 1/8 in. hole to 285 ft. subsurface. Stuck drill bit at 285 ft. when air rate dropped off probably due to air loss in fractures. Worked bit loose after switching to foam, drilled to 424 ft. and switched to core assembly. Foam cored with 5 in. core bit and 20x4 5/8"x3" barrel 424 to 440 ft. Camera 937, Solenoid 1291, Clock 1385, Target 5192, TD 440 ft.
3/25/81	Foam cored 440 to 498 ft. with 5 in bit and 20'x 4 5/8"x3" barrel. Camera 1132, solenoid 188, clock 1422, target 3807. Target was non-magnetic camera 1132, solenoid 188, clock 1422, target 3807, TD 498 feet.
3/26/81	Foam cored 498 to 536.75 ft. after resurveying 440 to 498 ft. Used 5 in. bit with 20'x4 5/8"x3" core barrel, camera 937, solenoid 1291, clock 1385, target 5192, TD 536.75 feet.
3/27/81	Foam cored 536.75 to 577.5 ft. using 5 in. bit and 20'x4 5/8"x3" core barrel. Camera 937, solenoid 1291, clock 1385, target 5192 for 536.75 to 564.5 ft. and camera 1132, solenoid 188, clock 1422, target 5192 for 564.5 to 577.5 ft., TD 577.5 ft.
3/28/81	Foam cored 577.5 to 616.5 ft. with 5 in. bit and 20'x4 3/8"x3" core barrel. Camera 937, solenoid 1291, target 5192, for 577.5 to 598 ft. Camera 1132, solenoid 188, clock 1422, target 5192 for 598 to 616.5 feet, TD 616.5 feet.
3/29/81	Foam cored 616.5 to 652.2 ft. with 5 in. bit and 20'x4 3/8"x3" core barrel. Camera 937, solenoid 1291, clock 1422, target 5192. Started reaming with 6 1/8 in. bit. TD 652.2 ft.
3/30/81	Foam reamed to 658 ft. started to mud up. Had lost circulation problems. Called out second truck and more lost circulation material. TD 658 ft.

3/31/81 Circulated mud with lost circulation material. Mud loss rate slowed down, topped off hole with mud plus lost circulation material, screwed on well cap and rigged down. TD 658 ft.

4/01/81 Demobilized location and moved all equipment to Grand Junction, shipped oriented core equipment to Sperry Sun and Christensen.

GC-1B COREHOLE

WELL DRILLING SUMMARY

12/4/80	Moved rig to location, rigged up, air drilled 17 ft. surface hole, set 15 ft. of 7½ in. casing. Started air drilling 6 1/8 in. hole, drilled to 200 feet, tripped shutdown and cemented surface casing, let cement set overnight. TD 200 ft.
12/5/80	Air drilled to 400 ft. Tripped out with air drilling assembly, rigged up non-magnetic collar, subs and orienting core assembly, foam cored 400 to 450 ft. tripped out and secured rig (storm starting) TD 415 ft.
12/6/80	Traveled to location - too stormy to work - checked rig and returned to Grand Junction. TD 415 ft.
12/7/80	Too stormy to work. TD 415 ft.
12/8/80	Rigged up orienting assembly and foam cored 415 - 470.8 ft. tripped out. Secured rig. TD 470.8 ft.
12/9/80	Rigged up orienting core assembly and foam cored 470.8 - 529.0, tripped out, secured rig. TD 529 ft.
12/10/80	Rigged up orienting core assembly and foam cored 529 - 584 ft., tripped out, secured rig. TD 584 ft.
12/11/80	Rigged up orienting core assembly and foam cored 584 - 598 ft., tripped out core assembly and rigged up drill collars and 6 1/8 bit, foam reamed to 600 ft. tripped out, secured rig, TD 600 ft.
12/12/80	Rigged up 6 1/8" bit and mudded up, circulated well, tripped out, logged hole. Left well filled with mud and with removable cap on casing. TD 600 ft.
12/14/80	Rigged down, started to demobilize, storm and melting snow made roads too slippery to move rig downhill.
12/15/80	Moved rig and water trucks off hill early in morning while everything was frozen. Moved rig to Grand Junction and shipped oriented core equipment to Sperry Sun and Christensen.

GC-1C COREHOLE

WELL DRILLING SUMMARY

11/19/80	Move to location and rig up.
11/20/80	Waiting on modification of Sperry Sun/Christensen oriented coring equipment.
11/21/80	Air drilled 9 5/8 in. surface hole to depth of 15 feet and set 10 ft. of 7 in. casing. Air drilled 6 1/8 in. hole to 320 ft. Compressor failed, tripped out and tore down compressor. Cemented in surface pipe. TD 320 ft.
11/22/80	Repaired compressor, air drilled to 350 ft. Laid down drill collars and prepared to start coring. TD 350 ft.
11/23/80	Took core barrel to town for machine work. TD 350 ft.
11/24/80	Waiting on core barrel repairs. TD 350 ft.
11/25/80	Set up core barrel and foam cored 350 to 368 ft. Inner barrel came loose and had to be reset and reoriented with orienting bar and shoe. TD 368 ft.
11/26/80	Foam cored 368 - 426 ft., no problems. Laid down coring equipment and secured for Thanksgiving holidays. TD 426 ft.
11/27/80-11/30/80	Thanksgiving Holiday
12/01/80	Rigged up coring equipment and foam cored 426 - 482.5 ft., laid down equipment. TD 482.5 ft.
12/02/80	Foam cored 482.5 - 527.5 ft. had camera problems. Laid down coring equipment. TD 527.5 ft.
12/03/80	Foam cored 527.5 - 551 ft. laid down coring equipment, set up drill collars and 6 1/8 in. bit and reamed hole to 500 ft. TD 551 ft.
12/04/80	Foam reamed and drilled hole to 552 ft. mudded up and circulated hole., rigged down and moved off location. Left screw cap on surface casing and hole filled with mud. TD 552 ft.

APPENDIX B

GONIOMETER

The information recorded in the core orienting log, columns 5, 7 and 13, is used for establishing dip direction, dip angle and strike of formation and can be recorded in columns 15, 16 and 17.

Proceed as follows:

A - Select Proper Inserts for Size of Core: 1-7/8, 2-1/8, 2-5/8, 3, 3-1/2, 4; (5-1/4 does not require an insert).

B - Set Drift Direction: Rotate compass card until DRIFT DIRECTION TRUE is at fixed pointer at front of head, (column 7, orienting log sheet).

C - Set Reference Groove: Rotate knurled ring until red mark reads AZIMUTH REFERENCE GROOVE TRUE, (column 13, orienting log sheet).

D – Mount Core: Align reference groove of core with red mark on knurled ring, section of core to be measured should be about 2" above head.

E – Set Drift Angle: Set pointer and scale on right side of head and lock, (column 5, orienting log sheet).

F - Dip Direction: Rotate strike and dip indicator (outer ring with protractor) until highest arc of bedding plane is bisected by vertical line of strike indicator and read dip direction at blue pointer on outer ring.

G – Dip Angle: Align parallel bars with bedding plane, then read the dip angle.

H – Strike: Read the angle at yellow pointers.

The concept of "dip" and "strike" is basic to an understanding of the structure of the rocks in the earth's crust. Most of these rocks form layers, called "strata" and were originally formed in an essentially horizontal position. Many subsequent events in the earth's history have resulted in the fracturing, folding, and tilting of these strata. Sometimes they are pushed to a vertical position and occasionally overturned.

"Dip" is defined as the angle between a sloping stratum and a horizontal (imaginary) plane.

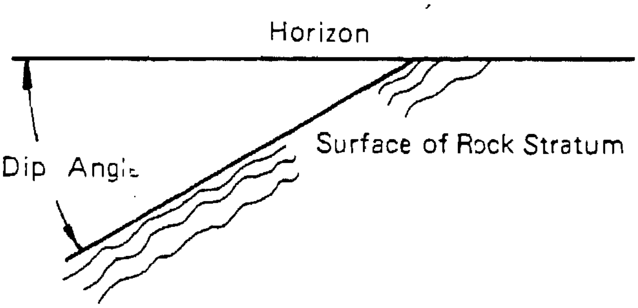


Figure 13

"Strike" is the direction of the imaginary line at the intersection of the sloping stratum and the horizontal.

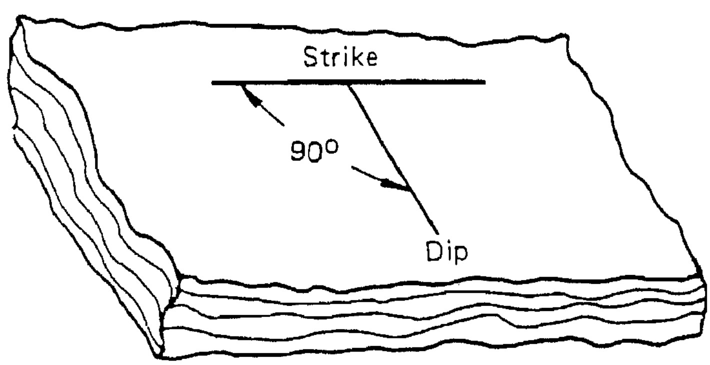
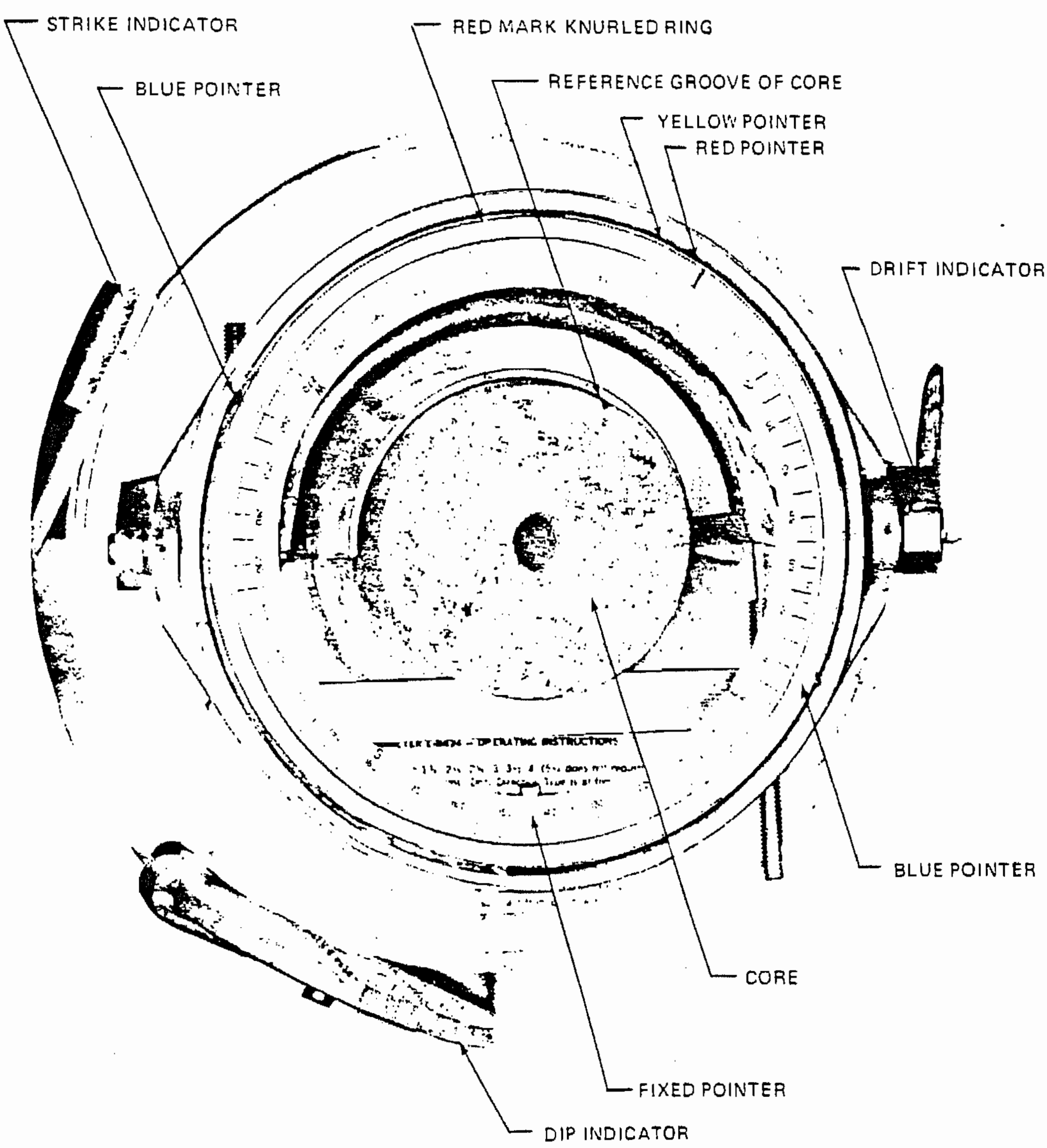
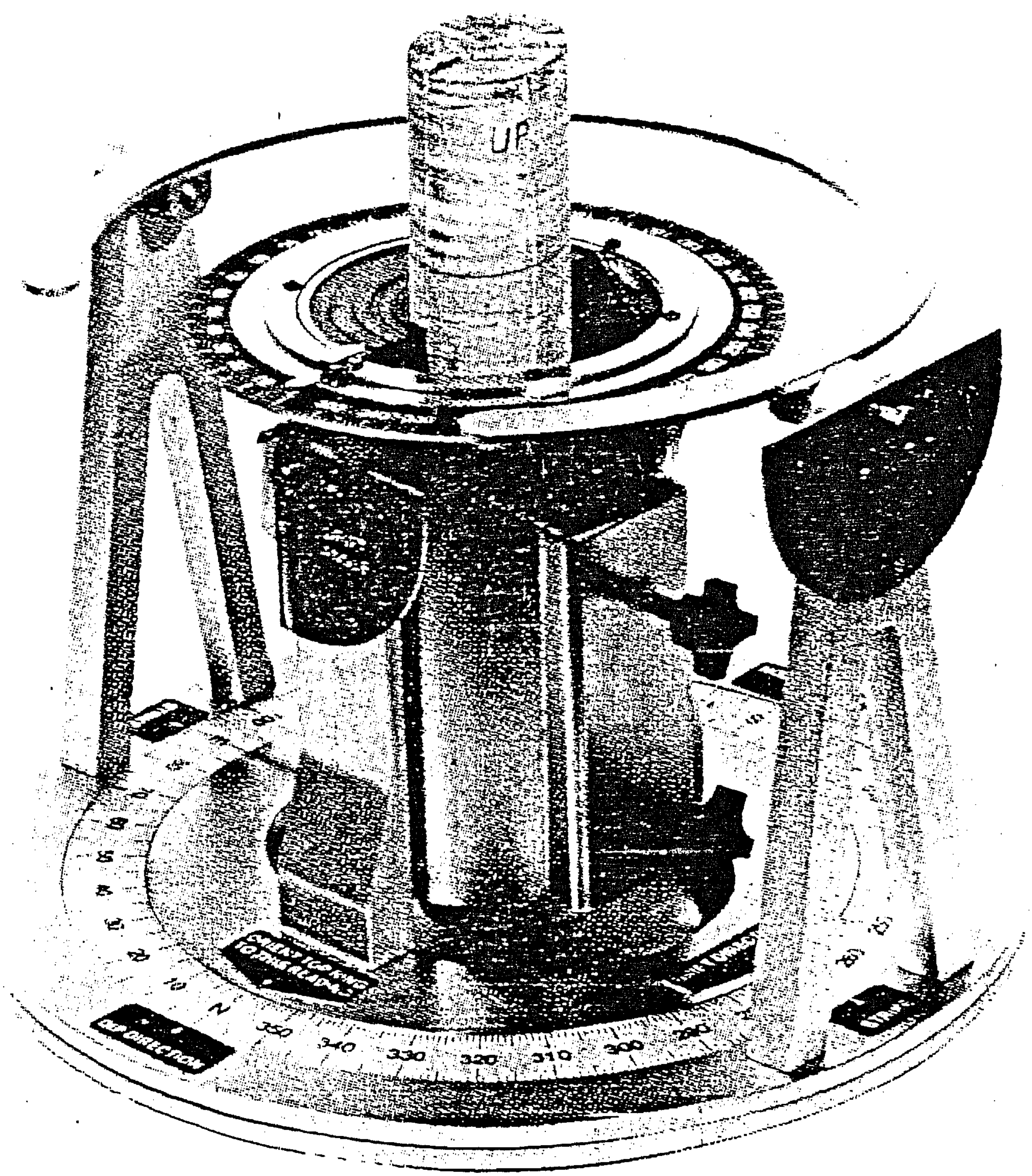


Figure 14

Dip and Strike are always at right angles to each other.



GONIOMETER TOP VIEW



Core Goniometer

CHRISTENSEN DIAMOND PRODUCTS — CORE ORIENTING LOG

Date 12-1-66
Page 1 of 1

WELL INFORMATION

Company: Calif. Dept. of Water Resources
Contractor:
Well Name: Pyramid Power Plant PP-32
County: Los Angeles State: Calif.
Hole Size: 5 1/8 Core Barrel: 4 7/8
Formation Name: Ridge Basin
Formation Description: Silty Shale

PERFORMANCE

Interval Cored: Finish 75
Start 65
Footage Cored
Remarks:

MULTISHOT INSTRUMENT

Make:
Serial No.
Clock Interval: 1 Min.
Station Record By: [illegible]
Film Read By: [illegible]

CORRECTIONS

Declination 16 Degrees [X] East [ ] West

Azimuth Correction for Declination
East Declination [ ] Add to Azimuth
West Declination [ ] Subtract from Azimuth

Reference Groove Correction
From Above, Groove is 0 Degrees [ ] Right [ ] Left of Orientation Lug.
[ ] Right Add to Lug Azimuth
[ ] Left Subtract from Lug Azimuth

STATION				DRIFT			ORIENTATION							DIP STRIKE			REMARKS
					Direction		Orienting Lug, Magnetic		Declin.	Or. Lug	Reference Groove						
No.	Time	Picture No.	Depth	Angle	Magnetic	True	Direction	Azimuth	Corr.	Az. True	Corr.	Az. True	Direction True	Dip Dir.	Dip Angle	Strike	
1	56:00	1	66	1	S18E	S2E	N25E	025	16E	041		041	N41E	N65W	20W	N25E	laminated
2	72:00	2	67	1	S20E	S4E	N33E	033	16E	049		049	N49E	N73W	21W	N17E	silty shale
3	92:00	3	68	1	S17E	S1E	N36E	036	16E	052		052	N52E				
4	108:00	4	69	1	S14E	S2W	N47E	047	16E	063		063	N63E				
5	124:00	5	70	1 1/4	S15E	S1W	N52E	052	16E	068		068	N68E				
6	166:00	6	71	1 1/4	S12E	S4W	N63W	307	16E	323		323	N37W				
7	184:00	7	72	1	S10E	S6W	N48W	312	16E	328		328	N32W	N64W	26W	N26E	Laminated
8	198:00	8	73	1	S16E	S	N42W	318	16E	334		334	N26W	N59W	21W	N31E	silty shale
9	216:00	9	74	1	S14E	S2W	N34W	326	16E	342		342	N18W	N63W	16W	N27E	〃
10	232:00	10	75	1	S16E	S1W	N28W	332	16E	348		348	N12W				
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18

SAMPLE OF ACTUAL FIELD DATA FROM CORE ORIENTATION JOB

To visually confirm Goniometer settings, the base with the large scale should be aligned with North and placed on a stable level surface.

1. Remove the outer strike and dip direction ring. Select plastic inserts to match the core size.

2. Rotate the core holder to set "Drift Direction" of the hole.

3. Set the hole or "Drift Angle" on the protractor mounted at the side of the core holder.

4. Align the short bent end of the drift angle pointer to the small top scale, with the same reading indicated directly below on the large scale.

5. To position the "Orienting Lug" rotate the double ended pointer over the small top scale to the specified asimuth reading.

6. Place the core in the core holder. Position the Master Scribe on the core in line with the double ended pointer. Clamp the core in position.

   THE CORE IS NOW IN A RELATIVE INSITU POSITION............

7. Place the outer strike and dip direction ring back in position.

8. Rotate and angle the sighting ring so that it appears to be a parallel extension of the planar feature to be examined.

9. Read the "Strike" of the feature at the appropriate pointer located in a northern quadrant on the base ring.

10. Read "Dip Direction" at the appropriate pointer on the base ring.

11. Read "Dip Angle" on the protractor mounted at the side of the outer strike and dip direction ring.

APPENDIX C

SCHLUMBERGER WELL SERVICES
5000 GULF FREEWAY, P.O. BOX 2175
HOUSTON, TEXAS 77001, (713) 928-2511

PLEASE REPLY TO
WE' ROCKY MOUNTAIN DIVISION
'4. ETROBANK BUILDING
475 SEVENTEENTH STREET
DENVER, COLORADO 80202
303) 534-6234

September 5, 1981

C. K. Geoenergy Corporation
Suite 145
3376 S. Eastern Ave.
Las Vegas, Nevada 89109

Attention: C. Knutson

Dear Mr. Knutson,

Re: Dipmeter Interpretation on the C. K. Geoenergy Corporation, DOE-GC-1B, Grand County, Utah

Enclosed are the interpretations of the sands from 426' to 506' in the C. K. Geoenergy Corporation, DOE-GC-1B well in Grand County, Utah. The interpretations are based on the Geodip plot and 1'X4"X20°X2 Cluster plots only as no porosity or resistivity log was available.

The interval from 426' to 450' appears to be a channel oriented nearly North-South. The data does not indicate a transport direction.

The fluvial channel from 470' to 482' shows transport to the south and what looks like drape into the channel to the NE. The borehole apparently hit the upstream end of what may be a point bar.

The sand from 492' to 506' shows drape into the channel near the top of the body and transport to the west. Sand lineation is primarily E-W.

Thank you for using our services, feel free to call on us at anytime.

Sincerely,

SCHLUMBERGER WELL SERVICES

Steve Jorgensen

Steve Jorgensen
Sales Engineer - Dipmeter

SDJ:jaw

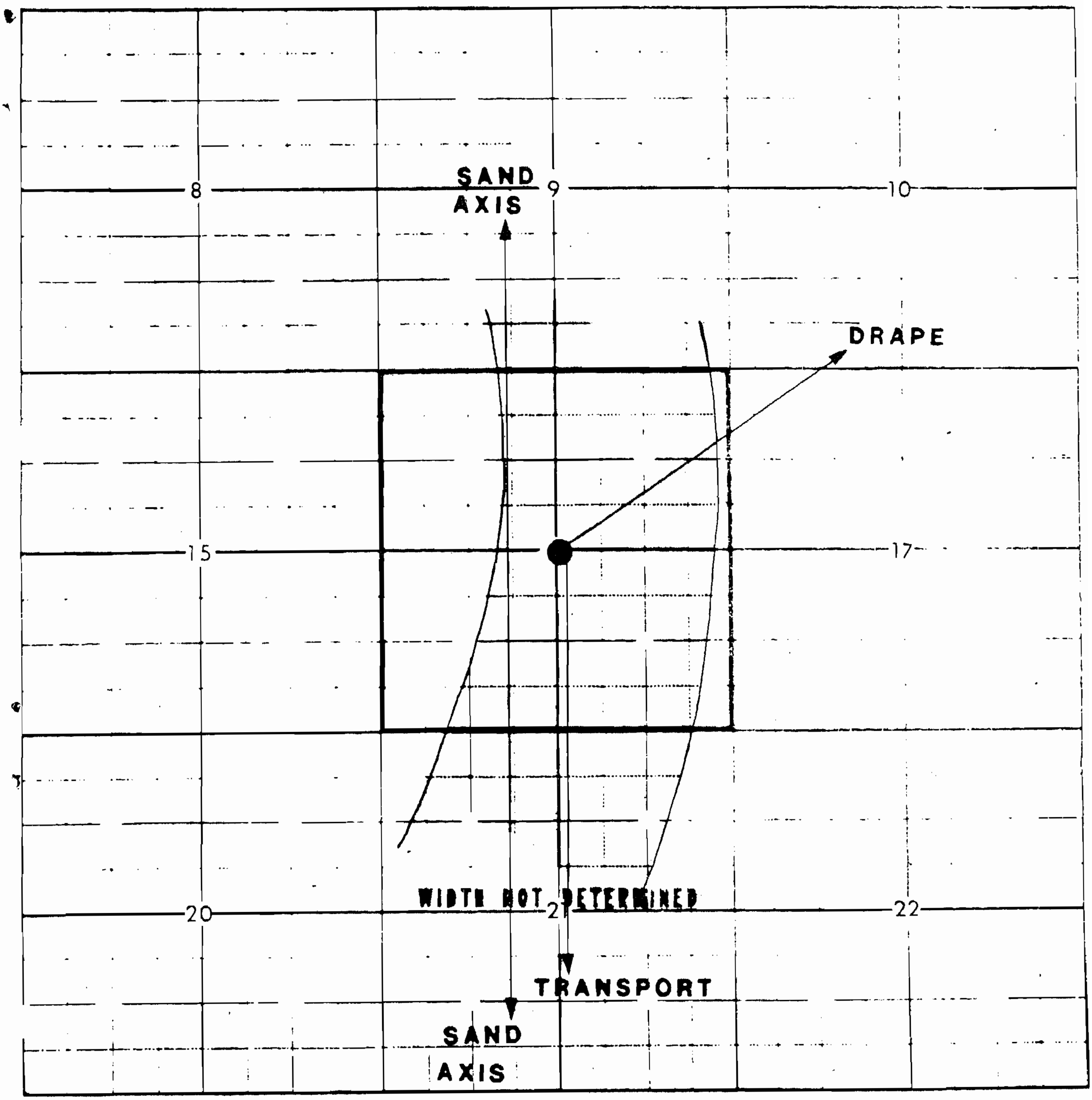
Job #11037

DOE-GC-1B

Township 12S, Range 25E, County GRAND, State UTAH,

LOCATION OF WELL IS PLACED IN CENTER OF SECTION AS NO SPOT LOCATION WAS AVAILABLE.

470'-482'

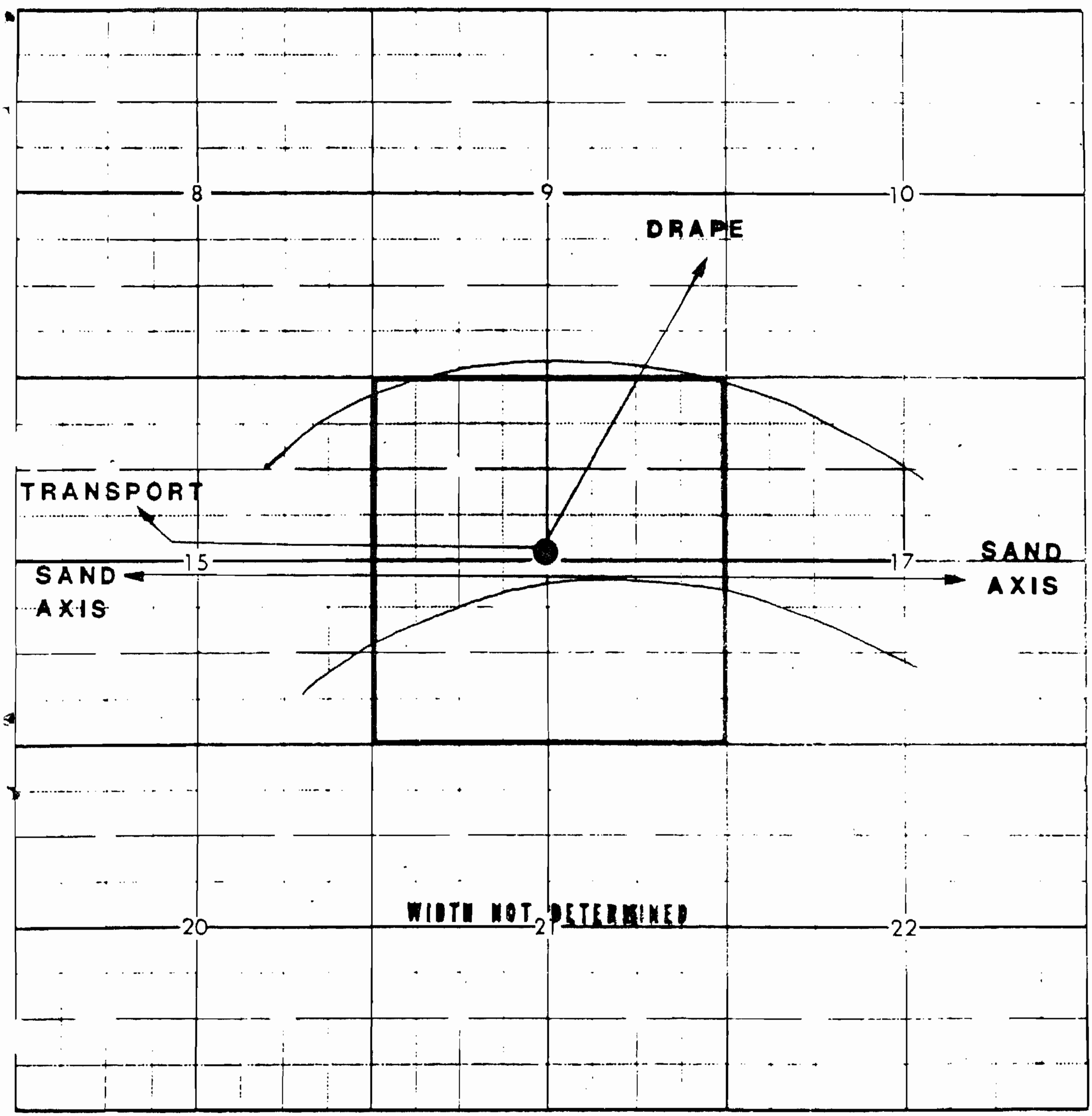


FORM 53

Township 12S, Range 25E, County GRAND State UTAH.

LOCATION OF WELL IS PLACED IN CENTER OF SECTION AS NO SPOT LOCATION WAS AVAILABLE.

492'-506'

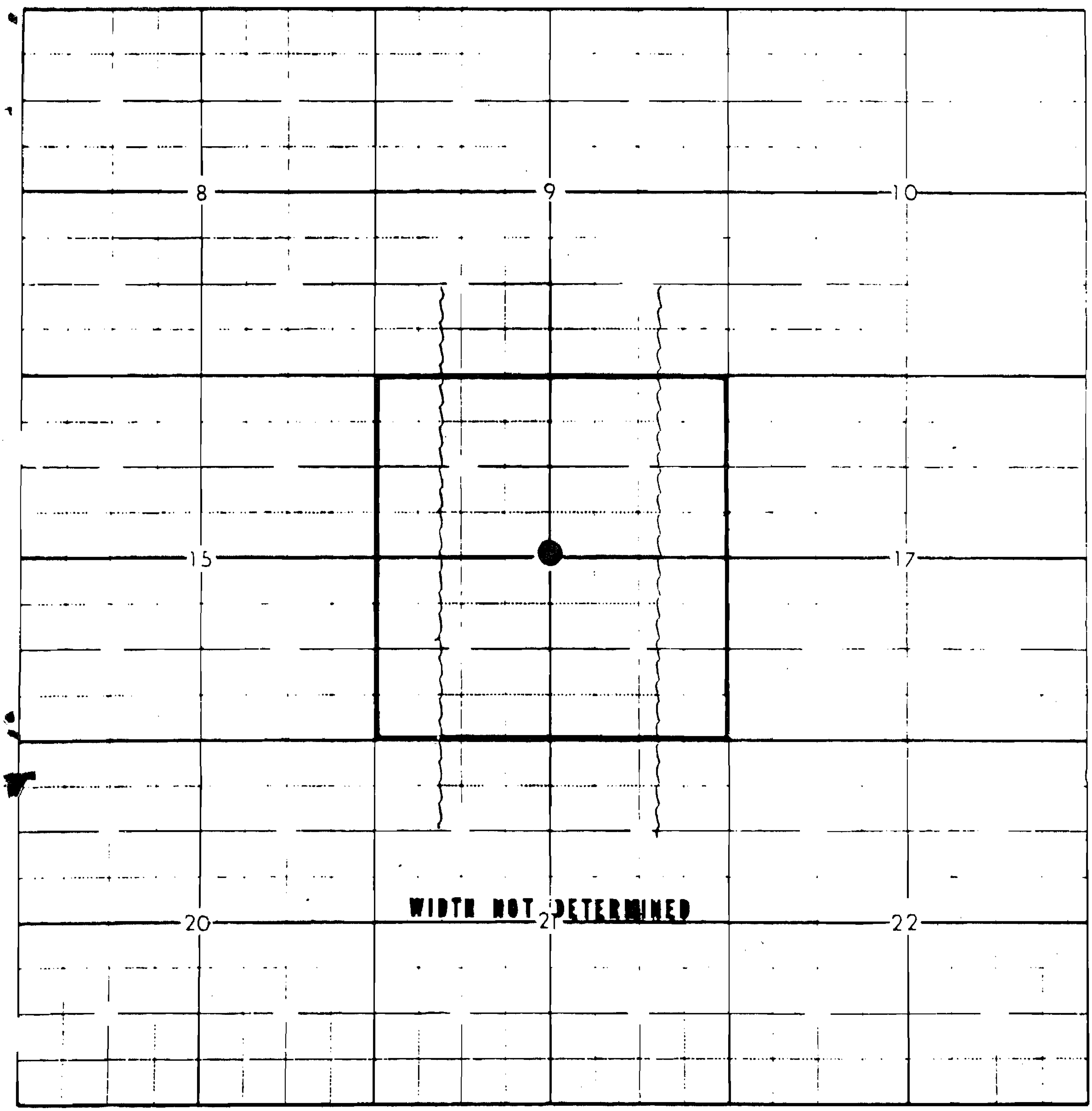


FORM 53

Township 12S, Range 25E, County GRAND, State UTAH,

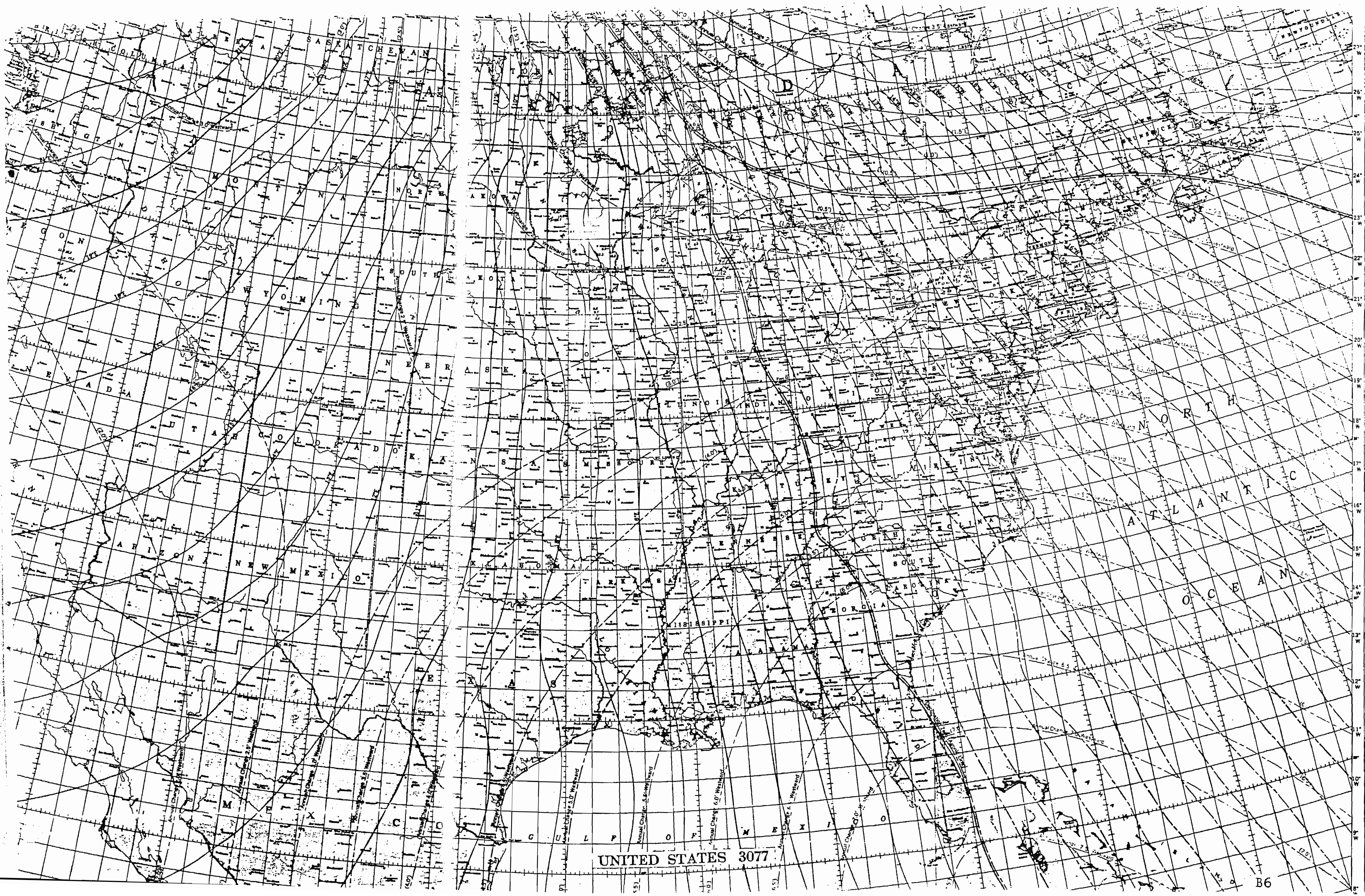
LOCATION OF WELL IS PLACED IN CENTER OF SECTION AS NO SPOT LOCATION WAS AVAILABLE.

426'-450'



FORM 53

4.6


UNITED STATES 3077
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GULF OF MEXICO
MEXICO