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GEOLOGIC EVALUATION AND DRILLING PROGNOSIS FOR EGSP-TENNESSEE NO. 9 WELL GRAINGER COUNTY, TENNESSEE

LAVERNE B. COBB

PAUL LANGSTON

SUBMITTED TO
U.S. DEPARTMENT OF ENERGY
MORGANTOWN ENERGY TECHNOLOGY CENTER
UNDER CONTRACT NO. DE-RP05-79MC0838

GRUY FEDERAL, INC.
2500 TANGLEWILDE, SUITE 150
HOUSTON, TEXAS 77063

AUGUST 24, 1979

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GEOLOGIC EVALUATION AND DRILLING PLAN

EGSP-TENNESSEE 9 WELL

I. INTRODUCTION AND SUMMARY

The Eastern Gas Shale Project (EGSP) was initiated in 1976 at the Department of Energy's Morgantown Energy Research Center with the ultimate objective of increasing production of natural gas from shale formations in the Appalachian, Illinois and Michigan Basins through advanced exploration and extraction techniques. To date numerous projects involving state agencies, the U.S. Geological Survey (USGS) and private industry have been completed. A part of this program has been the evaluation of the Devonian-Mississippian age Chattanooga Shale in eastern Tennessee. The evaluation of the Chattanooga Shale in eastern Tennessee has involved the cooperative effort of personnel from the Tennessee Division of Geology (TDG) and the USGS to define the structural and stratigraphic relationship of the Chattanooga and its resource potential. To date two Vibroseis seismic surveys and eight NX core holes have been completed in northeastern Tennessee as part of the EGSP. Evaluation of the seismic lines, core samples and geophysical logs is in progress and reports on this work by the principal investigators are in preparation. A summary of the EGSP exploration program in Tennessee by Dean (May, 1979) is included as Appendix A.

Gruy Federal, Inc. (GRUY) has been selected as prime contractor to DOE to provide drilling, coring and well evaluation services on up to 22 wells in the Appalachian, Michigan and Illinois Basins. As part of this

contract, GRUY will be responsible for the continued drilling program in Tennessee. GRUY has reviewed the work completed to date and has discussed work in progress with the principal investigators. An evaluation of the geologic data and site availability and accessibility indicates that an area along the Saltville Fault in Grainger County, Tennessee (Dean's Prospect P3) would provide an excellent opportunity to evaluate the Chattanooga beneath the Saltville Fault thrust sheet in a location that has numerous technical and economic advantages.

The site proposed in this report is located in the Grainger County Industrial Park along U.S. Highway 11-W and is accessible by paved roads into the industrial park. At the proposed location it appears that it is possible to penetrate both the Pumpkin Valley Shale member of the Conasauga Group and the Rome Formation (Cambrian age) in the hanging wall of the Saltville Fault. A nearly complete section of Grainger (Mississippian age) and a complete section of the Chattanooga should be present beneath the fault. Additionally the proposed location would provide an opportunity to evaluate the Clinch Sandstone (Silurian age) at a prospective depth. At the proposed location a trapping mechanism exists at the truncation of the Chattanooga and Clinch by the thrust sheet. The proximity to the fault and the breached synclinal structure of the Chattanooga and Clinch at the proposed location should produce high fracture density. The total depth of the hole is not likely to exceed 3000 feet which will result in reasonable drilling cost. The proposed site is owned by Grainger County who will retain all mineral rights and will take over the well following the completion of drilling and testing, should it prove productive. Site preparation cost will be

more reasonable than other location in the area because of the easy access to the site by paved roads into the industrial park.

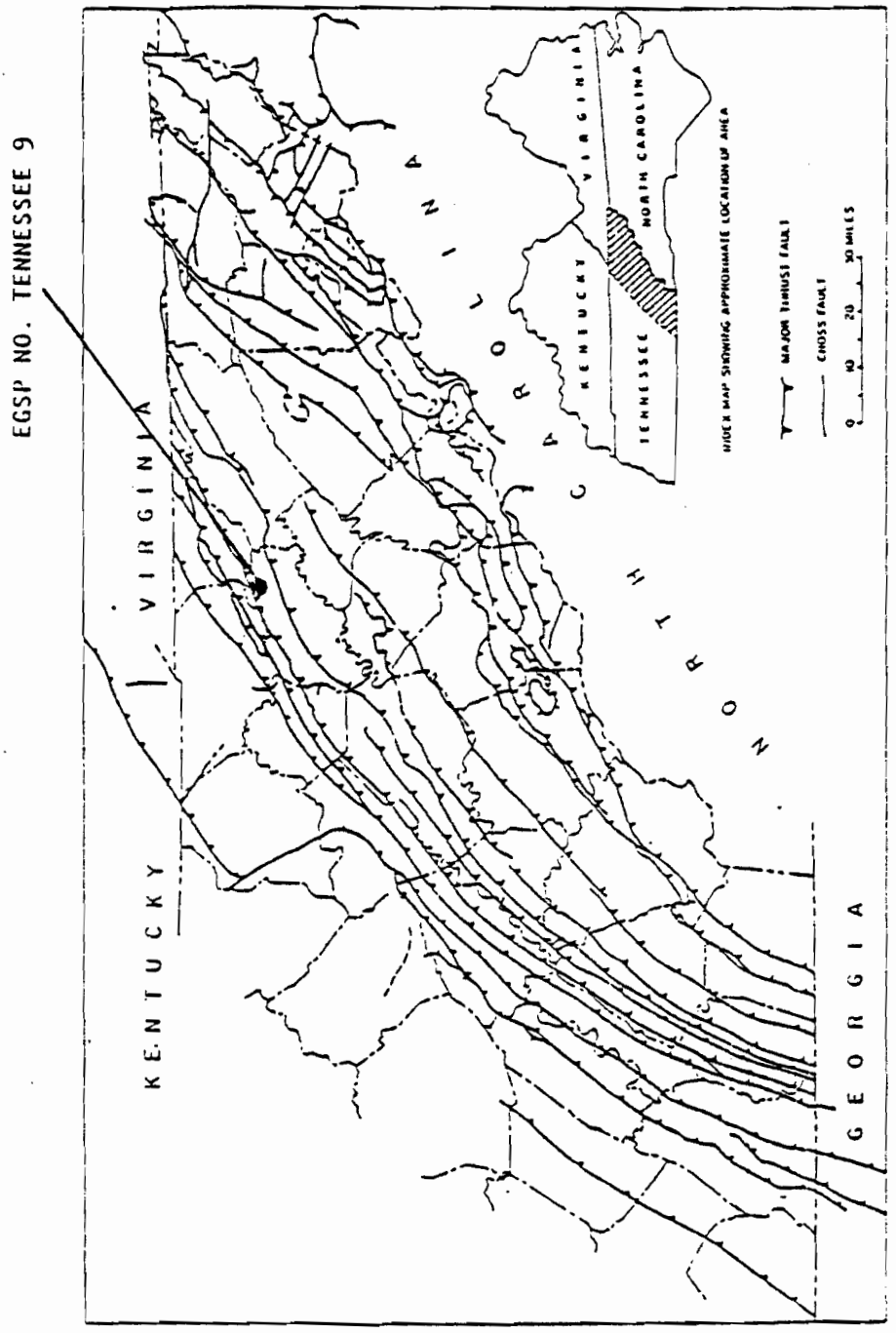
This report presents a summary of previous geological investigations in the area and a drilling prognosis with cost estimates for the Grainger County Industrial Park site, herein refered to as the EGSP-Tennessee No. 9 well.

II. GEOLOGIC SETTING

A. Structural and Topographic Features

The proposed EGSP-Tennessee 9 well is located in the southern Appalachian Valley and Ridge Province. The topography of the Valley and Ridge Province, as the name implies, is characterized by alternating broad valleys and narrow ridges. These topographic ridges and valleys reflect the predominant structural features of the area - parallel northeast-southwest trending folds and thrust faults (Figure 1). The ridges, averaging 500 feet of relief above the valley floors, are the result of differential weathering of rocks of varying resistance brought to the surface in the structural folds and thrust faults produced during the crustal deformation that occured in the late Paleozoic Appalachian Orogeny. The mechanism believed to have produced the Appalachian Valley and Ridge structures is discussed by Dean, 1979 (Appendix A).

The EGSP-Tennessee 9 drilling prospect will be located south of the surface trace of the Saltville Fault between Rutledge and Bean Station, Tennessee, as shown in figure 2. The drill site at the Grainger County Industrial Park is situated on rolling hills in Richland Valley at the base of Poor Valley Ridge. A segment of Cherokee Lake (resulting from the impoundment of the Holston River) forms the floor of Richland Valley to the south and east of the drill site. Poor Valley Ridge, north of the drill site, is formed by resistant sandstones in the Rome Formation (Cambrian age) and the Grainger Formation (Mississippian age). North of



Major thrust faults in eastern Tennessee. (*After J. D. Rogers, Bull. 58, Tennessee Div. Geol.*)

FIGURE 1. STRUCTURAL SETTING OF EGSP NO. TENNESSEE 9 WELL.

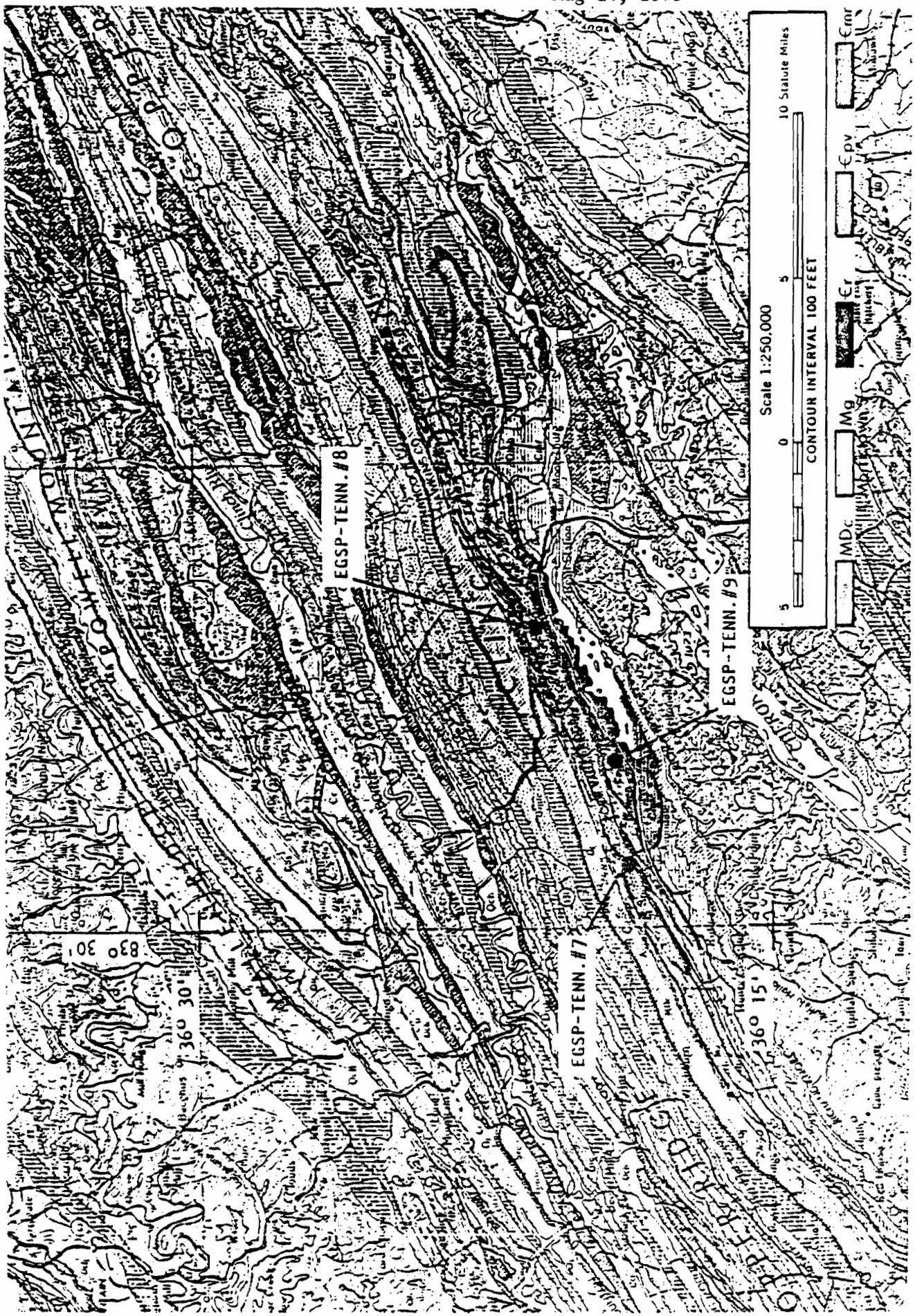


FIGURE 2. APPROXIMATE LOCATION OF EGSP-TENNESSEE WELLS 7,8, AND 9, PLOTTED ON GEOLOGIC MAP OF TENNESSEE (HARDEMAN, 1966).

Poor Valley Ridge is Poor Valley formed in the less resistant shales and siltstones of the Grainger Formation (middle and lower members) and the Chattanooga Shale. Poor Valley is bounded on the north by Clinch Mountain capped by the highly resistant Clinch Sandstone (Silurian age).

Clinch Mountain forms a drainage divide between the Clinch River on the north and the Holston River (Cherokee Lake) on the south. Clinch Mountain rises from 1,000 to 1,600 feet above the adjoining valley and is 400 to 800 feet higher than the parrallel Rome ridges. The photo in Figure 3 taken at the eastern entrance to the Grainger County Industrial Park at US 11-W shows Poor Valley Ridge and the higher Clinch Mountain in the backgroung. An excerpt from Jeran's 1965 M.S. thesis (Figure 4) illustrates the stratigraphic, structural, and topographic relationship of the rock units along a segment of Clinch Mountain and Poor Valley southwest of the proposed drill site on the adjacent Dutch Valley Quadrangle (154-SE).

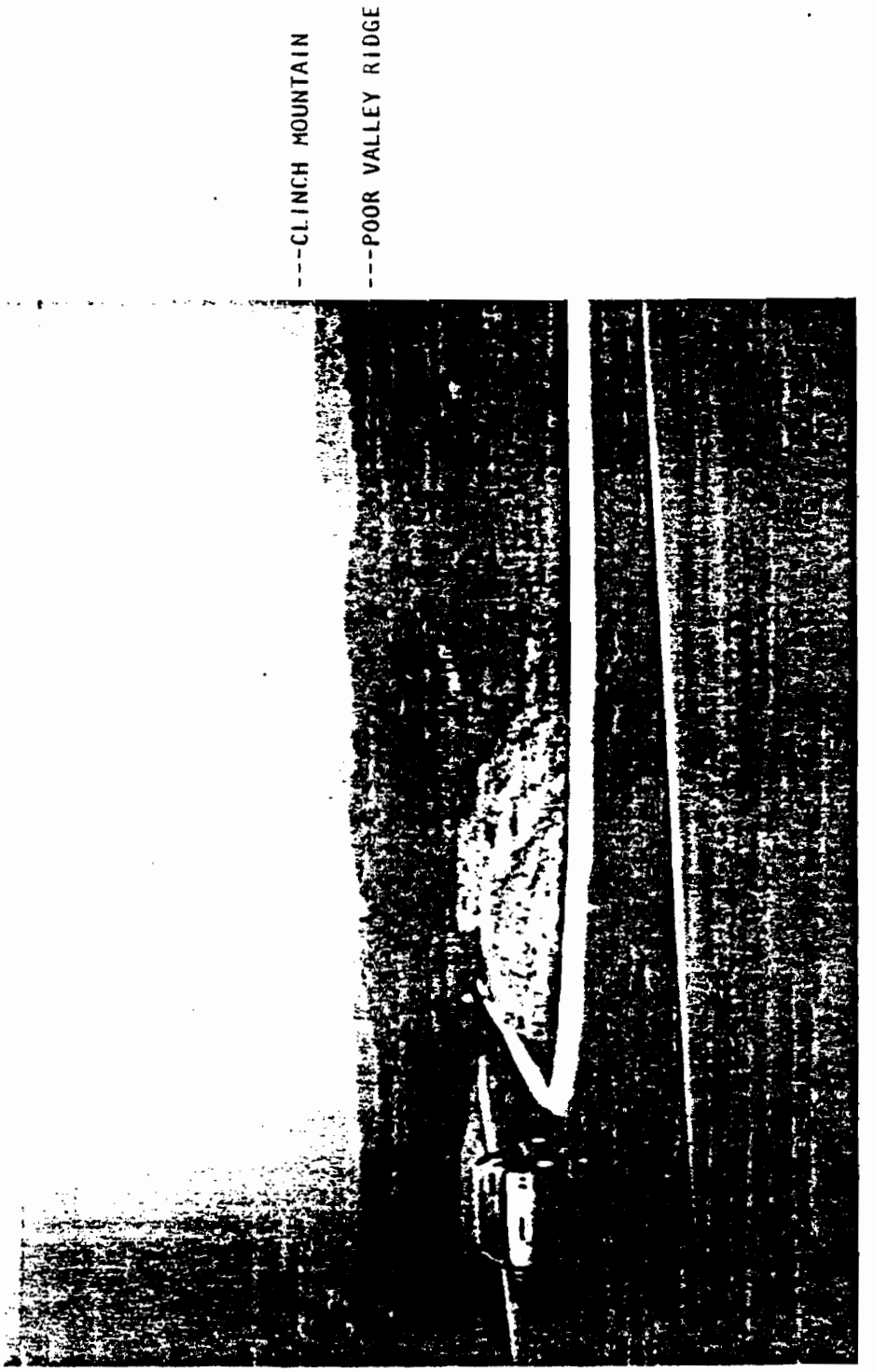


FIGURE 3. EASTERN ENTRANCE TO GRAINGER COUNTY INDUSTRIAL PARK. POOR VALLEY RIDGE AND CLINCH MOUNTAIN IN BACKGROUND.

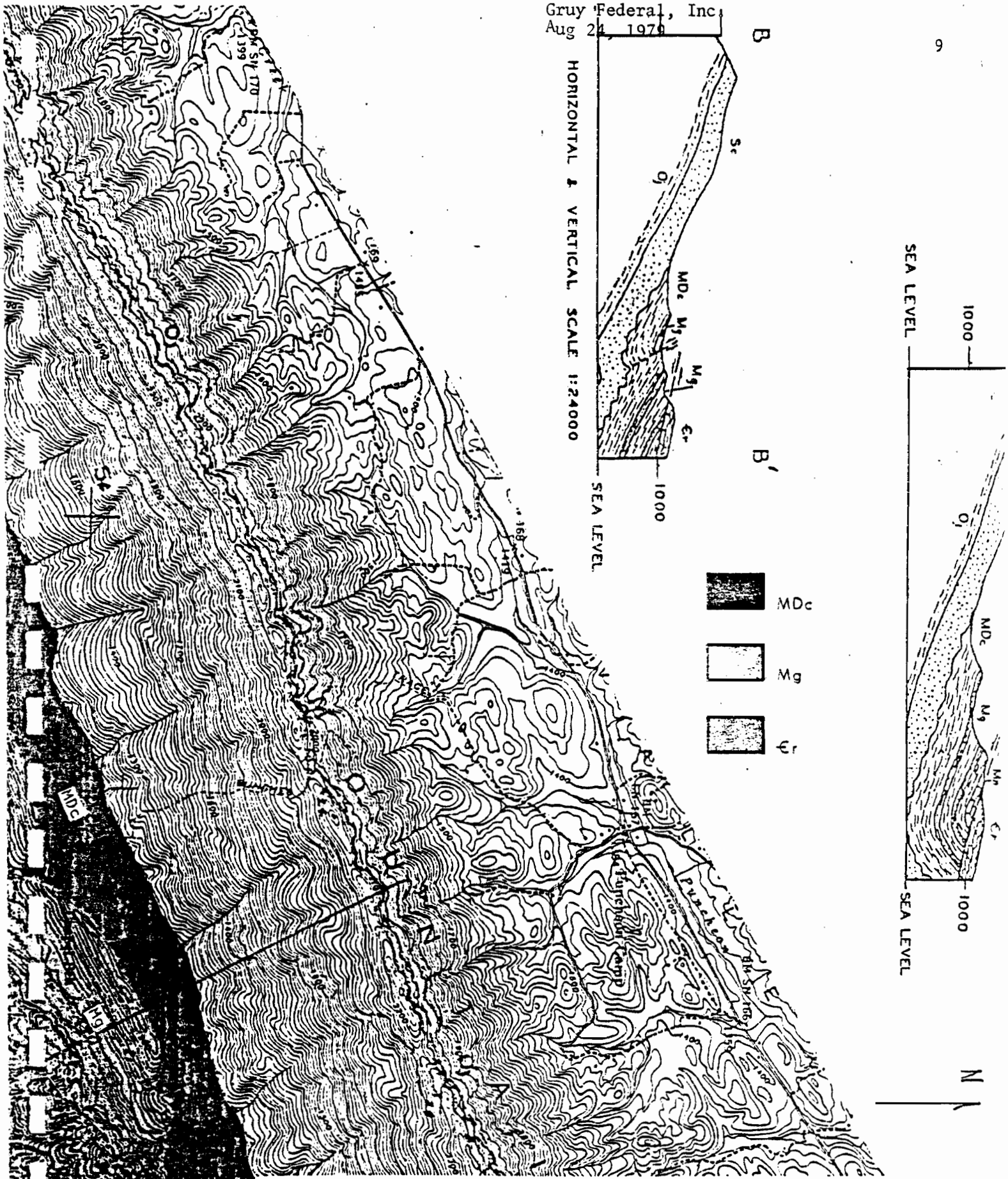


FIGURE 4. STRUCTURAL AND TOPOGRAPHIC RELATIONSHIPS ALONG A SEGMENT OF CLINCH MOUNTAIN AND POOR VALLEY SOUTHEAST OF THE PROPOSED EGSP-TENNESSEE 9 WELL. MAP SHOWN IS A PORTION OF THE DUTCH VALLEY QUADRANGLE IN GRAINGER COUNTY (JERAN, 1965)

B. Stratigraphy

As indicated in the previous discussions, all formations outcropping in the area near the drill site are Paleozoic in age. The Rome Formation (Lower Cambrian) is the oldest rock unit exposed; the Grainger Formation (Middle Mississippian) is the youngest. A generalized stratigraphic column for the Poor Valley area north of the well site in Grainger County (Jeran, 1965) is shown in Figure 5. The Pumpkin Valley Shale member of the Conasauga Group (Cambrian) stratigraphically comformable and immediately above the Rome formation, outcrops at the proposed drill site. Jeran's map area did not extend to Richland Valley; therefore, the Pumpkin Valley is not mentioned in Figure 5.

The name Chattanooga Black Shale was proposed by Hayes, 1891, for exposures at Cameron Hill in Chattanooga, Tennessee. The age of the Chattanooga Shale in the area of interest, while still subject to debate, is currently defined as Upper Devonian to Lower Mississippian. Hasson (1972) provides an interesting review of the history of the nomenclature of the "black shale" in northeastern Tennessee which is summarized in Figure 6. Conant and Swanson (1961) also have an extensive review of the nomenclature; however, their areas of concentration are west of the thick Chattanooga sections in northeastern Tennessee. The nomenclature problems of the Chattanooga can best be summarized by Safford (1869) when he refered to the "black shale" as the "geologist plane of reference, and his puzzle". A comparison of referenced stratigraphic sections for this area and other states (Swager, 1978) is shown in Figure 7.

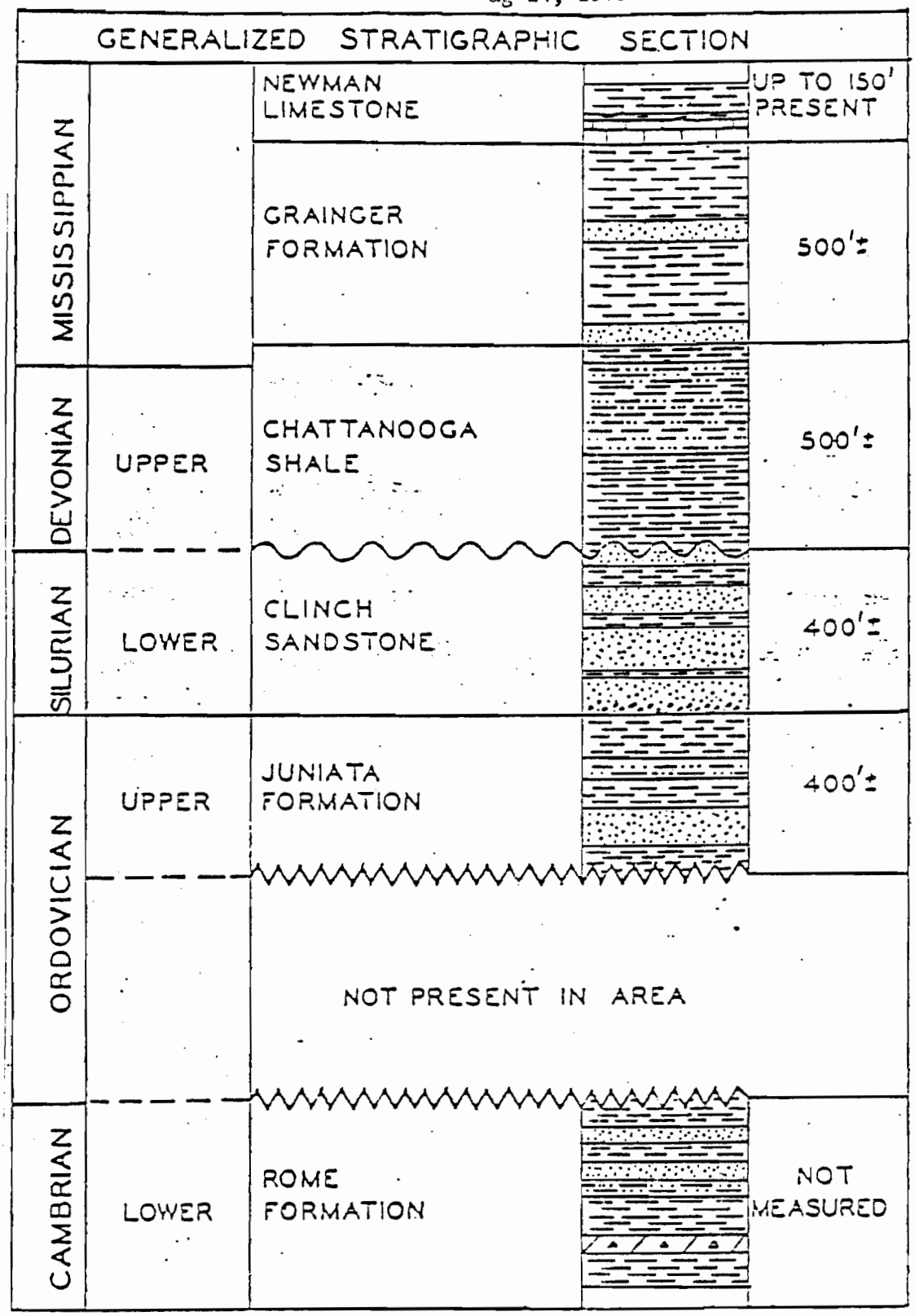
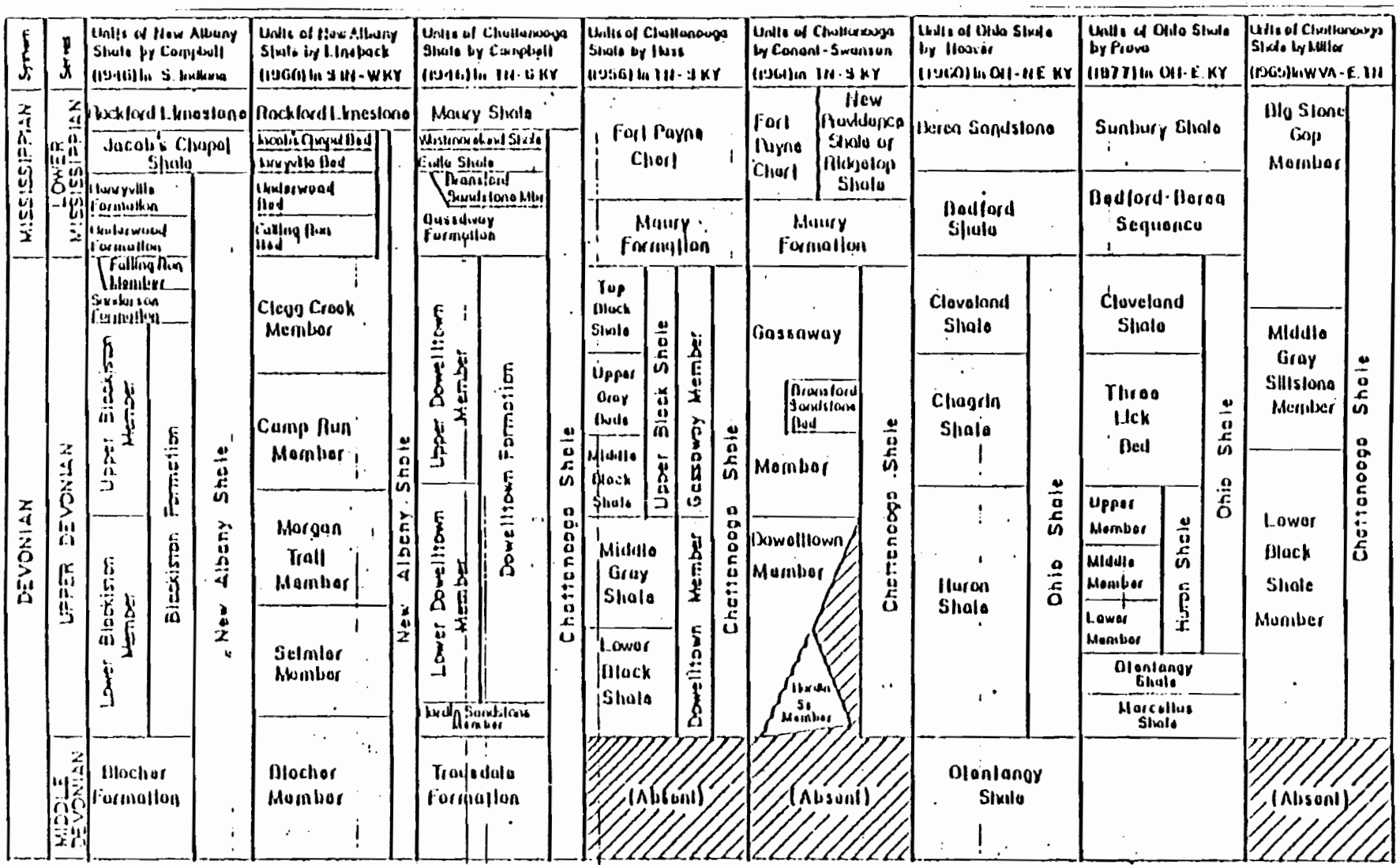


Figure 5. Generalized stratigraphic section in Poor Valley area of Grainger County, Tennessee (Jeran, 1965).

SAFFORD (1869)	Campbell (1894) Rutherfordville folio	Keith (1896) Harrisonburg folio	Stose (1923) SW Virginia	Stose SW Virginia (1929b)	Sanders (1952) Greendale Syncline	Harris and Miller (1958) (Duffield, Va. Quad.)	Rosa, et al. (1964) SW Virginia	Oliver, et al. (1969) Clinch Mtn.	Hasson, this report (Greendale syncline)
Siliceous Grp. Lithostrotion Mbr.	Newman Limestone	Newman Limestone	Newman Formation Haccrady Formation	Newman Ls. Haccrady Fm.	Newman Grp. Haccrady Fm.	Greenbrier Ls. Haccrady Shale			Newman Ls. Haccrady Fm.
Protean Member	Grainger Shale	Grainger Shale	Price Sandstone	Price Sandstone	Grainger Fm. Upper SS Mbr. Middle Mbr. Lower SS Mbr. Basal Mbr.	Price Sandstone	Price Formation	Grainger Formation	Grainger Fm. Upper SS Mbr. Middle Mbr. Basal Siltst. Mbr.
Black Shale	Chattanooga Shale: Black Carbonaceous shale unit Ash-colored sandy or micaceous unit Black carbonaceous shale unit	Chattanooga Shale	Chattanooga Shale: Big Stone Gap Shale Portage Genesee	Chattanooga Shale: Big Stone Gap Mbr. Olinger Sh. Mbr. Cumberland Gap Mbr. Chemung and Portage Fms.	Chattanooga Shale: Salt Lick Gap Mbr. Klepper School Mbr. Little Mer Gap Shale Mbr.	Big Stone Gap Siltstone Siltstone Unit Shale Unit	Big Stone Gap Mbr. Middle Gray Siltstone Mbr. Lower Black Shale Mbr.	Chattanooga Shale: Big Stone Gap Mbr. Gray Silty Shale Unit Lower Black Shale Unit	Chattanooga Shale: Big Stone Gap Mbr. Klepper School Mbr. Lower Black Shale Unit

Figure 6. Summary of Stratigraphic Nomenclature (Hasson, 1972).



Comparison of frequently referenced stratigraphic nomenclature for the shale sequence in southern Ohio, southern Indiana, Kentucky and Tennessee.

Figure 7. Comparison of referenced stratigraphic nomenclature (Swager, 1978).

III. EXISTING GEOLOGIC DATA

A. Previous Investigations

The previous geologic investigations along the Saltville Fault strike belt in Grainger and adjacent counties include several masters theses and doctoral dissertations at the University of Tennessee (Haney, 1966; Hasson, 1972; Hawkins, 1959; Jeran, 1965; Philly, 1961; Smith, 1968) and the seismic lines and shallow NX coring and logging program conducted under contract to DOE by the Tennessee Division of Geology and USGS as described by Dean (Appendix A).

Mr. Larry Knox, Mr. William Bent and Mr. Stuart Maher of the TDG in Knoxville provided GRUY with maps showing the location of core holes EGSP-Tennessee 1, 3, 4, 5, 6, 7, and 8 (Appendix B) and working copies of electric logs on Tennessee 7 and Tennessee 8 (Appendix C). Neither of the above named people were on location during coring of Tennessee 2; therefore, they were unable to spot that hole location. R. C. Millici, Virginia State Geologist, formally with the TDG, provided lithologic discription and gamma ray log curves for Tennessee 6 and 7 (Figure 8).

The seismic-geologic base map (Figure 9); the preliminary depth section interpretation (Figure 10) along line TC-1; Dr. Millici's re-interpreted depth section (Plate 1); and, Hassen's descriptions of stratigraphic sections at Avondale Springs and near Bean Station along 25-E (Appendix D) have been integrated into this evaluation.

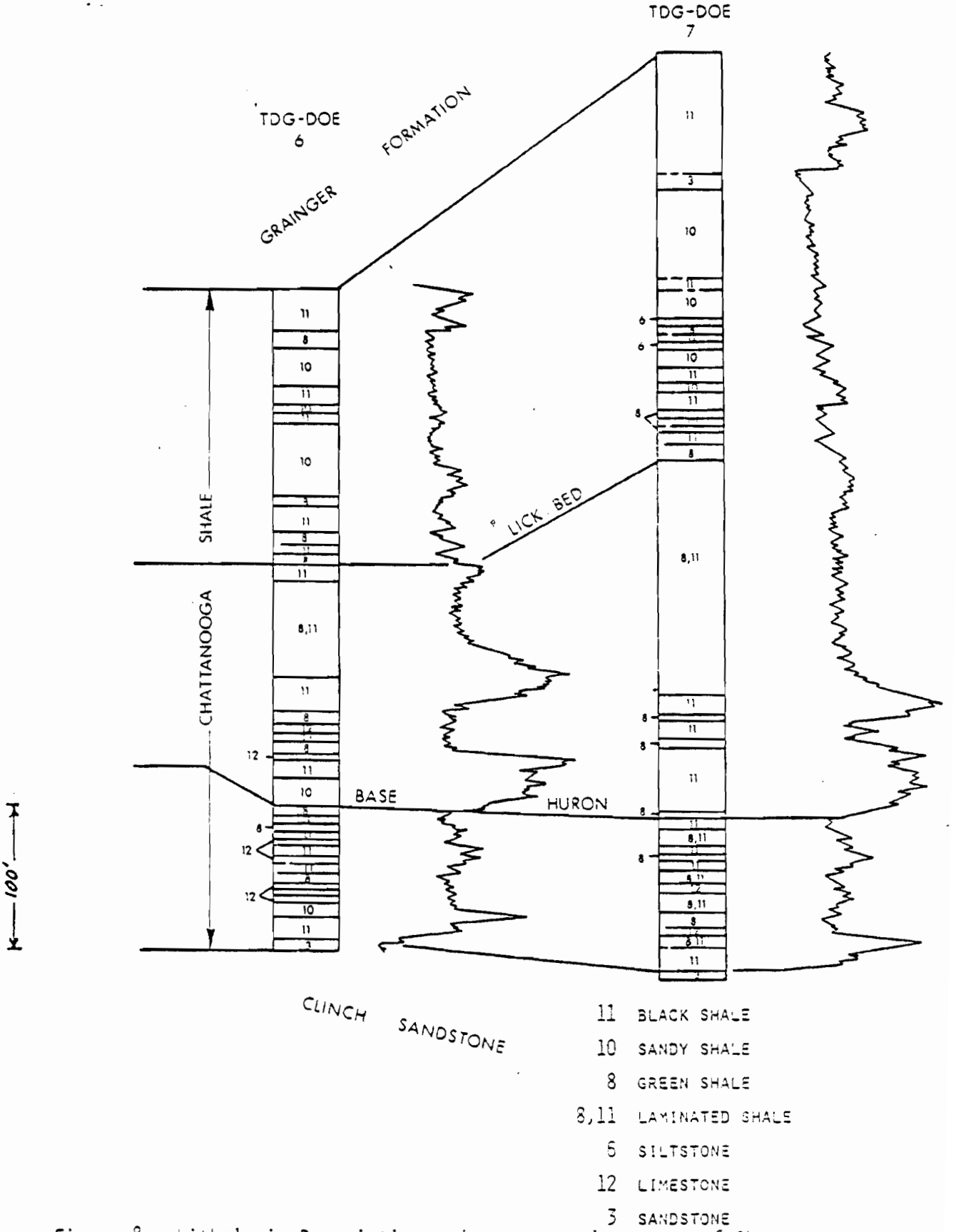


Figure 8. Lithologic Description and gamma ray log curve of Chattanooga Shale in vicinity of proposed well (Millici, in press).

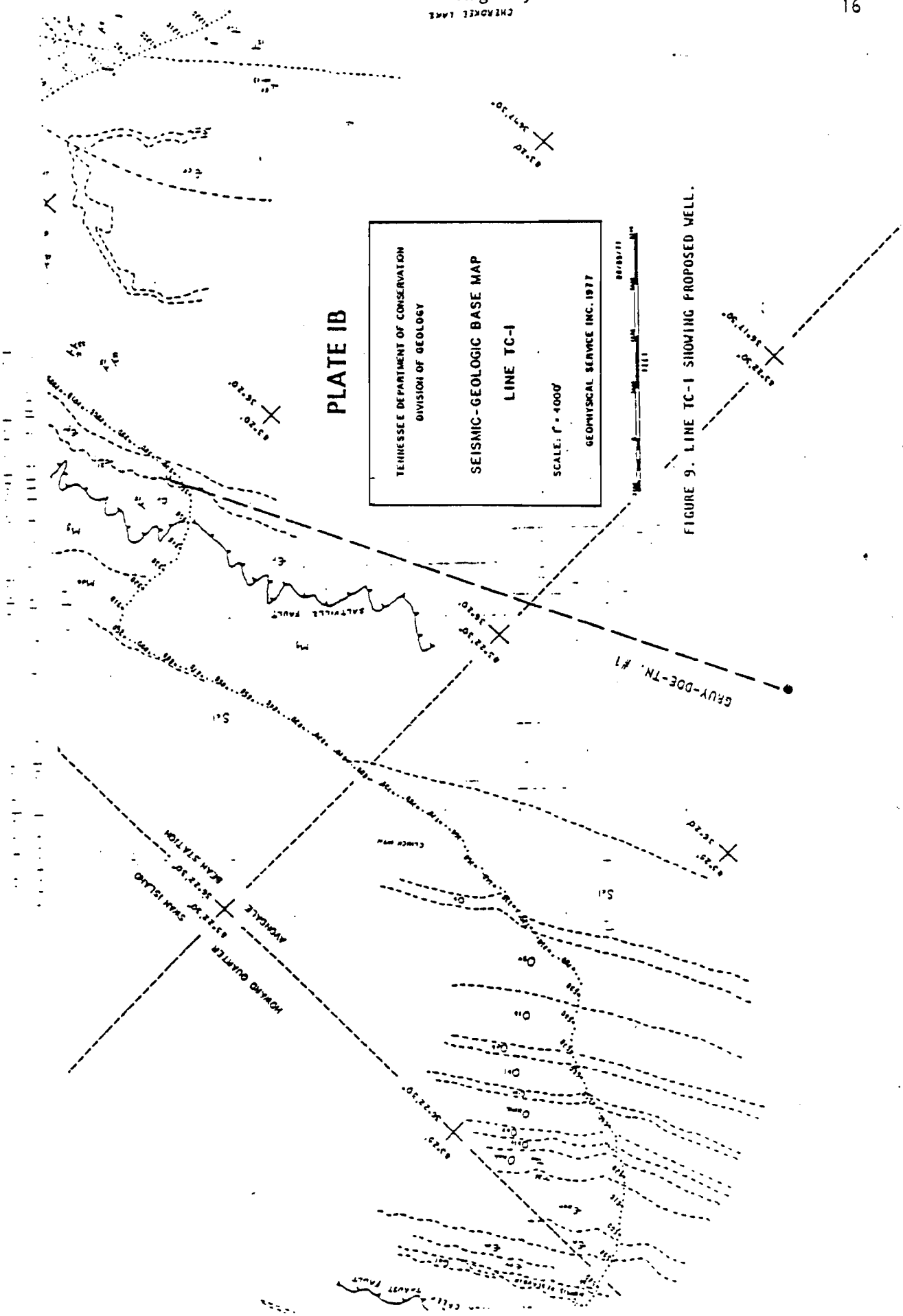


FIGURE 9. LINE TC-I SHOWING PROPOSED WELL.

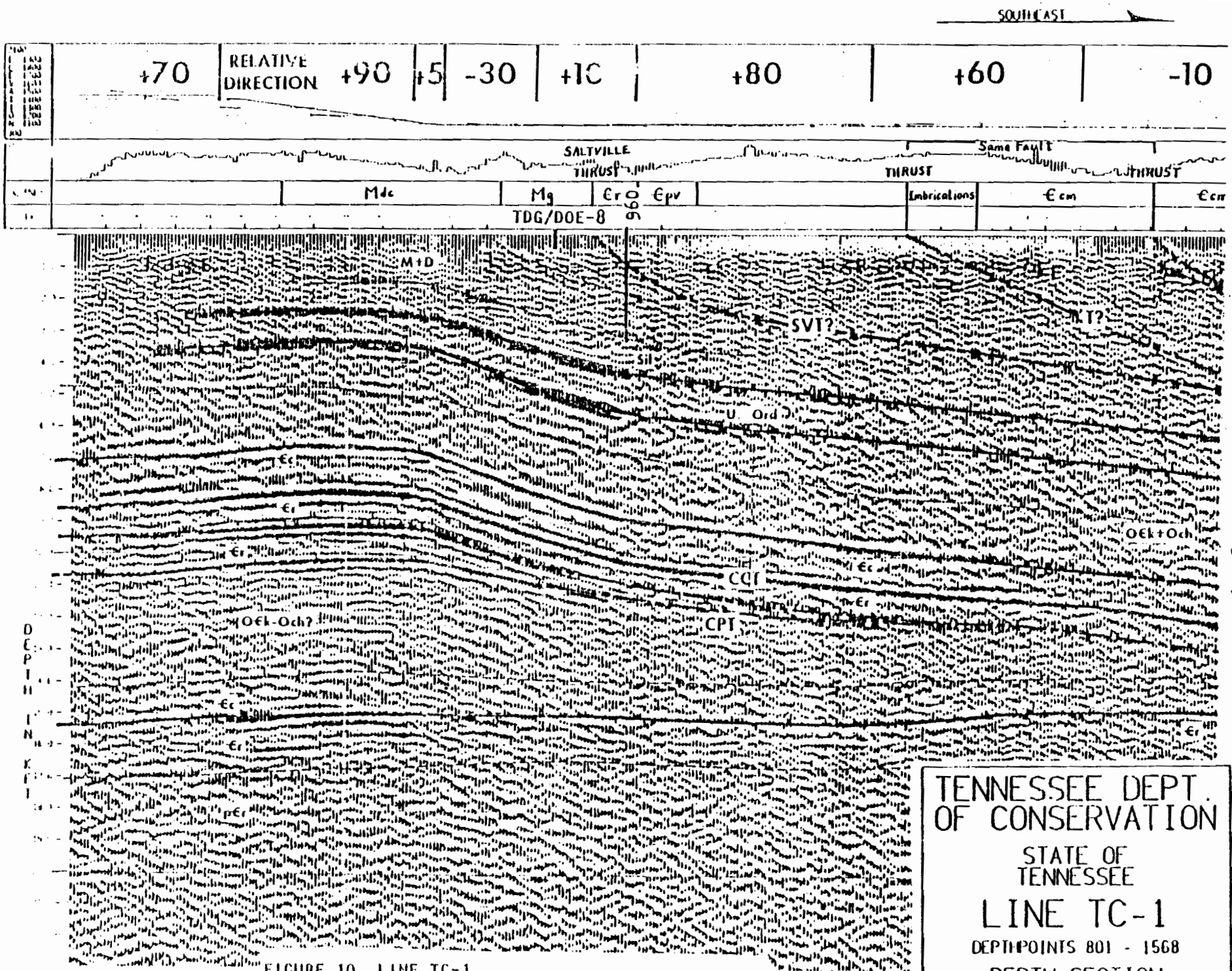


FIGURE 10. LINE TC-1

TENNESSEE DEPT. OF CONSERVATION

STATE OF TENNESSEE

LINE TC-1

DEPTHPOINTS 801 - 1568

DEPTH SECTION

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Hasson's outcrop sections T-11 and T-13 are proximal to EGSP-Tennessee 8 (Tennessee Coordinate: 723,500N; 2,783,250E) and Tennessee 7 (Tennessee Coordinate: 709,550N; 2,747,000E), respectively. Seismic line TC-1 (Figures 9 and 10) follows highway 25-E and passes along Hasson's section T-11 between depth points 900 and 960. Tennessee 8 was spudded near depth point 930. Hasson's section T-12 along old highway 25-E is approximately two miles northeast of the proposed Tennessee 9 (Tennessee Coordinate: 710,300N; 2,762,000E) well site. Section T-11 and seismic line TC-1 are approximately 5 miles northeast of the proposed location.

Sections T-11, T-12, and T-13 are summarized as follows:

T-11 Grainger County
Bean Station Quadrangle
Tenn. Coordinate: 724,600N
2,784,600E

AGE	Formation	Section Thickness (Feet)	
Cambrian	Rome	86.0	
	Saltville Fault		
Missippian	Grainger	437.8	
	Upper Sandstone Member		52.0
	Middle Shale-Siltstone Member (Glauconite Zone 35.6 feet from top of Middle Member is 7.7 feet thick)		301.3
	Basal Siltstone Member		134.5
	Chattanooga Shale		409.95
	---		---
	---		---
	Lower Black Shale Unit		23+

T-12 Grainger County
Avondale Quadrangle
Tenn. Coordinate: 718,400N
2,771,200E

Age	Formation	Section Thickness (Feet)
Cambrian	Rome	52+
	Saltville Fault	
Mississippian	Grainger	543.2
	Upper Sandstone Member	97.0
	Middle Member (Glauconite Zone 42.0 feet from top of Middle Member is 9.4 Feet thick)	297.7
	Basal Siltstone Mimber	148.6
	Chattanooga Shale	316+

T-13 Grainger County
Avondale Quadrangle
Tenn. Coordinate: 709,000N
2,748,000E

Age	Formation	Section Thickness (feet)
Cambrian	Rome	103+
	Saltville Fault	
Mississippian	Grainger	557.0
	Upper Sandstone Member	23.0
	Middle Member (Glauconite zone covered)	512.0
	Basal Siltstone Member	42.0
	Chattanooga	232.3+

Figure 11, Plate II from Hasson's dissertation illustrates his interpretation of the stratigraphic relationships along the Saltville Fault strike belt. An average of Hasson's thicknesses for the Grainger (487.8 at T-11, 543.2 at T-12, and 557 at T-13) has been used for an approximate thickness of the Grainger in the area.

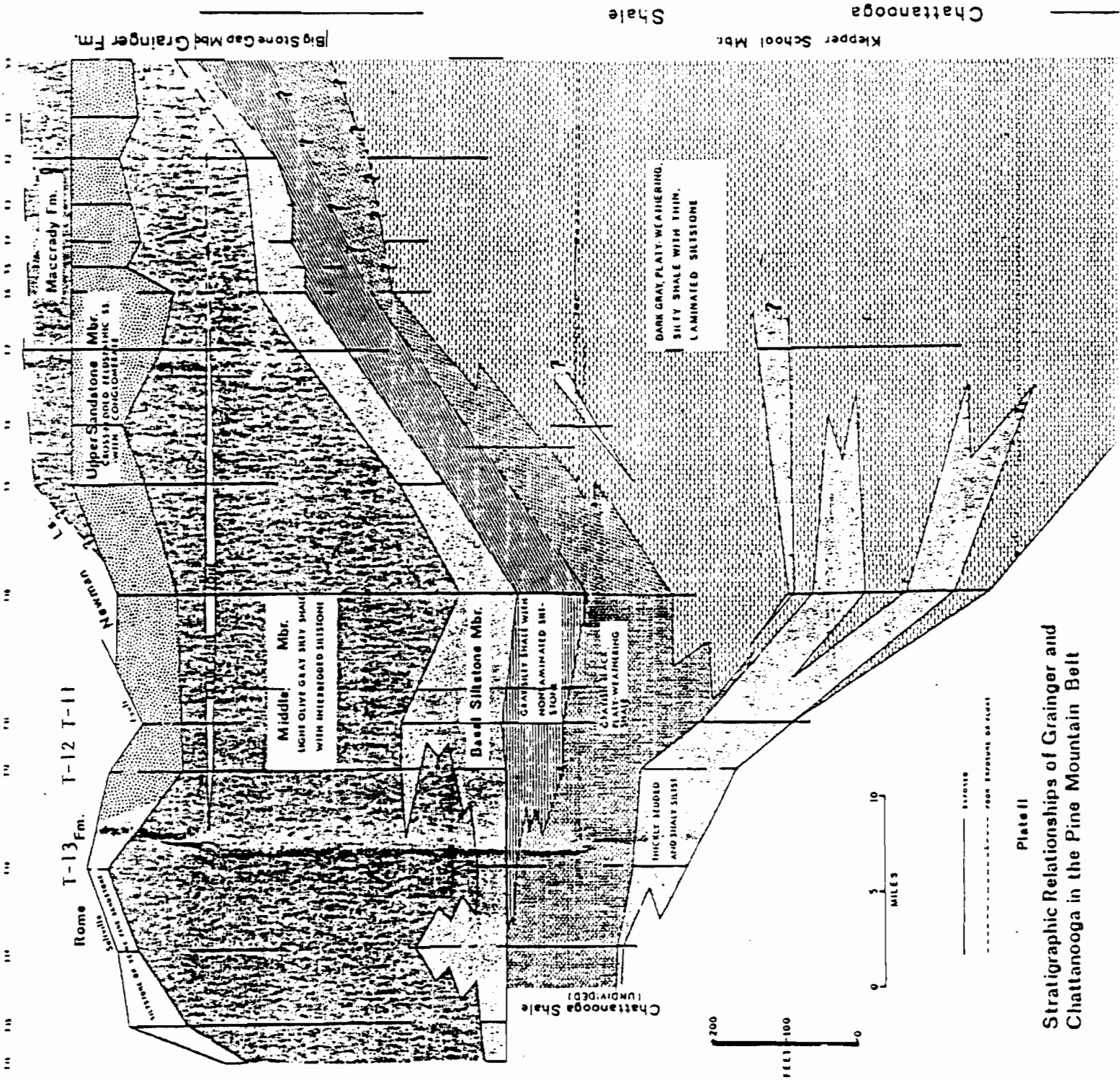

Figure 11. Hasson's (1972) interpretation of the stratigraphic relationships of Grainger and Chattanooga near EGSP-Tennessee 9.

Core hole Tennessee 7 at Avondale Springs was spuded in the Grainger and encountered the top of the Chattanooga at 165 feet and the bottom of the Chattanooga at 827 feet. Tennessee 8 also spuded in the Grainger with the top of the Chattanooga at 140 feet and bottom at 900 feet. The average of the Chattanooga thickness in Tennessee 7 (662 feet) and Tennessee 8 (760 feet) has been used to estimate the thickness of the Chattanooga in Tennessee 9.

The boundary between the Grainger and Chattanooga is subject to interpretation. Some workers have defined the boundary as occuring at the first black shale zone, which may be 10 feet lower than the boundary defined by Hasson. For the purposes of well planning, these differences in definition will be minor. It has been assumed for well planning that the Grainger will have a minimum thickness of 500 feet and the Chattanooga will be a minimum of 700 feet thick at Tennessee 9.

In estimating the thickness of the Rome and Pumpkin Valley near Tennessee 8, the seismic-geologic map for line TC-1 (Figure 9) shows the areal "thickness" of the Rome to average 2500 feet with a dip of less than 20°. The Pumpkin Valley appears to have an areal "thickness" of 1000 feet with similar dips. A simple construction (Figure 12) indicates that the Rome probably has a true thickness on the order of 900 feet and the Pumpkin Valley has a true thickness of approximately 350 feet along TC-1. Assuming the fault plane and rock units above and below have a uniform 20° dip, true thicknesses translate to hole sections of approximately 200 feet of Pumpkin Valley and 950 feet of Rome above the fault near depth point 970. Using previous core hole and outcrop data

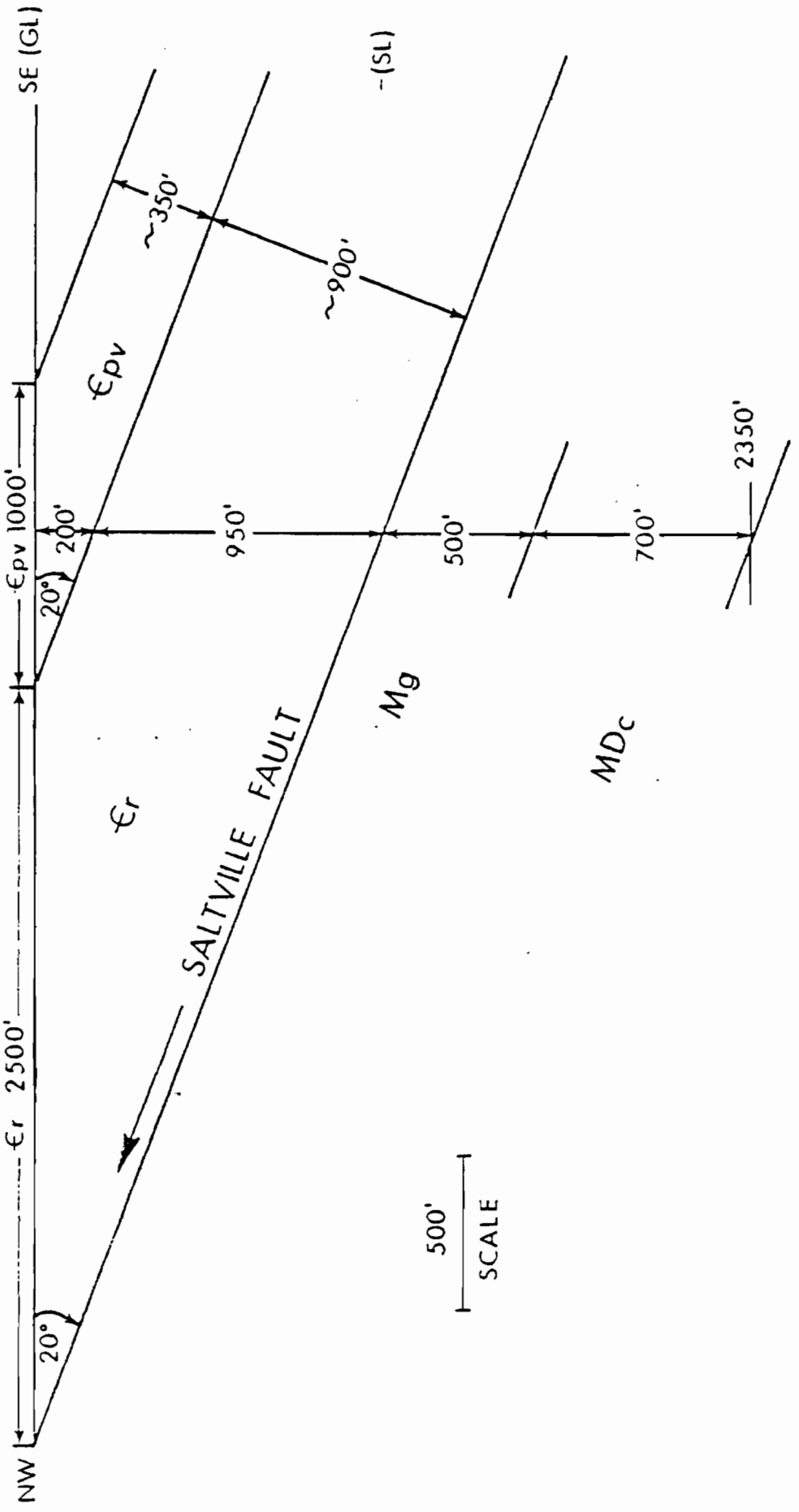

FIGURE 12. ILLUSTRATION OF AREAL EXTENT, TRUE THICKNESS & HOLE SECTION THICKNESS.

indicating at least 500 feet of Grainger and 700 feet of Chattanooga, maintaining the 20° dip below the fault plane and assuming that the thickness of all units remains constant along strike, then a minimum bottom hole depth of 2350 feet could be expected at Tennessee 9.

Other interpertations of this data are possible. As shown in Figure 13, a sketch by Mr. Bill Brent of the TDG in Knoxville, it is possible that the Grainger and Chattanooga could be truncated at a shallower depth.

Figure 14 shows the location of core and stratigraphic data described in this report. At the site of Tennessee 9, the areal extent of the Rome Formation and Pumpkin Valley Shale (based upon projections of Hasson's T-13 and T-12 sections and the topographic expression of various formations) appears to be greater than at Tennessee 8. This could be attributable to a lesser dip on the fault plane, rather than more section. A construction of the apparent areal "thickness" with a 15° dip would indicated that the bottom of the Chattanooga would be at approximately 2,000 feet. A similar construction using a 30° dip would place the bottom of the Chattanooga at 4,200 feet. Outcrop strike and dip measurement by Jeran (1965), Haney (1966) and on the seismic-geologic map of TC-1 indicate that the Grainger, Chattanooga, and Clinch along Poor Valley Ridge are more steeply dipping than the Rome. The higher dips shown at the surface for these formations reflect the synclinal structure of Clinch Mountain and Poor Valley. The formation dip can be expected to decrease as the limbs of the syncline flatten. This is clearly indicated by seismic line TC-1 (Figure 10, Plate I). A con-

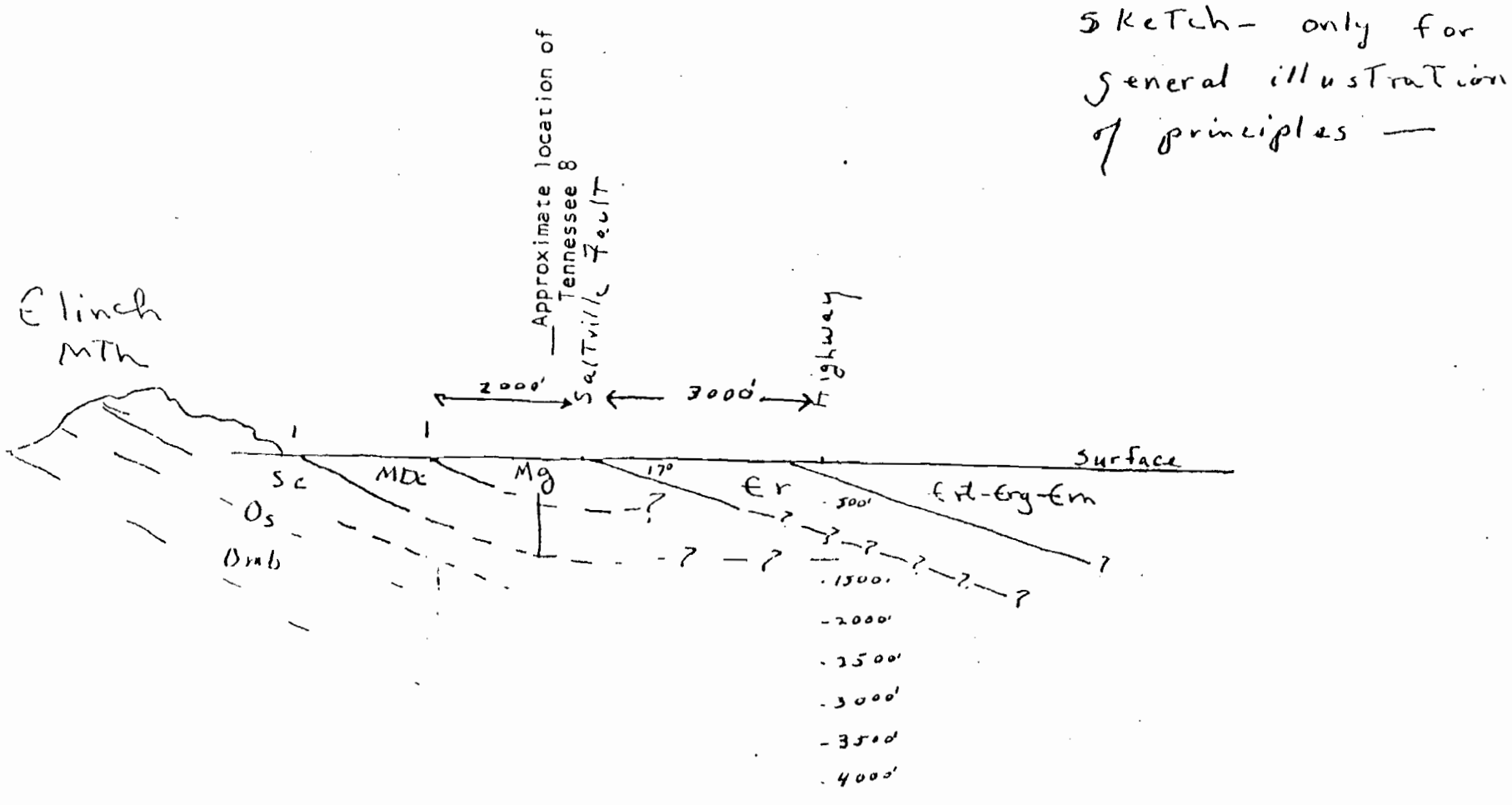

Figure 13. Sketch by Mr. Bill Brent, Tennessee Division of Geology, Knoxville, showing possible truncation of section beneath fault.

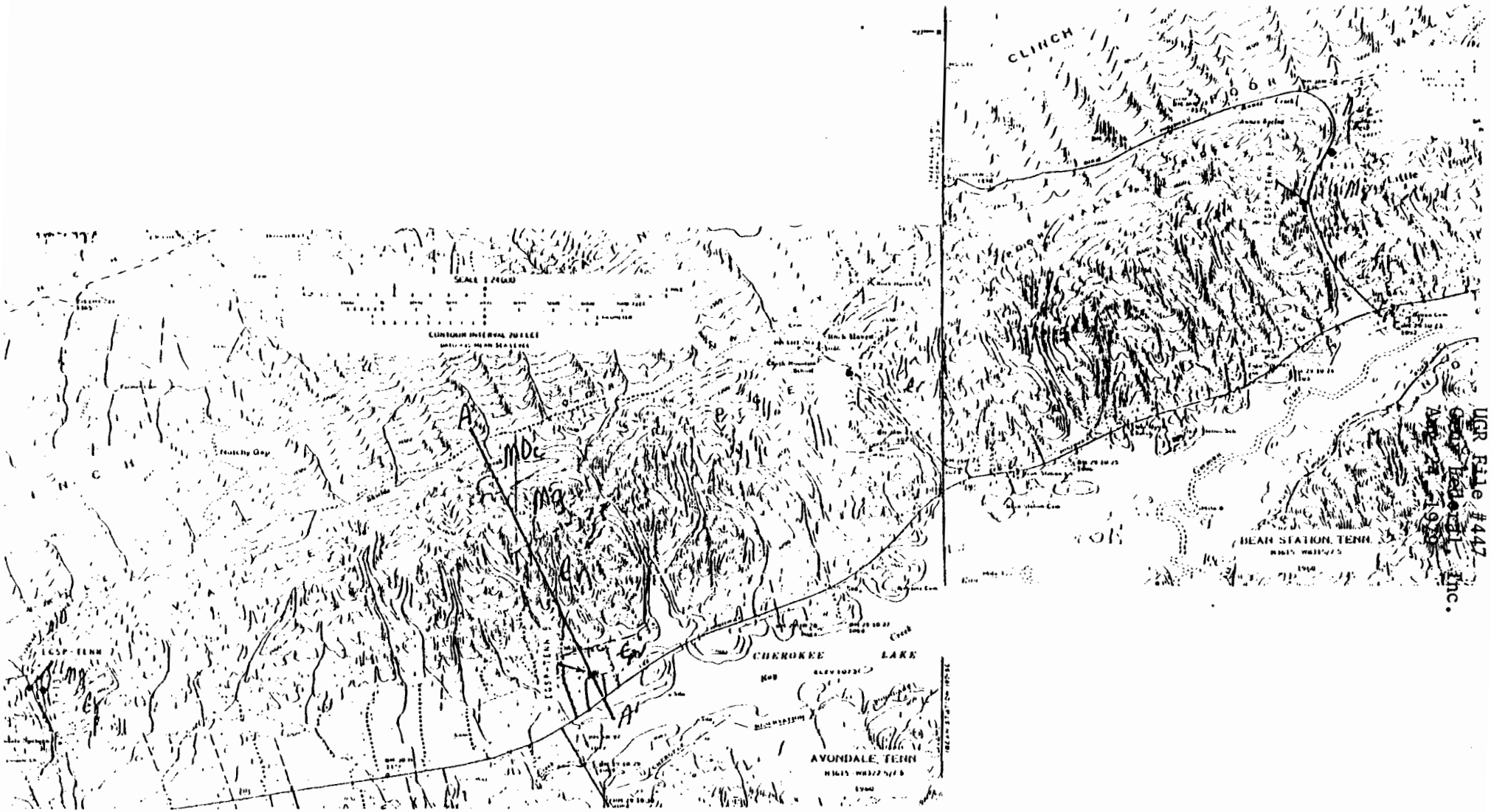

Figure 14. Location of core holes Tennessee 7, 8 and proposed 9 and Hasson's stratigraphic sections T-11, T-12 and T-13.

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struction using this interpretation is shown in Figure 15. This interpretation would place the bottom of the Chattanooga at approximately 2,700 feet hole depth, very close to the depth shown on the reinterpretated seismic line TC-1. The dip used in this interpretation results in and extremely large Grainger section, however. This raises the possibility that the Newman Limestone is present beneath the fault at the Tennessee 9 well location. The Newman, although not shown on TC-1, is known to outcrops along Poor Valley Ridge in other locations (Jeran, 1965; Haney, 1966).

B. Interpretations and Recommendations

As the above exercise indicates, the EGSP Tennessee 9 well is a true wildcat, i.e., the determination of formation boundaries can only be made while drilling. Although the existing data are not conclusive, the Tennessee 9 well has a high probability of encountering a highly fractured, kerogen rich Chattanooga Shale sequence beneath the fault. The Clinch Sandstone beneath the Chattanooga source rock has potential of being a productive reservoir in this location. The drilling, coring, and logging program described in section IV of this report provides for a dual evaluation program.

A limited number of cores in the Chattanooga will be taken during drilling since the previous eight EGSP wells in Tennessee have shown a clean log/rock section interpretation to be possible. The recommended coring intervals are:

1. Base of Grainger - Top of Chattanooga

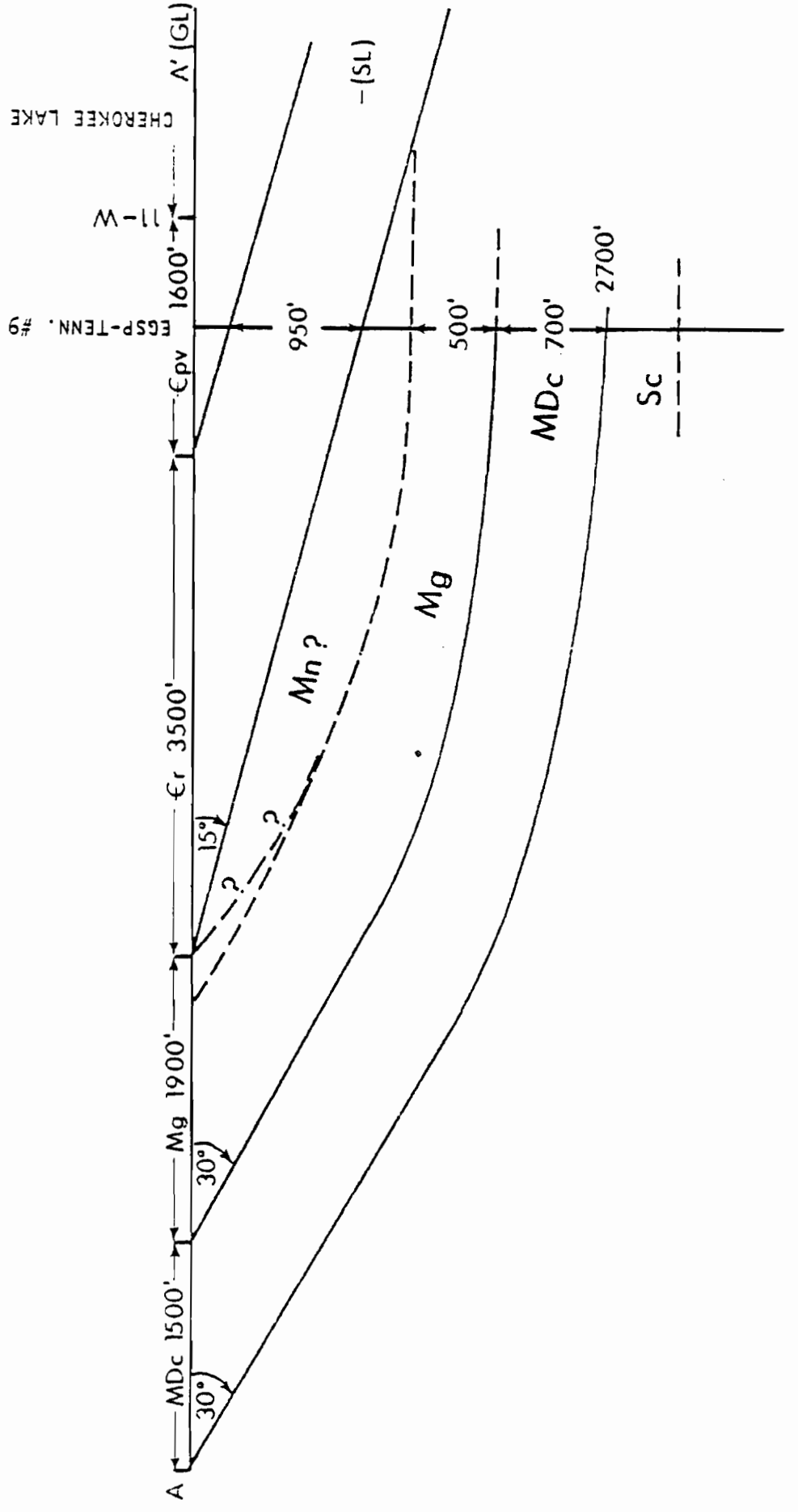


FIGURE 15. INTERPRETED CROSS SECTION AT EGSP-TENNESSEE #9.

2. 180 foot section of Lower Huron member (Figure 8)

3. Base of Chattanooga - Top of Clinch

A 60-foot section of core at the Grainger/Chattanooga boundary is recommended to enable an accurate projection on the depth to the coring interval in the Lower Huron. The cost of obtaining a core at this point during drilling would be less than the cost of mobilizing the logging company and would provide the same information. The Lower Huron core is desirable for geochemical analysis. Another 60-foot core interval at the base of the Chattanooga and top of Clinch (40 feet of Clinch) should be taken to characterize this possible reservoir formation.

The logging program recommended for Tennessee 9 is different than previous EGSP and is intended to provide the same information at less cost. This is described fully in Section IV-Logging Program.

Since the proposed drilling plan does not include continous coring, a cutting sample program is recommended. The sampling interval will be specified by the DOE Technical Project Personnel.

IV. DRILLING PROGNOSIS

A. Well Location

Location: Grainger County, Tennessee
Avondale Quadrangle (7-1/2")
Latitude: 36°18'56"N
Longitude: 83°24'33"W
Tennessee Coordinates: 710,300N
2,762,000E
Elevation: 1100 feet

Lease/Project Agreement: Appendix E

B. Drilling and Coring Procedures

1. Prepare the location to landowner's requirements and as to minimize impact on the land surface. Remove curbing at road side to facilitate a turn-in. Apply 2" gravel stone to the 100' x 200' area and dig the reserve pits.
2. Move in a rotary rig (capacity 3000') and rig up for air drilling.
3. Drill a 17-1/2" hole to approximately 20' with air.
4. Set a joint of 16" O.D. line pipe and cement by wheelbarrow.
5. Drill a 15" hole to approximately 200 feet.
6. Set 13-3/8"-48#-ST-H40 casing at approximately 200 feet with guide shoe and float collar. Cement with Halliburton using type A and circulate cement back to surface. Re-cement from surface around casing if needed.
7. Drill 7-7/8" hole under the 13-3/8" casing to the top of the Devonian Shale. If no free water has been encountered and the hole stays dry, drilling will proceed. If the open hole produces too much water for efficient air drilling, this

section will be drilled with fluid and a mud pump.

8. If any free water is entering the hole, this can cause severe caving of the Devonian shale and make coring very difficult.

9. If no water has been found from 200' to the shale top or after 8-5/8" casing has been set, drill 7-7/8" hole through the shale using dry air, no soap, no foam, to the Chattanooga shale coring point as picked by the geologist at the well site.

10. The geologist may choose to cut a core at the top of the Devonian shale for corelation.

11. At coring point, run a 3-1/2" x 7-7/8" diamond core head below a 6-1/4" x 4" x 60' core barrel with plastic sleeve. Three 60-foot lengths of oriented core will be taken, marked, and delivered on site to Cliff Minerals.

12. Upon completion of coring through the Lower Huron member of the Chattanooga Shale, continue drilling through the base of the Chattanooga Formation into the top of the Clinch Sandstone as directed by the geologist on site. During drilling of this interval, the geologist will designate a 60-foot core interval near the base of the Chattanooga to include the top of the Clinch Sandstone.

13. Following completion of drilling, the hole will be electrically logged. A complete suite of open-hole logs will be run, as described later.

14. Following logging, a period of time (not to exceed 6 months) will be required to determine the feasibility of completing the well.

15. If the hole is to be completed for later stimulation or evaluation, 4-1/2" casing (K-55, 9.5, STSC) will be run to the base of the Chattanooga and cemented. A 4-1/2" x 2000-psi Bradenhead will be welded on top of the casing for stimulation and testing. If hole is not to be completed for testing, it will be plugged and abandoned in accordance with the rules and regulations of the Tennessee Oil and Gas Board. A schematic for a well completed for testing is shown in Figure 16.

C. Drilling Time Curve

A drilling time curve is shown in Figure 17. It is estimated that all drilling activities will be completed within 25 days.

D. Rig Specifications

A drilling rig with the following characteristics is needed for the ESGP-Tennessee 9 well.

1. Drilling Depth, 7-7/8" hole to 4500'.
2. Capable of circulating mud at 5 barrels per minute against 500 psi.
3. Capable of circulating a minimum of 2,400 cubic feet of air per minute, with foam or soap.
4. Capable of circulating combinations of air, mud, foam, etc.
5. Circulation head and Pack-Off Equipment for air drilling that can shut off and hold a maximum wellbore pressure of 500 psi.
6. Fuel capacity to operate rig for several days minimum.

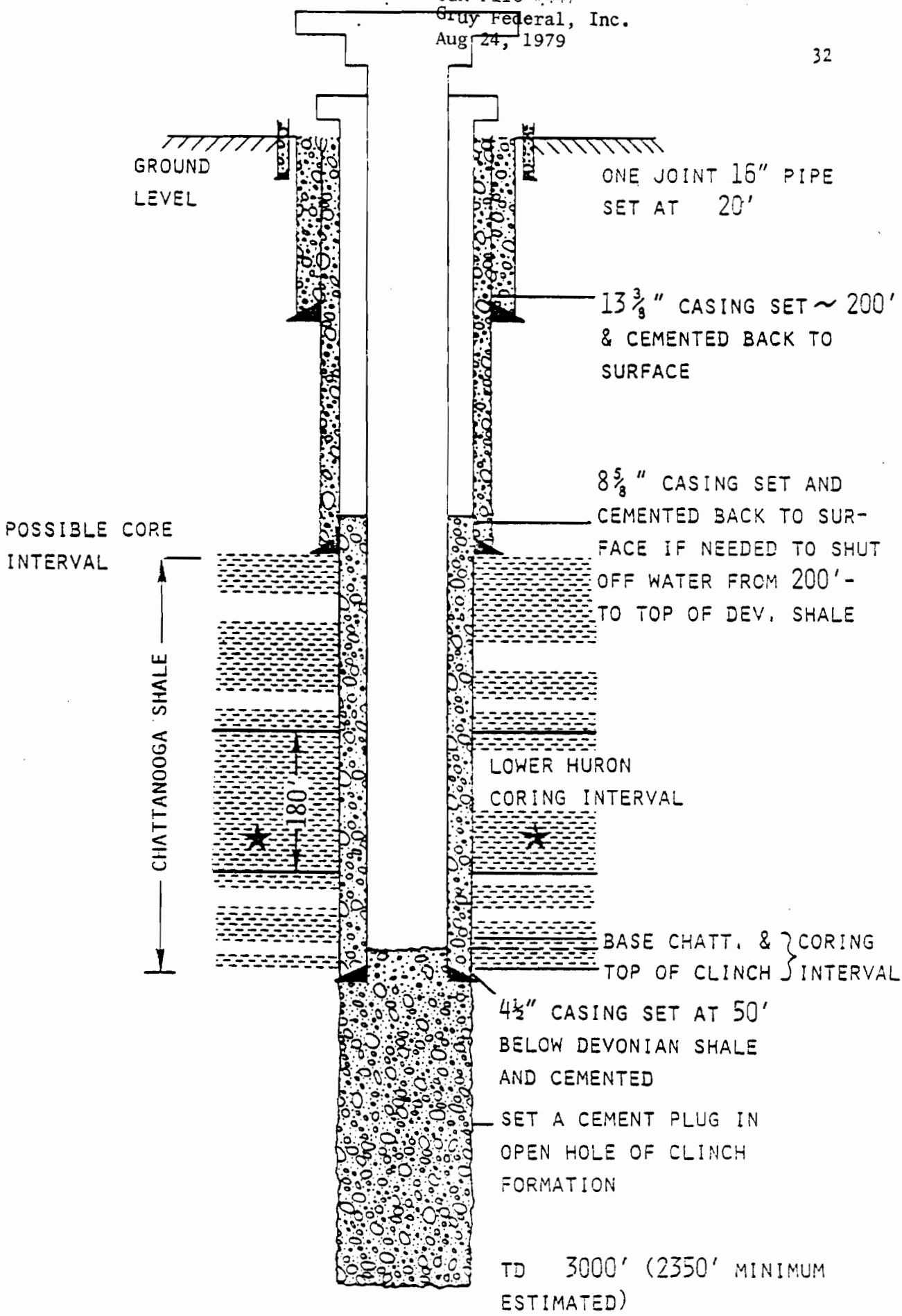
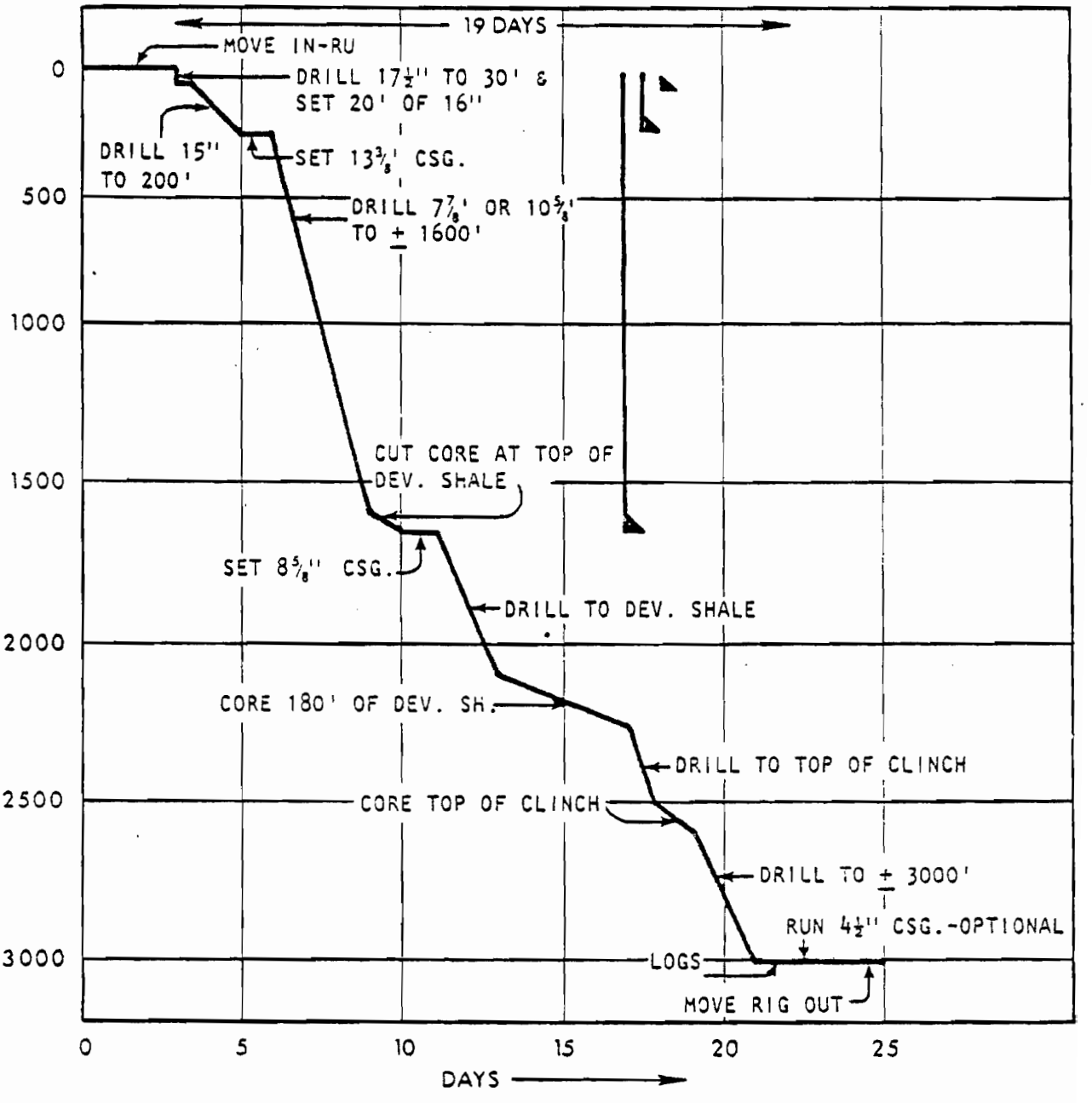


FIGURE 16. EGSP-TENNESSEE NO.9 WELL SCHEMATIC

ESTIMATED DRILLING / CORING TIME CURVE

EGSP TENNESSEE WELL NO.9



TOTALS	R.U.- R.D.	= 5	DAYS - MOB./ DEMOB.
	DRILLING	= 13	"
	CORING	= 6	"
	LOGS	= 1	"
		25 DAYS / 20 DAYS NET	

FIGURE 17. ESTIMATED DRILLING TIME CURVE

7. Water tankage capacity for 150 barrels water.
8. Pipe racks for maximum 2,000' of 8-5/8" casing.
9. Pipe handling tools for 16" conductor, 13-3/8" surface and 8-5/8" intermediate casing.
10. B.O.P.E., 10" x ser 900 with companion flanges for 13-3/8" 8R and 8-5/8" 8R casing.
11. Adequate safety equipment for rig/crew and to protect environment.

E. Logging Program

The exact suite of logs to be run in Tennessee 9 has not been determined. The logs to be run will depend upon whether it is possible to drill a completely dry hole. A typical suite of well logs run on EGSP wells includes the following:

DRY-HOLE LOGS

Gamma Ray
Temperature
Sibilation/Noise
Caliper
Formation Density Compensated

WET-HOLE LOGS

Compensated Neutron
Gamma Ray
Formation Density Compensated
Caliper
Dual Induction
Laterolog - 8
Borehole Compensated Sonic
Variable Density
Fracture Identification
Coriband Kerogen

If the hole is filled with fluid for wet-hole logging, there will be

a high probability that it will become unstable. Hence, if future well testing is planned, it will be necessary to set 4-1/2 inch casing to maintain the hole (item 15, Drilling and Coring Procedures). An alternate suite of dry hole logs will provide most of the information obtainable from the combined wet and dry log suite. The recommended suite of logs to be run in Tennessee 9 is as follows:

1. Dual Induction.
2. Compensated Density Log/Caliper.
3. Sidewall neutron.
4. Temperature.
5. Noise log.
6. Spectral gamma-ray log.

This recommended suite will not require a fluid filled borehole, which could contribute to an unstable open hole; however, it will provide sufficient information for formation analysis. A brief discussion of each recommended logging device and the expected information is included below:

Dual Induction - This is an "inductance" type resistivity device. In a dry borehole, it records "medium" and "deep" formation resistivities, from which the true undisturbed formation resistivity may be determined. This device is used to determine the water saluration, porosity, or water salinity when the other two parameters are known.

Compensated Density Log - This device actually records the electron density which is then converted to a bulk density (porosity). By using a dual detector system, borehole variations may be compensated for. When combined with a compensated and/or sidewall neutron devices, other

potential uses are:

a. identification of lithology and minerals present

b. identification of gas-bearing formations

c. determination of hydrocarbon density

d. evaluation of complex lithology

Sidewall Neutron - This is a dual detector "epithermal" neutron device. By recording the ratio of the fast neutron counts, the fluid filled porosity may be measured with minimal effect from the borehole. By mounting the neutron source and both detectors in a spring loaded shoe, the device may be run in dry holes where compensated neutron tape tools are useless. This log is used (in conjunction with the density log) for:

a. delineation and analysis of porous intervals

b. identification of gas bearing zones

c. lithology identification and evaluation of shale content.

Temperature Log - This device may be run in either open or cased holes. When run in a dry, open hole, the uses are essentially:

a. location of gas producing zone.

b. determination of geothermal gradients.

c. identification of thermal anamolies

Noise Log (SONAN) - This device records down-hole "noise". Frequency recordings are taken at four peak levels, usually between 200 and 2,000 hertz. In a dry open hole this device should indicate gas producing strata and any intervals which may be producing fluid.

Spectral Gamma Ray Log - This device records the total natural gamma activity of the formation and in addition records the relative concentration of potassium, uranium, and thorium. This device is very new and preliminary reports indicate that it is an excellent fracture identification device.

A brief discussion of each logging device used in the typical EGSP wet and dry suite logging program and the expected information is included below:

1. Compensated Neutron - This is a dual detector, borehole compensated porosity device. It is run in combination with the formation density/gamma-ray/and caliper devices. The uses of this log are:
   a. delineation of porous intervals and the determination of their porosity
   b. identification of gas bearing zones
   c. lithology identification and evaluation of shale content
2. Gamma Ray - This device records the natural radioactivity of the formations. In sedimentary formations this log normally reflects the shale content of the formations. It may be run in either open or cased holes and serves as an excellent correlation device.
3. Compensated Formation Density - This is a pad-type, dual detector, borehole compensated porosity device. When run in combination with the compensated neutron device, other potential uses are:
   a. identification of lithology and minerals present

b. detection of gas

c. determination of hydrocarbon density

d. evaluation of complex lithologies

Density data may be integrated with sonic-log information to yield the mechanical properties of the formation matrix. While not conclusive in itself, the density "rho" correction curve may indicate zones of fracturing.

4. Caliper - While simply a recording of borehole diameter, the caliper is important for a number of reasons:

   a. determination of borehole diameter required to correct other log responses

   b. determination of porous permeable zones as indicated by the presence of mud-cake

   c. identification of "fractured" zones where the borehole may be rugose and/or enlarged.

   The caliper is an integral part of the Compensated Density/Neutron system.

5. Dual Induction/Laterolog 8 - This is a focused type resistivity device. It records three resistivity measurements obtained from three different "depths-of-investigation". From the resistivity profile obtained, the depth of filtrate invasion and the true undisturbed formation resistivity may be obtained. This device is used to determine the water saturation, porosity or water salinity when the other two parameters are known.

6. Borehole Compensated Sonic - This is a recording of the time, ΔT, required for compressional sound wave to traverse one foot of formation. When used in conjunction with other porosity devices,

the sonic log yields acurate lithology information. Integrated sonic transit times are used as time-depth correlations for seismic applications.

7. Variable Density Log - This is a particular presentation of the cement bond log. When run in the open hole, fracturing may be apparent in the variable density presentation of the sonic wave-train. When run in its normal cased hole mode, the log is used to:
   a. evaluate the effectiveness of the casing-formation cement bond
   b. locate cement top
   c. check effectiveness of squeeze cementing

A casing collar log is normally run in conjunction with this device, where applicable when combined with sonic and density data, the mechanical properties of the formation matrix may be determined.

8. Fracture Identification - 4 Arm - Dipmeter - This device is run to determine:
   a. formation dip and direction
   b. structural identification
   c. hole geometry
   d. location and evaluation of significant fracturing

If necessary, the information may be processed to yield a hole survey and/or to convert log depths to true vertical depths.

9. Temperature Log - This device may be run in either open or cased holes. The uses are primarily as follows:
   a. location of cement top
   b. location of gas producing zones
   c. determine geothermal gradient
   d. locate lost circulation zones and fluid entry zones

This device is capable of recording temperature changes as small as 5° F.

10. Sibilation/Noise Log - This device records down hole "noise". Frequency recordings are taken at four peak levels, usually between 200 and 2,000 hertz. This device is used primarily to:

    a. locate fluid flow and gas entry within or behind the casing

    b. locate lost circulation zones

    c. determine gas well product within the open hole.

    d. locate tubing leaks.

All logs will be digitally recorded and fifteen (15) copies of each log will be provided to the DOE Technical Project Officer upon completion of the logging program.

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APPENDIX A

DEAN (May, 1979)

Department of Energy
Morgantown Energy Technology Center
P.O. Box 880
Collins Ferry Road
Morgantown, West Virginia 26505

May 18, 1979

A. E. Hunt, Assistant Project Manager, Eastern Gas Shales Project

EGSP EXPLORATION PROSPECTS ASSOCIATED WITH THE NEWMAN RIDGE AND GREENDALE SYNCLINES IN EASTERN TENNESSEE AND SOUTHWESTERN VIRGINIA; AND

TRIP REPORT -- TENNESSEE DIVISION OF GEOLOGY, KNOXVILLE, TENNESSEE -- DECEMBER 7 AND 8, 1978

December 7 and 8, 1978, I visited Robert C. Milici in Knoxville, Tennessee. He was then still the principle investigator on EGSP contract EY-76-C-05-5196 with the Tennessee Division of Geology (TDG), for which I am Technical Project Officer. (He now is state geologist for the state of Virginia, but he continues to fulfill his obligations to the contract.) The primary purpose of my visit was to develop EGSP exploration prospects associated with the Newman Ridge and Greendale Synclines in eastern Tennessee and southwestern Virginia. Having recently acquired responsibility for this resource assessment contract, now nearing completion, I also desired a first-hand overview of the project, which has been the focus of some controversy recently. At my request, Glenn Sundheimer, geophysicist employed by Mound Laboratory but stationed at METC, accompanied me. His intimate understanding of exploration seismology was needed to render an informed, objective opinion on the significance and credibility of the seismic profiles and their interpretation obtained under contract that are the crux of the prospects here presented.

We spent the first day in the field examining the geology along several roads that traverse the Newman Ridge and Greendale Synclines, including those followed by the K1S-TC1 seismic line purchased under contract. The experience was valuable in that it enabled me to obtain an intuitive understanding of the tectonic style of the area. We also witnessed NX coring in progress at the site of core hole #7. We reviewed the regional tectonics of the southern Appalachians and its impact on the Devonian shale. Out of this review came the seven exploration prospects presented herein.

Background Review

Devonian and Mississippian strata occur in the cores of the Newman Ridge and Greendale Synclines in northeastern Tennessee and southwestern Virginia (Figure 1). Apart from these two prominent structures, the strongly deformed Valley and Ridge province, lying between the Cumberland Plateau (west) and the Blue Ridge (east), exposes only rocks older than Devonian. Prior to the initiation of EGSP Contract ET-76-C-05-5196 with the Tennessee Division of Geology (TDG), it was known that:

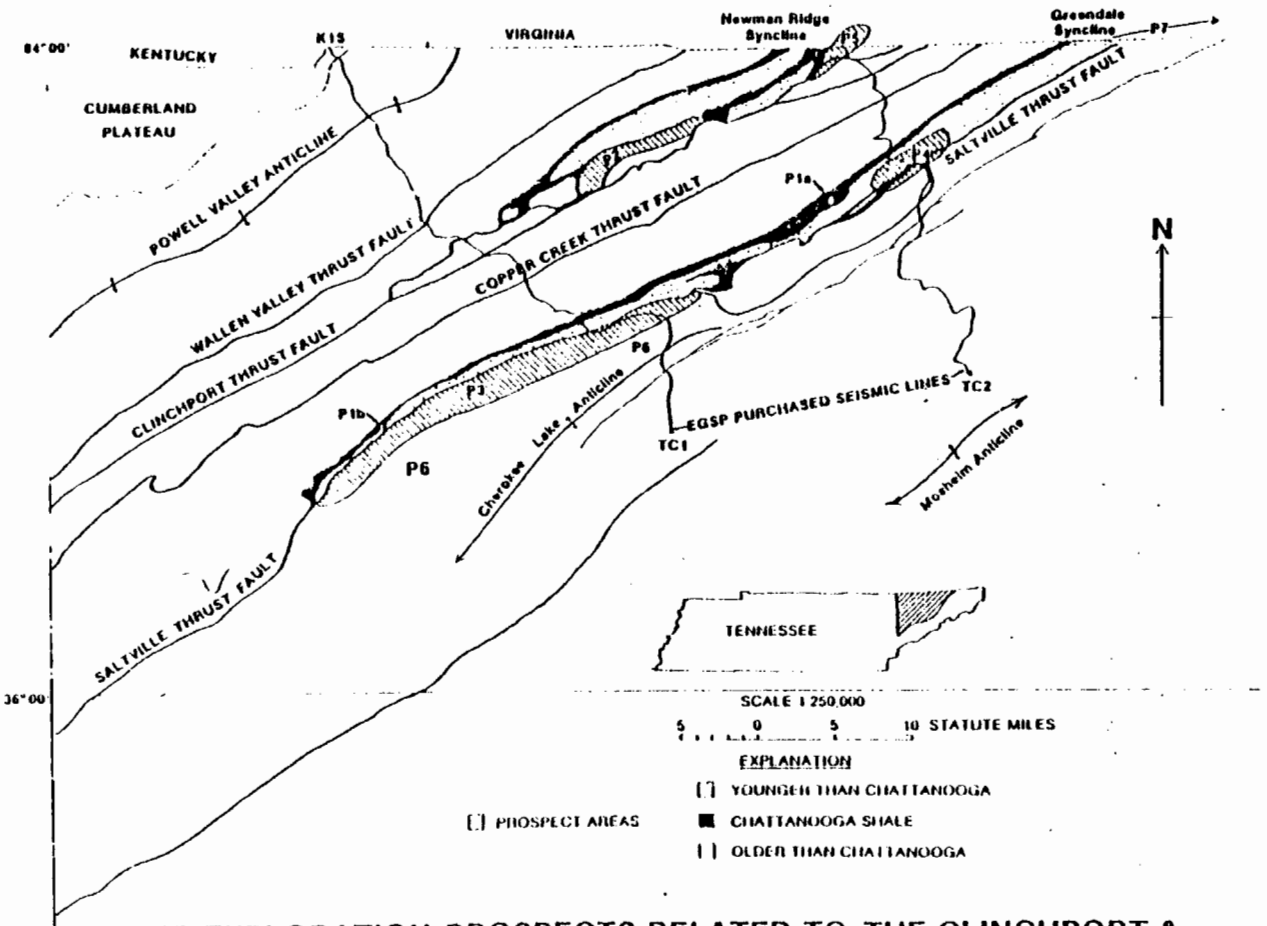
1. Both synclines contain sections of the black Devonian-Mississippian Chattanooga Shale an order of magnitude thicker than the 50-100 foot section underlying the Cumberland Plateau.

2. Both synclines are bounded to the southeast by major thrust faults of regional extent, the Hunter Valley, Clinchport, and Saltville Thrust Faults (Figure 1). The Chattanooga Shale passes into the subsurface beneath these southeast dipping thrusts.

Inasmuch as the shale erodes preferentially relative to the more resistent adjacent units (the Silurian Clinch Sandstone and the Mississippian Granger Formation), it is poorly exposed; consequently, its true thickness and internal stratigraphy were essentially unknown. Also unknown was the extent to which the Chattanooga carried under the Hunter Valley, Clinchport, and Saltville Thrusts. Resolution of these unknowns was the object of the contract.

To define the subsurface extent of the Chattanooga Shale, the Tennessee Division of Geology retained Geophysical Service, Inc., (GSI) to conduct a Vibroseis seismic survey along two lines, KIS-TC1 and TC2, crossing the Valley and Ridge Province at right angles to strike (see Figure 1). To learn the true thickness and internal stratigraphy of the Chattanooga Shale, they sponsored a core drilling program along the two major outcrop belts of the shale in northeastern Tennessee (Figure 1). It consists of eight diversely located NX core holes spudded near the upper contact of the formation; most of the cores obtained span the entire shale section.

The Chattanooga Shale is not imaged on the seismic reflection profiles generated by GSI. Apparently, it is largely confined to depths of 3,000 feet or less; near surface resolution of Vibroseis surveys designed for regional reconnaissance is very limited. Resolution of strata below 3,000 feet varies from fair to good. GSI rendered the first interpretation of the seismic profiles after processing (Tegland, 1978); it is very general and lacks geologic credibility. R. C. Milici, L. D. Harris (USGS), and A. T. Statler (in press) reinterpreted the profiles for the Tennessee Division of Geology. They had the advantage of many years field experience mapping the geology of the southern Appalachians and a viable tectonic model for the region as a whole (Harris & Milici, 1977, USGS Professional Paper 1018). Their interpretation appears to be qualitatively as near the truth as possible given available data. Quantitatively, it is



EGSP EXPLORATION PROSPECTS RELATED TO THE CLINCHPORT & SALTVILLE THRUST FAULTS, EASTERN TENNESSEE & SOUTHWESTERN VIRGINIA

only a rough approximation because the seismic velocities of the various strata are not known and had to be estimated. Although the Chattanooga Shale is not directly imaged on the seismic profiles, its subsurface distribution is nonetheless restricted by, as it were, two boundary constraints:

1. From above, the distribution of strata exposed at the surface.

2. From below, the interpretation of seismically resolved strata.

The NX core drilling program is nearing completion; seven core holes have been drilled; the eighth and final one will soon be spudded. (One of the previous holes was prematurely terminated; it must be re-entered and deepened.) R. C. Milici visually logged the cores as they were taken, noting structural features (fractures, fractured intervals, folds, etc.) as well as lithology. Two of the core holes (#4 & #6) produced significant shows of gas. Detailed analysis of the cores (stratigraphic correlation, maturation studies, outgassing, etc.) is the responsibility of the U.S. Geological Survey; that work is barely begun.

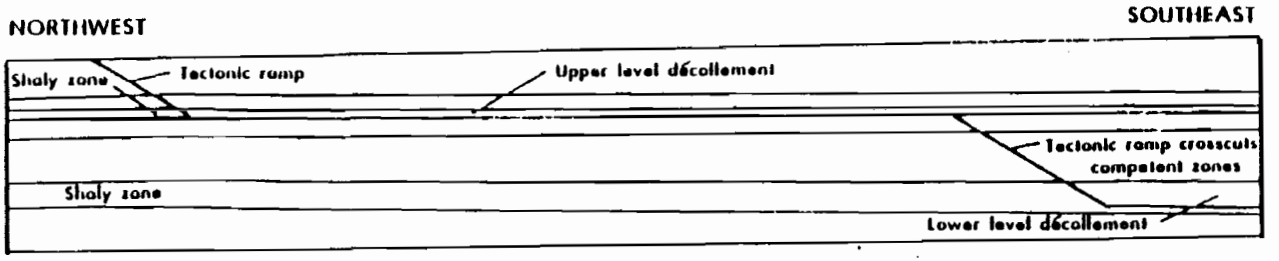
Exploration Rationale

In my memo of December 28, 1978, I defined an exploration rationale as "a theory of how several known or suspected geological circumstances may combine to create a favorable environment for the generation and accumulation of producible hydrocarbons." "Shale specific rationales are characterized by a hypothesized geological mechanism for the creation of a natural fracture system, because the producibility of the shale depends on fracture permeability." The seven Devonian Shale prospects presented herein are based on a single exploration rationale, IB1b in the EGSP Exploration Inventory, Attachment A to my December 28. The rationale states that the Devonian Shale, here represented by the Chattanooga Shale, should be anomalously fractured wherever it occurs in proximity to detachment-type thrust faults, such as are the dominant tectonic element of the southern Appalachians. The highest degree of fracturing in the shale is expected where:

1. It occurs immediately above on upper level detachment (Harris & Milici, 1977).

2. It occurs in the footwall of a detachment thrust making the transition between ramping mode and upper level mode.

The geologic structure of the southern Appalachians is bewilderingly complex in detail; yet, the tectonic mechanism that produced the structural complexity is fundamentally simple. Prior to deformation, the region was a depositional basin consisting of a "cover" of sedimentary rocks, some 20,000 feet thick, resting on a "basement" of hard crystalline rocks, granites and gneisses. The crustal deformation that produced the major structures of the southern Appalachians occurred approximately 250 million years ago, following deposition of the youngest sediments in the basin.



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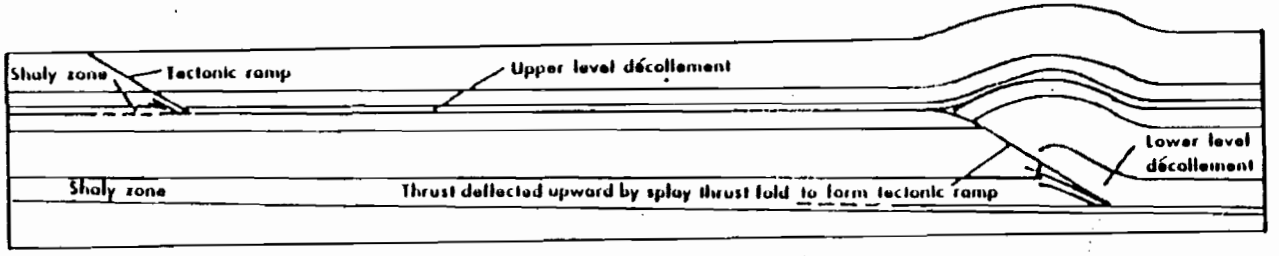
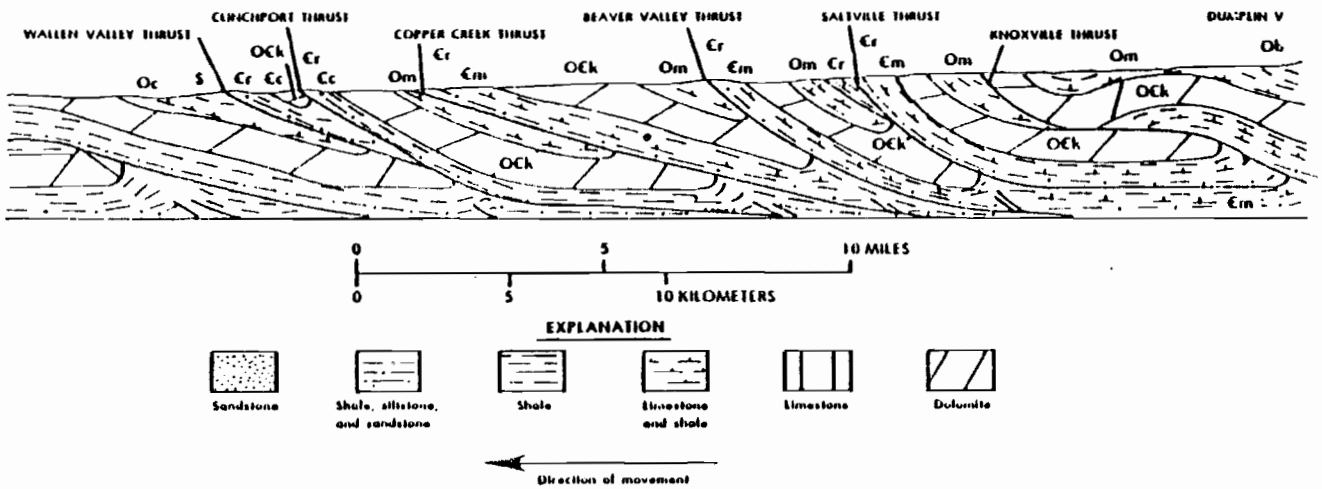


(after Harris & Millici, 1977, fig. 4)

B

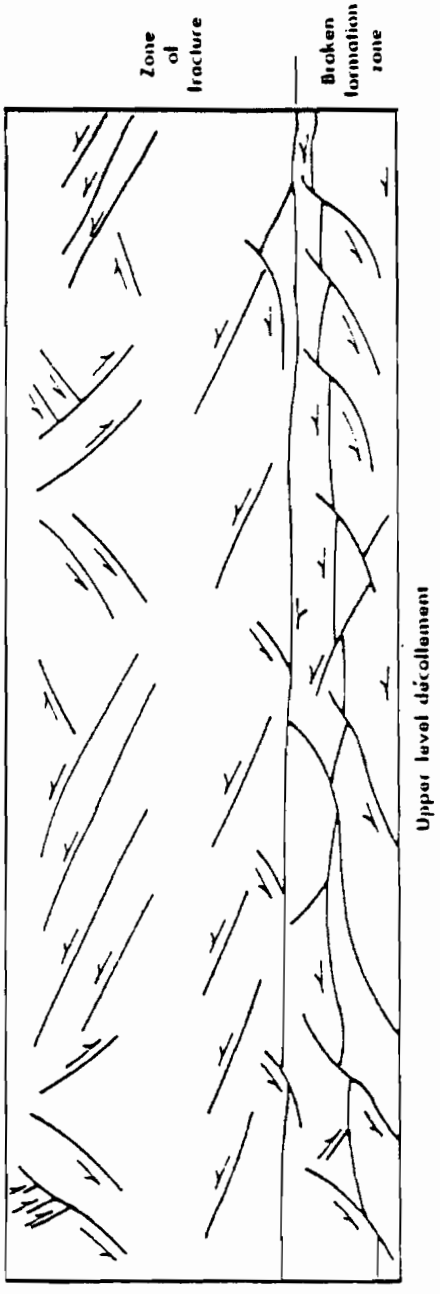
Two Stages in the development of a ramping Décollement System

Figure 2



(after Harris & Milici, 1977, pl. 6)

IMBRICATE STRUCTURE
of the
VALLEY AND RIDGE PROVINCE
Figure 3

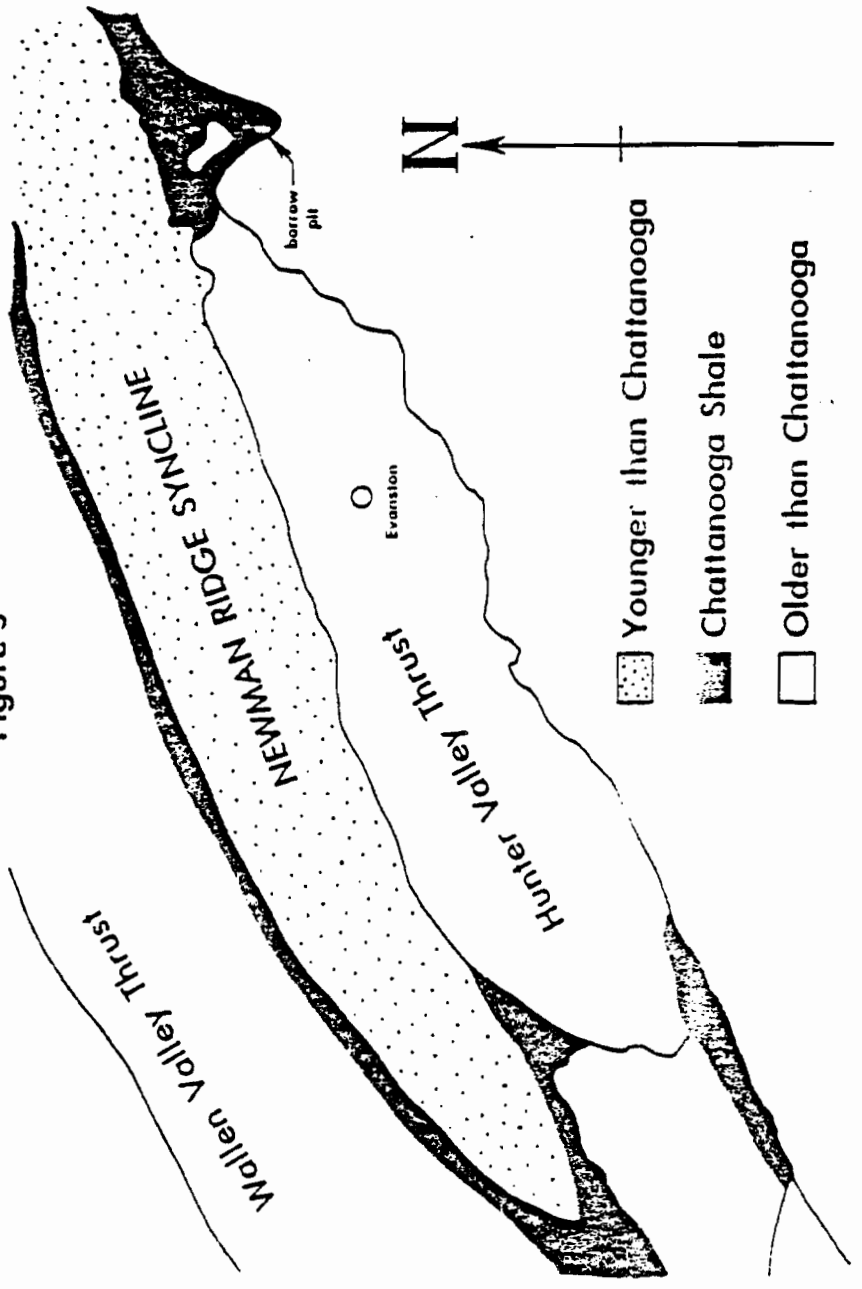


(after Harris & Milici, 1977, pl. 5)

FRACTURING IN ROCKS OVERLYING AN UPPER LEVEL DÉCOLLEMENT

Figure 4

Figure 5



GEOLOGIC MAP OF THE EVANSTON AREA, TENNESSEE

The presumption of anomalous fracturing in the Devonian Shale is a necessary, but not an all sufficient, condition for a viable prospect. Other factors that influence or indicate potential gas production must also be favorable, which they are in the Newman Ridge and Greendale Synclines. The Chattanooga Shale in the Newman Ridge and Greendale Synclines is thick; the NX core holes establish a range of thickness from 500 to 1,500 feet. A substantial proportion of the section is black shale; interbedded siltstone and shale occur near the middle. Conodont Color Alteration Indices (CAI) for Devonian and Mississippian rocks range from 1.5 to 2.0 in the Newman Ridge Syncline and from 1.5 to 3.0, but mostly 2.5 to 2.0, in the Greendale Syncline (Harris & Milici, 1977). CAI in the range 1.5 to 4.5 indicate thermal maturity conducive to the generation of natural gas in commercial quantities. Commercial gas production was achieved in the now-abandoned Early Grove Gas Field situated in the Greendale Syncline just north of the Tennessee state line. Production was from a Mississippian age limestone, but the gas had undoubtedly migrated upward from the underlying Chattannoga Shale. One well was deepened to the Chattanooga and achieved minor production without stimulation. NX core holds No's. 4 and 6 exhibited substantial shows of gas; in these and several other cores the shale was naturally fractured.

The Newman Ridge and Greendale Synclines are bounded to the southeast by major southeast dipping thrust faults; the Chattanooga Shale passes into the subsurface beneath these thrusts. Most of the prospects presented in the next section call for drilling through the upper plate of one of these thrusts in order to penetrate the shale in the lower plate. According to a old geological rule of thumb, a map unit that is persistent along strike should be proportionately persistent down dip. Because of the fundamental nature of southern Appalachian structures, this rule of thumb cannot be applied to the Chattanooga Shale. It would be advantageous to encounter the shale under a thrust as far downdip as possible in that there is more likelihood of the gas being trapped in the fractures rather than leaking off to the surface. The danger in drilling too far back from the surface trace of the thrust fault is that the thrust may truncate the Chattanooga Shale in the subsurface up dip of the point where the well penetrates the fault. Thus, the shale would not be encountered below the thrust, but rather some older unit. Unfortunately, the lack of shallow resolution seismic along the EGSP purchased lines makes it impossible to know precisely how far the Chattanooga Shale carries into the subsurface before being truncated.

Prospects

In this section I identify seven EGSP exploration prospects in northeastern Tennessee and southwestern Virginia (Figure 1) associated with the Newman Ridge and Greendale Synclines that are based on the above stated exploration rationale. I present them for management consideration ranked according to decreasing value of a subjectively appraised attractiveness index,

that is, attractiveness from the present perspective of the EGSP exploration program, all pertinent factors considered. The index is directly proportional to production potential and logistic ease (lease acquisition, permission to drill, possible private sector participation, etc.) and inversely proportional to dry hole risk, risk of entirely missing the shale at depth, and total cost as suggested by the inferred depth of the target interval. The application of some exploration technique, particularly high resolution shallow seismic, could dramatically enhance the attractiveness of some of these prospects. A factor that affects the logistic ease in testing these prospects is the availability of leases. A lease play involving three majors, Amoco, Exxon, and Chevron is reported to be underway in the area, probably stimulated by our release to the public of the EGSP purchased seismic. Cooperative agreements may be possible and should be pursued.

Prospect P1

Ream out to full bore, log, case, perforate, and stimulate NX core hole No. 4 (P1a), or alternatively No. 6 (P1b), or both. Both of these cores are located near the upper contact of the principal Chattanooga Shale outcrop belt in the Greendale Syncline; they penetrate the entire shale section. Both core holes had substantial shows of gas attributable to specific fractures or fractured intervals in the core. In that respect, P1a (core hole No. 4) is preferred over P1b (core hole No. 6). The projected depths of the wells, equivalent to the thickness of the Chattanooga, is 1,500 feet for P1a and 500 for P1b, both very shallow. Obtaining permission from landowners should pose no serious problem; since permission to drill the existing core holes was readily granted. The production potential is probably low. The black shales penetrated are in close proximity to the outcrop; hence, rock pressures encountered are likely to be low. The natural gas shows suggest, however, that the risk of a completely dry hole is slight. The positive factors, cost and dry hole risk, more than compensate for the negative one, production potential; I rate this an attractive prospect.

Prospect P3

Drill two or three wildcat wells through the upper plate of the Saltville Thrust, but less than a couple miles back from the leading edge, between Lea Springs and Bean Station, Tennessee. Milici, Harris, & Statler's, (in press) interpretation of seismic line TC1 shows the Chattanooga Shale carrying back under the Saltville thrust at least that far before being truncated. The Chattanooga is reasonably thick, about 500 feet, and in the correct strutural setting to develop a high degree of fracturing. Core hole No. 6 (P1b) drilled into the outcrop belt in the Greendale syncline opposite the prospect displayed a good natural show and the core was fractured. The logistics of drilling a well in this area seems at first glance not to be difficult. TVA owns some of the land and a private property owner hearing of our interest approached me with an informal offer of cooperation.

The estimated depth of the prospect is 3,000 feet, shallow from the aspect of drilling cost, but deep enough to insure that the gas has not leaked off to the surface. There is some risk, not great, that the Chattanooga Shale may be cut out or disrupted in subsurface by some unsuspected structural complication, e.g., a thrust splay. This is an attractive prospect. The production potential is relatively high. The logistics may be uncomplicated; the risks are minimal; and the cost should be reasonable.

Prospect P4

Drill a wildcat well in the general vicinity of Alumwell, Tennessee. According to Milici, Harris, & Statler's (in press) interpretation of TC2, the Chattanooga Shale should be encountered as a depth of 4,000 feet or less forward of the trace of the Saltville thrust. If core hole No. 4 at P1a can be taken as an indication, the shale ought to be very thick (1,500 feet) and highly fractured; the fractures should contain gas at reasonable pressure. Again, there is some risk that the Chattanooga Shale could be prematurely cut out in the subsurface by small undetected faults; it is more likely, however, to be duplicated by the same, a possible advantage. I rate this prospect reasonably attractive.

Prospect P2

Drill one or two wildcat wells through the upper plate of the Hunter Valley Thrust where it is isolated by the Clinchport Thrust in the general vicinity of Evanston, Tennessee (Figure 5). The wells must be drilled fairly close to the leading edge of the Hunter Valley Thrust in order to avoid missing the Chattanooga Shale altogether. Small fensters (erosional windows in the upper plate) adjacent to the Clinchport Thrust reveal rocks older than Devonian, indicating that the Chattanooga Shale is truncated by the Hunter Valley Fault somewhere between its leading edge and the fensters. One can reasonably guess where the truncation is likely to occur, but only high resolution shallow seismic can accurately define it. The stratigraphic thickness of the Chattanooga Shale in the prospect area is approximately 500 feet. If the exposure in the borrow pit less than a mile south of Sneedville is any indication (see previous discussion, page 4), the shale below the Hunter Valley Thrust is almost certainly very highly fractured. I am concerned, however, that much of the gas may have dissipated to the surface through a highly developed fractured system; the prospect is a shallow one, perhaps less than 1,000 feet. All of the three cores taken along Chattanooga outcrop in the Newman Ridge syncline were highly fractured, but the core holes evinced no natural shows. Appraisal is difficult because of the uncertainties involved. Yet, the prospect is highly intriguing and could be a good one; the cost of a wildcat or two should be relatively low.

Prospect P5

Drill a wildcat well in the general vicinity of the Surgener Cemetary on the Trail of the Lonesome Pine about 2 miles northwest of Kyles Ford, Tennessee; the prospect is located on the Tennessee-Virginia boundary. The interpretation of seismic line TC2 by Milici, Harris, & Statler (in press) predicts the Chattanooga Shale below the Hunter Valley Thrust Fault at a depth of 3,000 feet. Stratigraphic thickness of the shale is about 600 feet and it is in the correct structural position to be highly fractured. Core hole No. 3, drilled on the outcrop in the Newman Ridge syncline about 5 miles away, yielded a somewhat fractured core, but no natural show. The interpreted seismic profile TC2 suggests that a small buried thrust splay either duplicates or cuts out the Chattanooga in the subsurface. Appraisal of this prospect is difficult.

Prospect P7

Re-enter, deepen, and stimulate at least two old wells in the Early Grove Gas Field approximately 5 miles southeast of Hilton, VA. This now-abandoned field is confined to a small anticline within a broad stretch of the Greendale syncline. It was the only commercial gas field in the Valley and Ridge Province of the southern Appalachians; it produced from Mississippian age limestone. The anticline is probably the surface expression of a subsurface thrust splay system (Harris & Milici, 1977). Whether so or not, the gas undoubtedly derived from the underlying Chattanooga Shale. One well was drilled into the shale and obtained minor production without stimulation. The risk of a dry hole is virtually nil and the production potential would appear to be good. Logistics (obtaining permission, re-entering an abandoned well, etc.) may be difficult, but cannot be evaluated without more information. If the undertaking turns out to be fairly straightforward, a low cost success could be achieved. I rate this an uncertain prospect that could markedly improve with more information.

Prospect P6

Drill three wildcat wells through the upper plate of the Saltville Thrust Fault in the region between the P3 area and the Cherokee Lake Anticline. This prospect is an extension of Prospect P3; most of what was said about P3 applies to P6 also. P6, however, entails a great deal more risk that the Chattanooga Shale may not be present under the Saltville Thrust Fault than P3. The shale, if it is encountered, ought to have a greater rock pressure as a consequence of greater depth (4,000-5,000 feet) and lateral distance from the outcrop. I rate Prospect P6 highly speculative. It should not be attempted without the benefit of a local high resolution seismic survey, and then probably only in conjunction with a wildcat in

the P3 area. A sonic log from the P3 wildcat would be required to develop a seismic velocity profile, without which it would be difficult to interpret the high resolution seismic.

Claude S. Dean
Geologist
Resource Characterization

CSD:bm:303c

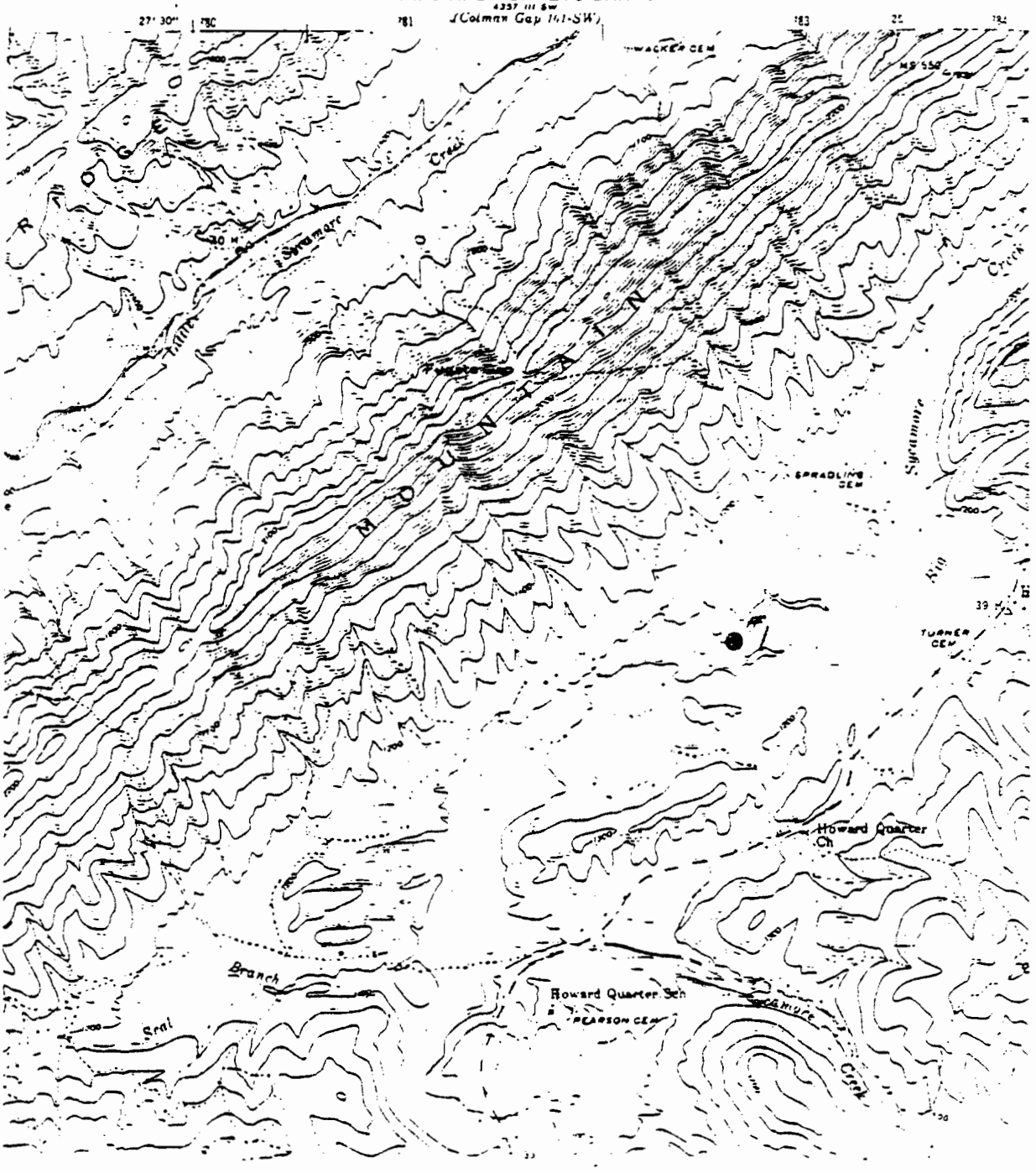
cc: AAPitrolo
LASchrider
RLWise
WKOverbey
CAKomar
ABYost
CDLocke
RJWatts
CWByrer
PYWilliams
JCurtis, SAI
GFingleton, SAI
ETarr, SAI
GRSundheimer, Mound
RCMilici, VGS
LDHarris, USGS
WJPerry, USGS
WdeWitt, USGS
RCShumaker, WVU
RLWheeler, WVU
BRKulander, Wright State

APPENDIX B

EGSP TENNESSEE CORE

HOLE LOCATIONS

UNITED STATES
TENNESSEE VALLEY AUTHORITY
MAPS AND SURVEYS BRANCH



Howard Quarter -162-NW

EGSP No. Tennessee 1 (well data not available)

Speedville - 170-SW

EGSP-No. Tennessee 3. MDc top-137 feet, MDc bottom-742, MDc thickness-605 feet
Bottom of hole-755 feet.

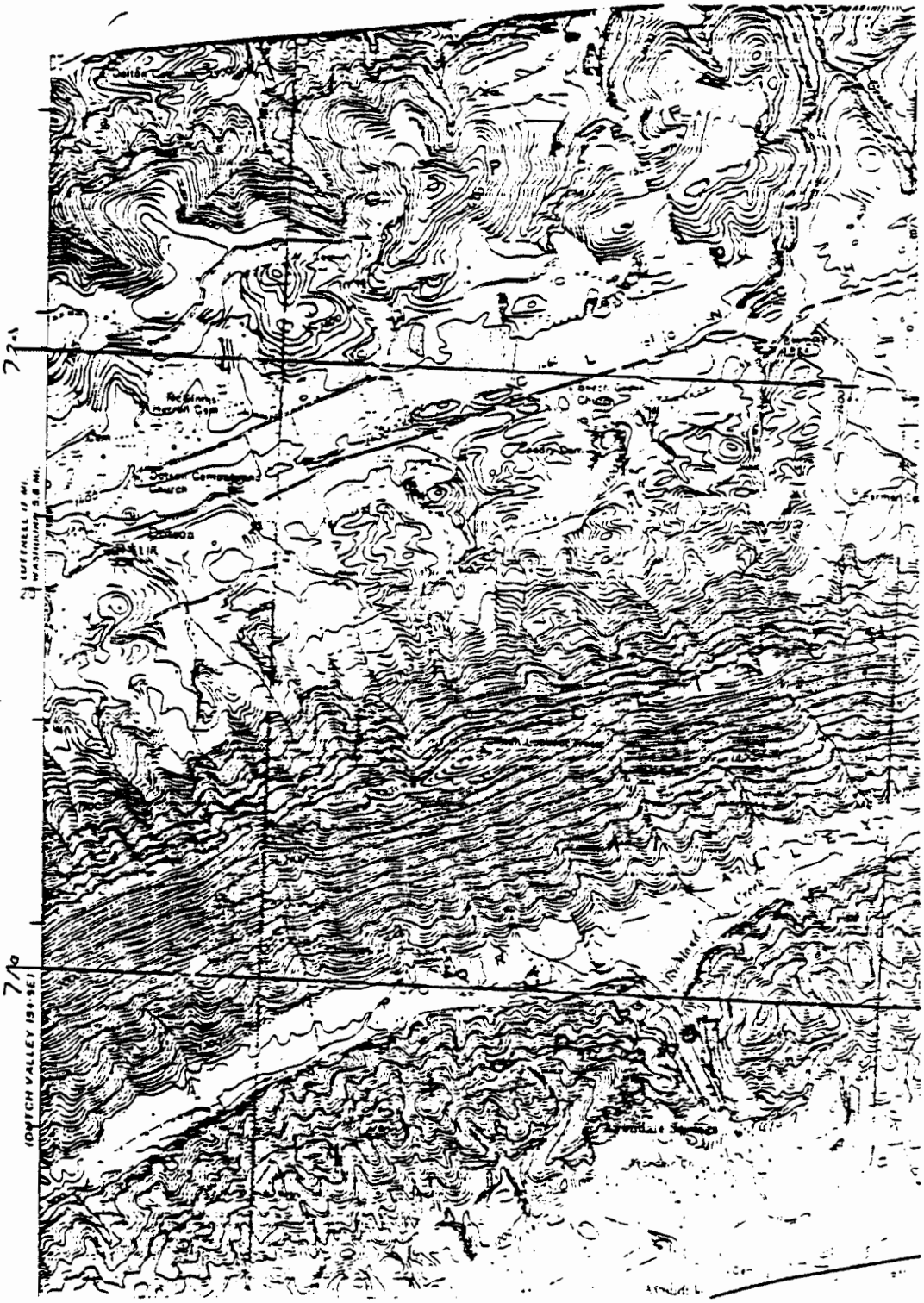
Cumelot - 171-NE

EGSP No. Tennessee 4. MDc top-collar, MDc bottom-1590 feet, MDc thickness-1590 feet, Bottom of hole-1625 feet.

EGSP NO. Tennessee 5. MDc top-90 feet, MDc bottom-300 feet, MDc thickness-300 feet, Bottom of hole-300 feet.

155-NE
Jappa

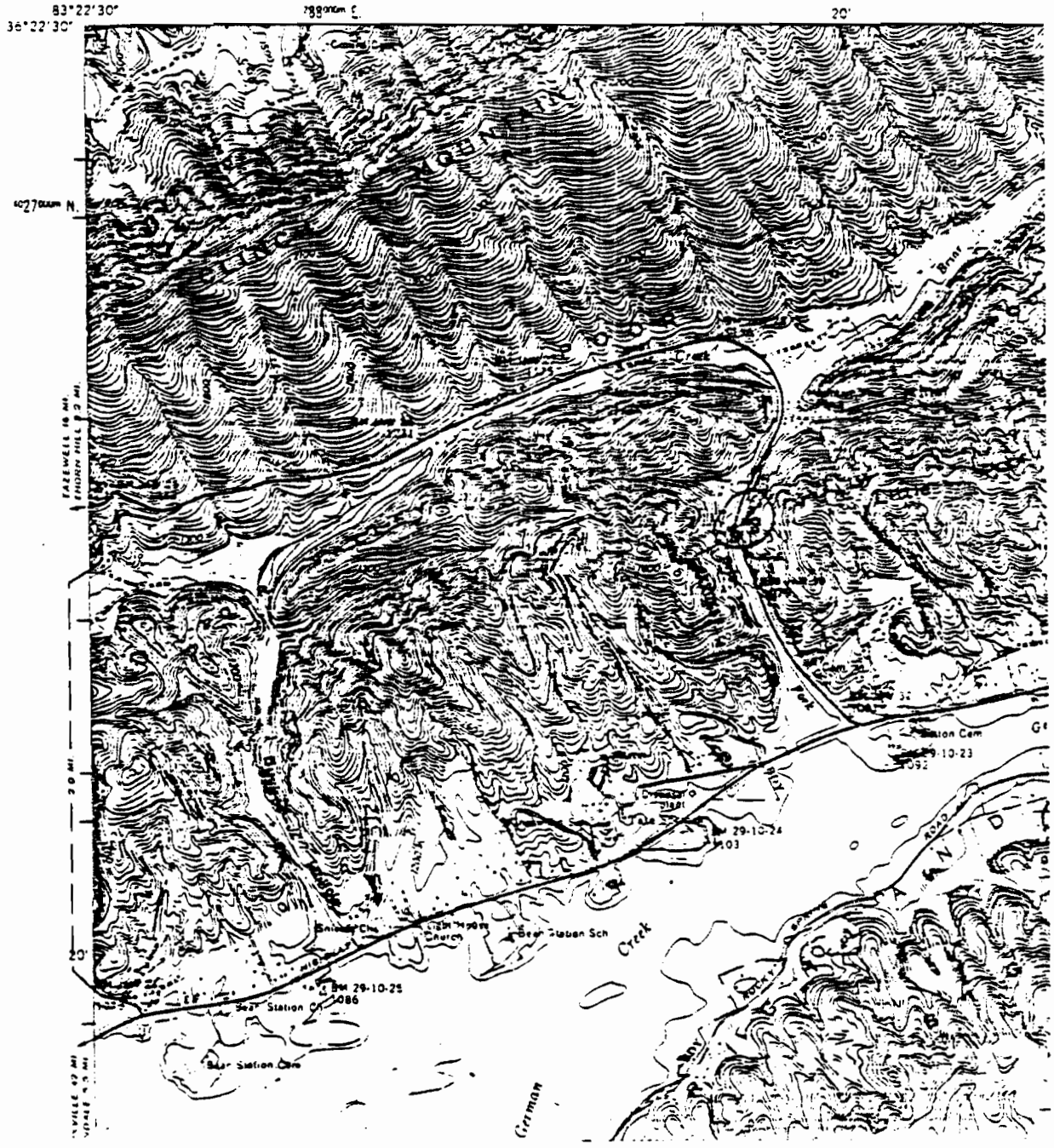
EGSP No. Tennessee 6. MDc top- at collar, MDc bottom-600 feet, MDc thickness-600 feet, Bottom of hole 625 feet.



162.5W – Avondale Springs

EGSP No. Tennessee 7. MDc top- 165 feet, MDc bottom-327 feet, MDc thickness 662 feet, Bottom of hole-900+ feet.

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY



Bear Station - 162 - 5E

EGSP No. Tennessee 8. MDc top- 140 feet, MDc bottom-890 feet, MDc thickness-750 feet, Bottom of hole 915 feet.

APPENDIX C

ELECTRIC LOGS

TENNESSEE 7 & 8

Type: Neutron Porosity DATE: 4-12-79 District or Project: _____

LOCATION: State Tn. County Grainger Town Annadale Springs FILE LOCATION NO.: _____

LOGGING INFORMATION

Operator(s) JERRY MILLER
Equipment Address: Dalton Cold UA ATL GA
Logger type: Gulf A-Cen No. 10043
Tool type: USGS 4780
Detector type: He 3 1 x 8
Source type: Amer
Source size: 3 C; _____ Mf
Source spacing: 16"
Tool length, cable head to detector _____ ft ____ in
Calibration: Not working as is 8" hole cps
Logging speed: 33 ft/min (up) down
Log vert. scale: 20 ft/in

MODULE SETTINGS

Scale switch (rate or counts): 1000 cps / API } chart div (or) full scale
(circle as applicable)

T. C. switch: 2 sec.
Position Pot. (Base, zero, or suppression): 10 Dial Div.
Sensitivity Pot. (Span): 5 Dial Div.
Discrimination Pot.: _____ Dial Div.
Input pulse: _____ volts; Polarity _____
Output switch: (normal) reverse
Actual scale: 400 (cps) API } chart div (or) full scale
(circle as applicable)

RECORDER SETTINGS

	Ch 1	Ch 2	Ch 3
Position Pot.:			
Sensitivity Pot.:			

Run No. ____ of ____

Remarks: _____

WELL INFORMATION

Well No. (USGS): _____
Other: _____
Map or Quad _____
Site description _____

Agency or Owner: _____
Address: _____
Altitude of L.S. _____
Log M.P. _____ Log TD _____ ft
Btm log interval: _____ ft Well ID: _____ ft
Top log interval: _____ ft
Type of finish: _____
Casing: Elev. of top _____ ft/in Above / Below L.S.

I.D. ____, from ____ to ____, type ____
I.D. ____, from ____ to ____, type ____
I.D. ____, from ____ to ____, type ____

Cement: from ____ to ____

Perf. interval(s) from ____ to ____, type ____
Open hole diameter: ____ from ____ to ____
____ from ____ to ____

Fluid level: ____ ft/in Above / At / Below L.S., Top Csg

Fluid type: _____. temp ____ °F, °C
Fluid resist.: _____ ohm-m
Driller: _____
Address: _____
Type of rig: _____
Date started: _____ completed _____
Aquifer or formation: _____

NOTE: This log is not to be used to fulfill private contractual obligations.

Other data and logs available for this well: _____

Gruy Federal, Inc.
Aug 24, 1979

TYPE: Natural Gamma DATE: 4-12-79 District or Project: _____

LOCATION: State Tn. County Grainger Locale Town Avondale Spring FILE LOCATION NO.: _____

LOGGING INFORMATION

Operator(s) Jerry Idler
Equipment Address: Denver, Colo via Atl Ga
Logger type: Gri A. Con No. 10043
Tool type: USGS
Detector type: Crystal 1x4 Gr
Source type: _____
Source size: _____ C; _____ MC
Source spacing: _____
Tool length, cable head to detector _____ ft _____ in
Calibration: Noted _____ cps
Logging speed: 25 ft/min (up) down
Log vert. scale: 20 ft/in

MODULE SETTINGS

Scale switch (rate or counts): 500 cps } chart div (or)
_____ API } full scale
(circle as applicable)

T. C. switch: 4 sec.
Position Pot. (Base, zero, or suppression): 10 Dial Div.
Sensitivity Pot. (Span): 10 Dial Div.
Discrimination Pot.: _____ Dial Div.
Input pulse: _____ volts; Polarity _____
Output switch (normal) reverse
Actual scale: 100 (cps) (chart div) (or)
_____ API } full scale
(circle as applicable)

RECORDER SETTINGS

	Ch 1	Ch 2	Ch 3
Position Pot.:			
Sensitivity Pot.:			

Run No. _____ of _____

Remarks: _____

WELL INFORMATION

Well No. (USGS): _____
Other: _____
Map or Quad _____
Site description _____

Agency or Owner: _____
Address: _____
Altitude of L.S. _____
Log M.P. _____ Log TD _____ ft
Btm log interval: _____ ft
Top log interval: _____ ft
Well TD: _____ ft
Type of finish: _____
Casing: Elev. of top _____ ft/in Above Below L.S.

I.D. _____, from _____ to _____, type _____
I.D. _____, from _____ to _____, type _____
I.D. _____, from _____ to _____, type _____

Cement: from _____ to _____

Perf. interval(s) from _____ to _____, type _____
Open hole diameter: _____ from _____ to _____
_____ from _____ to _____

Fluid level: _____ ft/in Above At Below L.S., Top Csg

Fluid type: _____, temp _____ °F, °C
Fluid resist.: _____ ohm-m
Driller: _____
Address: _____
Type of rig: _____
Date started: _____ completed _____
Aquifer or formation: _____

NOTE: This log is not to be used to fulfill private contractual obligations.

Other data and logs available for this well _____

UGR File #447
Gruy Federal, Inc.
Aug 24, 1979

TYPE: Gamma Gamma Density DATE: 4-12-79

District or Project: _____

LOCATION: State Tn. County Grainger Town Avondale Spring FILE LOCATION NO.: _____

LOGGING INFORMATION

Operator(s) Jerry Idlor
Equipment Address: Denver Colo. USA Atl Ga
Logger type: Will M-Cor No. 160 # 3
Tool type: USGS
Detector type: Crystal 1 x 4 AT
Source type: Co 60
Source size: _____ C; 5 MC
Source spacing: 16"
Tool length, cable head to detector _____ ft _____ in
Calibration: NA cps
Logging speed: 33 ft/min (up) down
Log vert. scale: 20 ft/in

MODULE SETTINGS

Scale switch (rate or counts): 1000 cps / API } chart div (or) full scale
(circle as applicable)

T. C. switch: 2 sec.
Position Pot. (Base, zero, or suppression): 10 Dial Div.
Sensitivity Pot. (Span): 10 Dial Div.
Discrimination Pot.: _____ Dial Div.
Input pulse: _____ volts; Polarity _____
Output switch: normal; (reverse)
Actual scale: 200 (cps) / API } chart div (or) full scale
(circle as applicable)

RECORDER SETTINGS

	Ch 1	Ch 2	Ch 3
Position Pot.:			
Sensitivity Pot.:			

Run No. _____ of _____

Remarks: _____

WELL INFORMATION

Well No. (USGS): _____
Other: _____
Map or Quad _____
Site description _____

Agency or Owner: _____
Address: _____
Altitude of L.S. _____
Log M.P. _____ Log TD _____ ft
Btm log interval: _____ ft
Top log interval: _____ ft
Well TD: _____ ft
Type of finish: _____
Casing: Elev. of top _____ ft/in Above / Below L.S.

I.D. _____, from _____ to _____, type _____
I.D. _____, from _____ to _____, type _____
I.D. _____, from _____ to _____, type _____

Cement: from _____ to _____

Perf. interval(s) from _____ to _____, type _____
Open hole diameter: _____ from _____ to _____
_____ from _____ to _____

Fluid level: _____ ft/in Above / At / Below L.S., Top Csg

Fluid type: _____. temp _____ °F, °C
Fluid resist.: _____ ohm-m
Driller: _____
Address: _____
Type of rig: _____
Date started: _____ completed _____
Aquifer or formation: _____

NOTE: This log is not to be used to fulfill private contractual obligations.

Other data and logs available for this well _____

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Gruy Federal, Inc.
Aug 24, 1979

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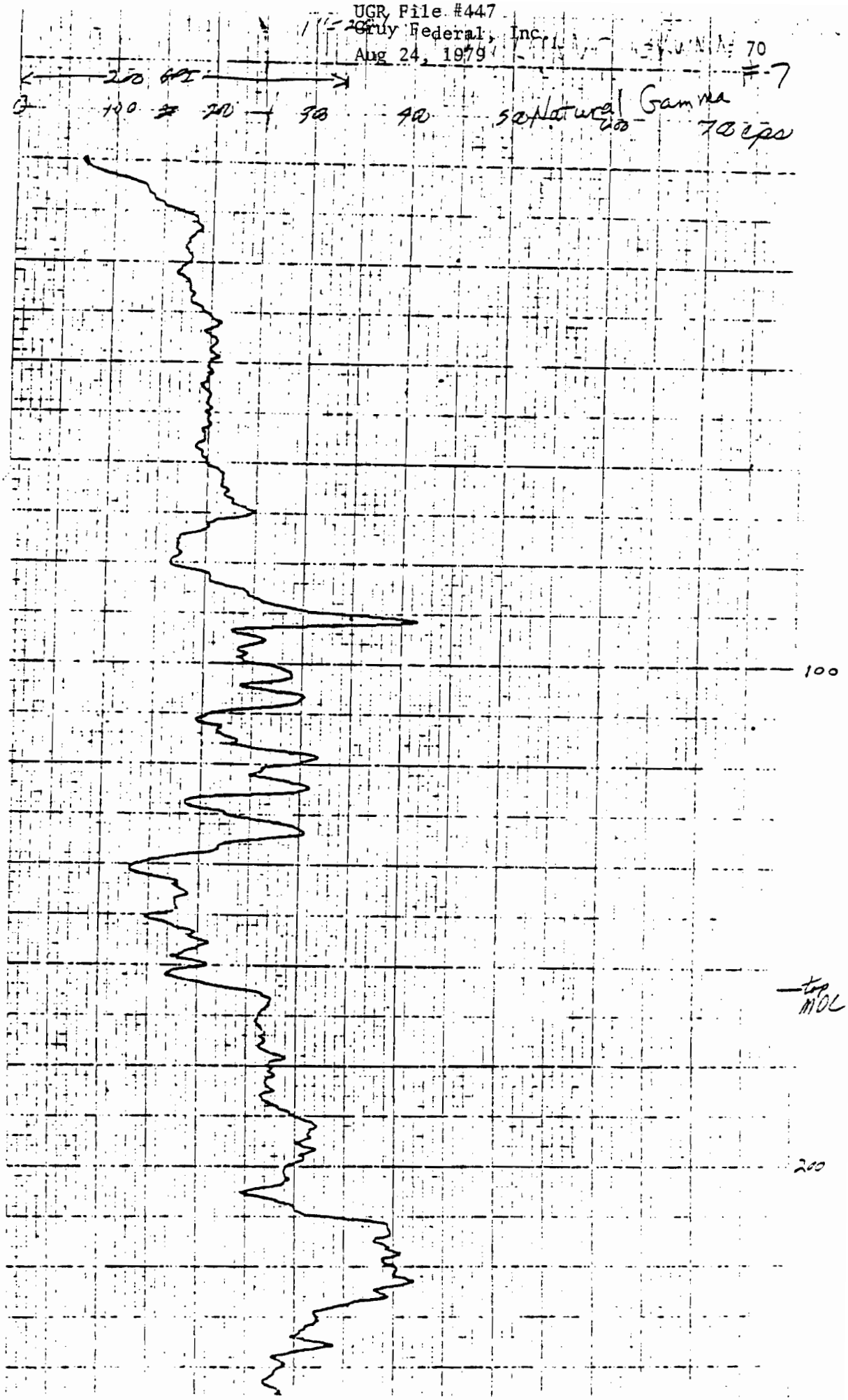
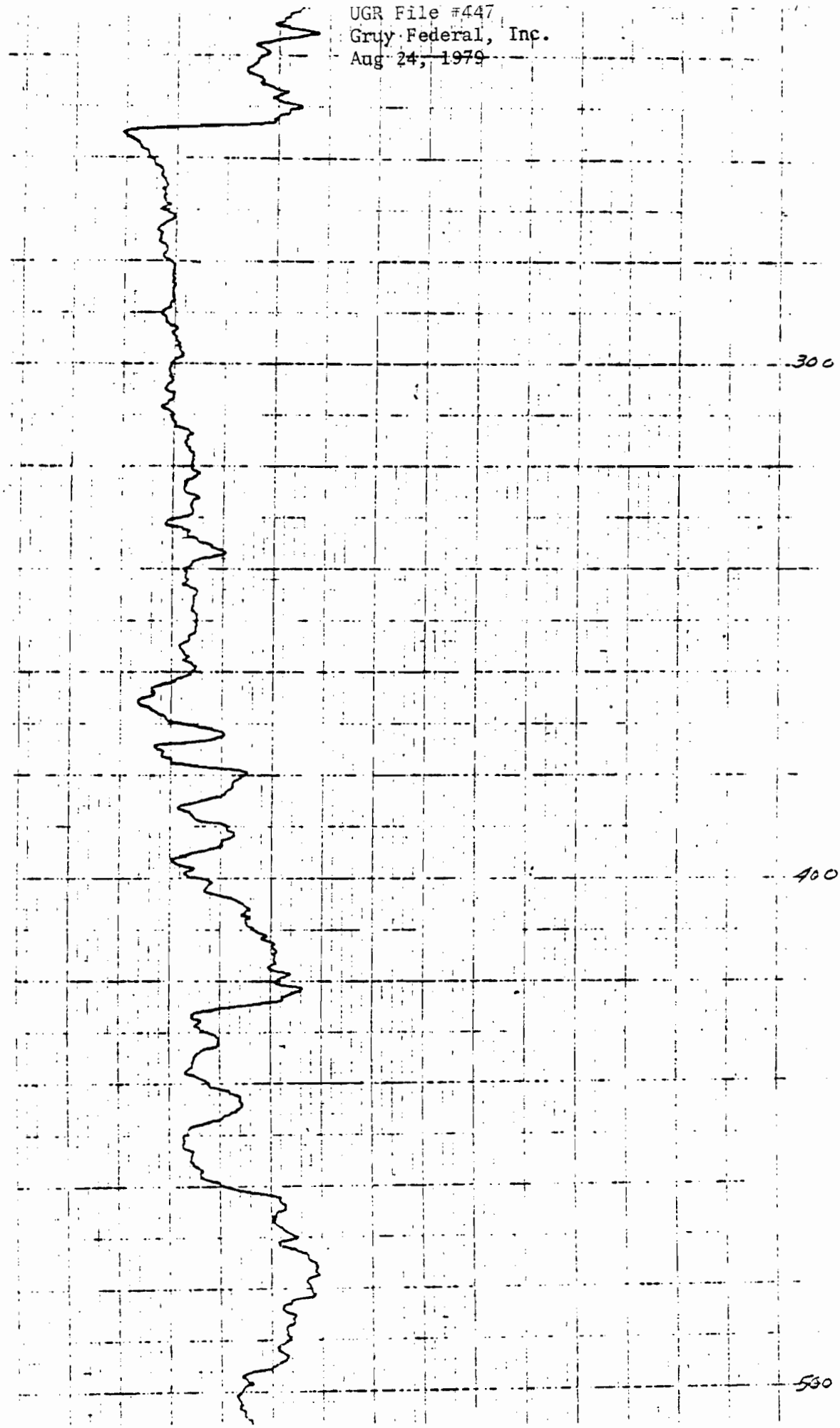
Gruy Federal, Inc.
Aug 24, 1979

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Aug 24, 1979
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400
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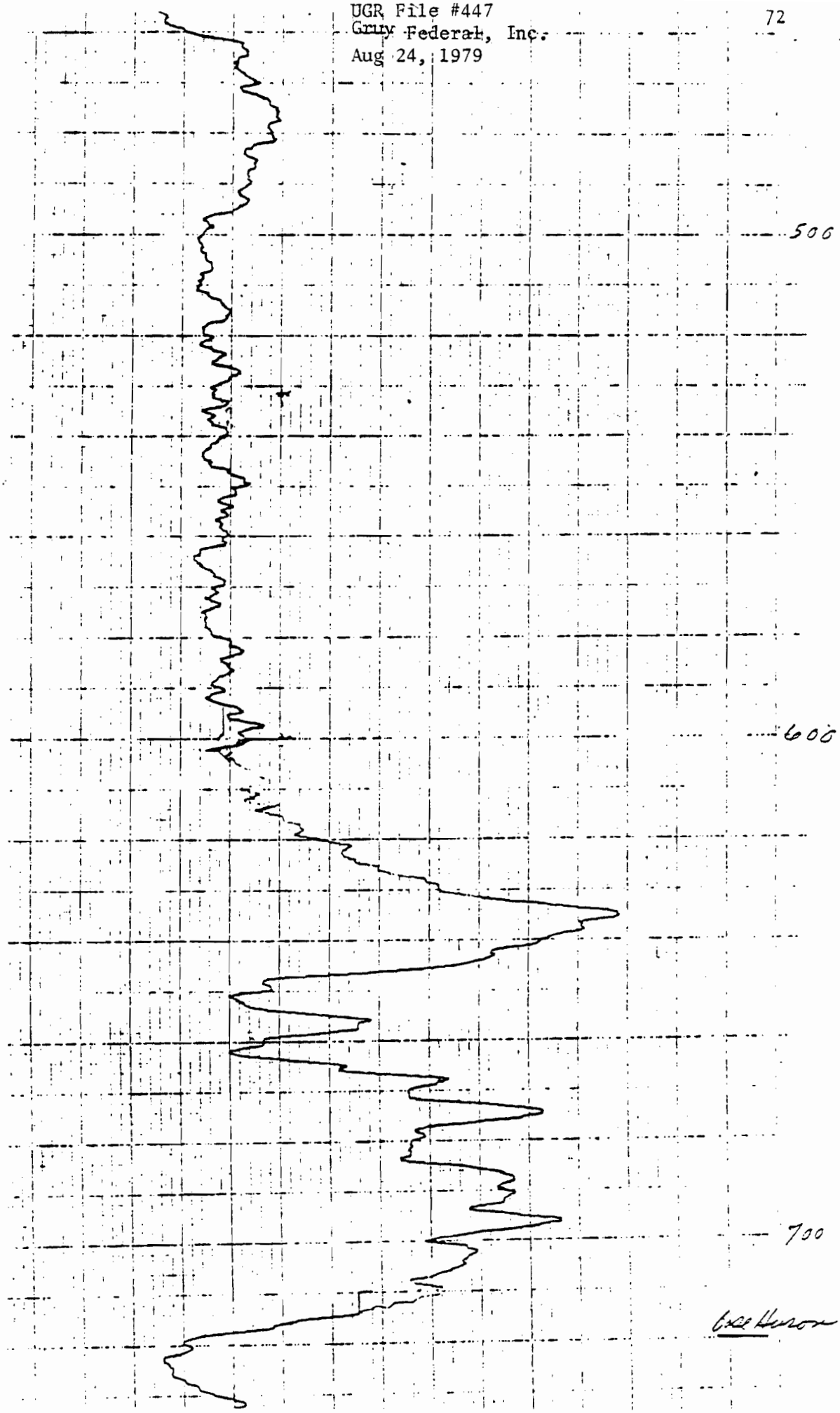
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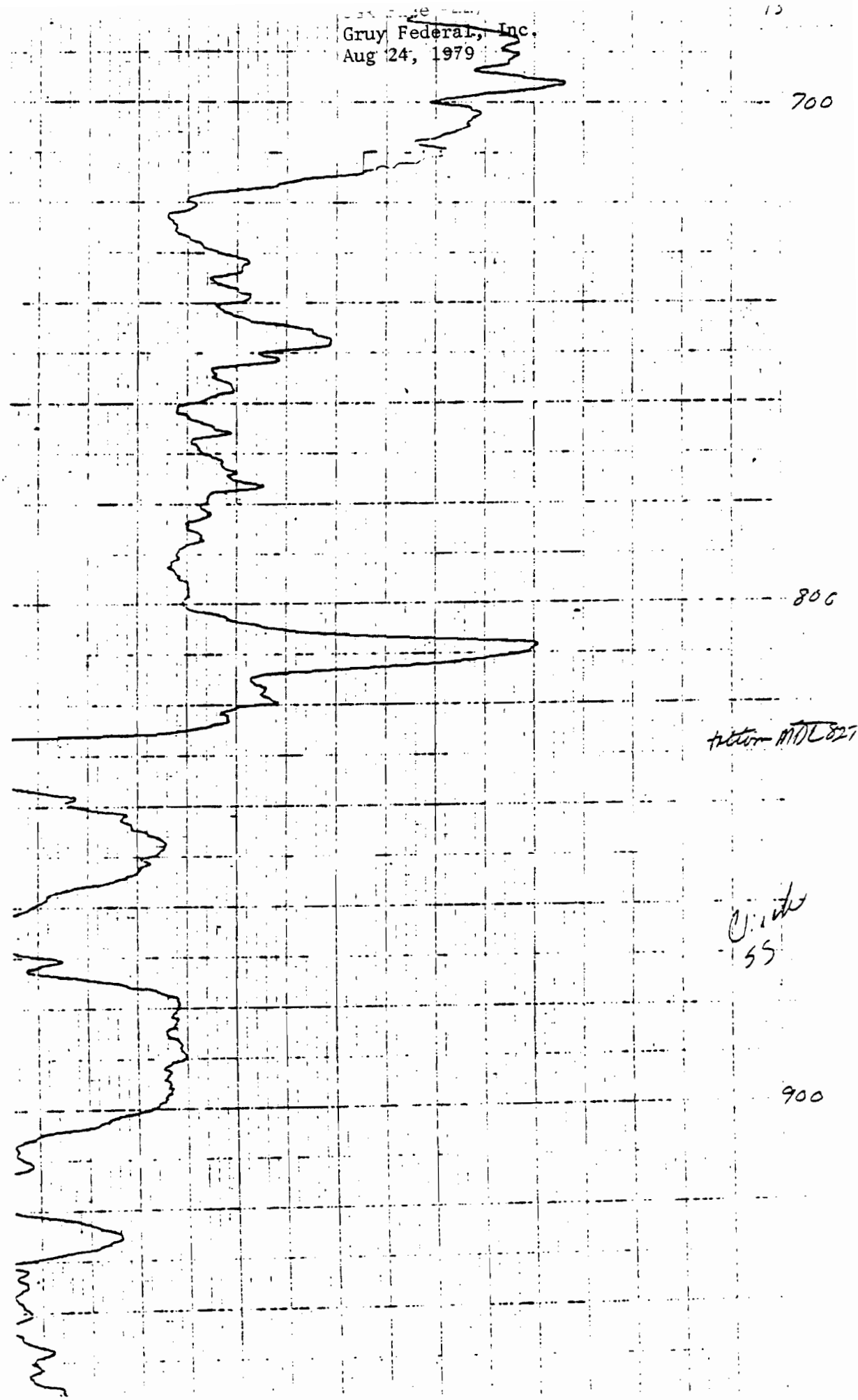
Lake Huron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Aug 24, 1979
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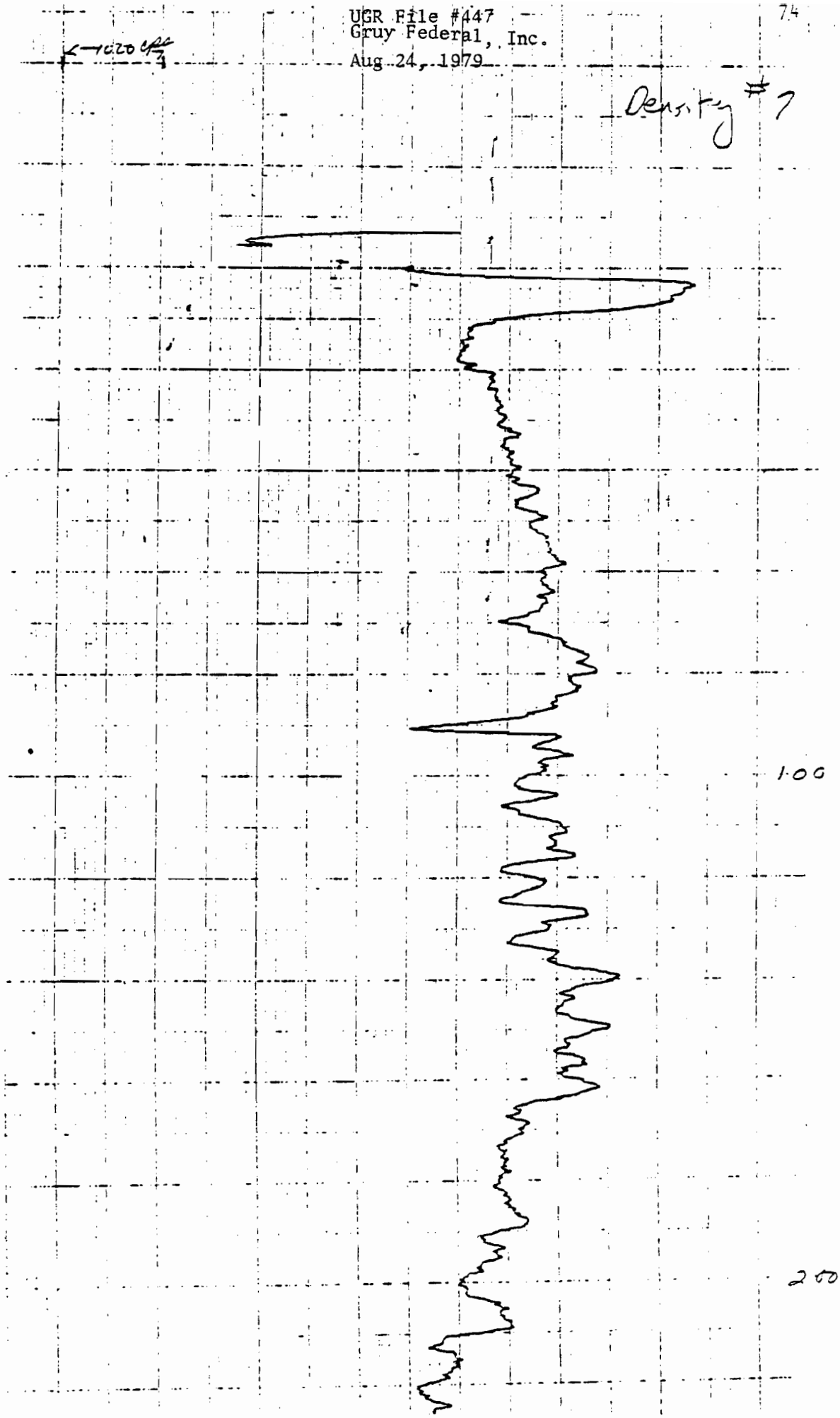

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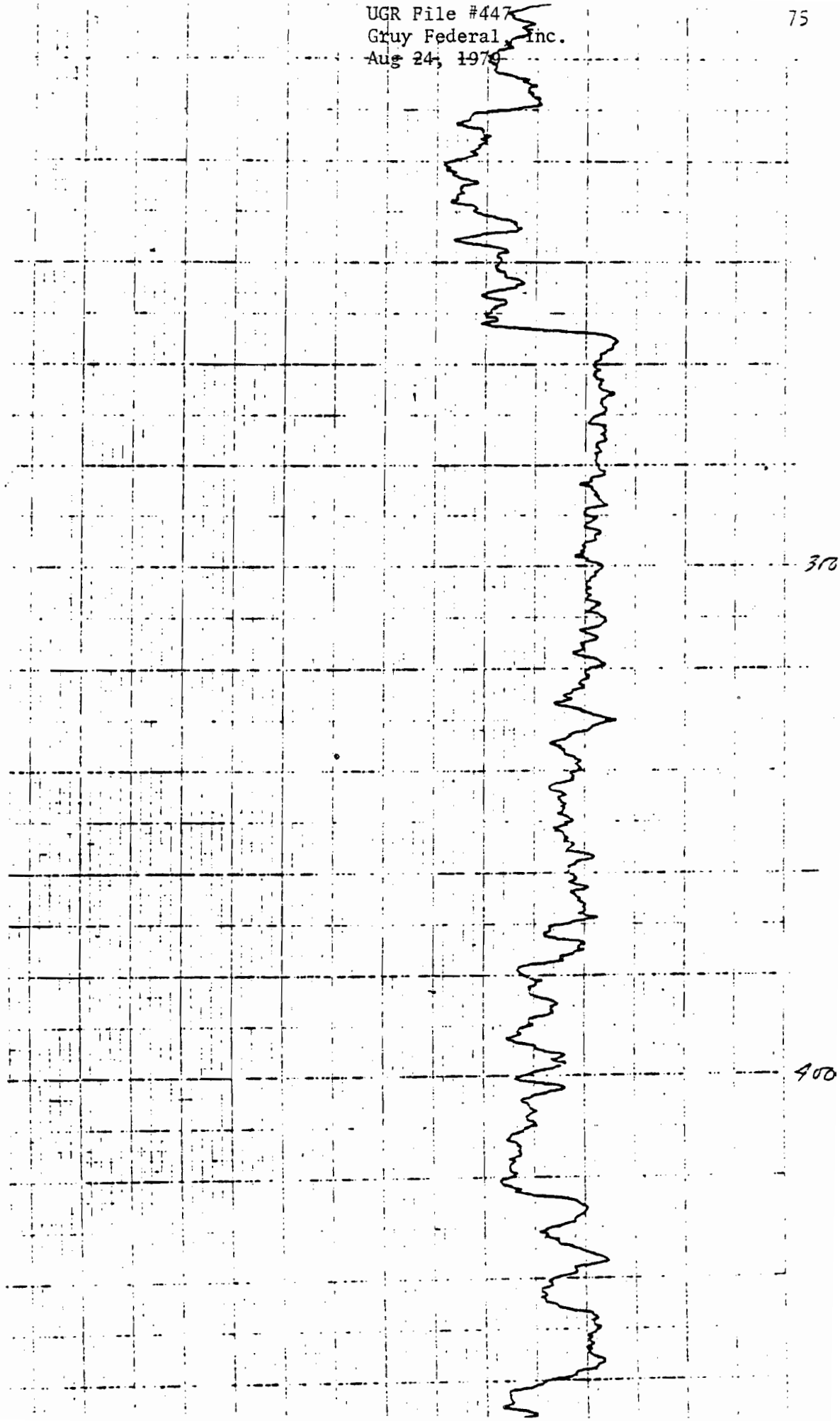

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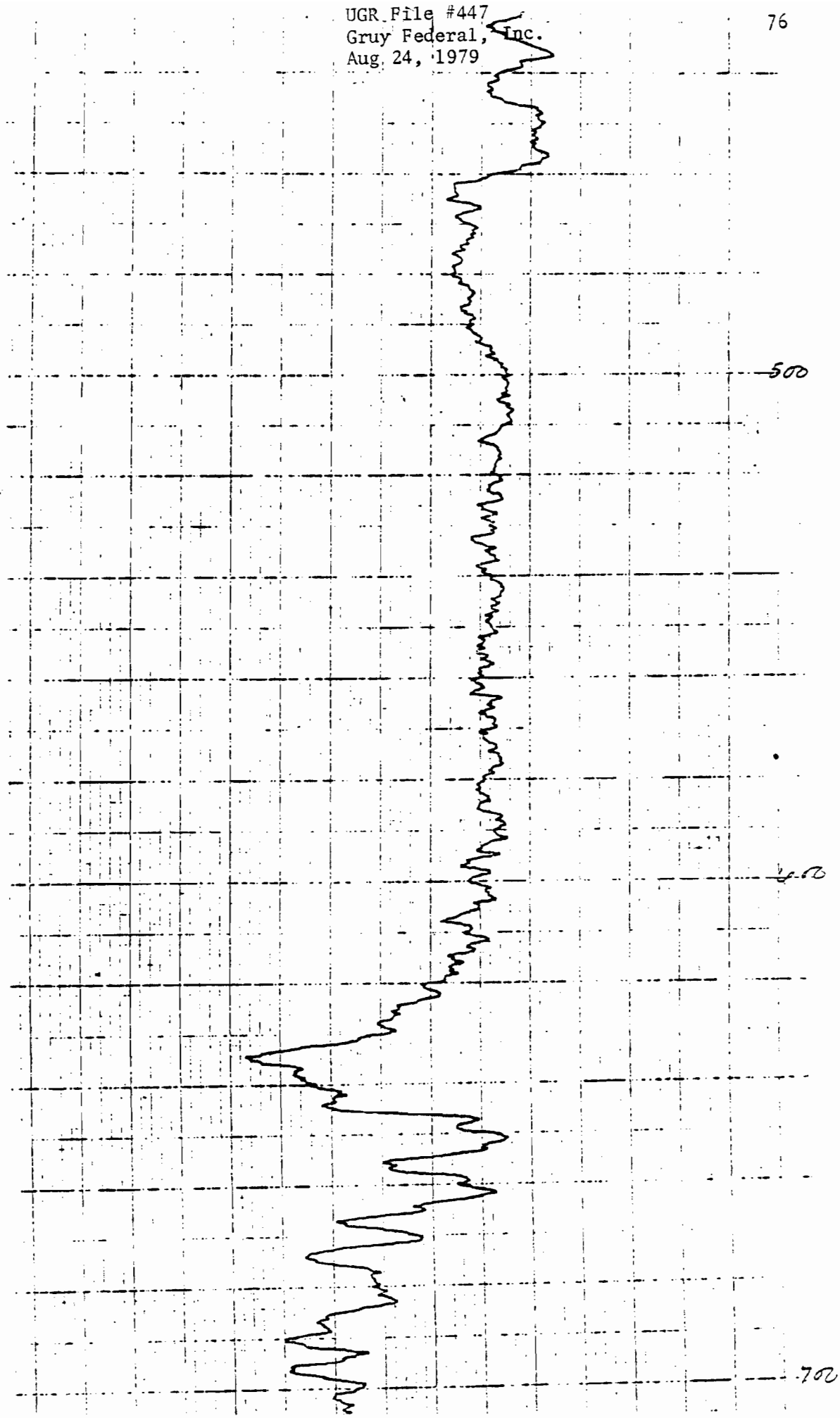
Aug. 24, 1979



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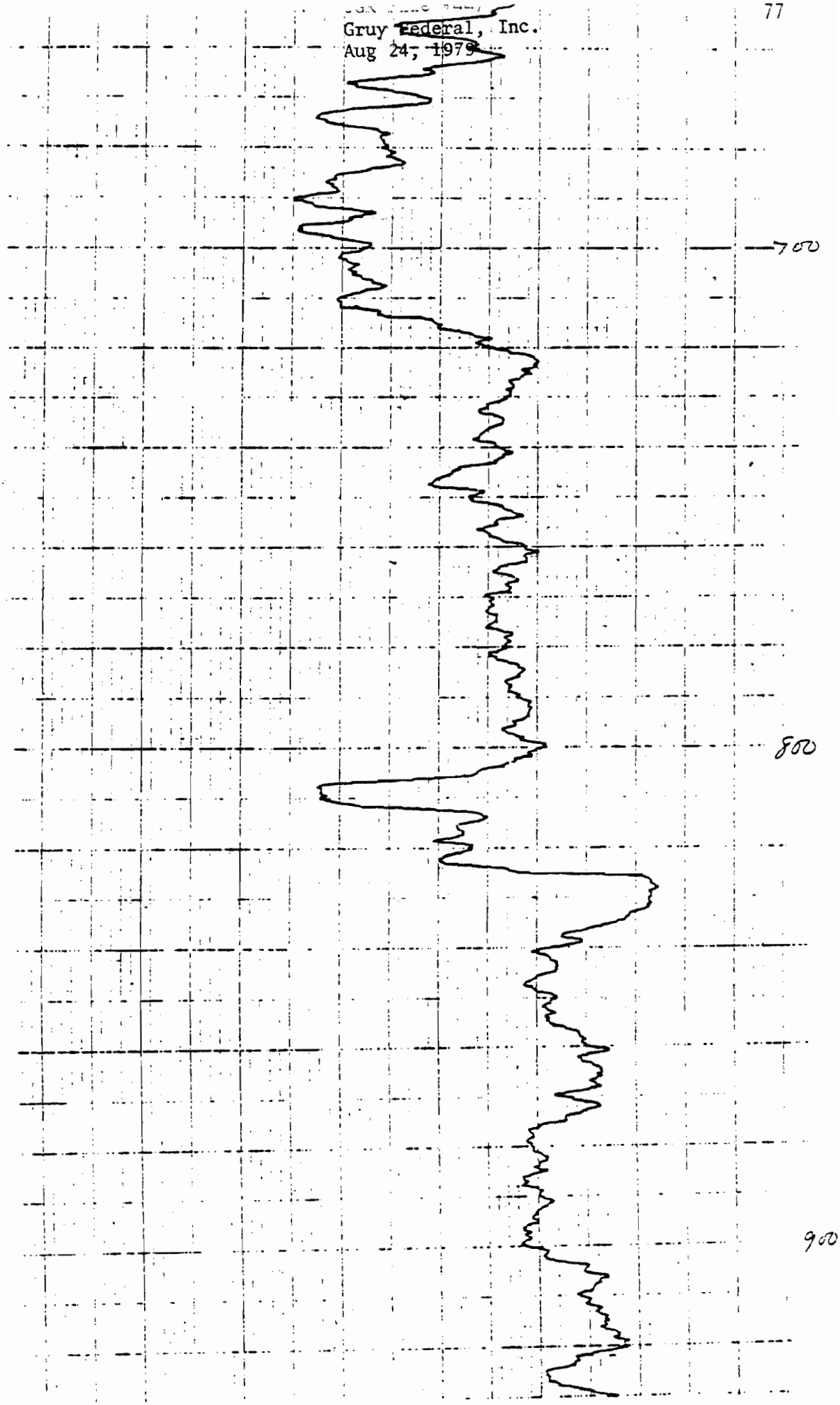

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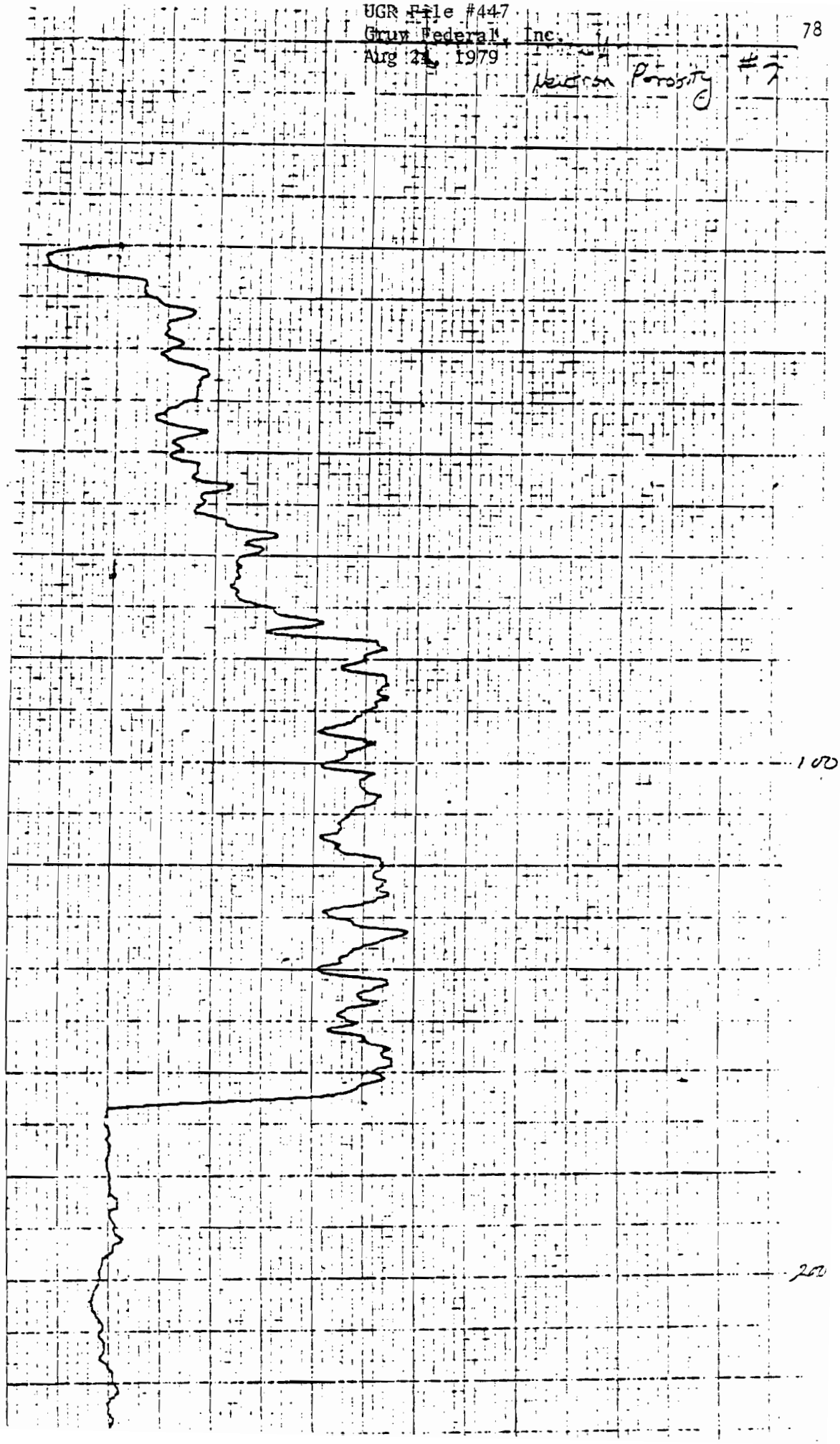
Aug 21, 1979

Neutron Porosity #7



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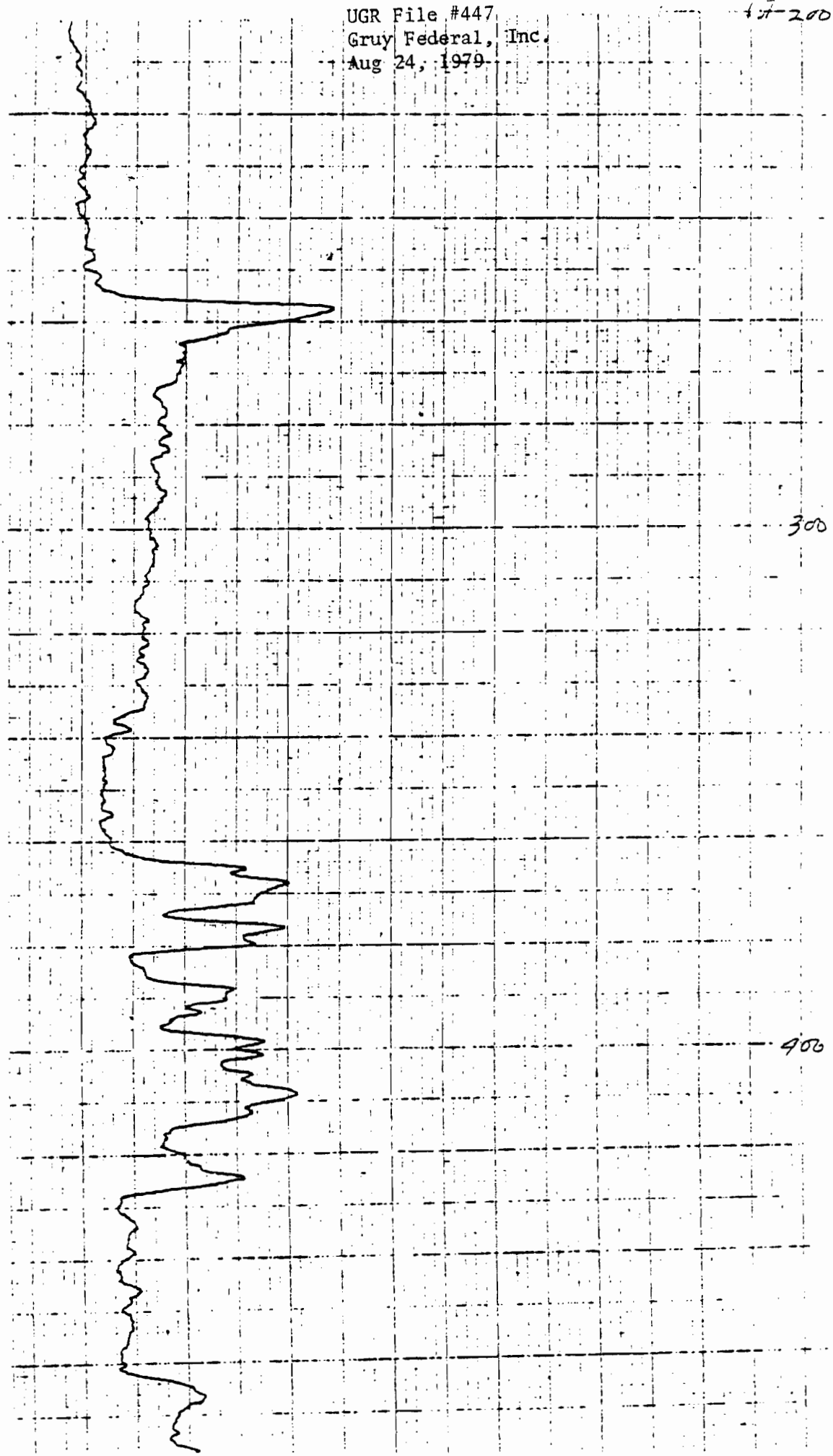

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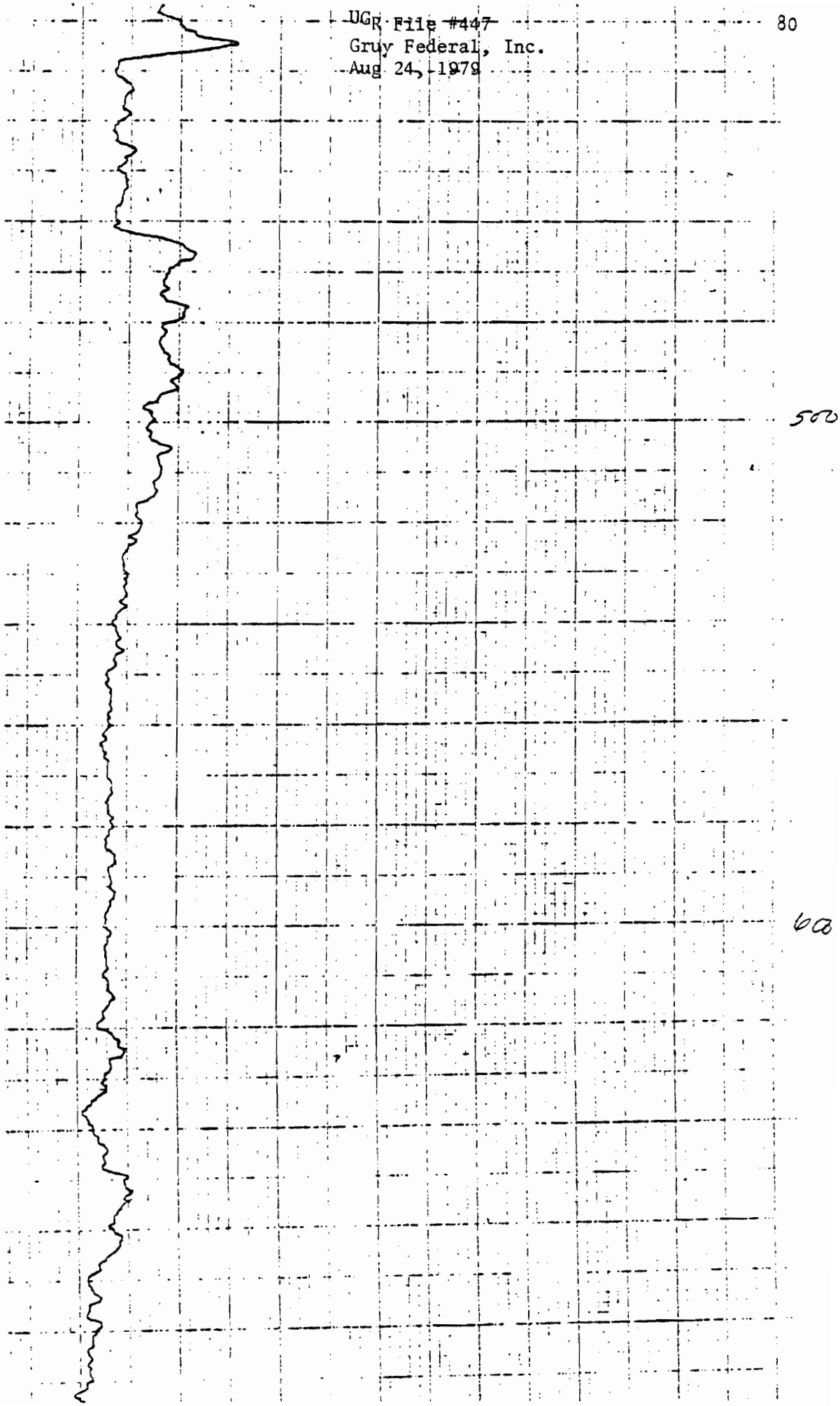

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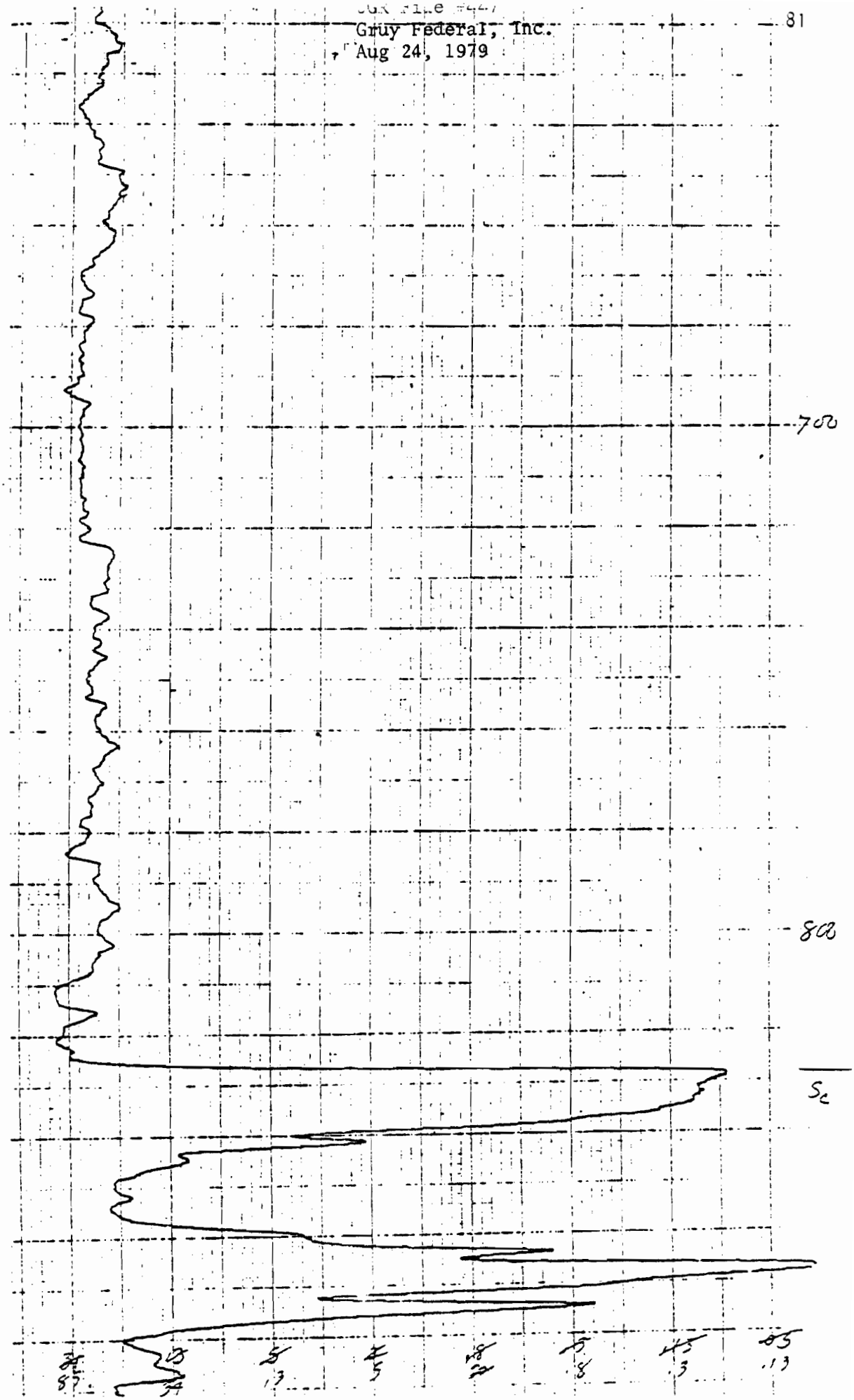
Aug 24, 1979



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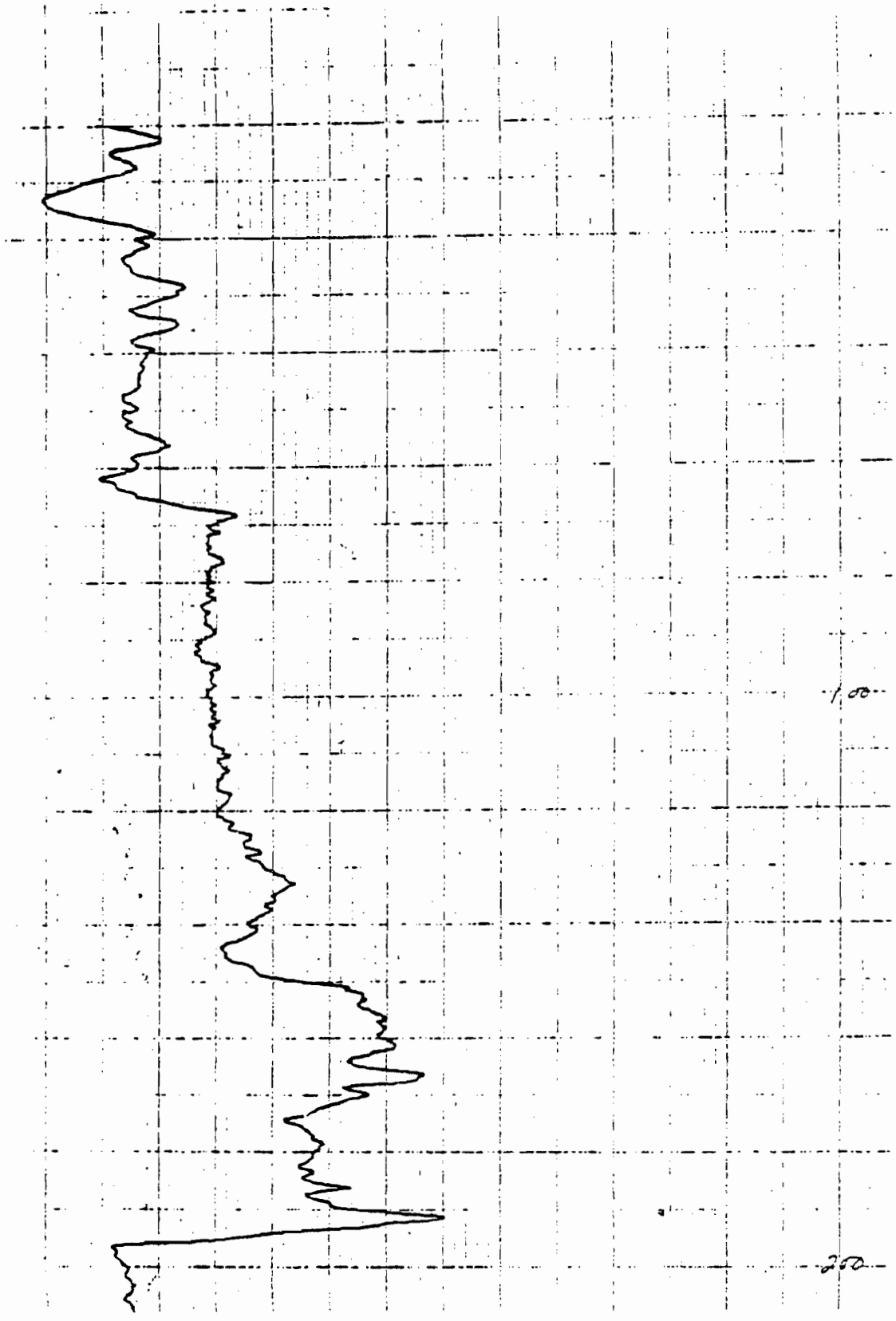
Aug 24, 1979

#8 natural gamma



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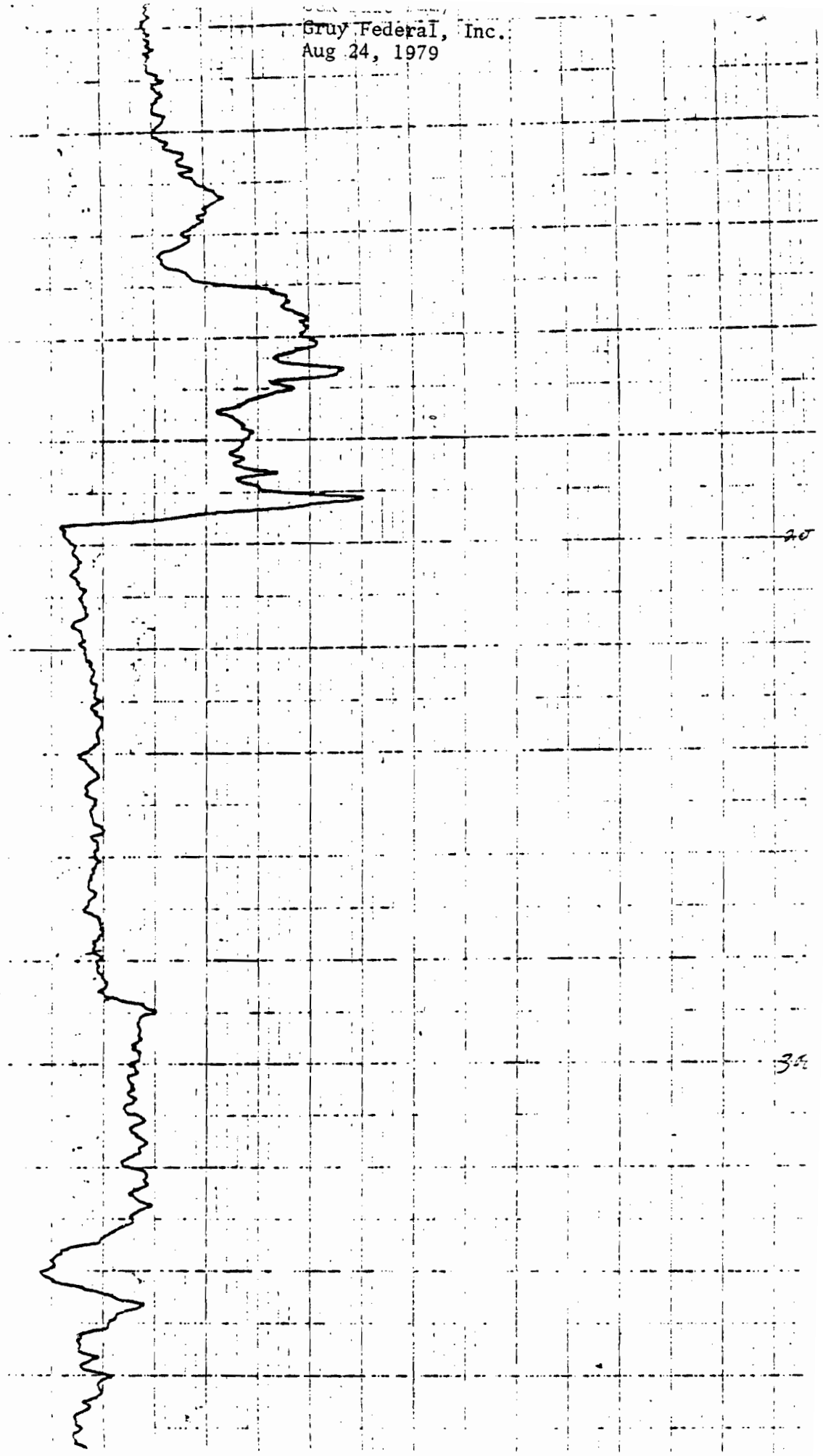
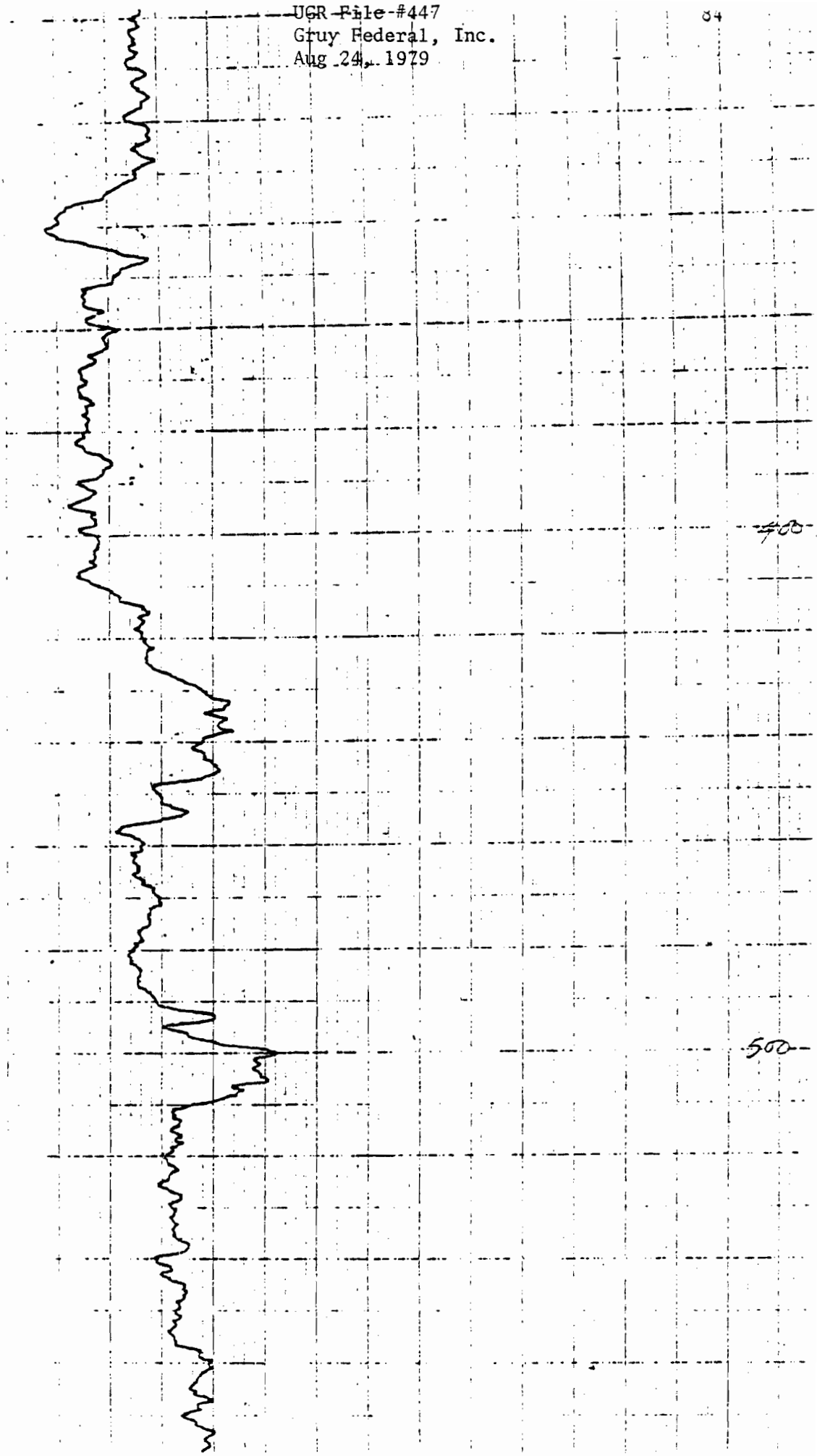
Aug 24, 1979

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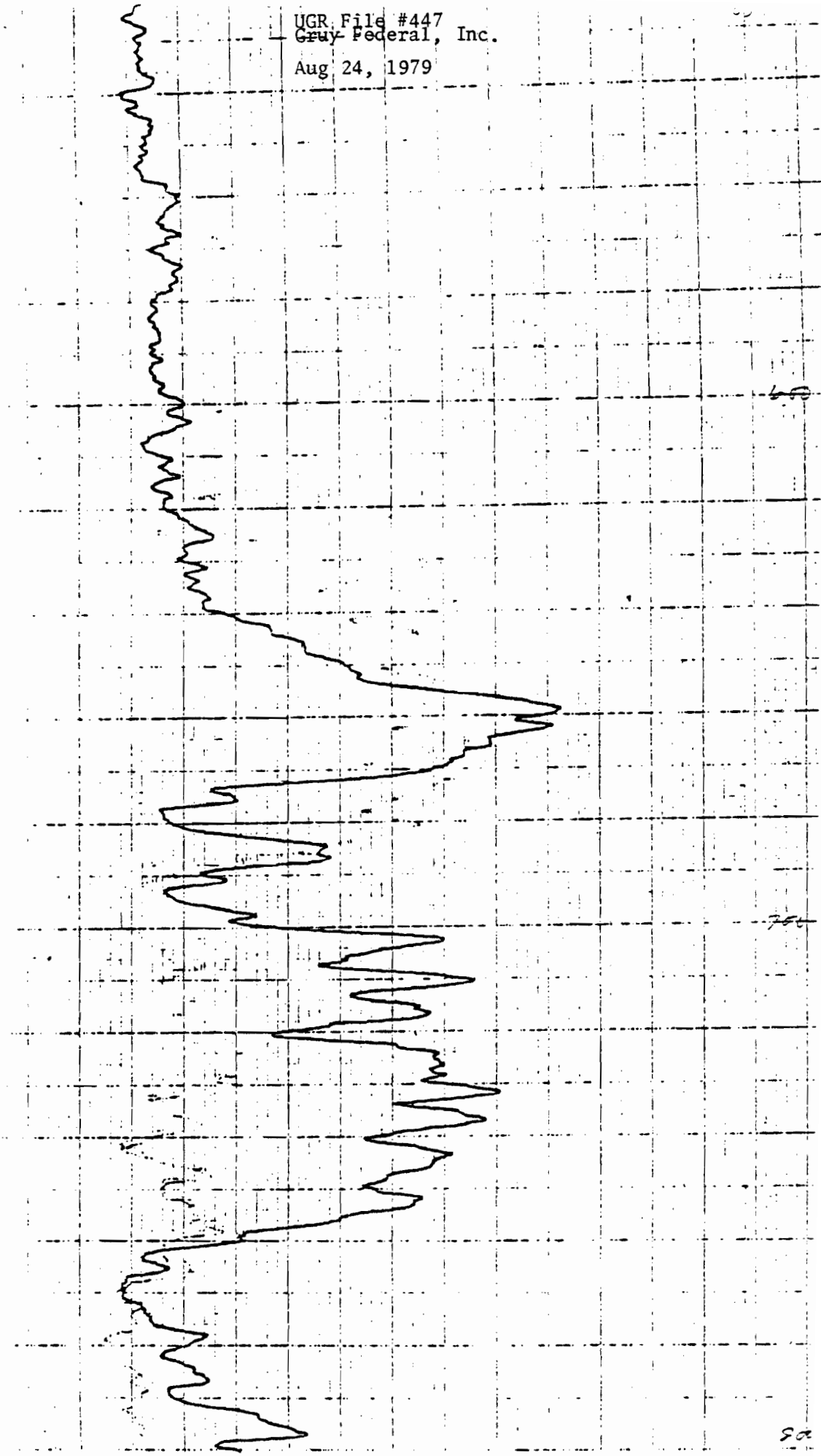
~~Gruy~~ Federal, Inc.
Aug 24, 1979



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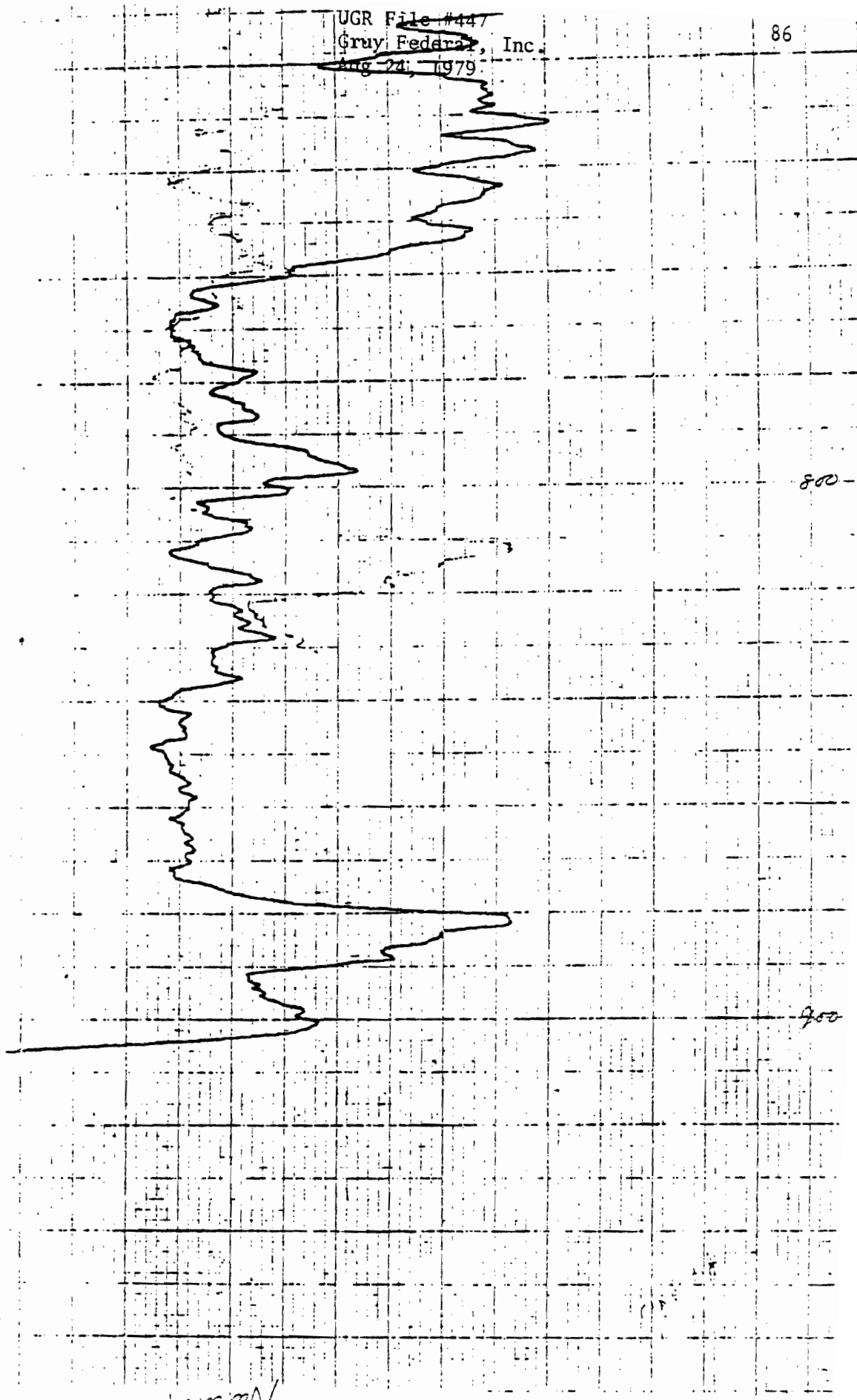

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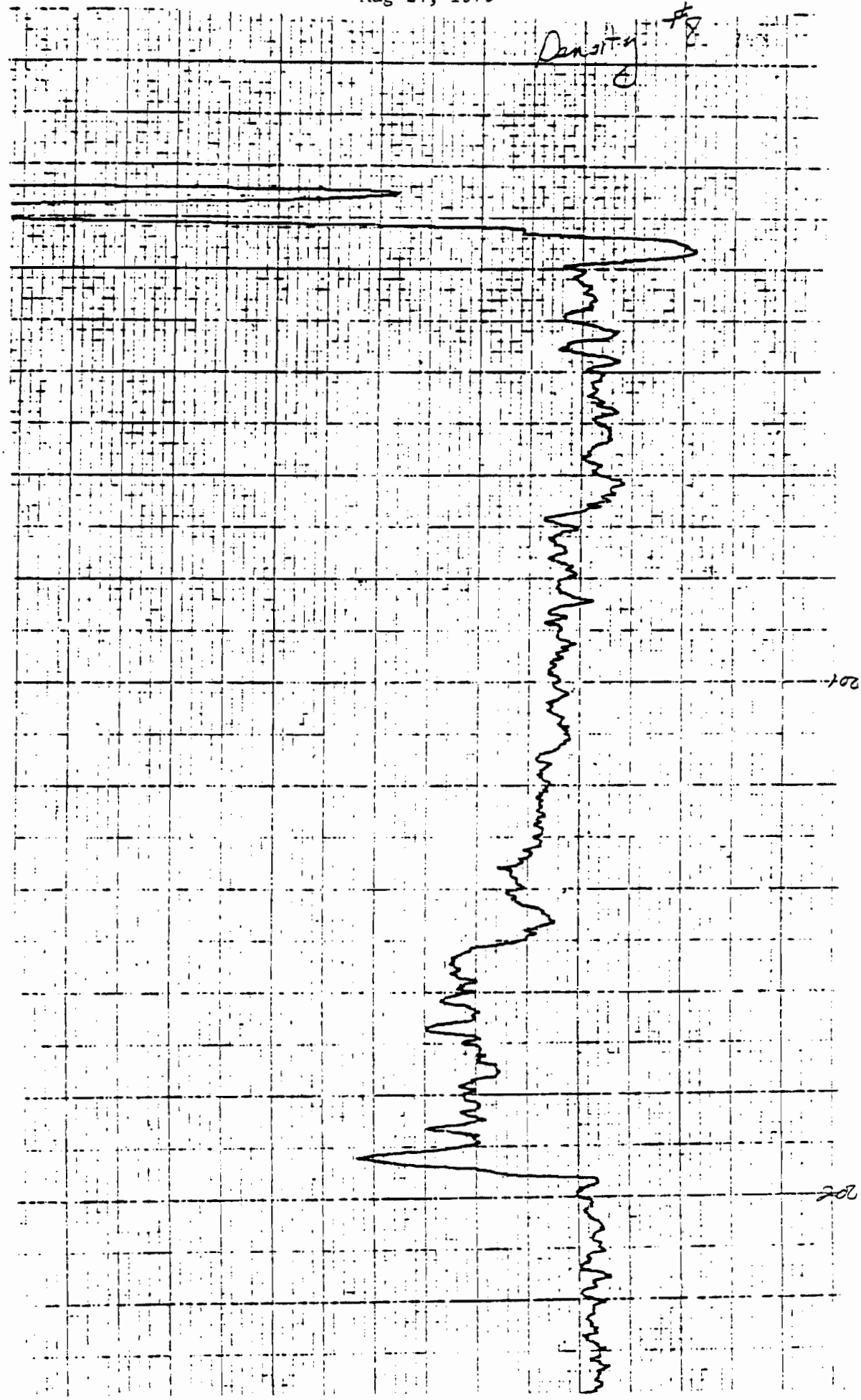

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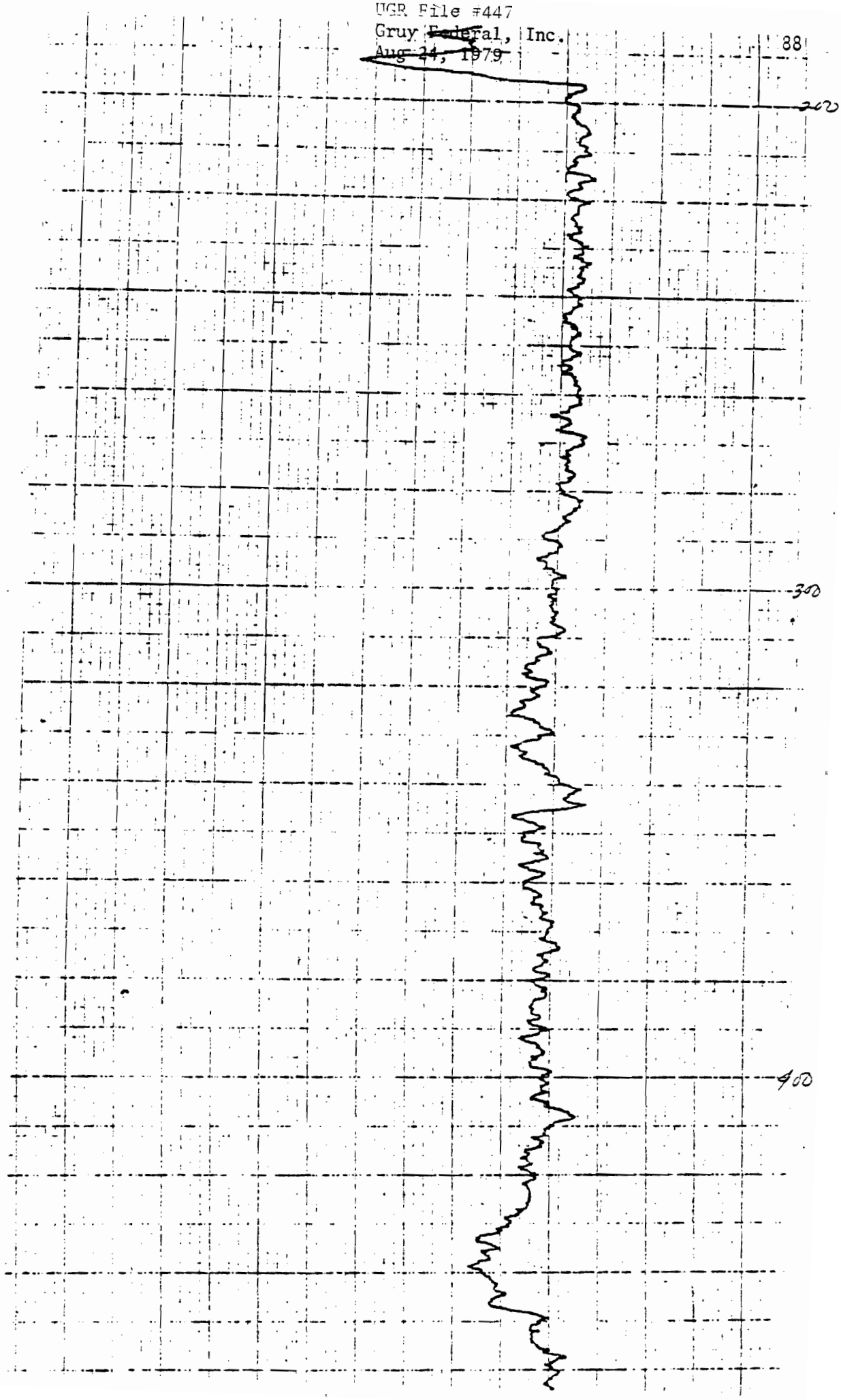

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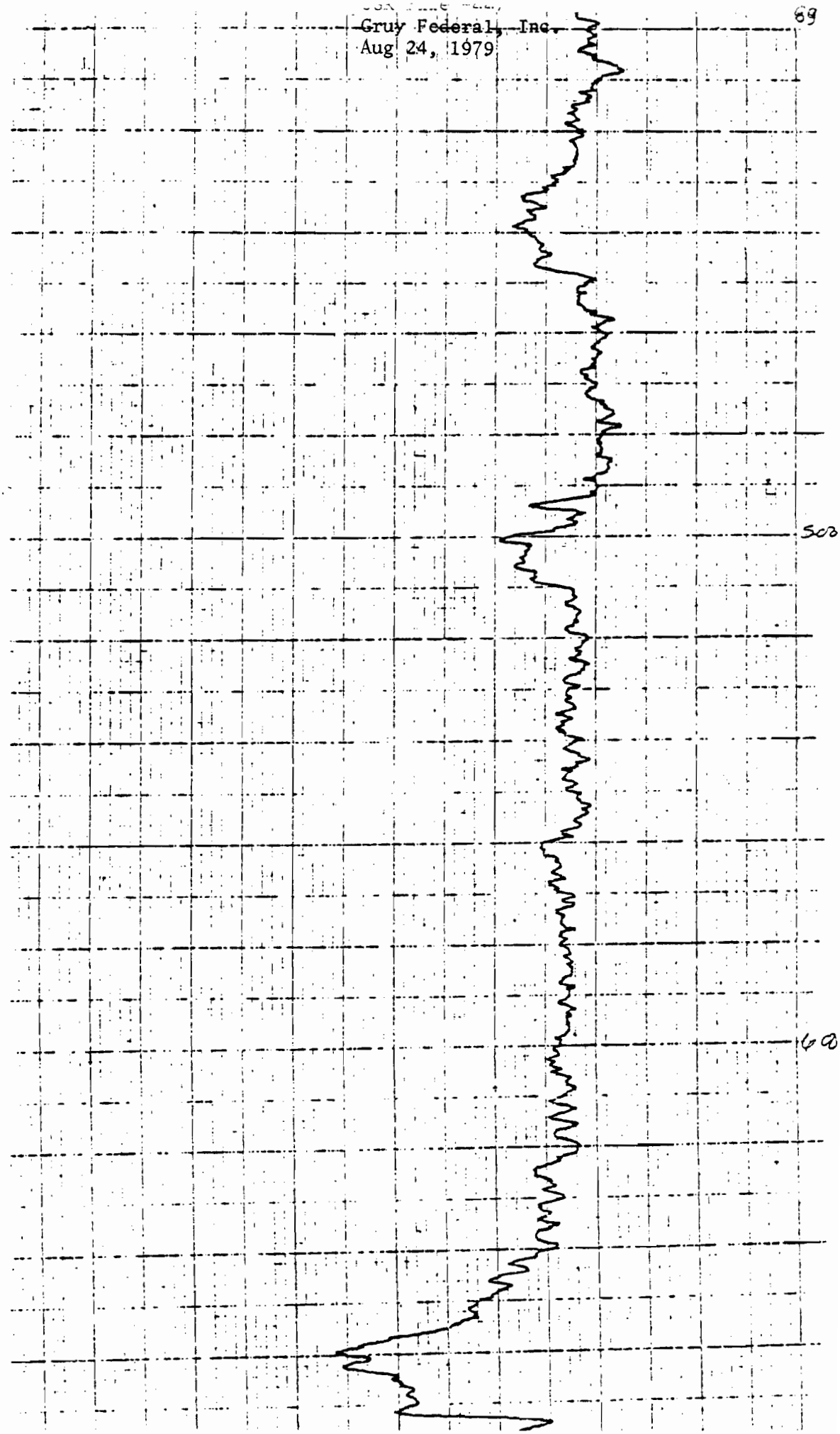

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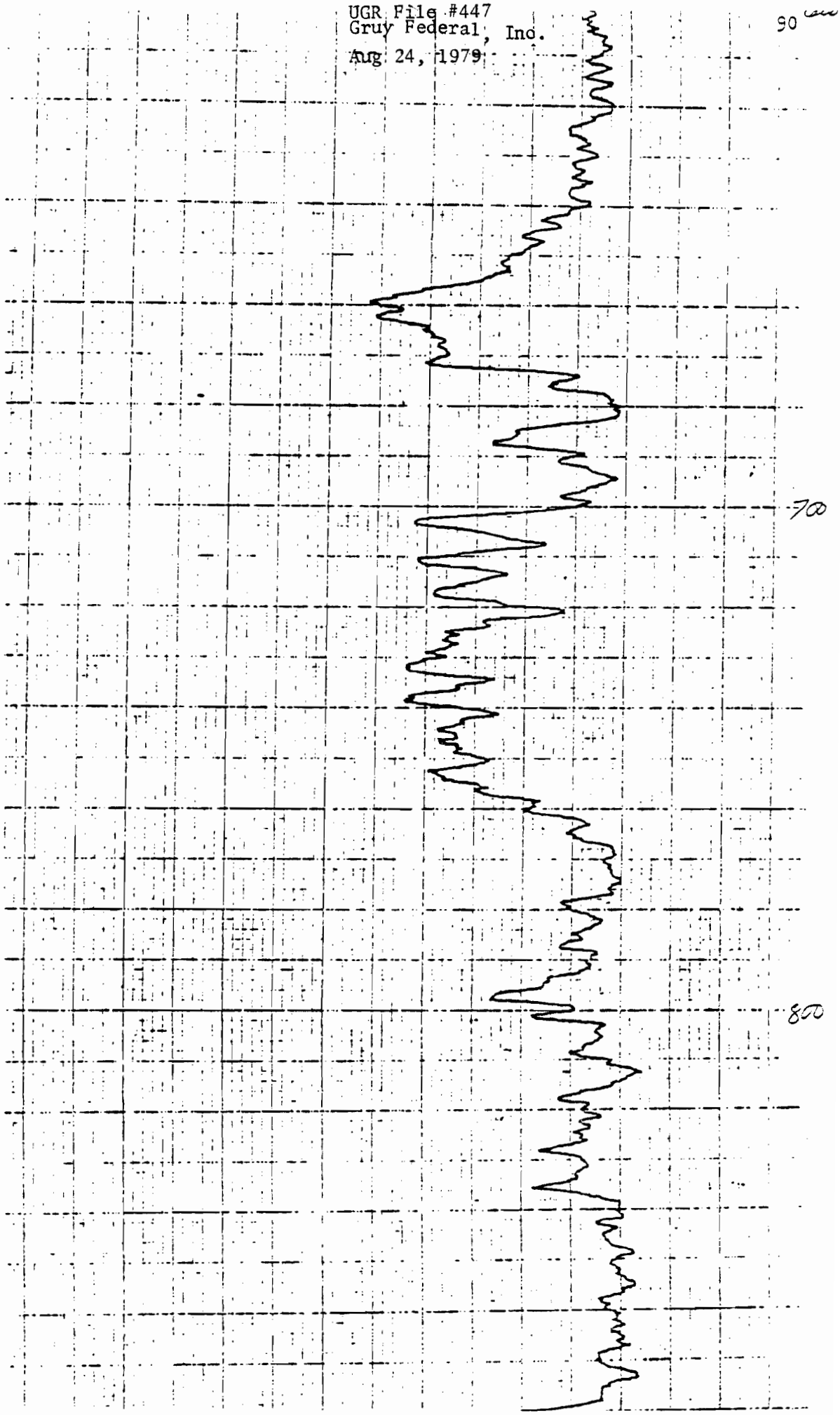

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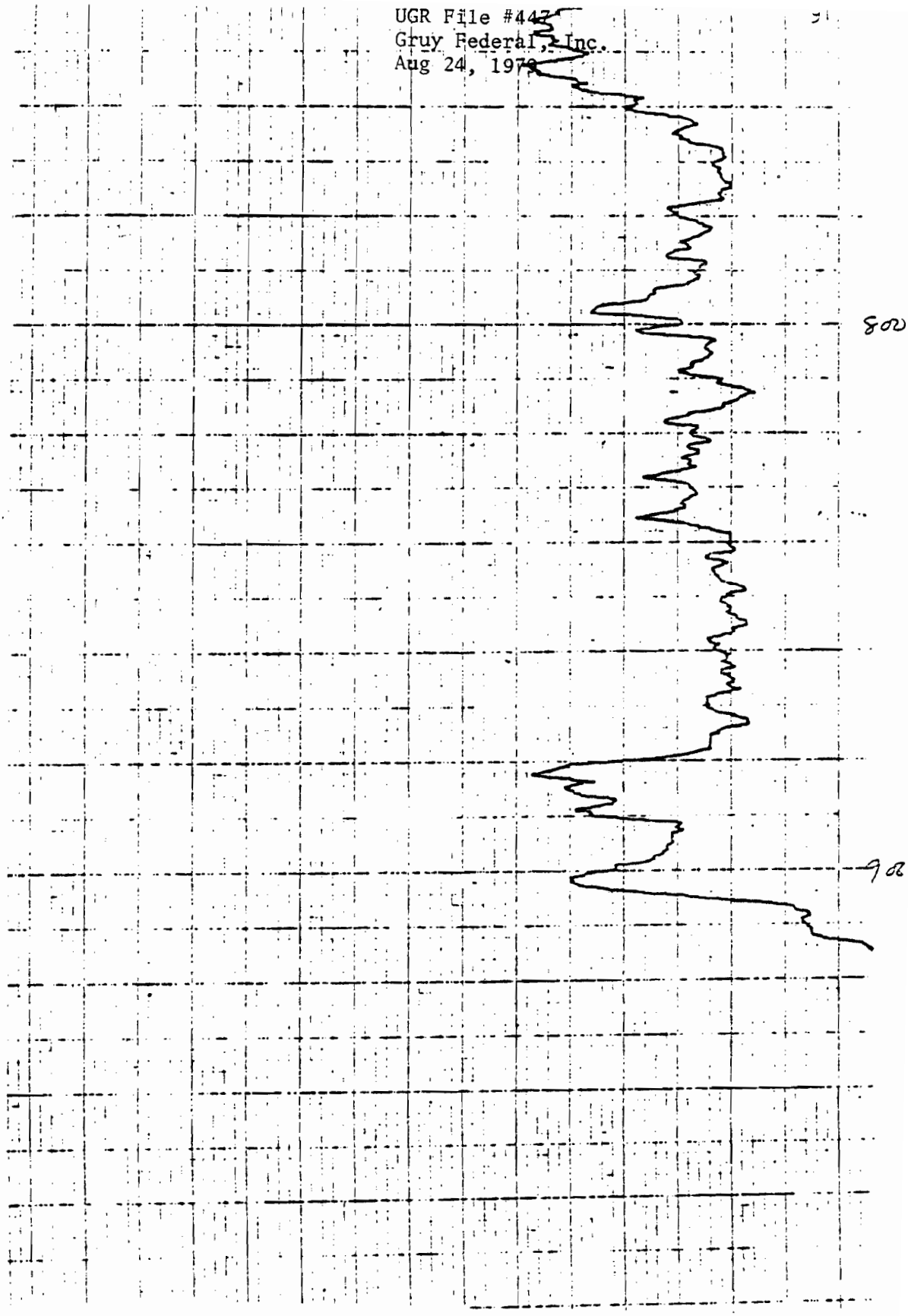
Gruy Federal, Inc.
Aug 24, 1979



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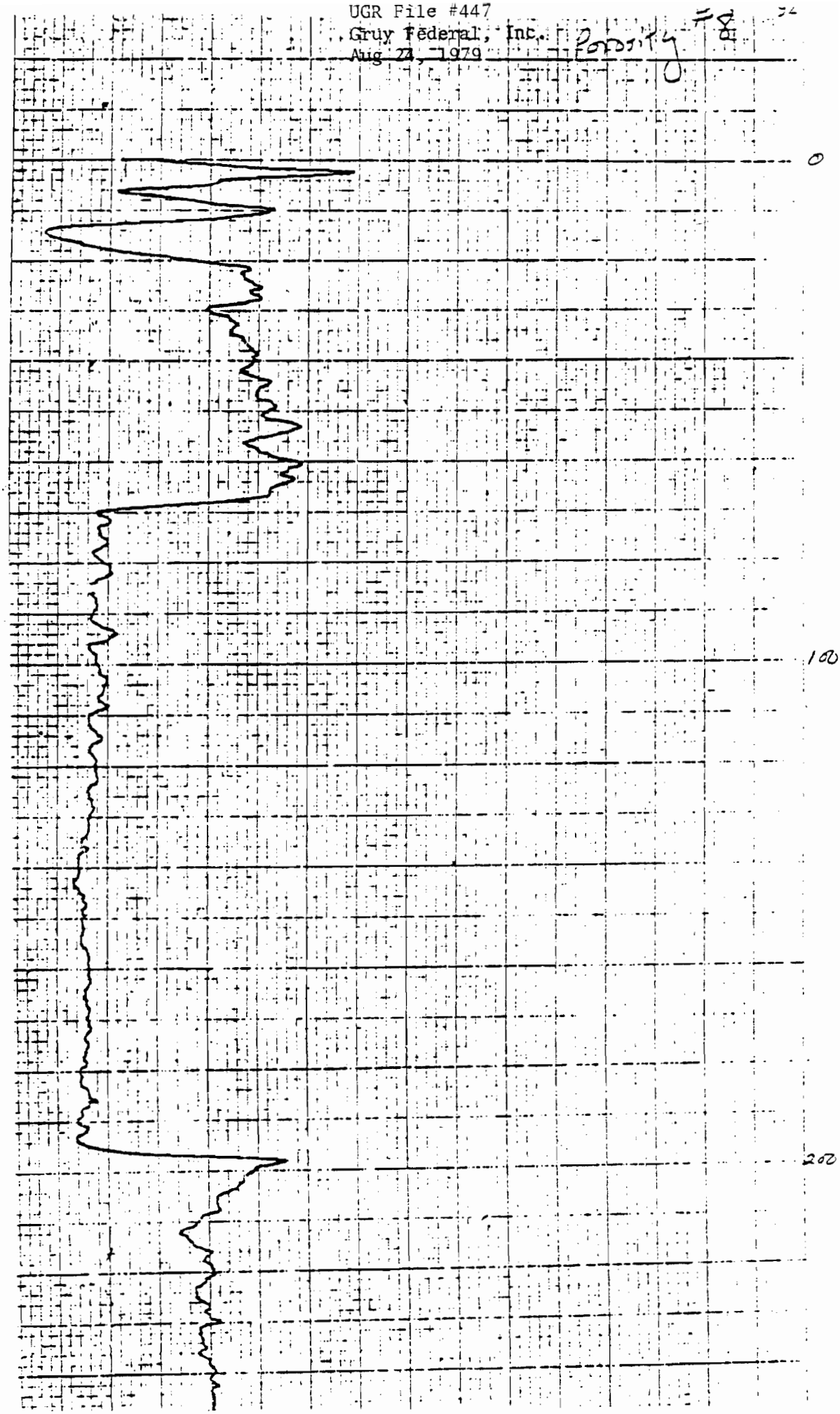
Porosity #8



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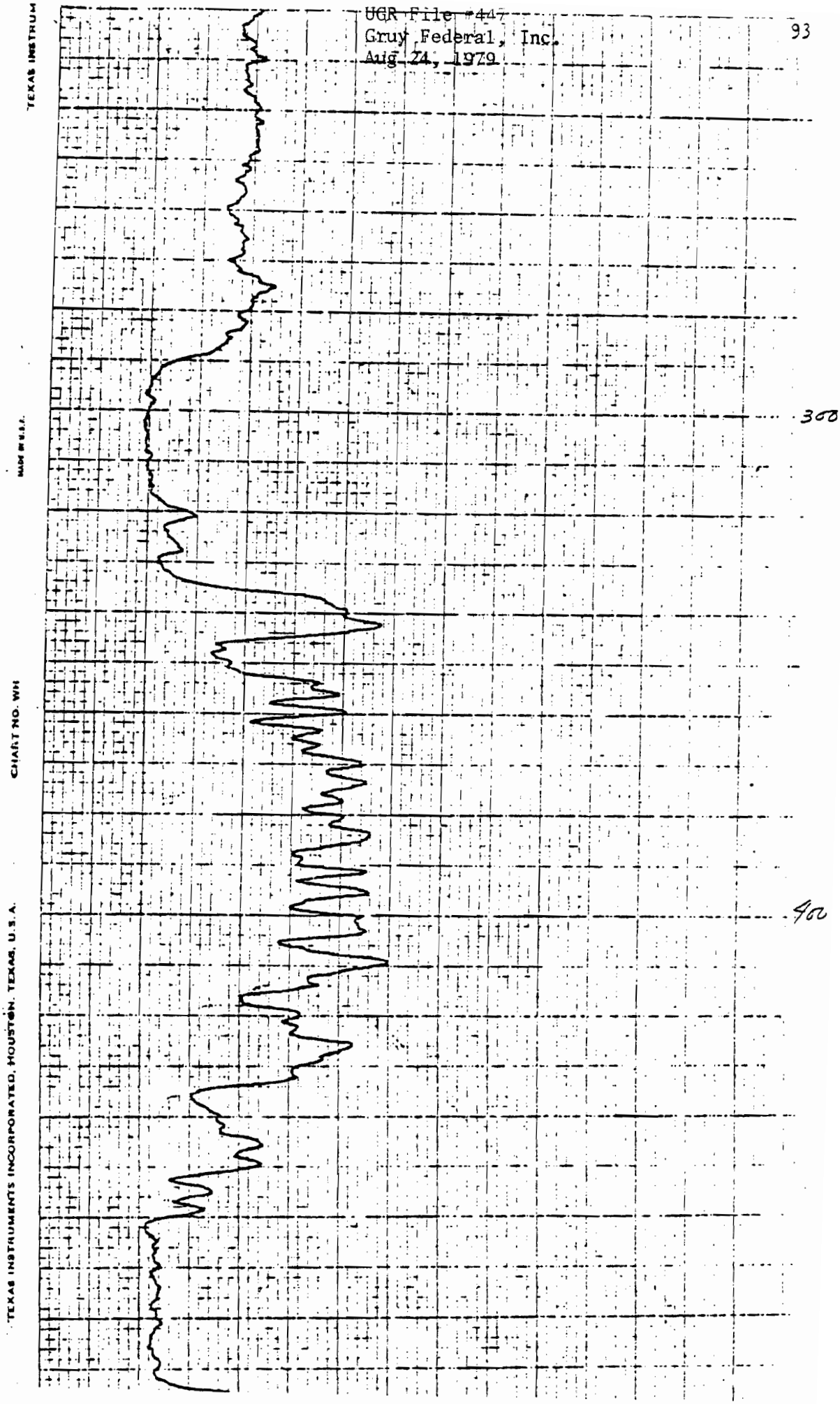
Aug 24, 1979



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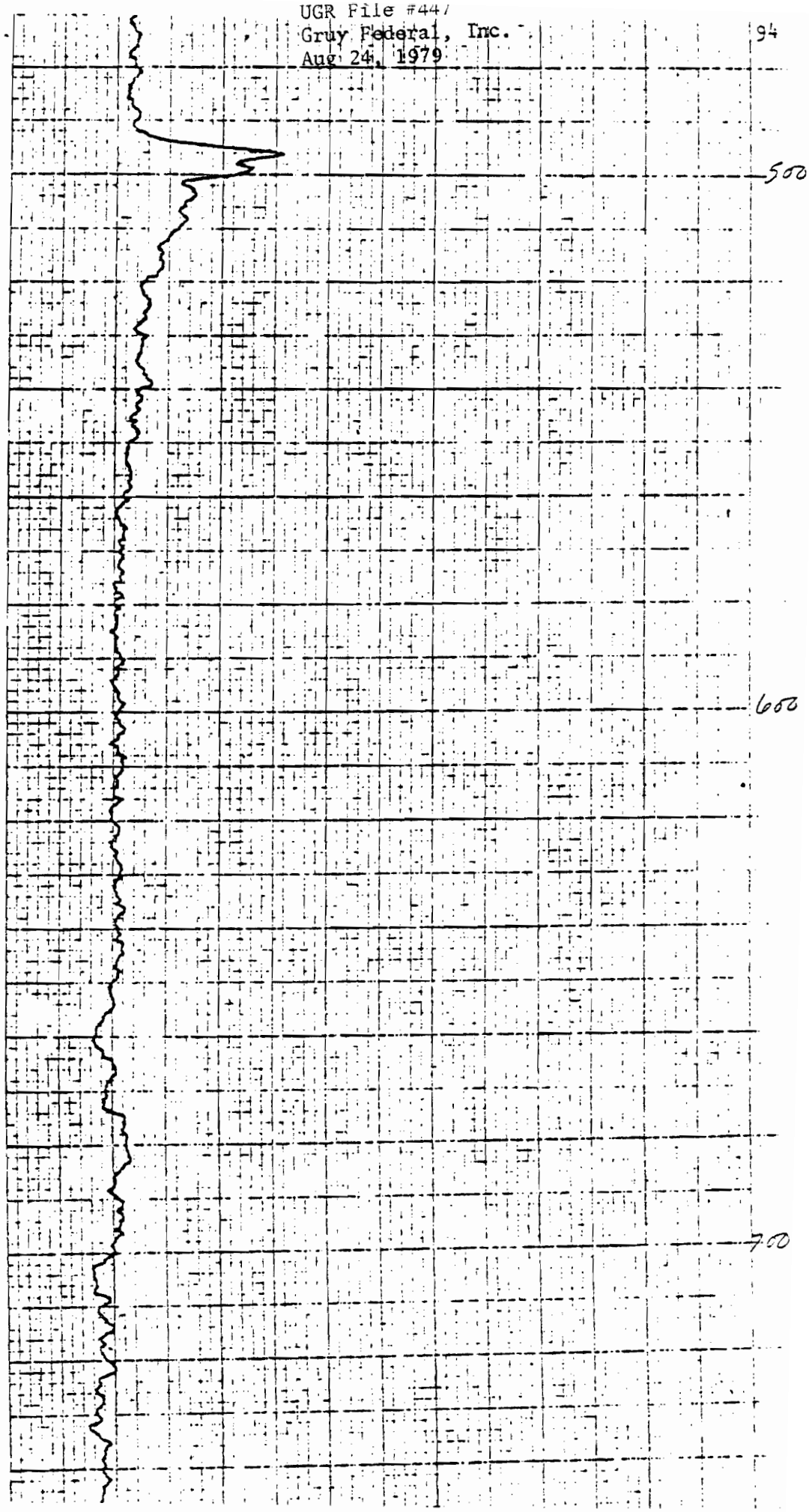
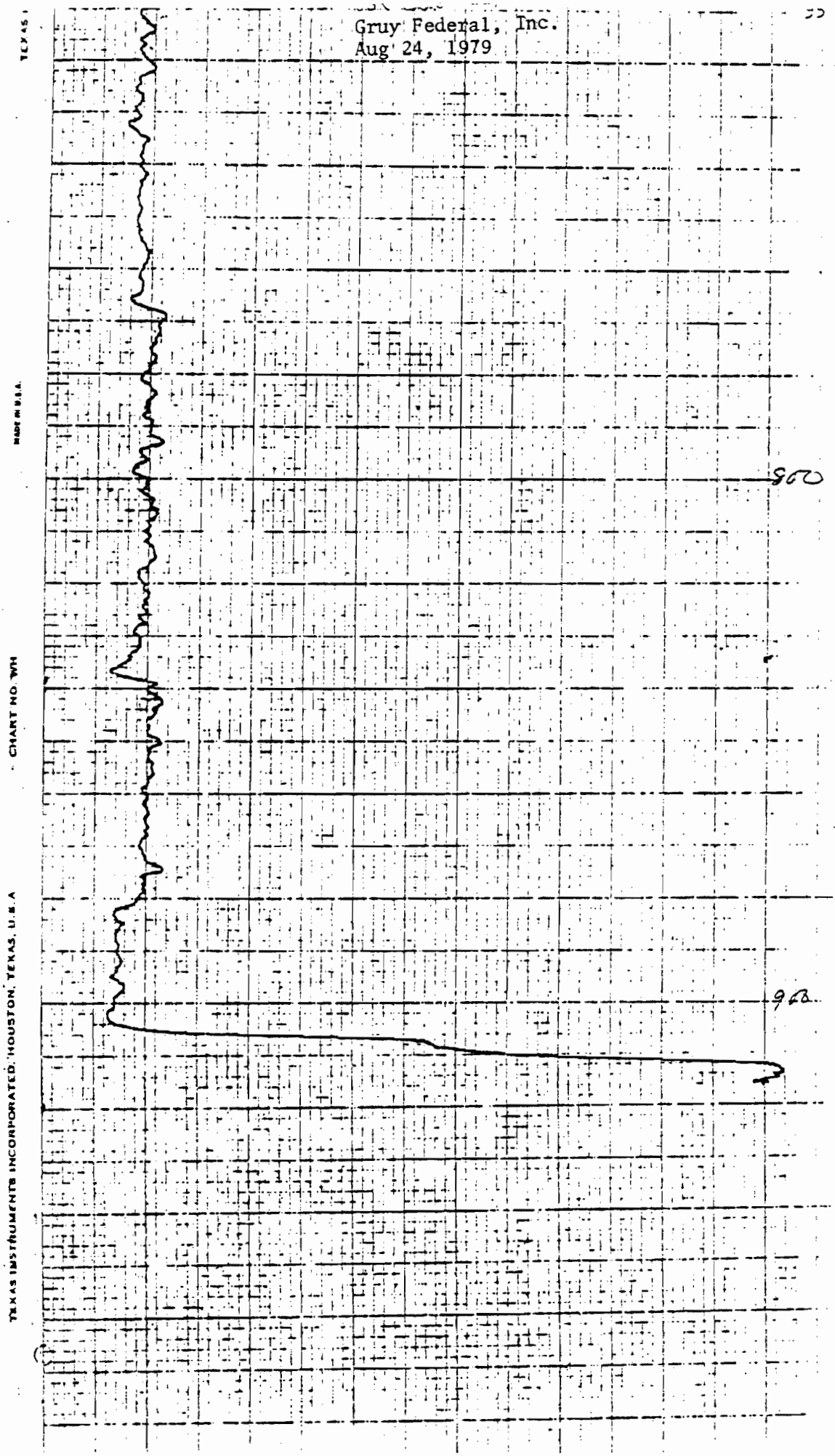
Aug 24, 1979



TEXAS INSTRUMENTS INCORPORATED, HOUSTON, TEXAS, U.S.A.
CHART NO. W11

Gruy Federal, Inc.
Aug 24, 1979



APPENDIX D

HASSON'S SECTIONS

T-11, T-12, T-33

Grainger County

Section T-11. Bean Station Quadrangle. 724,600 N, 2,784,600 E. This is the type section of the Grainger Formation. Measurement made in cuts on the northeast side of U.S. 25-E. Section begins about 500 feet south of intersection with dirt road leading to Mountain View Church and proceeds toward U.S. 11-W.

		Feet
	Rome Formation (86.0 Feet)	
69	Not measured.	
68	Siltstone, indistinctly bedded.	4.0
67	Shale, very thickly laminated, grayish red. Typical Rome red shale.	5.0
66	Siltstone, thinly bedded.	4.0
65	Siltstone, massively bedded, micaceous. Bedding not distinct like that of Grainger.	22.0
64	Covered. Base of interval taken as Rome-Grainger contact and position of Saltville fault. Contact probably correct within 25 feet.	51.0
	Grainger Formation (487.8 Feet)	
	Upper Sandstone Member (52.0 Feet)	
63	Sandstone, very fine to fine grained; medium to thickly bedded; medium gray, weathers light olive gray. One foot bed quartz pebble conglomerate grading into conglomeratic sandstone about 6 feet below top of interval; minor crossbedding; lower 4 feet very silty shale.	19.0
62	Covered.	18.0
61	Sandstone, medium to fine grain, feldspathic, medium gray; beds up to 1.5 feet; very thinly bedded near top of interval.	15.0
	Middle Member (301.3 Feet)	
60	Shale, thickly laminated, light olive gray, very silty.	30.6
59	Siltstone, single bed.	0.6
58	Shale, as in unit 60, weathers spheroidally.	4.4
	Glauconite Zone (7.7 Feet)	
57	Shale (glauconitic) with stringers of light brown-weathering very fine grained limestone. Glauconitic material grades into shale above.	3.9
56	Glauconitic fine grained limestone, weathers light brown (5YR 5/6).	0.3
55	Glauconite, sand size in matrix of silt and carbonate; weathers dusky blue-green (5BG 3/2).	1.3

		Feet
54	Limestone, very fine grained, silty, weathers light brown.	0.4
53	Shale, glauconitic.	1.5
52	Limestone, very fine grained, silty, weathers light brown.	0.3
51	Shale, very silty, almost siltstone, but bedding indistinct; light olive gray with grayish red (5R 4/2) splotches.	39.0
50	Covered.	192.0
49	Shale, very silty, bedding indistinct and irregular, light olive gray; upper 1.5 feet weathers blackish red (5R 2/2).	13.0
48	Covered. Probably as above.	14.0
	Basal Siltstone Member (134.5 Feet)	
47	Siltstone, medium to thinly bedded, light olive gray, becoming shaly toward top. About 4 feet of shale interbedded in interval.	24.0
46	Shale, silty, weathers light olive gray and chippy.	1.0
45	Siltstone, light olive gray with grayish red splotches. Single bed.	4.0
44	Siltstone, weathers light olive gray and grayish red. Single bed.	5.5
43	Siltstone, thickly to medium bedded, light olive gray.	19.0
42	Shale, very silty, very thickly laminated, light olive gray.	3.0
41	Siltstone, thickly bedded, light olive gray. Beds approximately 2 feet thick.	5.0
40	Siltstone, light olive gray, single bed.	4.0
39	Siltstone, light olive gray with shaly partings at top. Single bed.	2.5
38	Siltstone, medium bedded with shaly partings.	2.5
37	Shale, thickly laminated, light olive gray.	1.0
36	Siltstone, thickly to medium bedded, weathers light olive gray and grayish red (5R 4/2). Beds are very distinct, well jointed.	47.0
35	Siltstone, weathers grayish red, single bed.	4.0
34	Siltstone, thin to medium bedded with shaly partings.	3.0
33	Siltstone, thickly bedded, light olive gray.	5.0

		Feet
32	Siltstone, weathers peculiarly as though nodules have weathered out in face of outcrop.	1.0
31	Siltstone, thickly bedded, limonite coating. Base of this interval is base of Grainger Formation.	3.0
	Chattanooga Shale (403.95 Feet)	
30	Shale, very thickly laminated, silty, weathers light olive gray.	4.0
29	Siltstone, single bed, nonlaminated, medium gray.	0.3
28	Shale, silty, weathers lumpy, chippy and dark gray.	2.0
27	Siltstone, single bed, nonlaminated, medium dark gray.	0.1
26	Shale, as in unit 28.	2.0
25	Siltstone, single bed, nonlaminated, medium dark gray.	0.2
24	Siltstone, single bed, nonlaminated, medium dark gray.	0.1
23	Shale, as in unit 28.	0.5
22	Siltstone, single bed, nonlaminated, medium dark gray.	0.1
21	Shale, thickly laminated, light olive gray.	2.0
20	Siltstone, single bed, nonlaminated, medium dark gray.	.05
19	Shale, thickly laminated, light olive gray.	3.5
18	Siltstone, single bed.	0.2
17	Shale, as above.	0.4
16	Siltstone, single bed.	0.2
15	Shale, thickly laminated, light olive gray.	9.0
14	Siltstone, single bed.	0.3
13	Shale, as in unit 15.	0.7
12	Siltstone, single bed.	0.3
11	Shale, thickly laminated, weathers light olive gray, fresh color medium gray. Not silty. Weathers yellowish gray and lumpy on outcrop face.	60.0
10	Shale, grayish black, thinly with some thickly laminated, silty. Weathers to small dark gray plates and chips.	44.5
9	Covered.	136.0
8	Shale, thickly laminated, grayish black, very stiff and silty; weathers to large chips.	10.0

		Feet
7	Siltstone and shale. Siltstone very thickly bedded, individual beds 4 feet and over and some shaly partings; shale grayish black, thickly to thinly laminated, weathers dark gray. This interval has odd relationship to rest of formation. It appears to be a channel fill with dip 30° and rest of section 15°. Bottom of silts also appears concave.	26.5
6	Covered.	2.0
5	Siltstone, shaly, medium dark gray, weathers to large plates. Individual sheets up to .4 inch, with fine laminations within these boundaries. Some thin, laminated siltstones are associated.	11.0
4	Siltstone, blocky, essentially single bed. Nonlaminated.	5.0
3	Siltstone, shaly, very dark gray, thickly to very thickly laminated to medium bedded; siltstones are finely laminated within larger units; laminae occur as thin quartz layers which show white against the dark background. Weathers to large plates and sheets.	83.0
	Lower Black Shale Unit (23+ Feet)	
2	Shale, grayish black, thinly laminated.	23+
1	Covered, not measured.	

Section T-12. Avondale Quadrangle. 718,400 N, 2,771,200 E. Section measured in cuts on northeast side of old U.S. 25-E and in bed of unnamed stream beside road. Section begins in back of house about 5000 feet from intersection of road with U.S. 11-W.

		Feet
	Rome Formation (52+ Feet)	
55	Not measured.	
54	Sandstone, thin to medium bedded, light-colored.	43.0
53	Conglomerate, quartz pebble.	1.0
52	Sandstone, as above. Position of Saltville fault and base of Rome Formation.	8.0
	Grainger Formation (543.2 Feet)	
	Upper Sandstone Member (97.0 Feet)	
51	Sandstone, very fine grain, becoming fine grained upward, feldspathic, medium to thickly bedded, conglomeratic sandstone near top; poorly preserved plant fragment, Minor interbedded shale.	13.5
50	Covered.	24.5
49	Sandstone, thinly to medium bedded, mostly thinly, very fine grained, cross-bedded, light olive gray; weathers reddish gray.	44.0
48	Sandstone, medium to thickly bedded, very fine grained, weathers yellowish brown. Two feet of micaceous sandstone in interval.	7.0
47	Sandstone, very fine grained, thinly to medium bedded.	7.0
46	Sandstone, very fine grain, single bed.	1.0
	Middle Member (297.7 Feet)	
45	Shale, thickly laminated, light olive gray.	4.0
44	Siltstone, single bed.	1.0
43	Shale, very thickly laminated, silty, verges on siltstone but lacks bedding. Weathers light olive gray and grayish red.	37.0
	Glauconite Zone (9.4 Feet)	
42	Glauconite, sand-sized, with interbedded calcitic shale.	3.0
41	Micrite, silty with some sand-sized glauconite.	1.3
40	Glauconite, sand-sized, weathers dusky blue-green (5BG 3/2) and grayish red purple (5RP 4/2).	1.5
39	Micrite, silty; weathers light brown (5YR 5/6).	0.4
38	Shale, glauconitic.	1.0

		Feet
37	Micrite, silty; weathers yellowish brown.	0.2
36	Shale, glauconitic, probably also calcitic. Base Glauconite zone.	2.0
35	Siltstone, light olive gray. Upper 4 feet has yellowish brown punky beds which were probably limey. Voids appear to result from leached shells.	12.0
34	Shale, thickly laminated, light olive gray.	7.0
33	Shale, silty, very thickly bedded, verging on siltstones. Weathers grayish yellow (5Y 8/4). Lower 5 feet has punky intervals suggestive of deeply weathered lime.	9.0
32	Shale, light olive gray.	3.0
31	Shale, thickly bedded, approaches siltstone; weathers grayish red (5R 4/2).	2.0
30	Shale, thickly laminated, light olive gray.	2.5
29	Shale, very thickly bedded, nearing siltstone; weathers grayish red.	20.0
28	Shale, thickly laminated, weathers light olive gray and chippy.	11.0
27	Shale, thickly bedded, weathers light olive gray and grayish red.	3.0
26	Shale, thickly laminated, weathers light olive gray and chippy.	2.5
25	Siltstone.	1.0
24	Shale, thickly laminated, light olive gray.	4.0
23	Siltstone, light olive gray.	1.3
22	Shale, thickly laminated, light olive gray.	1.5
21	Siltstone, part shaly, part distinctly bedded; weathers light olive gray and grayish red.	7.0
20	Shale, thickly laminated, silty, light olive gray; weathers chippy. Almost grades into bedded siltstone in places. *Dictyoclostus* sp., *Fenestrellina* sp., *Imbrexia?* sp., *Chonetes* sp., *Tylothyris?* sp., *Spirifer grimesi*, *Pugnoides?* sp., *Dictyoclostus fernglenensis*, *Rhynchopora?* persinuata, *Rhipidomella missouriensis*, *Athyris?* sp., *Rhipidomella* cf *oweni*, *Cleiothyridina* cf *sublamellosa*, *Taonurus* sp.	124.0
19	Covered.	7.0
18	Shale, silty, thickly laminated, light olive gray. Interval mostly covered.	16.5

		Feet
17	Siltstone, light olive gray, weathers grayish red. Single bed.	2.5
16	Covered. Base of Middle Member.	9.5
	Basal Siltstone Member (148.5 Feet)	
15	Siltstone, medium to thickly bedded, light olive gray; weathers grayish red (5R 5/2). About 20 percent of interval is silty, light olive gray shale.	25.5
14	Covered, probably shale.	51.0
13	Siltstone, very thickly bedded, light olive gray; weathers grayish red; few or no shale partings.	50.0
12	Siltstone, medium bedded.	6.0
11	Siltstone, thickly bedded, weathers light olive gray and grayish red (5R 4/2). Base of Grainger Formation.	16.0
	Chattanooga Shale (316+ Feet)	
10	Covered. Float is deeply weathered Chattanooga-type shale with intermixed siltstone. Shale non-silty; weathers to small plates.	70.0
9	Shale, thinly laminated, very dark gray, weathers platy.	10.0
8	Covered.	105.0
7	Siltstone, medium to thickly bedded with some shaly siltstone in middle of interval. Siltstones nonlaminated, medium to medium dark gray; weathers yellowish brown.	61.0
6	Siltstone, medium bedded, nonlaminated, no interbedded shale, weathers blocky.	8.0
5	Siltstone, shaly, thinly to very thickly laminated to thickly bedded. Siltstones are finely laminated. Color very dark gray, weathers medium gray and platy. Outcrop gives appearance of single siltstone bed, but this is due to jointing.	23.0
4	Covered.	17.0
3	Shale, thickly laminated, medium gray; weathers platy.	6.0
2	Siltstone, shaly, very thickly laminated to thickly bedded. Larger units laminated. Color medium dark gray; weathers to thick sheets and blocks. Base of exposure and approximate base of Chattanooga siltstones.	16.0
1	Covered. Not measured.	

Section T-13. Avondale Quadrangle. 709,000 N, 2,748,000 E. Section measured in exposures on northeast side of dirt road leading from U.S. Route 11-W to Avondale Springs.

		Feet
	Rome Formation (103+ Feet)	
40	Covered. Not measured.	
39	Shale and siltstone, reddish gray, thin to medium bedded with small fold and thrust fault.	14.0
38	Covered. Rome type float in bank. Telephone pole opposite large springhouse at base of interval.	80.0
37	Covered. Fault contact with Grainger Formation at base of interval. Location of contact interpreted to be at base of springhouse. Sandstone like that at section T-12 projects to this point.	9.0
	Grainger Formation (557.0 Feet)	
	Upper Sandstone Member (23.0 Feet)	
36	Sandstone, very fine grained, light olive gray.	5.0
35	Covered.	9.0
34	Sandstone, thinly-bedded, may be cross-bedded; very fine-grained, similar to sandstone at top of Section T-12.	9.0
	Middle Member (512.0 Feet)	
33	Covered.	57.0
32	Siltstone, thickly to medium-bedded, probably some silty shale in interval; light olive gray.	14.0
31	Covered.	91.0
30	Siltstone and very silty shale; weathers light olive gray and chippy.	5.0
29	Siltstone, thinly bedded, light olive gray.	1.0
28	Covered.	155.0
27	Siltstone, medium bedded with interbedded very silty shale; shale thickly laminated, light olive gray.	17.0
26	Siltstone, single bed.	2.0
25	Covered.	170.0
	Basal Siltstone Member (42.0 Feet)	
24	Siltstone, light olive gray, thickly to medium bedded.	12.0
23	Siltstone, single bed, lower 2 feet weathers spheroidally.	5.0
22	Siltstone, as in unit 24. Base of Grainger Formation.	25.0

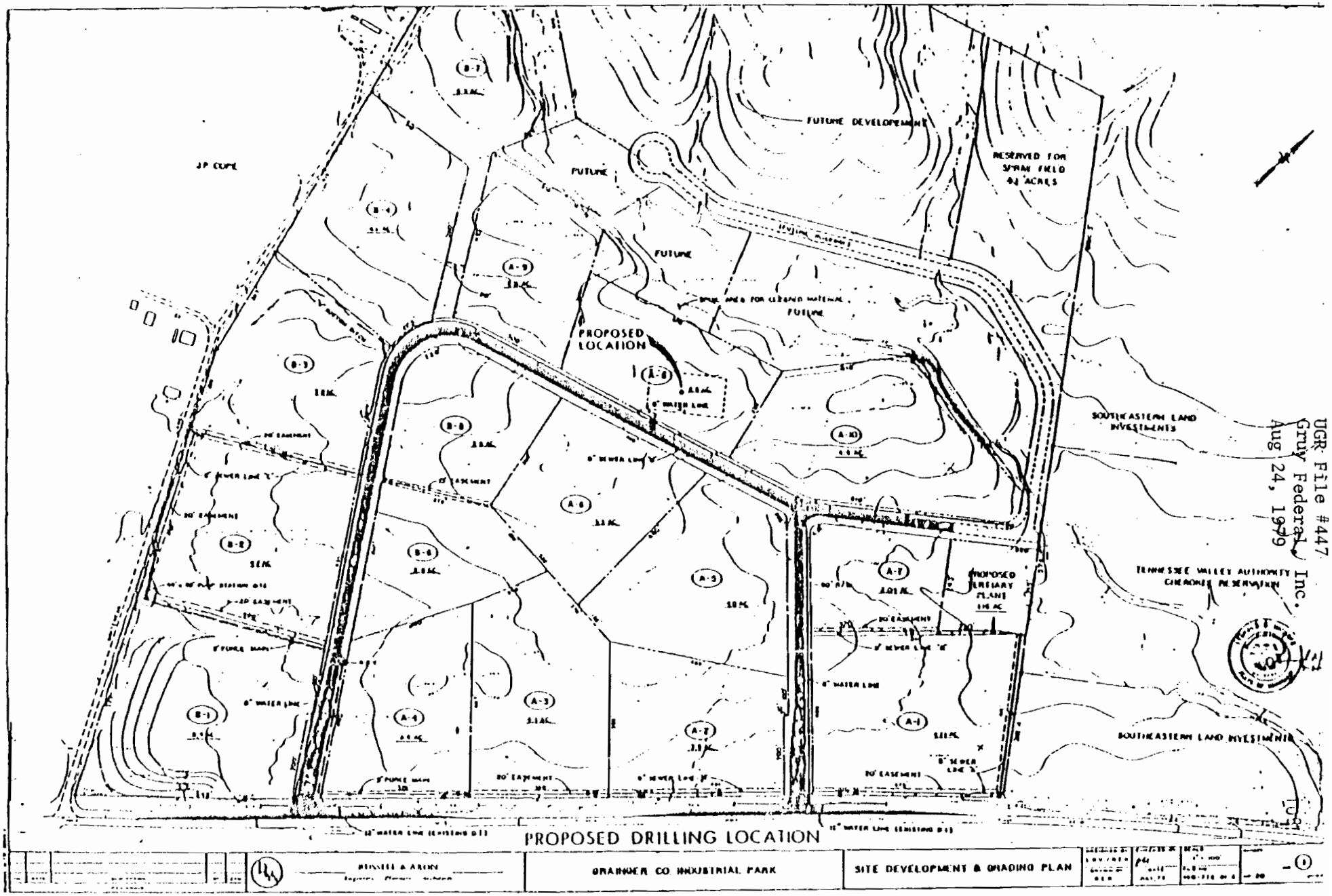
		Feet
	Chattanooga Shale (232.3+ Feet)	
21	Shale, thickly laminated, weathers splintery to chippy, however, some platy weathering, non-silty Chattanooga-type shale is in this interval. The thin siltstone beds of the transition zone appear to be absent here.	12.0
20	Shale, grayish black, thinly laminated, slightly silty; weathers medium dark gray into flat chips. This interval is partly covered but is definitely Chattanooga-type shale.	44.0
19	Covered.	77.0
18	Shale, thickly laminated, weathers light olive gray. No siltstones observed. Exposed in cut behind house.	30.0
17	Covered.	12.0
16	Siltstone, shaly weathers into stiff shale plates.	7.0
15	Siltstone, thickly to medium bedded, very dark gray. Bedding not uniformly distinct; appears structureless. Resembles middle siltstone of T-12; possible small fault in interval.	19.0
14	Shale, thickly laminated, silty, very dark gray.	1.5
13	Siltstone, light olive gray, nonlaminated, flaggy.	2.0
12	Shale, very thickly to thickly laminated, very silty, very dark gray with visible quartz laminae. Resembles siltstone until weathered and then weathers into large sheets.	7.5
11	Siltstone, medium dark gray.	1.5
10	Shale, as in bed 12.	3.0
9	Siltstone.	0.3
8	Shale, as in bed 12.	1.0
7	Siltstone.	0.5
6	Shale, as in bed 12.	1.0
5	Siltstone, flaggy, light olive gray.	0.5
4	Shale, as in bed 12.	2.5
3	Siltstone, laminated, very dark gray, single bed. Gradational from shale below.	1.0
2	Siltstone, shaly, very thickly to thickly laminated, dark gray with visible quartz laminae; looks like flaggy siltstone until weathered and then weathers into large sheets.	9.0
1	Covered. Not measured.	

Section T-14. Dutch Valley Quadrangle. 698,800 N , 2,726,200 E. Exposures along southwest side of road to Noe Chapel and in stream bed more or less parallel to road. Measurement begins at exposures opposite Noe Chapel and proceeds southeastward along road from that point.

		Feet
	Rome Formation (69+ Feet)	
17	Thickly bedded, light olive gray siltstone and silty shale with some prominent blocky siltstones, which are not typical of the siltstones in the upper part of the Grainger. Exposure in rear of house.	21.0
16	Covered. Probable position of Saltville. Fault at base of this interval and at top of siltstone below.	48.0
	Grainger Formation (537.0 Feet)	
	Upper Sandstone Member (31.0 Feet)	
15	Siltstone, light olive gray, medium to thickly bedded, with interbedded thickly laminated silty shale; weathers chippy.	31.0
	Middle Member (378.0 Feet)	
14	Covered.	74.0
13	Shale, thickly laminated, to thinly bedded, not silty, color indeterminate. Exposed in stream bed, forming low rapids. This unit occupies a rather broad flat valley at the base of Poor Valley Ridge.	127.0
12	Covered.	177.0
	Basal Siltstone Member (128.0 Feet)	
11	Siltstone, medium bedded, probably light olive gray, judging from partial exposures along road. Exposed in stream bed.	65.5
10	Covered. Probably shale.	6.0
9	Siltstone, single bed.	4.0
8	Covered.	3.5
7	Siltstone, single bed.	2.0
6	Covered.	29.0
5	Siltstone, thinly bedded, light olive gray.	18.0
	Chattanooga Shale (180+ Feet)	
4	Shale, grayish black, thinly laminated, weathers into small plates; this interval partly covered, partly exposed all the way down to intersection.	154.0
3	Siltstone, light olive gray, exposed in stream bed.	6.0
2	Shale, grayish black, thinly to thickly laminated, weathers very dark gray and platy.	10.0
1	Shale, light olive gray, thickly to thinly laminated. Not measured.	10.0+

APPENDIX E

LAND AGREEMENT


UGR File #447
Gray Federal Inc.
Aug 24, 1979
FUTURE DEVELOPEMENT
RESERVED FOR SPRAY FIELD 42 ACRES
FUTURE
FUTURE
FUTURE
PROPOSED LOCATION
SOUTHEASTERN LAND INVESTMENTS
TENNESSEE VALLEY AUTHORITY CHEROKEE RESERVATION
PROPOSED SANITARY PLANT
SOUTHEASTERN LAND INVESTMENTS
JP COPE
PROPOSED DRILLING LOCATION
RUSSELL & ARON
GRAINGER CO INDUSTRIAL PARK
SITE DEVELOPMENT & GRADING PLAN

GRUY FEDERAL, INC.
PROJECT AGREEMENT
Grainger County Tennessee

THIS AGREEMENT made and entered into this 7TH day of AuGust 1979 by and between Grainger County, Rutledge, Tennessee 37661 (hereinafter referred to as Owner), and Gruy Federal, Inc., 2500 Tanglewilde, Suite 150, of Houston, Texas 77063 (hereinafter called the operator).

WHEREAS the Operator, under contract to DOE-Morgantown Energy Technology Center, Morgantown, West Virginia, desires to obtain cores and logs from the Chattanooga shale (as described in Exhibit "A") for the purpose of characterizing a potential source of unconventional gas on the following described lands and bounded substantially by lands now owned by the undersigned Owner, as follows:

on the North by SOUTHEASTERN LAND INVESTMENTS &
on the East by U.S. ROUTE 11 J
on the South by WHITEHEAD LANE & HATFIELD PROP.
on the West by SOUTHEASTERN LAND INVESTMENTS

and more particularly described by deed on record in Warranty Deed Book 136, pages 228, 229, in the Registers' office of Grainger County, Tennessee containing 100 acres, more or less.

WHEREAS, the undersigned Owner is the holder of surface and mineral rights in and to the above-described lands and is willing to permit Operator to drill, core, log and test, or cause to be drilled, cored, logged and tested, a core hole or test hole (hereinafter referred to as "the hole") on Owner's said lands, subject to the following terms and conditions:

NOW, THEREFORE, for and in consideration of the premises, provisions, covenants, terms and conditions herein contained, and the parties intending to be legally bound hereby, it is hereby agreed as follows:

1. INCORPORATED DOCUMENTS: The following exhibits are attached hereto and incorporated herein by reference, including:

Exhibit A - Lithologic description and gamma ray log curve of Chattanooga Shale in vicinity of proposed hole.

Exhibit B - Authorization for execution of this Agreement by Judge Norman Acuff.

Exhibit C - Proof of insurance.

2. DEFINITIONS:

(a). "Sub-contractor" - Any person, company, partnership, corporation, or other entity whose services or materials are secured by the Operator to assist in the performances of any obligation or activity under the terms of this Agreement.

(b). "Drill" - Shall mean the drilling of a test hole capable of being cored, logged and possibly tested for the purpose of characterizing the potential of the Chattanooga Shale as a source of unconventional gas. Drilling shall <u>not</u> be construed to include or require that the Operator drill and/or complete any hole to the extent necessary to provide a well capable of producing oil or gas.

(c). "Cored" - Shall be construed to include all types and methods of coring which, in the sole and absolute discretion of the Operator, are necessary or useful in achieving the objectives of this Agreement.

(d). "Logged" - Shall be construed to include any and all methods of logging determined in the sole and absolute discretion of the Operator to be necessary or useful in achieving the objectives of this Agreement.

(e). "Tested" - Shall be construed to include any and all methods of testing which, in the sole and absolute discretion of the Operator, are determined to be necessary and useful in achieving the objectives of this Agreement.

3. For a term of twelve (12) calendar months from the date of signing of this Agreement by all parties, the undersigned Owner hereby grants to Operator and its sub-contractors, and to the agents, employees and representatives of the Operator and its sub-contractors the right to drill, log, core and test a hole or holes, together with such easements and other rights as might be necessary or convenient to so drill, core, log and test.

4. Operator, shall select,subject to consent of the Owner of, the location of each hole drilled under this Agreement. It is understood and agreed that, if the original hole is lost, is otherwise not in mechanical condition to be deepened to the Chattanooga Shale, or is otherwise deemed unsatisfactory in the sole and absolute discretion of the Operator, then a replacement hole may be drilled at another location selected mutually by the Owner and the Operator. All holes will be drilled, logged, cored and tested in accordance with prudent operating procedures.

5. As consideration to the Owner for the rights granted Operator in this Agreement, all data secured or developed hereinafter by the Operator will be made available to the Owner through the Federal Government's Morgantown Energy Technology Center, P.O. Box 880, Morgantown, West Virginia 26505, upon request of the Owner.

6. The total depth of any hole drilled shall be determined by the Operator in its sole and absolute discretion. Operator shall ordinarily drill to a total bottom hole depth equal to the bottom of the Chattanooga Shale, or to a depth of 3,000 feet subsurface, which ever depth is first encountered. No coring or testing shall be conducted in any geologic formation other than the Chattanooga Shale. In the event that, in the sole and absolute discretion of the Operator, any hole is determined to be capable

of production of gas or oil from the Chattanooga Shale, the Operator agrees to leave the surface casing and other then-installed wellhead equipment in and on the hole as full consideration to the Owner for the right to drill and to conduct the other operations authorized herein and as full settlement of all damages directly caused thereby. It is agreed and understood by the parties that Operator does not guarantee, and does not warrant, that any hole so provided will be capable of producing oil and/or gas or will be completed to any extent necessary to provide for the production of oil and/or gas. Any additional completion or other additional procedures necessary to render such hole capable or producing oil and/or gas shall be the sole and entire responsibility of the Owner. A full analysis of all data obtained for a given hole under this Agreement, and a determination by Operator whether said hole is potentially capable of producing oil and/or gas from the Chattanooga Shale, shall be made not later than six (6) calendar months from the date of termination of on-site work by Operator on said hole.

7. The Operator shall be responsible to the Owner for all indirect damages, including damages done to buildings, fences, gates, tanks and other surface improvements of the Owner on the above-described lands, if, and only if, said damages arise directly and proximately from the negligence of the Operator. The Operator shall not be liable for any damages resulting from the negligence of the Owner, [illegible] Operator shall repair all damages for which it is liable to the reasonable satisfaction of Owner, or shall make reasonable payment to the Owner for all such damages, within thirty (30) days after completion of operations under this Agreement.

8. Operator agrees to indemnify Owner for, and to hold Owner harmless from, any and all claims arising out of operations conducted on the above-described lands by the Operator to the maximum extent of twenty million dollars ($20,000,000) general liability insurance coverage. (A copy of proof of said insurance is attached hereto and incorporated herein as Exhibit C.

9. Upon termination of operations at each drilling location, if it is determined that such hole is non-productive of oil and/or gas, then Operator shall comply with regulations of the State of Tennessee applicable to the status of said hole at that time, including plugging and abandonment of said hole.

10. Owner shall retain all rights to all gas, oil, or minerals produced from the above-described lands. Operator shall not file any claim for royalty for any production of gas, oil, or minerals which could be derived from the above-described lands.

11. Owner shall provide the necessary authority (attached hereto and incorporated herein as Exhibit B) for Judge Norman Acuff to sign this Agreement on behalf of Owner and to bind Owner thereby.

12. Owner warrants to the Operator that Owner is the holder of full right, title and interest, in fee simple to all surface and mineral rights in the above-described lands; that no other person or entity holds any right, title, or interest in or to the surface or sub-surface rights in the above-described land that might be injured or jeopardized by the terms of this Agreement, or by performance of the terms of this Agreement; and that Owner will indemnify Operator for, and hold Operator harmless from, any and all claims which might arise from any known, or unknown, holder of any right, title, or interest of any kind or nature whatsoever in the above-described lands resulting from the execution or performance of this Agreement.

13. This Agreement constitutes the whole and entire agreement between the parties relevant to the matters set forth herein and supersedes all prior or presently existing agreements relevant thereto, whether written or oral. This Agreement shall not be amended or modified in anyway except by a separate, subsequent written instrument executed by all the parties hereto, specifically referring to the provision of this Agreement to be amended or modified, and specifically setting forth the nature of the amendment or modification to be made.

14. This Agreement shall be executed in multiple duplicate originals, anyone of which shall be of full force and effect.

15. This Agreement shall be construed and enforced under the laws of the State of Tennessee.

16. If any provision of this Agreement shall be found to be illegal, invalid or otherwise unenforceable, then the remaining provisions of this Agreement shall remain in full force and effect commensurate with said remaining provisions and the spirit and intent of this Agreement, as through said illegal, invalid, or unenforceable provision had not been included herein.

17. This Agreement shall not be assigned, transferred, given as a pledge or security, or otherwise encumbered by either party without the signed written consent of the other party.

WHEREFORE, Owner and Operator, intending to be legally bound hereby have subscribed their hands, names and seals on the dates indicated below.

GRUY FEDERAL, INC.

DATE: 7 Aug. 1979 BY: James H. Hartsock
James H. Hartsock
Vice President

GRAINGER COUNTY TENNESSEE

DATE: 7 Aug. 1979 BY: Norman Acuff
Judge Norman Acuff

A C K N O W L E D G M E N T

State of Tennessee)
) ss
County of Grainger)

On this 7TH day of AUG, 1979, before me, the issuing authority, personally appeared an individual known to me to be Judge Norman Acuff, who being duly deposed and sworn, hereby swears and affirms that he is a Judge of the Courts of Grainger County, Tennessee that he is empowered and authorized to execute the accompanying Agreement for and on behalf of said Grainger County, Tennessee and that he has executed and signed the attached Agreement on behalf of Grainger County, Tennessee for the intent and purposes set forth therein.

Sworn to and subscribed before me a
Notary Public in and for the County
of Grainger, State of Tennessee

Pauline C. Daniel
Notary Public

My Commission Expires November 13, 1982

UGR File #447
Gruy Federal, Inc.
Aug 24, 1979

ACKNOWLEDGMENT

STATE OF TENNESSEE

COUNTY OF GRAINGER

On this 7th day of August 1979, before me, the undersigned authority, personally appeared an individual known to me to be Robert B. Steffy, who being duly deposed and sworn hereby swears and affirms that he is Manager of the Pittsburg Operations of Gruy Federal, Inc., and as such is authorized to sign the name of James H. Hartsock Vice President of Gruy Federal, Inc. to the foregoing contract dated August 7, 1979 between Gruy Federal, Inc. and Grainger County, Tennessee for the intent and purposes set forth therein.

Oct. 21, 1979
My Commission Expires

Norman Acuff
NOTARY PUBLIC

UGR File #447
Gruy Federal, Inc.
Aug 24, 1979

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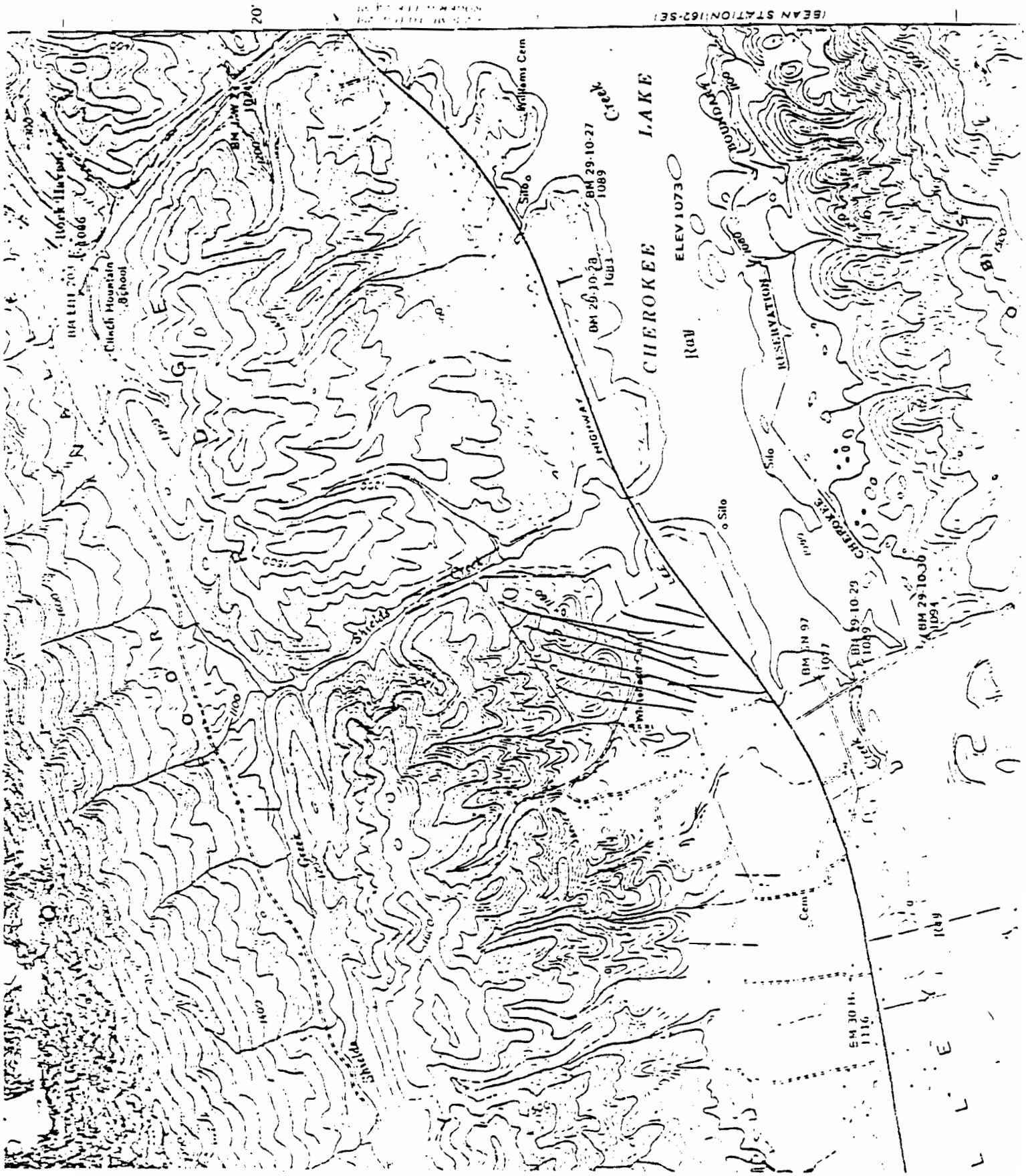


LINE TC-1

DEPTHPOINTS 101 - 1568

DEPTH SECTION

FIELD DATA

DIGITAL PROCESSING

EDIT AND TIME AMPLITUDE RECOVERY

TIME VARIANT DECONVOLUTION

EQUALIZATION

DATUM STATICS APPLICATION

VELOCITY EVALUATION

NORMAL MOVEOUT CORRECTIONS

FIRST BREAK SUPPRESSION

AUTOMATIC RESIDUAL STATICS

CONVERT TO DEPTH POINT STACK

EQUALIZATION

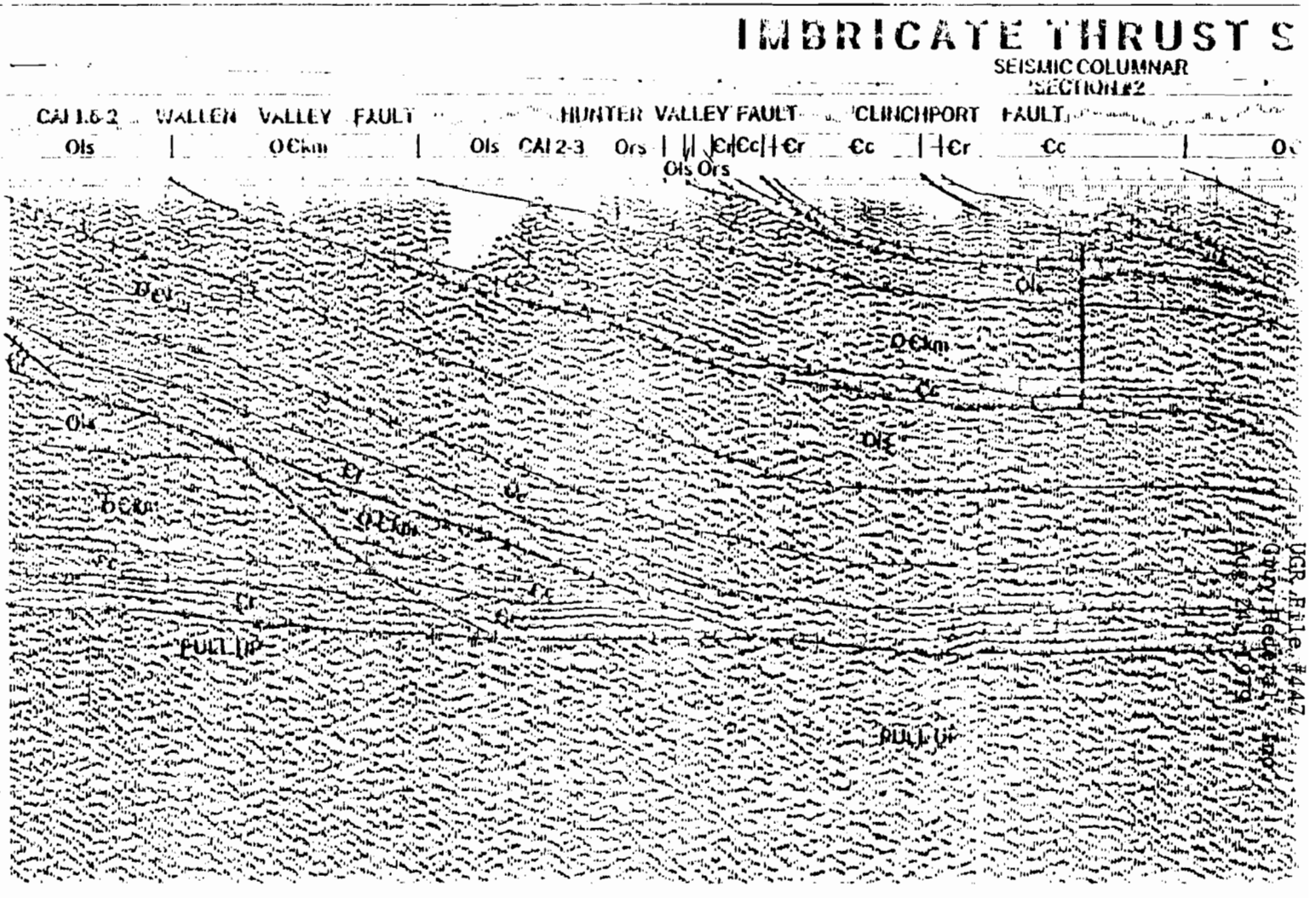
DIP FILTER

TIME VARIANT DIGITAL FILTERING

TIME DEPTH CONVERSION

DISPLAY SPECIFICATIONS

DISPLAY GAIN



UGR File #447

Figure 4. S...

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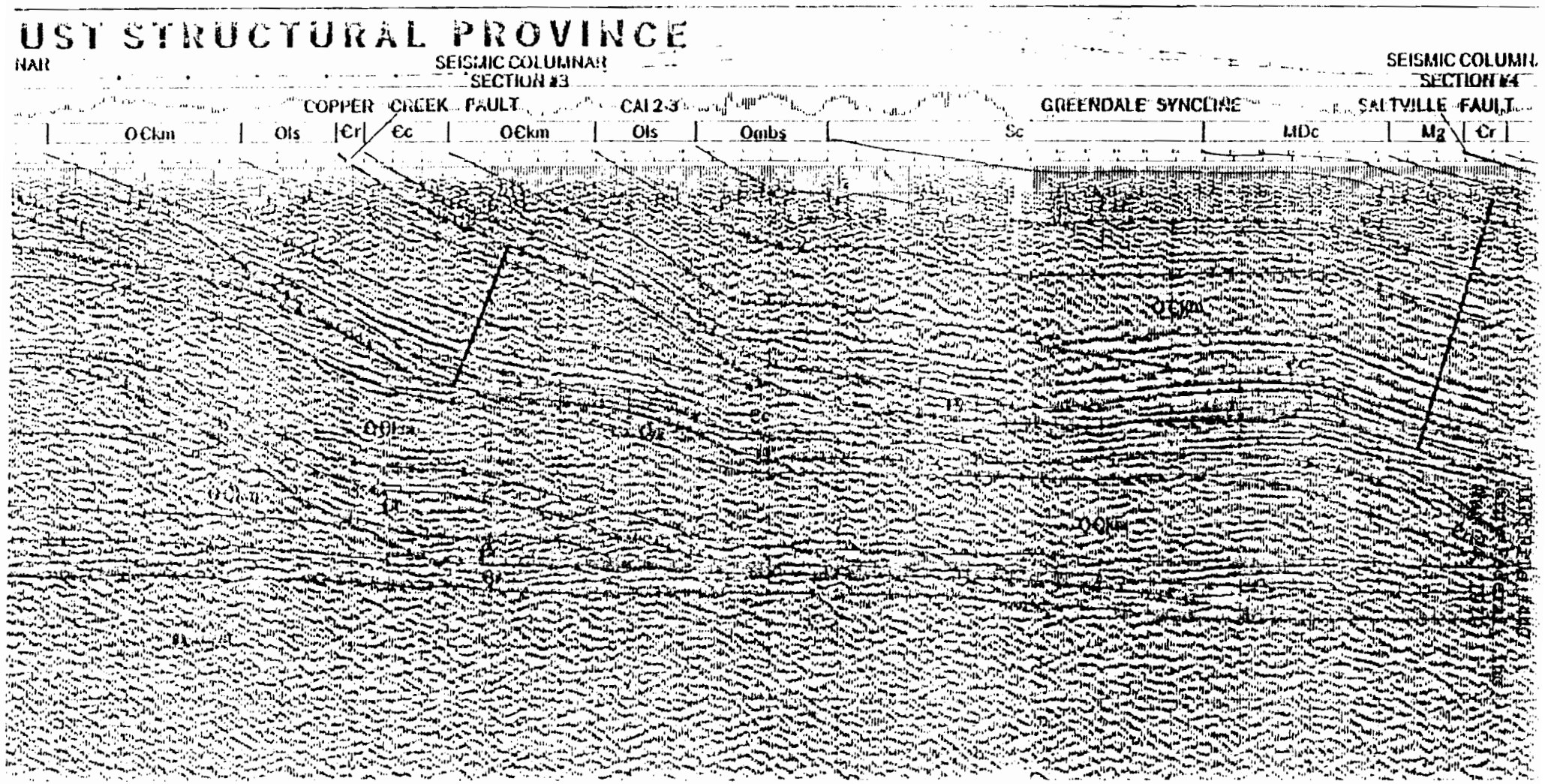
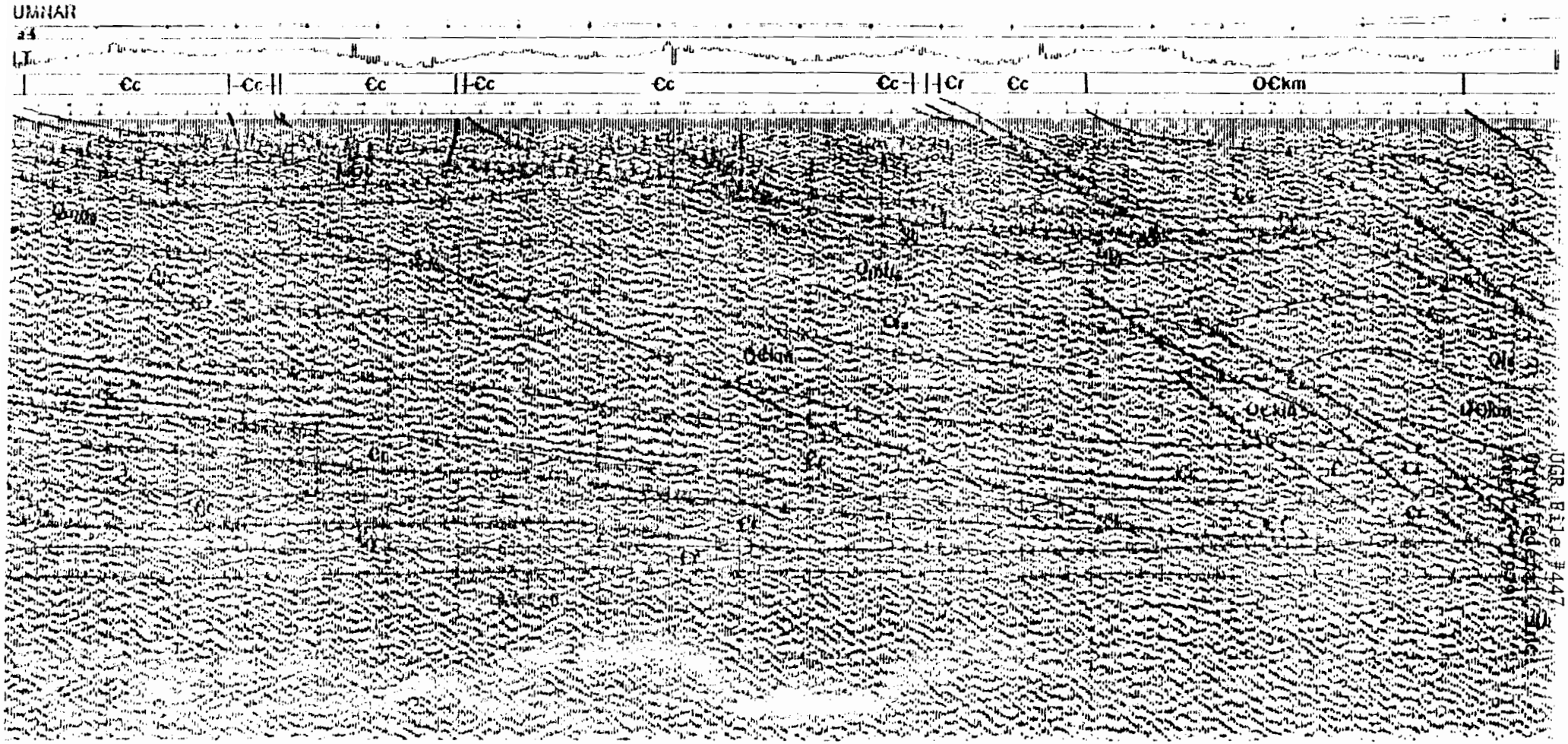


Figure 4. Seismic cross section K-1 (south)- TC-1. Seismic columnar sections are shown on Fig. 2. Conodont alteration indices (CAI) are interpreted from Epstein and others (1977) and Harris and Todd (1977). S.

0 1 2 3 4 MI

1 2 3 4 5 KM

EASTERN LOW ANGLE THRUST STRUCTURAL PROVINCE



77). See Table I for explanation of units.

PLATE 1 INTERPRETE
(MILLICI, I

UGR File #447
Gruy Federal, Inc.
Aug 24, 1979

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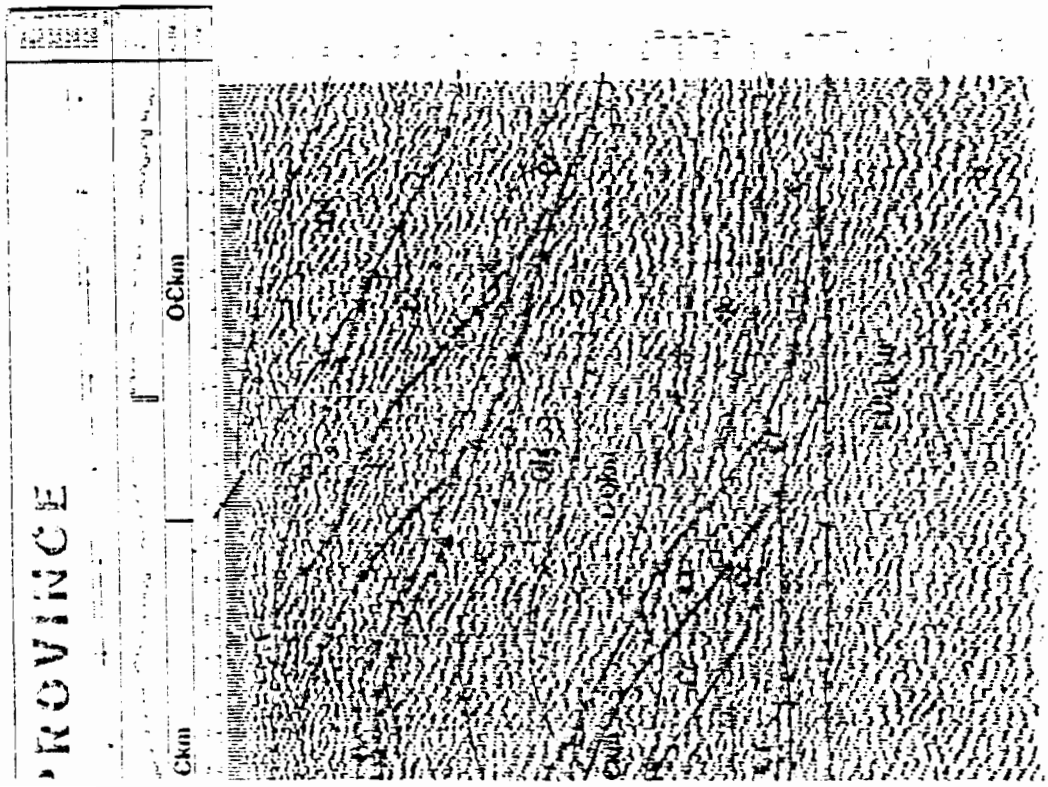

PLATE 1 INTERPRETED SEISMIC LINE 1C-1
(MILLICI, HARRIS AND STATLER, 1979)