DOE/METC/08199-1130

DOE/MC/08199--T12

DE82 015003

GEOLOGIC ANALYSIS OF DEVONIAN SHALE CORES

February 1982

Morgantown
United States Department of Energy
Technology
Center

DISCLAIMER

T A B L E O F C O N T E N T S

L I S T O F F I G U R E S

1.0 INTRODUCTION AND BACKGROUND

In December 1977, immediately following the successful completion of the DOE-funded core drilling project on the Naval Oil Shale Reserve #1 (Colorado), the Cleveland-Cliffs Iron Company submitted a bid for the "field retrieval and laboratory analysis" of an unspecified number of cores from the Devonian Shales of the Appalachian, Illinois and Michigan Basins of the Eastern United States. This was a federally funded ongoing project to explore these basins to determine the amount of natural gas being produced from the Devonian section, the potential of that section, and how to exploit that potential in the most expeditious manner. The geographic area involved was the following eleven states of the northeastern United States: Michigan, Illinois, Indiana, Ohio, New York, Pennsylvania, West Virginia, Maryland, Kentucky, Tennessee and Virginia. Cleveland-Cliffs' bid included a proposal that the physical properties testing of the rock specimens be done under subcontract at Michigan Technological University, Houghton, Michigan. The basis for this proposal was MTU's recent experience in working with the Devonian shales in a program associated with the Dow Chemical Corporation and its work in the Antrim (Devonian) shale in Sanilac County. Cliffs' bid was in response to a Request for Proposal (RFP) which originated at the Morgantown Energy Technology Center (METC) and was a method of improving the results then being obtained from the "Eastern Gas Shales Project."

A three-year contract was awarded to the Cleveland-Cliffs Iron Company on August 10, 1978. An eight-man team of geologists was assembled on August 16th in Morgantown, West Virginia to begin field operations then scheduled to begin August 20, 1978.

The method or approach to the basic problem included an analysis of current practices, experiments with the latest technology, and a detailed study of the shales themselves. The study was to include LANDSAT information, geochemical research, physical properties examination, structural, sedimentary and tectonic data. The information generated by the project would be distributed to and used by private industry for (1) locating Devonian gas wells in areas of high potential productivity and (2) using gas well completion technology demonstrated (by the project) to maximize overall gas recovery. The heavily industrialized eastern United States would then benefit by having available more natural gas from a domestic source.

Unfortunately, negotiations for the continued use of the core laboratory facilities used by the previous contractor broke down. Cliffs, starting from scratch, had to locate a suitable building and then make that building into a core laboratory which would suit the purposes of the contract. The METC staff was instrumental in this endeavor and their assistance was greatly appreciated. Construction of core tables, partitions, etc., and the installation of heat and lights in the building was done that fall and winter in addition to the field retrieval of cores from EGSP-New York #1, EGSP-West Virginia #7, EGSP-Kentucky #4 and EGSP-Illinois #3. The backlog of work was further increased by the previous contractor having left some work incomplete.

In the initial stages of the contract, as the volume of work became more apparent, the Cleveland-Cliffs Iron Company set up a subsidiary company, Cliffs Minerals, Inc., to deal more effectively with some of the problems.

In January 1979, preparations began for the first Phase II reports. Actual laboratory procedures and report format were finalized later that year and the first Phase II report was issued in January 1980. The problems encountered during this period prompted Cliffs to add two geologists and a secretary to the staff at Morgantown. During the period January 1980 to July 1981 numerous Phase II reports were generated. During this period also, about one-half of the Phase III reports were generated.

In 1980, further negotiations with the METC resulted in a separate contract for some additional analytical procedures associated with our basic EGSP function. These began that fall and will continue until mid-1982, and involved the employment of two additional geologists and some consulting expertise. This contract deals with a basin-wide analysis of data generated during the basic EGSP activities.

From October 1978 until March 1979, the laboratory work consisted primarily of converting a bare warehouse building into some semblance of a workable laboratory. The conversion included clean-up, construction, layout, table design and construction, equipment design, fabrication, acquisition and installation, lighting and heating procurement and installation, etc. When the construction was nearly complete, cores retrieved in the fall of 1978 and those inherited from the previous contractor were laid out and laboratory work began in earnest.

In March 1979, the sample preparation equipment, consisting primarily of diamond lapidary saws and industrial core drills, was started up and preparation of samples for physical properties testing began.

These would be forwarded to MTU for testing pursuant to the initial proposal. The physical properties tests to be conducted were (1) directional sonic velocity, (2) directional tensile strength, and (3) point load tests.

Sample sizes were tentatively set at 3 1/2"ϕ x 4" long for the ultrasonic velocity tests and at 2"ϕ x 3/4" long for the others. The samples prepared during the early stages were not very satisfactory. A combination of circumstances contributed to the problem, including: (1) Cliff's personnel lacked experience in preparing samples of this nature, (2) they were also unfamiliar with the equipment, (3) the equipment inherited from the previous contractor was not designed for precision work on rocks and also had suffered from neglect, and (4) MTU was having some trouble establishing specifications and tolerances for the samples to be tested. Slowly, these problems were resolved and the Morgantown laboratory began producing samples which were satisfactory to MTU. The worst problem encountered with the testing has been the tendency of the DTS samples to fracture along a bedding plane instead of diametrically and the tendency of the hydraulically fractured samples to fracture to the scribe lines on the core.

Actual start-up of physical properties testing sample preparation equipment was in March 1979, immediately after the 220 volt electrical circuit had been installed to the saw room. The DOE-supplied drill presses presented operational problems. Missing parts were ordered for them in early 1979 and some are still not delivered as of July 1981. A belt sander was purchased for grinding the samples to tolerance (±0.015") and after a Cliffs-built jig proved unworkable, the grinding was done by hand. When the shale was sufficiently cohesive, the sample could be undercored, then sawed. However, not all the shale could be done this way and some had to be cut, then undercored. This was much more work and produced poorer quality results.

This report discusses how the work was done and how the reports were prepared. For specific information the reader is referred to the individual well report involved. The Phase I reports cover field operations, the Phase II reports cover laboratory testing results and the Phase III reports summarize and include the physical properties testing results from MTU.

The following figures indicate the various steps of the field and laboratory procedures. The Index Map shows the location of the various wells which are numbered chronologically by state.

FIGURE 1.1

FLOW DIAGRAM OF FIELD RETRIEVAL PROCEDURES

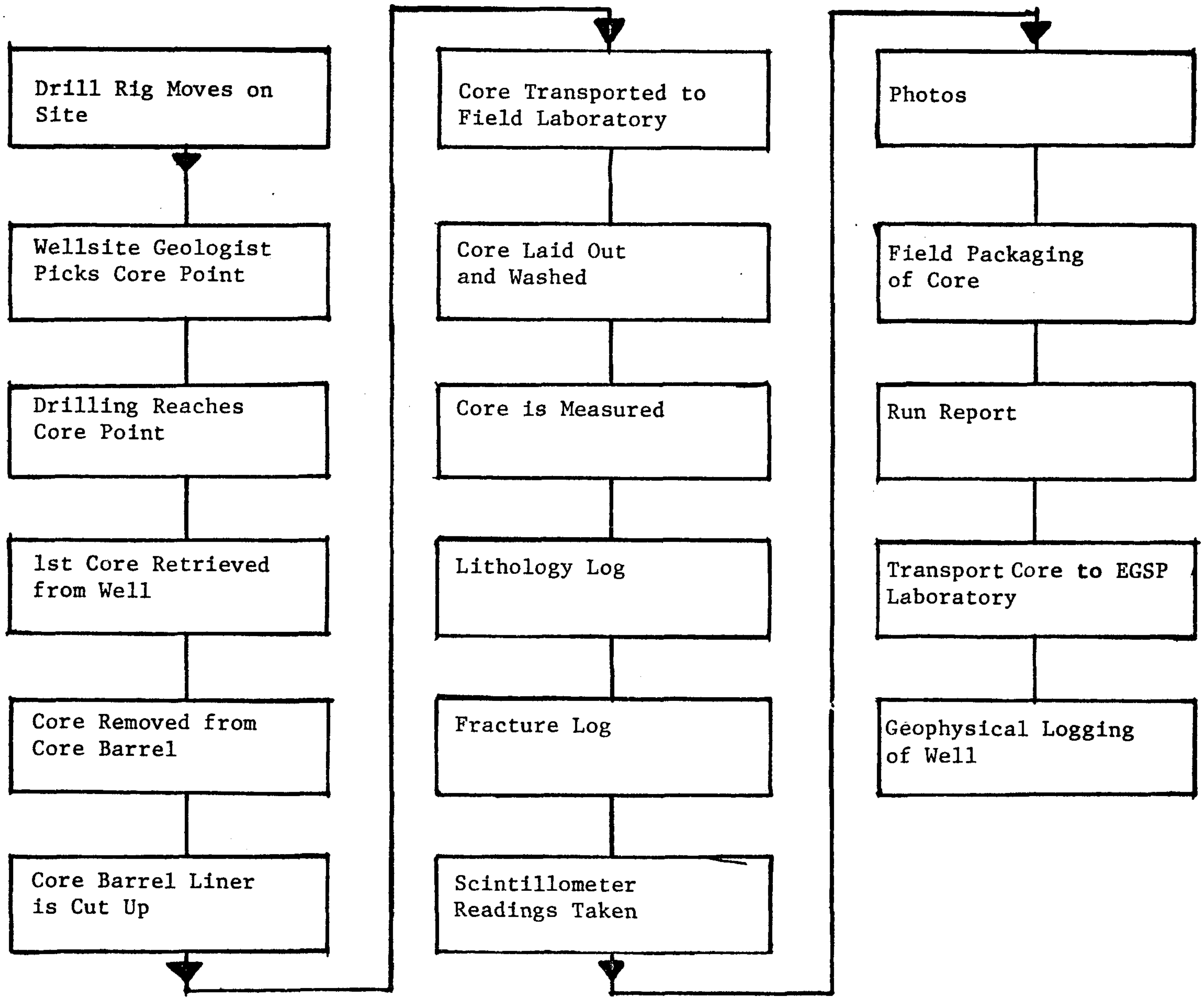
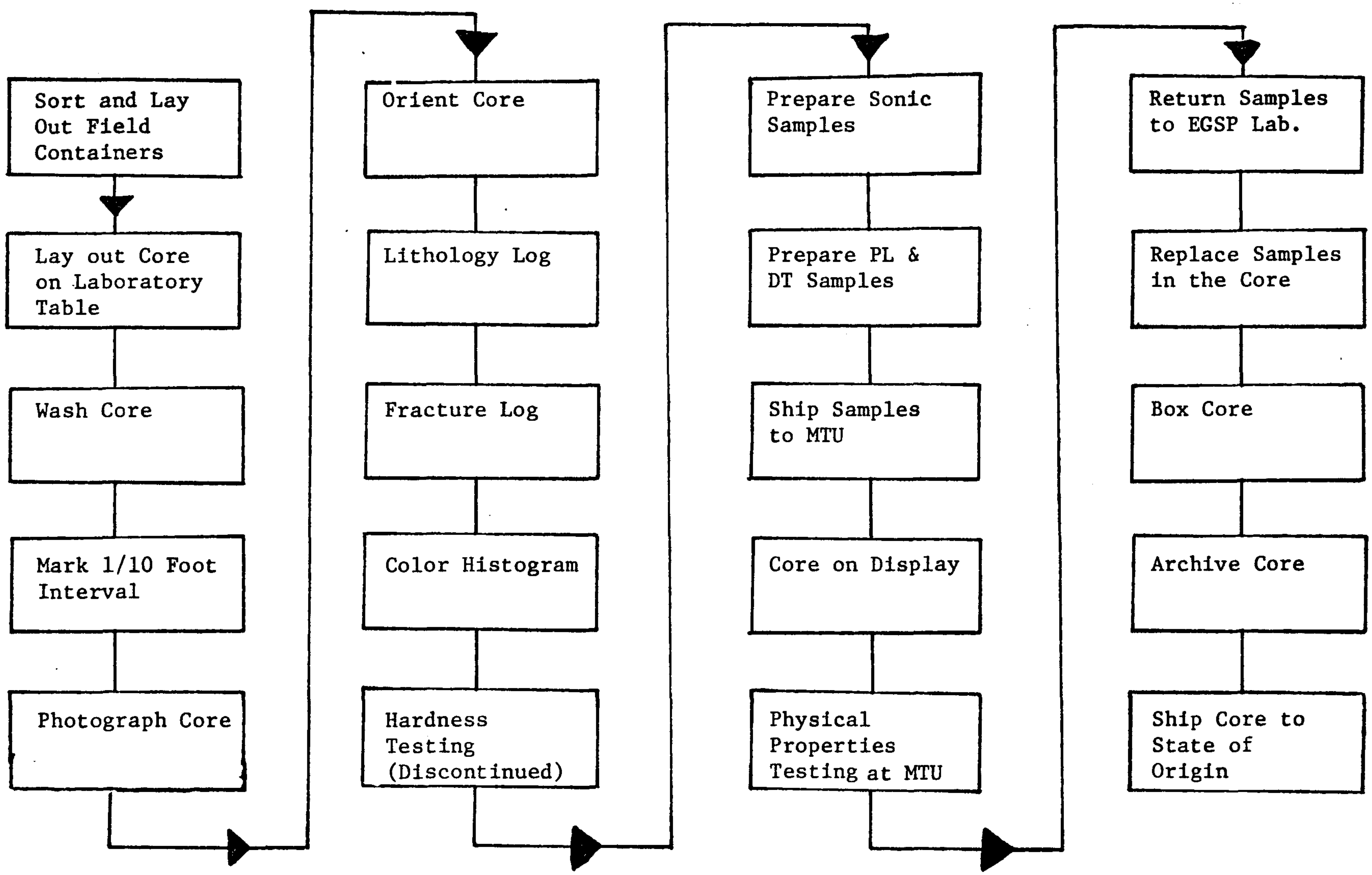


FIGURE 1.2

FLOW DIAGRAM OF LABORATORY PROCEDURES



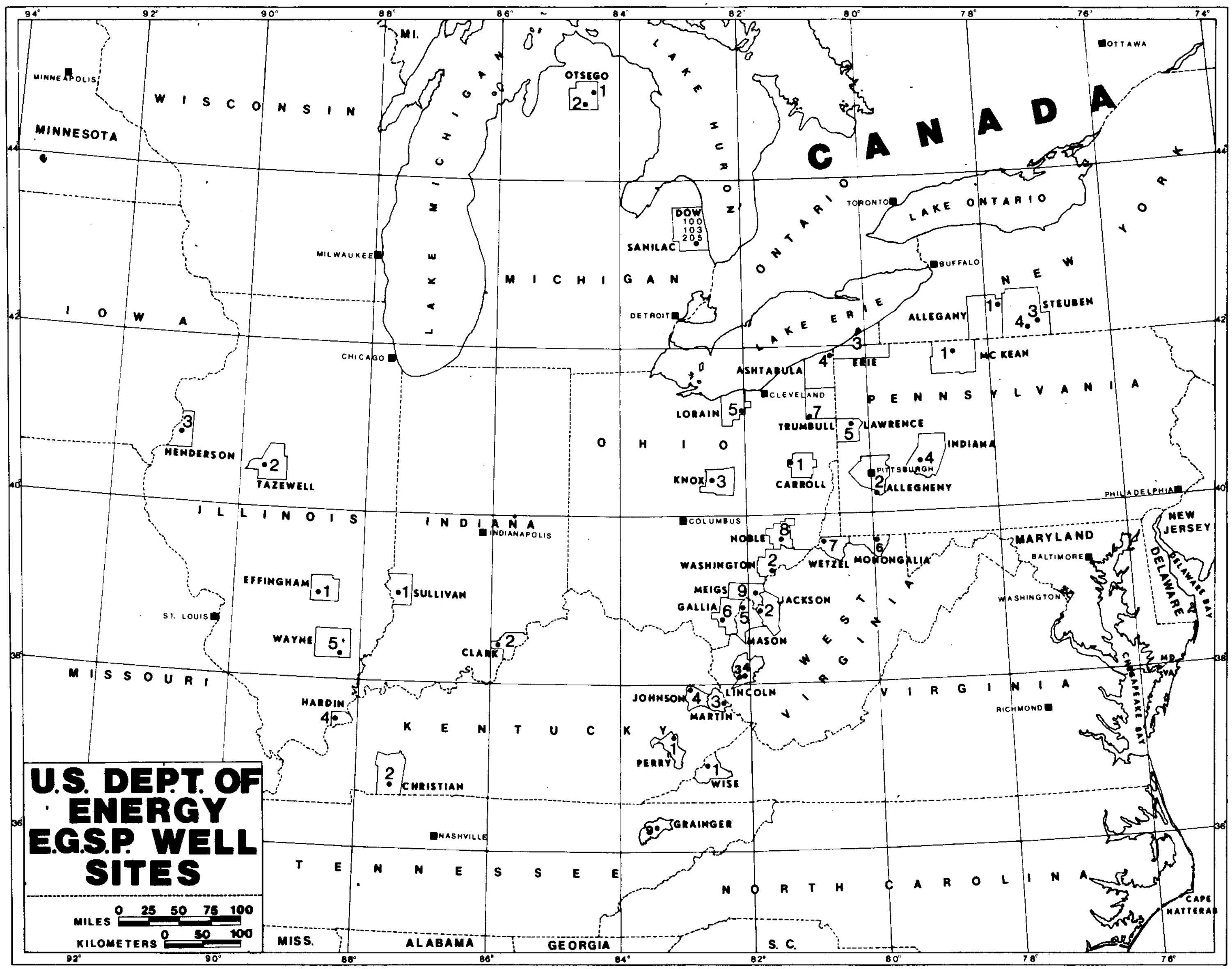


FIGURE 1.3

WELL LOCATIONS MAP

2.0 FIELD RETRIEVAL PROCEDURES

This section covers all the work associated with the field retrieval of the core. Due to the time limit set for the collection of good off-gassing samples, all the field work had to be performed quickly. The time limit normally accepted at the time was 1-1/2 hours after the core "came to daylight." This is about the maximum exposure time a sample can withstand and still give useable off-gassing data. So, it was determined that, whenever possible, the last sample from each core run should be canned no later than 1-1/2 hours after the core reached the surface. This meant that all the field processing had to be done in that time, except packaging for return to the EGSP Laboratory. This goal was, for the most part, met.

2.1 Taking Core from the Well

Generally, once the site selection and preparation had been conducted, the drilling contractor moved the drilling rig onto the site at his convenience. Since the Eastern Gas Shales Project is not of sufficient magnitude to warrant the purchase of a special drill rig for its own purposes, we were unintentional victims of drilling contractors' schedules, interruptions, breakdowns, work stoppages, etc. It usually took several days for the contractor to move his drill rig onto the site and "rig up" for drilling. The "rigging up" process included setting up the drill and all the various and sundry associated activities preparatory to the actual drilling of the well.

Before any core can be "taken" from the well, it must be drilled. In the case of the Eastern Gas Shales Project, the organization responsible for the coring of the cores was Christensen Diamond Products Company, Indianapolis, Indiana. For the most part, a plastic liner was used in the core barrel and a 3-1/2 inch diameter, oriented core was retrieved. The method worked extremely well and some core was recovered that otherwise would not have been recovered. The plastic liner, full of core, was removed from the core barrel all at once (two 30-foot lengths). These were then cut into ∿6 foot sections with a tubing cutter and transported by hand to the field laboratory. This sometimes was a very slick and treacherous way. When the field laboratory was not available for some reason, a makeshift tent was set up over Christensen's Core Barrell trailer and this was used as a field laboratory. A string of 100-watt incandescent lights was hung down the middle for use during non-daylight operation.

2.2 Field Laboratory

The field laboratory trailer was originally designed and proposed as an integral unit which could be transported from well site to well site and have adequate facilities for the field processing of core. The proposed design was accepted by the METC and the unit was ordered from a local dealer. About the time it was to be built (October 1978) the manufacturer went bankrupt. Consequently, Cliffs immediately purchased a 36' x 8' fifth-wheel style trailer for use as a field laboratory. This proved to be somewhat of a mixed blessing as the working area was very limited and conditions were frequently overcrowded. A vertical core rack 9' long and four double tiers high was designed by Cliffs and built by the METC to accomodate the 60-foot length of core to be processed each run. A 5500-watt generator was provided to supply electrical power to the trailer. However, when it was practical to do so, we hooked the trailer to the drill rig generator.

2.3 Layout and Washing

Once the core was delivered to the trailer, it was removed from the plastic tube and reassembled in the same order as it came from the well. It was then fitted together in the same length as in the ground and washed. Sometimes the washing fluid was KCl solution and sometimes plain water was used. The KCl presumably was beneficial in preventing swelling of the clays.

2.4 Measuring

After washing, the core was measured to determine core recovery and actual lengths of core retrieved. From this measurement and the drillers' records the depth of core was established and the depth footage was marked in one-foot increments on the core along with a series of arrows pointing down hole.

2.5 Field Lithology Log

One of the more important steps of any field core retrieval program is recording (logging) the lithology as soon as possible after it is laid out. In the case of the Eastern Gas Shales Project, the lithology in the producing zones is very similar to the lithology in the non-producing zones. Colorwise, the producing zones were much darker, but aside from the organic carbon content that makes them black, the shales are about the same. Primarily, the Devonian shales of the Appalachian Basin are illites with some contained pyrite. The silt content of the shale varies widely, becoming sandstone in spots and disappearing in other spots. Sometimes the siltstones act as a reservoir for gas or oil. The shale is calcareous in various spots. It contains fossils in spots, mostly those fossils common to the period.

2.6 Field Fracture Log

All the natural and induced fractures which occurred in the core when it was first laid out were logged. An attempt was made to note the occurrence of the natural fractures in the Phase I reports. Sometimes, as when the core was rubblized, determining the exact nature of a fracture became impossible. The criteria used were those proposed by Kulander and Dean (1976) and further refined by Claude Dean. Some of the natural fractures are mineralized and some are not. Of the induced fractures, petal fractures were a problem in the EGSP-West Virginia #5 core (Mason County) where mechanical troubles (soap pump quit) were experienced in drilling and in the EGSP-Ohio #9 core (Meigs County) where they were not. The cause of the occurrence of petal and petal centerline fractures remains a mystery.

2.7 Scintillometer Readings

During the coring of EGSP-Kentucky #4, the University of Kentucky researchers examined the core and tested for radioactivity with a scintillometer. The results were impressive so Cliffs purchased two scintillometers for field and laboratory use. The core in the field was subsequently tested for radioactivity with a scintillometer each foot of core length. This was a great aid in picking strata boundaries, which in shales, can sometimes be very difficult. In fact, the recognized strata boundaries are often times based on field geophysical log traces and may not be recognizable lithologic changes.

In the laboratory, the cores already retrieved were examined with the scintillometer both with and without a lead shield. The purpose of the shield was to minimize the effects of background radiation. As it turned out, the use of the shield provided only a lower count with the two curves being very similar otherwise.

2.8 Unusual Core Photographs

In the field and in the laboratory, the photography of unusual occurrences in the core was a must. Most of the unusual geologic features were easily explainable but some were not. All were photographed. A final photographic log has been prepared under separate cover and is being forwarded concurrently with this report. It includes photographs of field and laboratory procedures and some of the geologic phenomena encountered during this project.

2.9 Field Packaging of Core

All the core retrieved from the wells was packaged for shipping at the drill site. Most of it was returned to Morgantown via Cliffs' truck and subjected to laboratory examination. Some of it, however, was shipped as selected samples to other places for various testing, e.g. off-gassing, hydrocarbon content, geochemical analysis, clay study, etc. The off-gassing tests and geochemical analyses were done by Mound Laboratorys, Miamisburg, Ohio and by Battelle Columbus Laboratory, Columbus, Ohio, respectively. The hydrocarbon analyses were performed by Juniata College, Huntingdon, Pennsylvania, and Mound Laboratorys. The clay study was done by the U.S.G.S., Reston, Virginia. Testing was also carried out by the U.S.G.S., Denver, Colorado. Results of these tests were reported directly to METC so Cliffs has none of the test results. All of the material for analytical testing, however, was canned at the drill site by the use of an ordinary kitchen canner using juice-sized cans. Cliffs inherited this responsibility when Battelle's contract expired in September 1979. In sampling the core, each core sample removed was replaced by a 1-1/2" x 3" wood block showing the name of the recipient and the footage measurement of the top and bottom of the sample.

2.10 Run Reports

A "Run Report" was made for each core barrel "run" which was made down the well. These reports included such information as coring depth, coring time, coring footage, core description, notation of gas encounters, natural fracture occurrence, or any geologic phenomenon which would be important or even of interest. Data for samples was kept on a different set of papers which recorded such things as coring time, canning time, coring depth, time the core came out, etc., and copies were transmitted to the various laboratories along with the core samples.

2.11 Transport to the Laboratory

Cliffs generally used a stake bed one-ton truck to transport the packaged drill core and canned samples. This unit could transport a maximum load of about 600 linear feet of core.

2.12 Geophysical Logs

After each well was cored, a suite of geophysical logs was run. This was usually done by Schlumberger or Birdwell with one company doing the dry hole suite and one company doing the wet hole suite. Of all the logs which were run the combination that included gamma ray, neutron porosity, density, temperature and caliper was used by Cliffs' geologists more than any other data log because it had the most useable, verifiable information on it. The following is a comprehensive list of the logs which were run:

Wet Hole Logs	Dry Hole Logs
Gamma Ray	Sibilation
Compensated Formation Density	Temperature
Caliper	Gamma
Temperature	Compensated Formation Density
Dual Induction	Caliper
Spherical Focus	
Borehole Compensated Sonic	
Compensated Neutron Porosity	
Fracture Identification	

3.0 LABORATORY CHARACTERIZATION PROCEDURES

3.1 Laying out the Core

After the core was taken to the EGSP Core Laboratory from the field, the first step in the characterization process consisted of laying out the core on lab tables. The lab tables are made of eight rows of v-cut 2" x 4" lumber supported 42 inches off the floor. The tables are three feet wide by 36 feet long, and each is capable of holding from 250 to 300 linear feet of 3-1/2 inch diameter core.

When the core was taken to the lab, it was still sealed in the field containers. These containers consist of 3-1/2 inch inside diameter PVC pipe (core barrel liner) with the ends taped shut, and are approximately six feet in length. The pipe was marked with the depths and run number of the contained core. As the core containers were unloaded to be laid out, they were grouped by run number into piles on the floor. The tape was then cut off the ends of the pipe, and the core was slid out into the v-cut 2" x 4" on the lab tables. This process proceeded in order from the shallowest depth to the deepest until all the core was laid out. As the core was removed from the PVC pipe, it was reassembled if broken, and downhole orientation was continuously monitored. The core barrel liner (PVC pipe) was an expendable item since the coring contractor (Christensen) refused to reuse it.

3.2 Washing the Core

After the core was laid out and reassembled on the lab tables, it was thoroughly washed with clean water or KCl solution to remove all remaining drilling mud, salt crystals, cuttings and other foreign matter.

The core was scrubbed with a moderately stiff brush, rinsed and air dried. After washing, the core was laid back on the table and reassembled with the prime orientation groove facing up.

3.3 Marking the Core

Washing the core tended to erode some of the downhole arrows and footage marks that were put on in the field. Any symbols that had been rubbed off in processing were repaired at this time with a water proof felt-tipped marker.

The core was also marked at this time at 1/10-foot intervals between the footage lines. The depths of the 1/10-footage lines were labeled above the marks in small numerals using a fine-tipped felt marker. These depths were expressed as a decimal (i.e., 1,921.1', 1,921.2', 1,921.3', etc.). The lines marking the depths were approximately one inch long, and usually were placed along one side of the prime orientation groove.

3.4 Photographing the Core

In order to preserve a record of the core in the condition in which it was received from the field, a photographic log was made after the core was washed and marked. The core was photographed with a Canon FTB 35mm camera using a 50 mm F/1.4 lens. The photos were shot on Kodacolor ASA 400 color print film using the natural light in the lab. The lighting came primarily from overhead fluorescent tubes, with small amounts of daylight mixed in near the windows. Although the fluorescent lighting gave an overall greenish cast to the daylight-rated film, color correction during processing generally returned the finished prints to a more normal tone.

The photographs were taken with the camera mounted on the boom arm of a special cart that suspends the camera approximately six feet above the core table. This allowed each picture to encompass a field of view approximately three feet wide by two feet long. Since the core tables are three feet wide, a single shot recorded the entire width of eight rows of core. The cart was moved the length of the table, taking photographs every two feet, until the entire core was photographed.

3.5 Orienting the Core

After being photographed, orientation lines were drawn on the core with Sharpie markers. Christensen Diamond Products Company supplied orienting logs with the core; these logs give the true azimuth reading (corrected for magnetic drift) of the prime orientation groove for every two feet of depth. The logs also note deviation of the core from true vertical. In the laboratory a plastic ring marked off in one degree increments was placed over the core at the proper depth. The ring was rotated so that its azimuth reading over the prime orientation groove corresponded with the value given on the Christensen log. The ring was then held immobile and north, south, east and west marks were placed on the core. After the marks had been placed on a four to eight-foot interval, the core was tightly reassembled with the prime groove as straight as possible, and the marks were connected by straight lines. The lines were drawn with Sharpie markers and a 42-inch straight-edge; the lines were color coded as follows: north and south -- black, east -- blue, and west -- green. The lines were marked throughout their length with the appropriate symbol (N, S, E, W).

3.6 Fracture Log

Once the core was oriented, the fractures present in the rock could be recorded and measured. Fractures in the core consisted of two types: natural fractures, formed in the rock before the core was cut; and induced fractures, formed during the cutting, removal and handling of the core. These two fracture types were treated separately during fracture logging, and are described separately below.

3.6.1 Natural Fracture Log

Natural fractures in the core were formed as a reaction to local or regional stresses that have been applied to the rock throughout its depositional history. Natural fractures generally exhibit smooth or shiny surfaces when taken apart, and are often filled with minerals such as calcite, pyrite or gypsum. Natural fractures are classified as either faults or joints. In a fault, the two sides of the fracture have moved or slipped past each other. The displacement between the two sides ranges from several centimeters to several meters. A subclass of faults that exhibit a displacement on the order of several millimeters or less are known as microfaults. The two surfaces of the fault usually contain small parallel grooves or striations generated by the slipping of the fracture; these grooves are known as slickensides. The orientation of the slickensides gives the direction of fault movement.

Joints are smooth-surfaced natural fractures that display no relative movement of the sides. Joints are formed by either tension (pulling apart) or by compression (squeezing) in the rock. Joints can be further divided into two subclasses: simple joints, consisting of a single fracture surface, and compound joints, composed of several closely spaced, sub-parallel fractures. Joints contain mineralization more commonly than faults, and occur more often in a near-vertical orientation.

The core was systematically examined from top to bottom for natural fractures. When a fracture was found, measurements and information were recorded on a standardized fracture logging format. The data recorded for natural fractures were:

- Depth (from __ to __ ft.)
- Length (to nearest 1/10 foot)
- Lithology (rock type the fracture occurs in)
- Terminations (fracture exits core, dies as hairline, terminates at bedding plane, abuts another fracture, etc.)
- Character (planar surface or curviplanar surface)
- Strike and dip
- Fracture type (i.e., fault or joint)
- Mineralization (type and quantity, if any)
- Slickensides (trend and plunge)
- Fractographic features (hackle marks, arrest lines, etc.)

There is also a space on the form for comments about unusual fracture characteristics.

3.6.2 Induced Fracture Log

Induced fractures are formed as a result of twisting, pulling, bending, or otherwise deforming the core during cutting and transporting. Although they are not formed by regional stress on the rock, they tend to be oriented with respect to the residual stress field in the core.

Induced fractures generally exhibit coarse, irregular surfaces, often curved or spiraling, and contain arrest lines, twist hackles and hackle plumes. Induced fracture surfaces tend to curve around to meet the edge of the core at a right angle, and terminate against, rather than cut through natural fractures. Induced fractures are never mineralized. Induced fractures occur as several types, which are described below and illustrated in Figure 3.1.

A. Petal fracture: An oblique fracture, generally curviplanar, convex upward that originates at the edge of the core, travels downward and inward a short distance, and terminates against a bedding plane.

B. Petal-centerline fracture: A petal fracture that continues down the center of the core as a vertical fracture for a distance of up to several feet.

C. Torsional fracture: A spiraling or helical fracture with an irregular surface formed by the core twisting in the core barrel. A similar fracture can be obtained by twisting a piece of chalk.

D. Disc fracture: A horizontal break along bedding planes in the core. These fractures are generally caused by dewatering of the shale core, and are intensified by handling.

E. Disc-circular slickensides (D. C. S.): A horizontal break in the core that allows core in the barrel to rotate against a stationary core stump and produces circular slickensides.

The core was systematically examined from top to bottom for induced fractures. When a fracture was found, measurements and information were recorded on a standardized fracture logging format. The data recorded for induced fractures include:

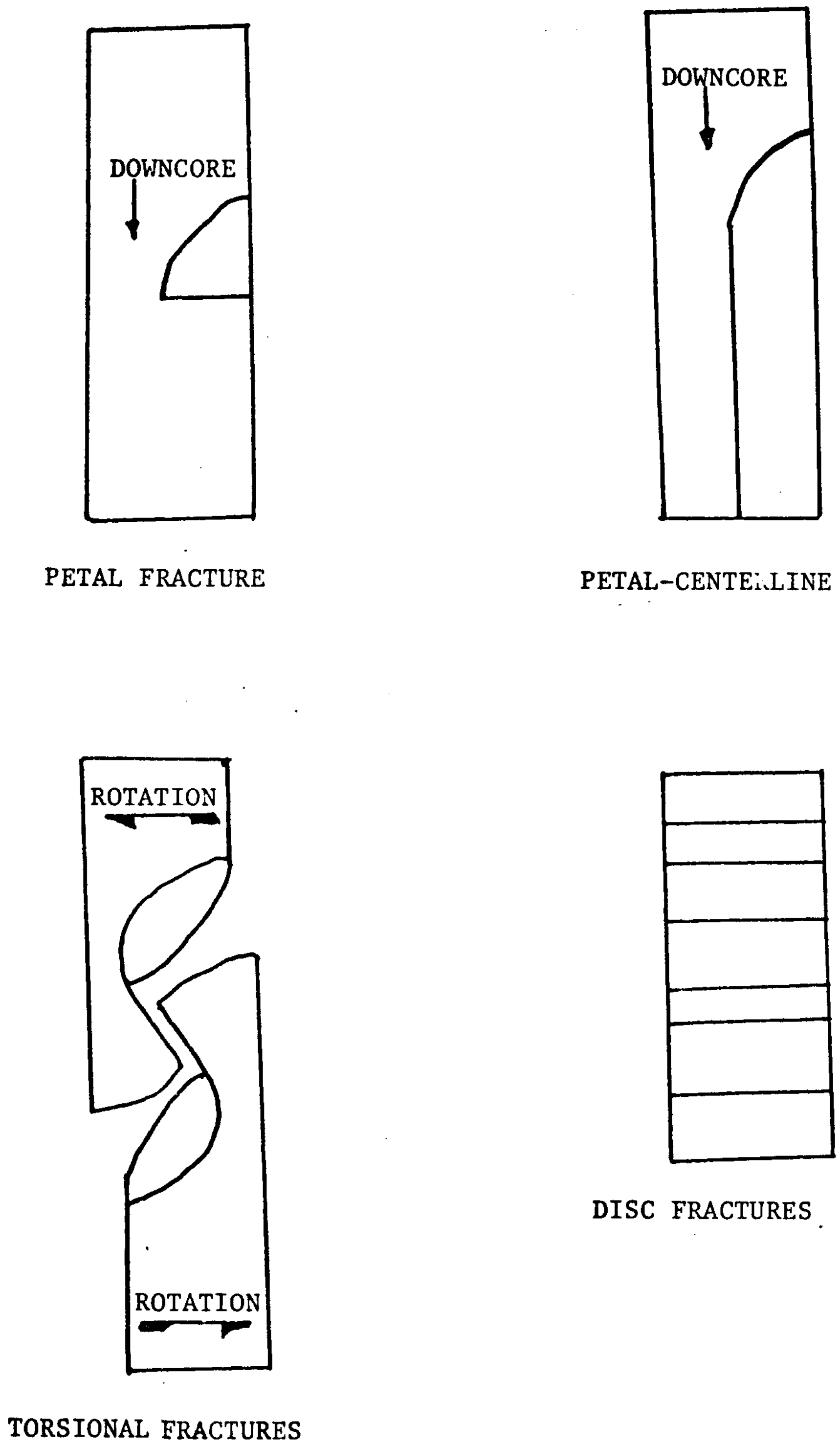


FIGURE 3.1

TYPES OF INDUCED FRACTURES PRESENT IN EGSP CORES

- Depth (from __ to __ ft.)
- Length (to nearest 1/10 foot)
- Lithology (rock type the fracture occurs in)
- Terminations (core margin, bedding plane, natural fracture, etc.)
- Character (planar or curviplanar)
- Strike and dip (measured on petal and petal-centerline fractures only)
- Fracture type (torsional, petal, etc.)
- Slickensides (presence noted for disc-circular slickensides)
- Fractographic features

There is also a space on the form for comments about unusual fracture characteristics.

Disc fractures are not recorded individually on the induced fracture log. Since these are the most common and least diagnostic type of fracture, their presence in the core is only useful as an indicator of the structural rigidity of the rock. The number of disc fractures is counted throughout the length of the core in five-foot intervals. The counts are converted to frequency per foot, and the information is recorded in the form on a histogram.

3.7 Color Histogram

After the fracture logs were completed, a color histogram was compiled of the core to provide a relative measure of the distribution of light and dark shales throughout the cored interval. Light and dark colors were determined by comparing the wet core with the standard rock color chart published by The Geological Society of America. Colors with values equal to or lighter than N3 (dark gray) were considered as light shale, and color values darker than N3 (grayish black and black) were counted as dark shale. Use of the term "value" refers to the Munsell system of color identification in which a specific color is identified by a unique hue (color), chroma (intensity or saturation) and value (lightness or darkness).

The percentage of light and dark shales was determined throughout the core in five-foot intervals. The percentage of shale darker than N3 was plotted between zero and 100% for each five-foot interval on a histogram.

3.8 Lithologic Description

After completion of the color histogram, a written description of the detailed lithology of the core was prepared for intervals which vary from about five to ten feet in length. The first sentence of the description consisted of a summary of the lithology, color, and internal stratification of the interval. Stratigraphic thicknesses in the core were described as follows:

BEDDING THICKNESS	TERM USED
Greater than 180 cm (6 ft.)	Massively bedded
180 cm (6 ft.) to 120 cm (4 ft.)	Very thick bedded
120 cm (4 ft.) to 60 cm (2 ft.)	Thick bedded
60 cm (2 ft.) to 2 cm	Thin bedded
2 cm to 1 cm	Very thin bedded
1 cm to 1 mm	Thickly laminated
Less than 1 mm	Thinly laminated

Core colors were described using the Rock Color Chart published by the Geological Society of America (1948). The colors were given as a descriptive name (olive gray, brownish black, etc.) and as a number designating the hue, chroma and value of the color in the Munsell system color classification. The color chips on the G. S. A. chart were compared with wet core until the closest match was found. It was reported on the color chart that wetting the specimen changes only the value (darkening the rock), although the chroma and hue remain unaltered. Wetting the core provides a more uniform determination of color and easier comparison with the color chart.

The lithologic terminology applied to the core was derived primarily from the texture of the rocks. The terms used for carbonate rocks were a textural classification taken from Dunham (1962). The terminology used in the detailed lithologic description is listed below, and the textural relationships between the terms are shown graphically in Figure 3.2.

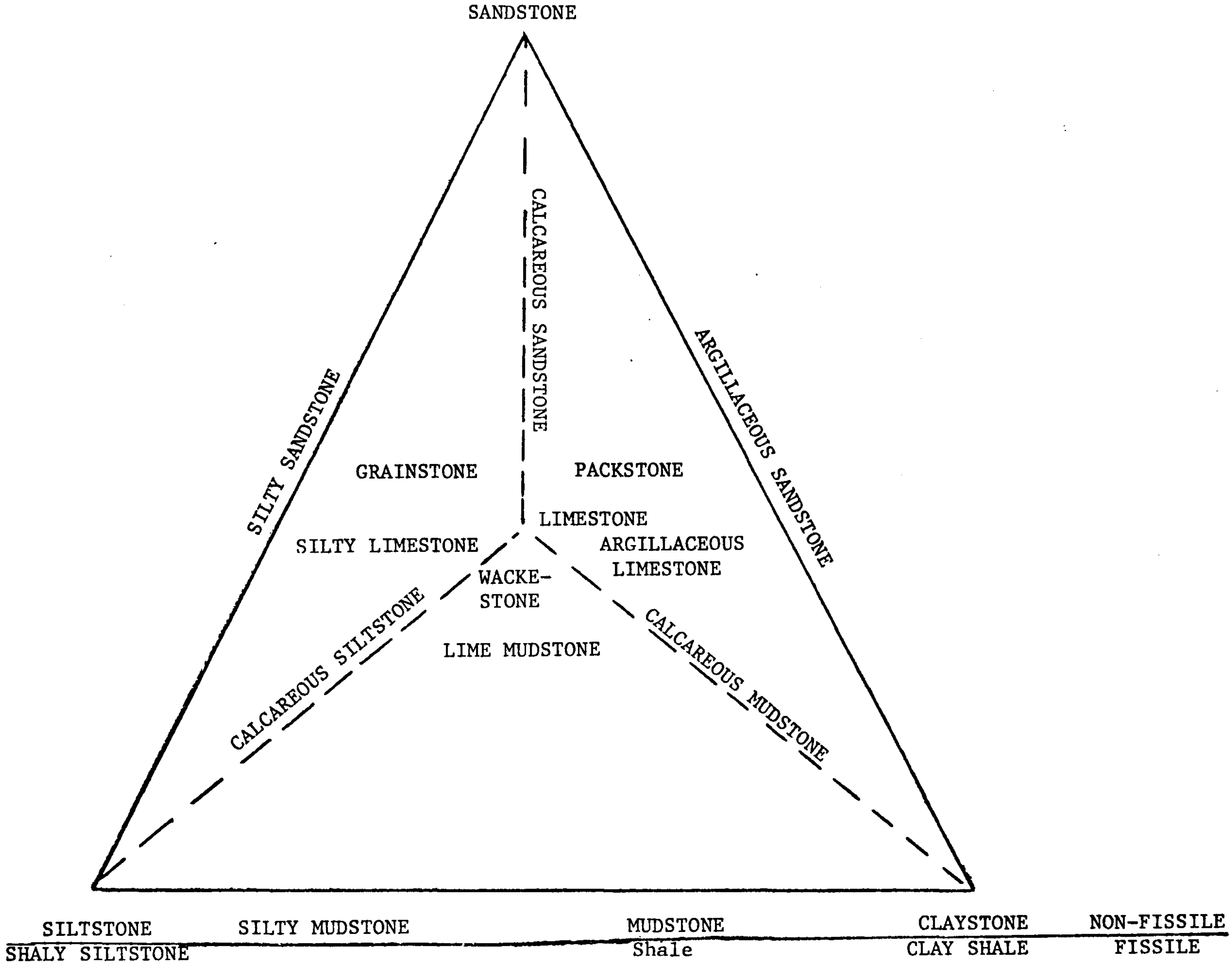
<u>Lithologic Terms Applied to EGSP Cores</u>

Clastic Rocks:

- Sandstone (coarse to fine)
- Silty sandstone ($\sim$50% silt)
- Argillaceous Sandstone ($\sim$50% clay)
- Calcareous Sandstone (<50% lime)
- Sandy Limestone (<50% lime)
- Siltstone (shaly siltstone if fissile)
- Calcareous Siltstone (<50% lime)
- Silty Limestone (>50% lime)
- Silty Mudstone (<50% clay)
- Silty Shale (fissile silty mudstone)

FIGURE 3.2

LITHOLOGIC TERMINOLOGY APPLIED TO EGSP CORES



- Mudstone ($\sim$50% clay, $\sim$50% silt)
- Shaly Mudstone (fissile mudstone)
- Calcareous Mudstone (<50% lime)
- Argillaceous Limestone (>50% lime)
- Claystone (>50% clay)
- Clay Shale (fissile claystone)

Carbonate Rocks:

- Lime Mudstone (carbonate mud containing less than 10% carbonate sand-sized grains)
- Wackestone (carbonate mud containing over 10% carbonate sand-sized grains)
- Packstone (sand-sized carbonate grains containing interstitial carbonate mud)
- Grainstone (sand-sized carbonate grains with no interstitial carbonate mud)
- Boundstone (biologically cemented carbonated grains, i.e., coquina, reef-rock, etc.)
- Crystalline Limestone (pure, hard limestone with no recognizable texture)
- Dolomitic Limestone (<50% dolomite)
- Dolostone (>50% dolomite)

Additional remarks were recorded in the detailed lithologic description to describe unique or unusual features present within the interval. These remarks may have concerned any or all of the following:

1. Coarse clastic interbeds with scour surfaces, cross-stratification, ripple lamination, or other sedimentary structures.

2. Fossil types and modes of preservation, including plant fragments, spores, conodonts, invertebrate shells, fish scales and teeth, etc. Fossils may be preserved as casts, carbonaceous

films, pyrite mineralization, etc. Fossils were identified to genus when possible.

3. Bioturbation, as discrete burrows or as mottled stratification with emphasis on distribution and association with other rock fabric features.

4. Concretions, slump features, clasts and other inorganic structures.

5. Modes of pyritization: as disseminated crystals, nodules, or coatings on fossils; as accessory mineralization in fractures and concretions; and as primary lenses or laminae in euxinic (anaerobic) black shales.

6. Occurrence of fissility, friability, oil shows, gas shows, and kerogen odors.

7. Carbonate content: as cement or calcareous zones in clastic units; presence of spar-filled vugs and stylolites in limestone beds; dolomitization or recrystallization in carbonate units.

It should be remembered that the lithologic description was concerned with macroscopic features of the core only. The description proceeded from the top of the core to the base, and was carried out with a hand lens, bioprobe, acid bottle, and a 30X binocular microscope. Fossils were identified with reference to published sources. An attempt was made to correlate the descriptive intervals with natural lithologic boundaries in the core.

3.9 Stratigraphic Section

A stratigraphic section of the core was prepared after completion of the detailed lithologic description. The stratigraphy of the core was determined from three sources:

1. Geophysical well logs, specifically the gamma ray log, formation density log, and sonic velocity log.

2. Detailed lithologic description of the core.

3. Published reference sources.

The gamma ray and density logs are generally the most useful correlation tools within the Devonian Shale sequence of the eastern United States. Much of the existing formation nomenclature for the Devonian Shales is based on characteristic, recognizable features on these logs. In several cases, formation boundaries and thicknesses can be determined more readily from gamma ray and density logs than from visual examination of the core itself.

After review of publications dealing with the Devonian stratigraphy of the area near the well site, the geophysical well logs were searched for a marker unit or easily identifiable formation from which to determine the stratigraphy of the core. Commonly used marker units are listed below:

° Sunbury Shale (Lower Mississippian): An isolated black shale giving a very high gamma reading, and overlying a sharp contact with the Berea Sandstone, which gives a very low gamma reading. Appalachian and Michigan Basins.

° Cleveland Shale (Upper Devonian): Uppermost black shale member of the Ohio Shale; isolated by gray Bedford Shale above and gray Chagrin Shale below. Central Ohio and Kentucky only.

° Pipe Creek Shale (Upper Devonian): Basal black shale member of the Java Formation; easily recognized by concurrent very high gamma reading and very low density reading. Fairly thin unit. Central/Northeastern Appalachian Basin only.

° Tully Limestone (Middle (?) Devonian): Upper member of Hamilton Group; low gamma ray/high density limestone sandwiched between high gamma reading Geneseo Shale above and Mahantango Shale below. East/Northeast Appalachian Basin only.

° Marcellus Shale (Middle Devonian): Basal member of the Hamilton Group; very high gamma ray reading. Eastern Appalachian Basin.

° Onondaga Group (Middle Devonian): Basal limestone underlying the Devonian Shale sequence in the Appalachian Basin. Low gamma reading and high density. Basinwide distribution.

Once a marker unit has been located on the well logs, the remaining stratigraphy can be readily determined.

Formation names, thicknesses and contacts taken from the geophysical well logs were compared with lithologic boundaries in the core (where present). Adjustments in the depths of contacts were made in favor of the core if the lithologic boundary was well defined, and in favor of the log if the core boundary was gradational or missing. Adjustments were only necessary if there was a lack of agreement concerning contact depths and formation thicknesses between the core and the logs.

3.10 Hardness Testing

After completion of the stratigraphic section, the core was tested for analysis of the physical properties of the rock. The first test performed was the hardness test. This test gives a quick analysis of the relative hardness of the cored interval. The test was performed with a scleroscope which uses the Brinell scale of hardness as a standard. The core was tested from the top to the base; tests were made taking ten readings per foot along the side of the core. These ten readings were added together, divided by ten, and an average hardness reading was obtained for each foot. This data was used in conjunction with well logs to determine depth intervals of varying strength characteristics which can be interpreted as barriers to vertical fracture growth. The data were recorded in the form of a histogram.

Questions have been raised concerning the validity of rock hardness data obtained with a scleroscope. The instrument used at the EGSP Core Laboratory employed the rebound principle, and its use is widely accepted in the field of metallurgical testing. Numerous checks of the instrument during rock testing, however, indicated that reproducibility of data was poor in this application. The instrument is also a high maintenance item when used on shale, especially when testing several hundred feet of shale core. For these reasons, the hardness testing was eliminated from the shale core characterization program early in the project. No suitable alternative devices for performing hardness tests on shale have been found.

3.11 Physical Properties Sample Preparation

Physical properties samples were taken from the core as the final step in the core characterization process at the EGSP Core Laboratory. Physical properties tests were performed at Michigan Technological University in Houghton, Michigan, acting as a subcontractor to Cliffs. The samples from the core were tested for the following properties:

° Ultrasonic Velocity Transmission

° Directional Tensile Strength

° Strength in Point Load

° Trends of Microfractures

° Hydraulic Fracturing (on some cores)

Two separate sets of samples were taken from the core for the above tests. The ultrasonic velocity and hydraulic fracturing tests were performed on full diameter (3-1/2 inches) core samples ranging in length from four to six inches. The samples were taken at a rate of one per ten feet of core. All intervals were sampled from the top to the base of the core except where excessive fissility, friability, fracturing, etc. made it impossible to obtain a minimum four-inch long sample. After the samples were removed from the core, they were run through a rock saw to plane off the ends. The top end of the finished sample was marked with the well number, interval, and north-south direction. Two copies of the data marked on the sample were recorded; one copy was filed and the other was packed with the samples. The ultrasonic velocity samples were then wrapped in newspaper, placed in open steel cans, boxed, and shipped to MTU for testing.

Samples taken for the directional tensile, point load, and trends of microfractures tests were two inches in diameter and 1/2 to 3/4 inches thick. These samples were undercored from the original 3-1/2 inch diameter core with a Rockwell/Delta drill press equipped with a two-inch inside diameter diamond coring bit from Sprague and Henwood. The undercoring was necessary since microfractures generated by inscribing the orientation grooves during coring penetrate 1/2 to 3/4 of an inch into the core. These microfractures would cause the core to break along the orientation grooves if left in place while testing.

The two-inch diameter cylinders were removed from the drill press and sliced into 3/4-inch thick discs in the rock saw. The samples were marked with north-south orientation, depth, interval, well number and downcore direction after the ends had been sanded flat in a belt sander. The faces were checked in a Doall micrometer for parallelism within ±0.015 inch. The samples were packed in Jiffy bags inside plastic Ziploc bags. The outside plastic bag was marked with a tape containing sample information, and the bags were shipped to MTU inside core boxes. As with the sonic velocity samples, two copies of the point load/directional tensile sample information were recorded; one for filing and one for shipping.

Directional tensile/point load samples were selected from the same ten-foot intervals in the core as the sonic samples. Enough core was gathered from the intervals to enable twelve to sixteen samples to be cut per interval. This was necessary because a minimum of six directional tensile samples were needed per interval, and some breakage occurred during transport.

3.12 Sample Testing

After the samples were received at MTU, they were unpacked, sorted, and prepared for testing. The testing procedures used on the samples are described below, taken from Byrer and Komar (1977).

A. Directional Tensile Strength Test

At intervals of 10 feet, six samples were selected for Line Load Tensile Strength Tests. Each sample was placed horizontally between the two platens in the instrument and compressed in the manner shown in the accompanying illustration. Tensile strength normal to the axes of loading was determined from the magnitude of the applied load at failure by the formula:

$$S_T = 2P\,(\pi dt)^{-1}$$

where: S_T = tensile strength, psi

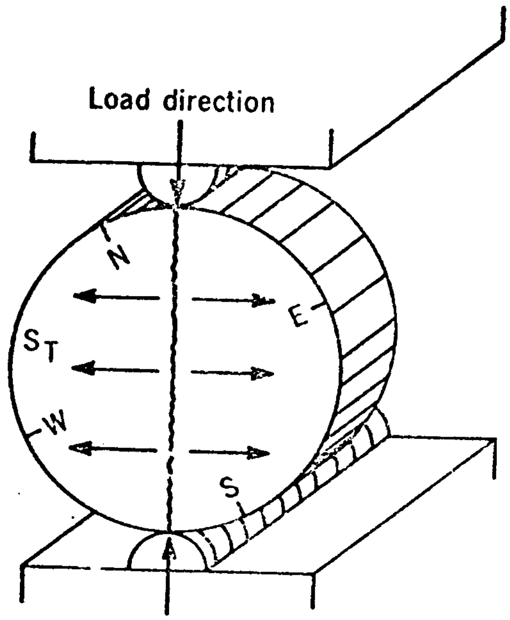
P = applied load of failure, lb.

d = diameter of disk, in.

t = thickness of disk, in.

FIGURE 3.3

METHOD OF SHOWING DIRECTIONAL TENSILE STRENGTH TESTS



1. Each sample was broken in one of six directions, 30° apart. For example, one sample was broken at N60°W, one at N30°W, and one at N0°. The remaining samples were broken at N30°E, N60°E, and N90°E, respectively.

2. The breaking load of each sample was recorded in pounds per square inch on a large circular scale (0-60,000 lbs.). The breaking point was then recorded on a composite sheet.

3. In the last phase of this test, the induced fractures on the sample were numbered according to the sample number and then the fractures were traced on paper. This gives an accurate visual record of all samples.

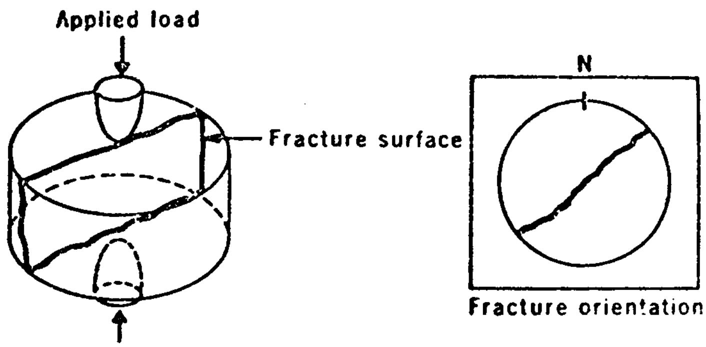
B. Point Load Test

The next test did not require grouped samples as in the previous test. The remaining samples were used in the Point Load Test. These samples had masking tape around their circumference in order to preserve the fractures after the point load test is performed.

1. These samples were compressed in a vertical direction by loading them directly in the center on both the top and bottom sides. Hemispherical platens are used in this test for both the top and bottom, as seen in the illustrations.

FIGURE 3.4

METHOD OF SHOWING INHERENT ROCK WEAKNESS IN POINT LOAD TEST



Fracture direction at random unless a "preferred direction" of failure exists.

2. The breaking point load was then read on the Tinius Olsen Scale and recorded on a composite sheet in pounds.

3. In the last phase of the Point Load Test, the induced fractures on the sample were numbered according to the sample number and then the fractures were traced on paper.

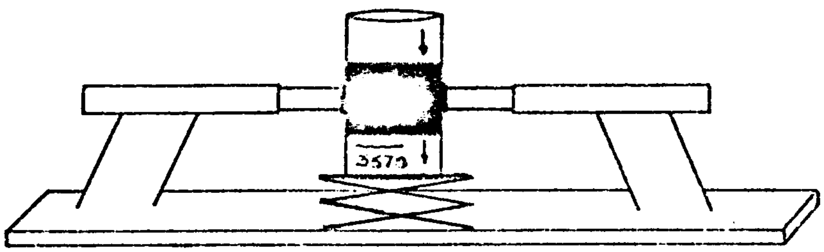
C. Directional Ultrasonic Velocity Test

Once the 4-8" samples for the Ultrasonic Velocity Test were selected, the orientation in 30° increments was recorded on one end of the sample, using a circular template. The orientations of the core to be tested were N0°, N30°E, N60°E, N90°E, N60°W, and N30°W. The diameter of the core was measured in each of the above directions using a vernier micrometer. The sample was then wrapped with black plastic tape so that the tape just touches itself but does not overlap, and no exposed core is found. The area taped was directly in the middle of the sample, and three widths of the tape were used yielding a taped area with a width of approximately two inches. The taped area of the sample was then coated with a di-electric silicon lubricant and the sample was then placed in the sonic velocity apparatus. The ultrasonic velocity was then measured in the six directions mentioned above and an average of ten values for each direction was used as the final measurement.

FIGURE 3.5

PROPER ALIGNMENT OF CORE SAMPLE FOR TESTING IN THE ULTRASONIC VELOCITY APPARATUS

Basic Design for Ultrasonic Velocity Equipment



3.13 Displaying the Core

After the core samples had been sent to MTU for physical properties testing, the core was placed on open display at the EGSP Core Laboratory in Granville, West Virginia for approximately two weeks.

The reason for displaying the core in this manner was to allow other EGSP contractors and other interested parties (i.e., universities, oil companies, etc.) to inspect and sample the core for their own purposes.

Before displaying the core, letters were sent on a regular mailing list to inform interested parties which core would be available for inspection and sampling, and for how long. An example of one of these letters is shown in Figure 3.6.

3.14 Preparation of the Phase II Report

Results of the preliminary laboratory characterization of the core were reported in a format known as the Phase II Report - Preliminary Laboratory Results.

The Phase II Report consists of a brief introduction, describing the objectives of the Eastern Gas Shales Project, followed by a section concerning the scope of work at the EGSP Core Laboratory. The laboratory procedures used in characterizing the core are described in the third section; the method of reporting the results of the laboratory work follows. The fifth section is a discussion of the results. It consists of a general introduction to the well site area, the geologic setting of the region, the stratigraphy of the core with a short discussion of each unit, and an analysis of the fractures present in the core.

Section five of the Phase II Report is followed by three appendices, which consist of the following:

APPENDIX A: The detailed lithologic description from the laboratory characterization of the core. An example is shown in Figure 3.7.

APPENDIX B: A key to the symbols, terms and abbreviations used in the fracture logs.

APPENDIX C: Copies of the laboratory-compiled natural and induced fracture logs. Example is shown in Figure 3.8.

Cliffs Minerals, Inc.

P.O. Box 408
Granville, West Virginia 26534
Phone: 304/599-4770

October 20, 1980

SAMPLE LETTER

RE: SAMPLING OF THE PENNSYLVANIA #5 CORE - LAWRENCE COUNTY

Dear

Cliffs Minerals, Inc. a subsidiary of The Cleveland-Cliffs Iron Company, has been recovering oriented Devonian Shale cores from the Appalachian, Michigan, and Illinois Basins under a three-year DOE Eastern Gas Shales Project Contract. Throughout this three-year project approximately 65 wells will be cored in an 11-state area.

The above subject core will be available to contractors and other interested parties for sampling during the period November 10-21, 1980. It will then be archived for 60 to 90 days at the EGSP Core Laboratory, 655 Main Street, Granville, West Virginia, before being returned to the Pennsylvania Geologic Survey for final storage.

Interested parties are requested to get written permission from Mr. C. A. Komar, Technical Project Officer, METC, prior to actual sampling. Persons desiring core samples are also requested to provide their own containers. The EGSP Core Laboratory will be open from 8:00 a.m. to 4:30 p.m. for your convenience.

Very truly yours,

Kevin L. Malmquist
Laboratory Supervisor

KLM/sbm

FIGURE 3.6

SAMPLE LETTER DESCRIBING DISPLAY AND SAMPLING PERIOD FOR THE EGSP-PENNSYLVANIA #5 CORE TO INTERESTED PARTIES

INTERVAL	DESCRIPTION
2,677.8' - 2,683.1' (5.3')	Mudstones, olive black (5Y 2/1) lightening downcore to olive gray (5Y 3/2), thick bedded. The interval is noncalcareous in the upper 1/2, very slightly calcareous near the base. Pyrite is common throughout, occuring in lenses and as laminae and nodules. Numerous pyrite nodules, 1 to 5 mm in diam., are present on a parting at 2,677.82'; a large nodule (2 cm diam.) occurs at 2,678.0'. A slight to moderate kerogen odor is present on fresh surfaces throughout the interval. Fossils are rare, consisting of a few pyrite-coated carbonaceous plant fragment and unidentified, pyritized spine-shaped objects. The spine-like objects are generally less than 1 cm in length and occur on partings at 2,677.91' and 2,680.9'.
2,683.1' - 2,689.0' (5.9')	Mudstones, olive gray (5Y 3/2), thin bedded to thick bedded, moderately to strongly calcareous. A slight kerogen odor is present on fresh surfaces throughout. This interval is moderately fossiliferous, containing carbonaceous plant fragments and casts of shells. A faint cast of a 1 cm diam., coiled cephalopod occurs at 2,683.95'. Calcite permineralized spine-shaped objects, less than 1 cm in length, are abundant on a parting at 2,684.35'. A poorly preserved cast of a pelecypod (?) occurs at 2,684.97'; casts of inarticulate brachiopods (_Orbiouloidea_ sp. ?) are present at 2,685.4'. Pyrite-coated spore bodies (_Tasmanites_) occur abundantly on a parting at 2,684.82'.
2,689.0' - 2,697.3' (8.3')	Mudstones with several thin beds of argillaceous lime mudstone, olive black (5Y 2/1) and olive gray (5Y 3/2, 5Y 4/1), thin to thick bedded. The interval is moderately to strongly calcareous. Argillaceous lime mudstone occurs at 2,689.0', 2,692.0', 2,692.4' and 2,696.0'. Occasional, thin pyritic laminae occur throughout; a few irregular concentrations of very fine pyrite crystals are distributed sparsely in the interval. A few pyritized spore bodies (_Tasmanites_) occur on a parting at 2,691.58'. A faint kerogen odor is present on fresh surfaces throughout.

FIGURE 3.7

EXAMPLE OF THE DETAILED LITHOLOGIC DESCRIPTION FROM THE EGSP-OHIO #7 PHASE II REPORT

FIGURE 3.8

EXAMPLE OF THE NATURAL FRACTURE LOG FROM THE EGSP-OHIO #9 PHASE II REPORT

E.G.S.P. REVISED FRACTURE LOGGING FORMAT

CORING DATE: FEBRUARY 1981

LOG DATE: MARCH 1981

WELL: EGSP-Ohio #9, MEIGS COUNTY

PAGE 1 OF 1

NATURAL FRACTURES

NUMBER	DEPTH EXTENT	LENGTH	LITHOLOGY	TERMINATIONS	CHARACTER	STRIKE / DIP	FRACTURE TYPE	MINERALIZATION	SLICKENSIDES	FRACTOGRAPHIC FEATURES	COMMENTS
1	3008.6 3008.8	0.2	Slty Mdst, Sltsn (5YR 2/1)(5Y 4/1)	M ?M	CP		Mcr. Flt	None	Present		Non-oriented core Curvilinear slickenlines
2	3038.0 3039.4	1.4	Slty Mdst, Sltsn (5YR 2/1)(5Y 4/1)		P	N72°E 90°	Spl. Jt.	None			
3	3039.4 3040.2	0.8	Slty Mdst, Sltsn (5YR 2/1)(5Y 4/1)		P	N72°E 90°	Spl. Jt.	None			Planar joint parallel to F2
4	3062.2 3063.3	1.1	Slty Mdst, Sltsn (5YR 2/1)(5Y 4/1)	BDG	P	N64°E 90°	Spl. Jt.	None			Initiates with a small petal fracture
5	3103.4 3104.0	0.6	Mdst, Slty Mdst (5GY 6/1)(5GY 4/1)	BDG	P	N76°E 85°NW	Spl. Jt.	None			Initiates with a small fracture
6	3126.6- 3127.2+	0.6+	Slty Mdst, sltsn (5GY 4/1)(5Y 4/1)	? ?	P	N72°E 85°NW	Spl. Jt.	None			Upper and lower termination absent due to sampling
7	3182.9 3183.0	0.1	Slty Mdst, mdst (5Y 4/1)(5GY 5/2)		CP	N75°E 25°SE	Mcr. Flt	None	23° S35°E		
8	3234.9 3234.9	<0.1	Slty mdst, mdst (5YR 2/1)(5Y 4/1)		CP		Mcr. Flt	None			Polished surface No distinct slickenlines
9	3270.6 3271.5	0.9		M CIF 752	P	N74°E 89°NW	Spl. Jt.	None			
10	3280.2 3280.8	0.6		? BDG	P	N73°E 88°NW	Spl. Jt.	None			
11	3296.5+ 3298.4	1.9		PI M	P	N75°E 88°NW	Spl. Jt.				Upper termination absent due to sampling, 2 fracture planes
12	3298.1 3298.7	0.6		CF 893	P	N79°E 90°	Spl. Jt.				
13	3349.0 3349.3	0.3	Slty mdst, mdst (5YR 2/1)(5Y 4/1)		P	N74°W 63 SW	Spl. Jt.				
14	3360.4 3360.7+	0.3+		M ?	P	N68°E 73°N	Spl. Jt.				Lower termination absent due to sampling
15	3360.6 3360.7	0.1		?	P	N62°E 69°NW	Spl. Jt.	Slight Calcite			
16	3360.6 3360.7	0.1		?	P	N62°E 68°NW	Spl. Jt.	Slight Calcite			
17											

C-1

In addition to the written portion of the Phase II Report, a correlation chart was compiled at a scale of one inch to twenty feet. The chart provides a visual display of the following information recorded for the core:

1. Stratigraphy column (age and formations)
2. Lithology
3. Color Histogram
4. Gamma Ray Log
5. Density Log
6. Depending upon availability, the Sonic Log, Temperature Log, Audio Log and Resistivity Log in various combinations.
7. Orientation and Distribution of natural fractures.
8. Orientation/Distribution of Petal Fractures (if numerous).
9. Frequency of Induced Fractures (Disc Fracture Histogram).

The correlation chart was drawn on gridded mylar from which a reversed sepia is made. The sepia copy was used to make blueprints of the chart, which were folded and stored in a pocket at the back of the Phase II Report. Examples of correlation charts are shown in Figures 3.9 and 3.10

3.15 Photographic Log Compilation

The photographs taken of the core when it was first laid out on the lab tables (Section 3.4) were assembled in order in a report-type format. The photos were sprayed on the back with Scotch Photo-Mount and positioned two to a sheet on a 8-1/2" X 11" page. The photos are

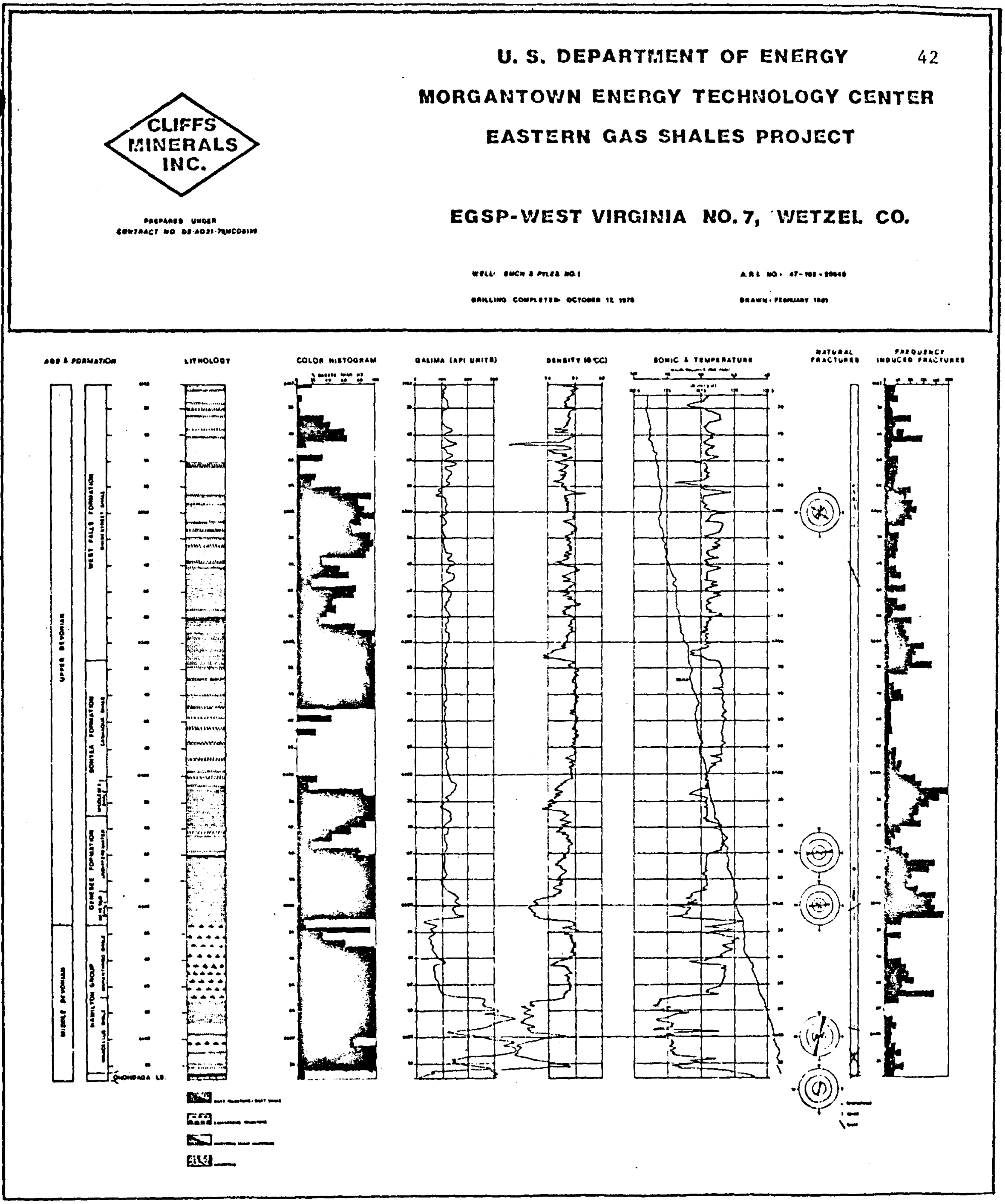


FIGURE 3.9

EXAMPLE OF THE CORRELATION CHART COMPILED FOR THE EGSP-WEST VIRGINIA #7 CORE

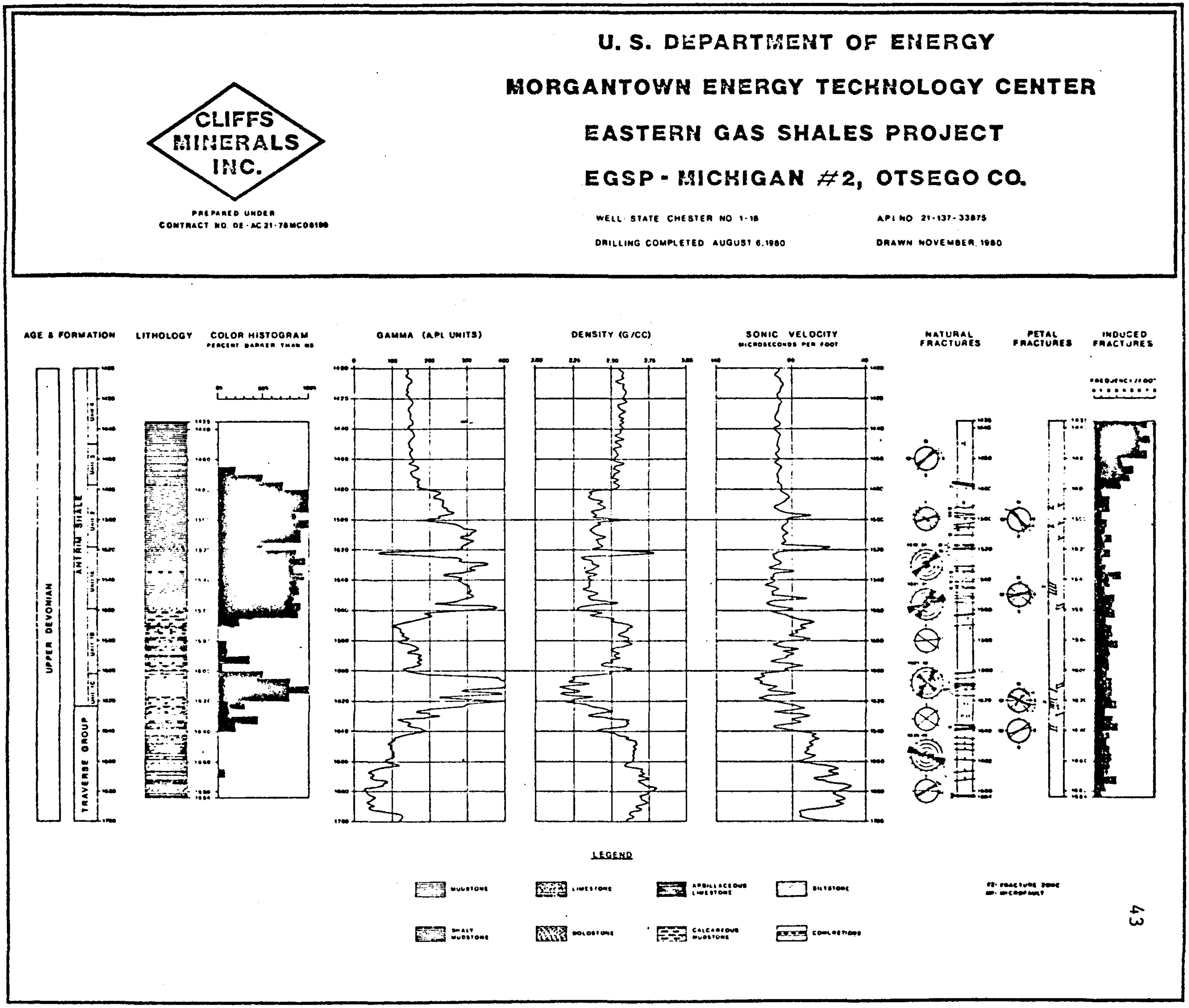


FIGURE 3.10

EXAMPLE OF THE CORRELATION CHART COMPILED FOR THE EGSP-MICHIGAN #2 CORE numbered in order by lab table, and an index was drawn to indicate the location of each picture on the core tables. The log was then bound and distributed.

Two copies of the photographic log were produced for each core. One copy was submitted as a separate document to the Morgantown Energy Technology Center together with the Phase II Report. The second copy was kept on file and made available for inspection at the EGSP Core Laboratory.

3.16 Replacing MTU Samples

After the physical properties testing of the core samples sent to MTU is completed, the samples were repacked and shipped back to the EGSP Core Laboratory. At the lab, they were unpacked and replaced in the core as close as possible to the position they occupied before being removed.

3.17 Core Packaging and Archiving

Upon completion of core characterization, display and sample replacement, the core was ready for packaging and temporary archiving at the EGSP Core Laboratory.

The core was removed from the wooden core tables in three-foot sections and laid in a plastic trough. A flexible polyethylene bag was slipped over the core and tied off at one end. The core was then slid into a standard three-foot long core box, and the other end of the plastic bag was tied off to form a vapor barrier. The boxes were numbered in order from shallowest to deepest, and were marked with the EGSP well number, county, and depth interval of core stored inside. The boxes were then shelved or stacked on pallets for storage at the EGSP Core Laboratory.

Following a ninety-day period, the core was shipped to the geological survey of the state in which it was drilled.

3.18 Report Preparation

A series of three reports were prepared for each well. The Phase I report contains the details of the field retrieval of the core. Phase II reports contain the details of the examination conducted at the EGSP Core Laboratory. Phase III reports contain a summary and also include the physical properties data from Michigan Technological University, Houghton, Michigan. These reports are on file at the METC and at Cliffs' Rifle, Colorado office. Interested parties are referred to Mr. C. Komar, Project Manager, EGSP, METC, Morgantown, West Virginia.

4.0 GEOLOGIC ANALYSIS (BY STATE)

This section contains the location map, the intervals cored, the well summary sheet and the well data chart for each well cored during Cliffs' participation in the project. This information is presented in tabulated form and is assembled on a well-by-well basis.

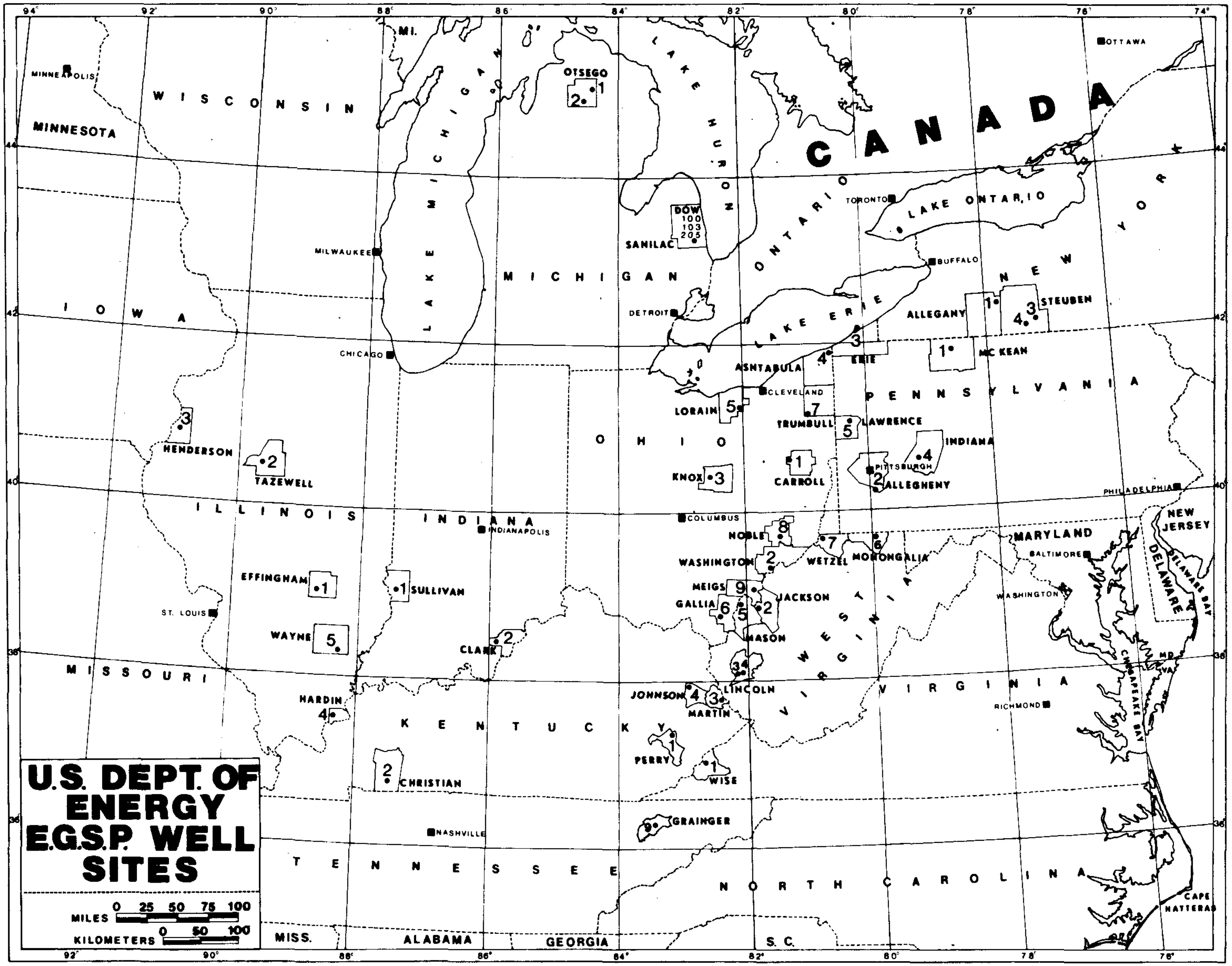


FIGURE 4.1

WELL LOCATIONS MAP

EGSP-ILLINOIS #1

FORMATION THICKNESSES

ILLINOIS GEOLOGICAL SURVEY RESPONSIBILITY

EGSP-ILLINOIS #2

FORMATION THICKNESSES

ILLINOIS GEOLOGICAL SURVEY RESPONSIBILITY

EGSP-ILLINOIS #3

FORMATION THICKNESSES

ILLINOIS GEOLOGICAL SURVEY RESPONSIBILITY

EGSP-ILLINOIS #4

FORMATION THICKNESSES

ILLINOIS GEOLOGICAL SURVEY RESPONSIBILITY

EGSP-KENTUCKY #4

FORMATION THICKNESSES

Formation	Depths	Thickness	Depths Cored
Berea Sandstone	872'- 987'	115'	967'- 987'
Bedford Shale	987'-1,002'	15'	987'-1,002'
Ohio Shale:			
Cleveland Shale	1,002'-1,095'	93'	1,002'-1,095'
Chagrin Shale	1,095'-1,121'	26'	1,095'-1,121'
Huron Shale:			
Upper	1,121'-1,188'	67'	1,121'-1,188'
Middle	1,188'-1,304'	116'	1,188'-1,304'
Lower	1,304'-1,423'	119'	1,304'-1,423'
Olentangy Shale	1,423'- *	---	1,423'-1,510'

* Undetermined Contact

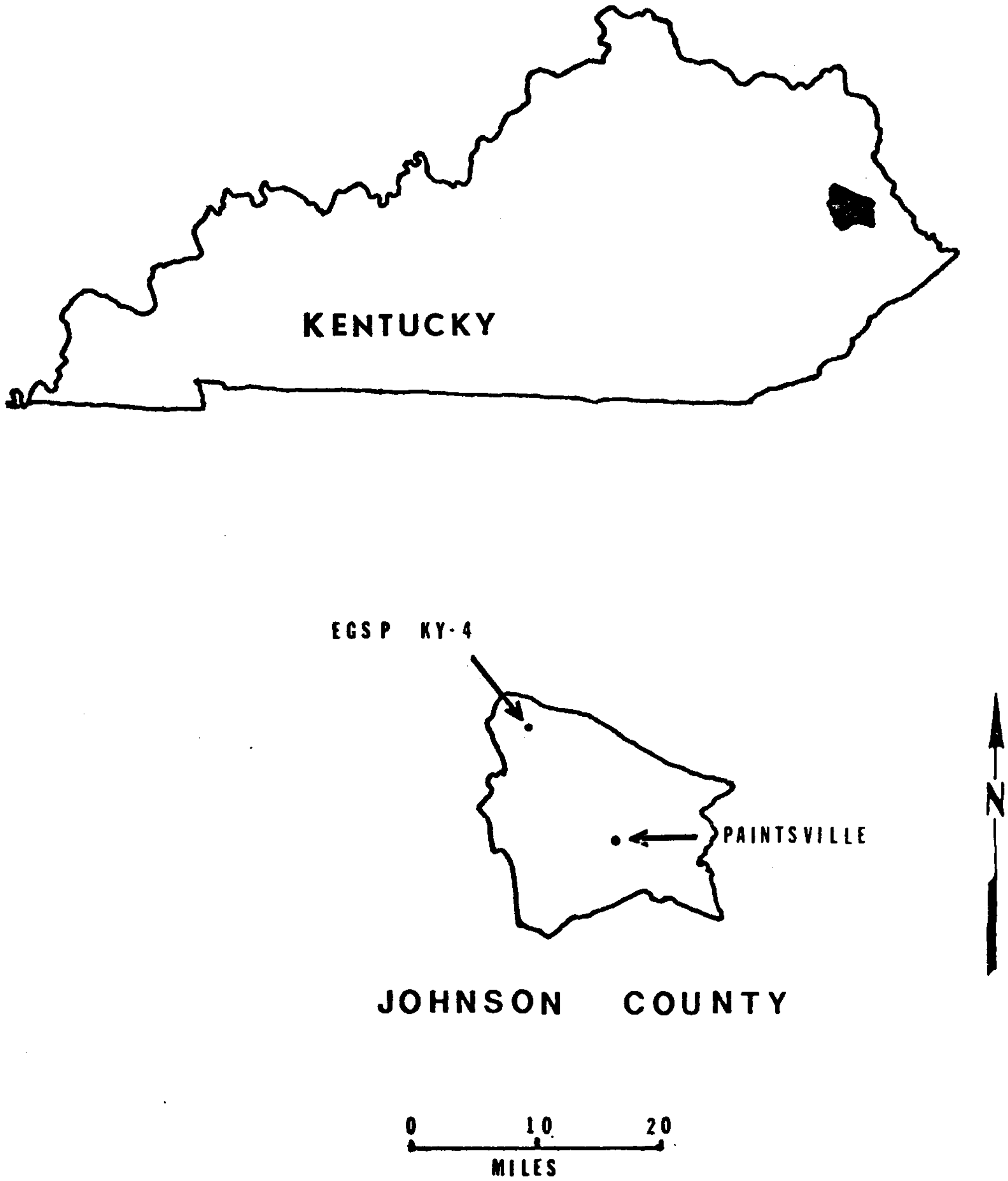
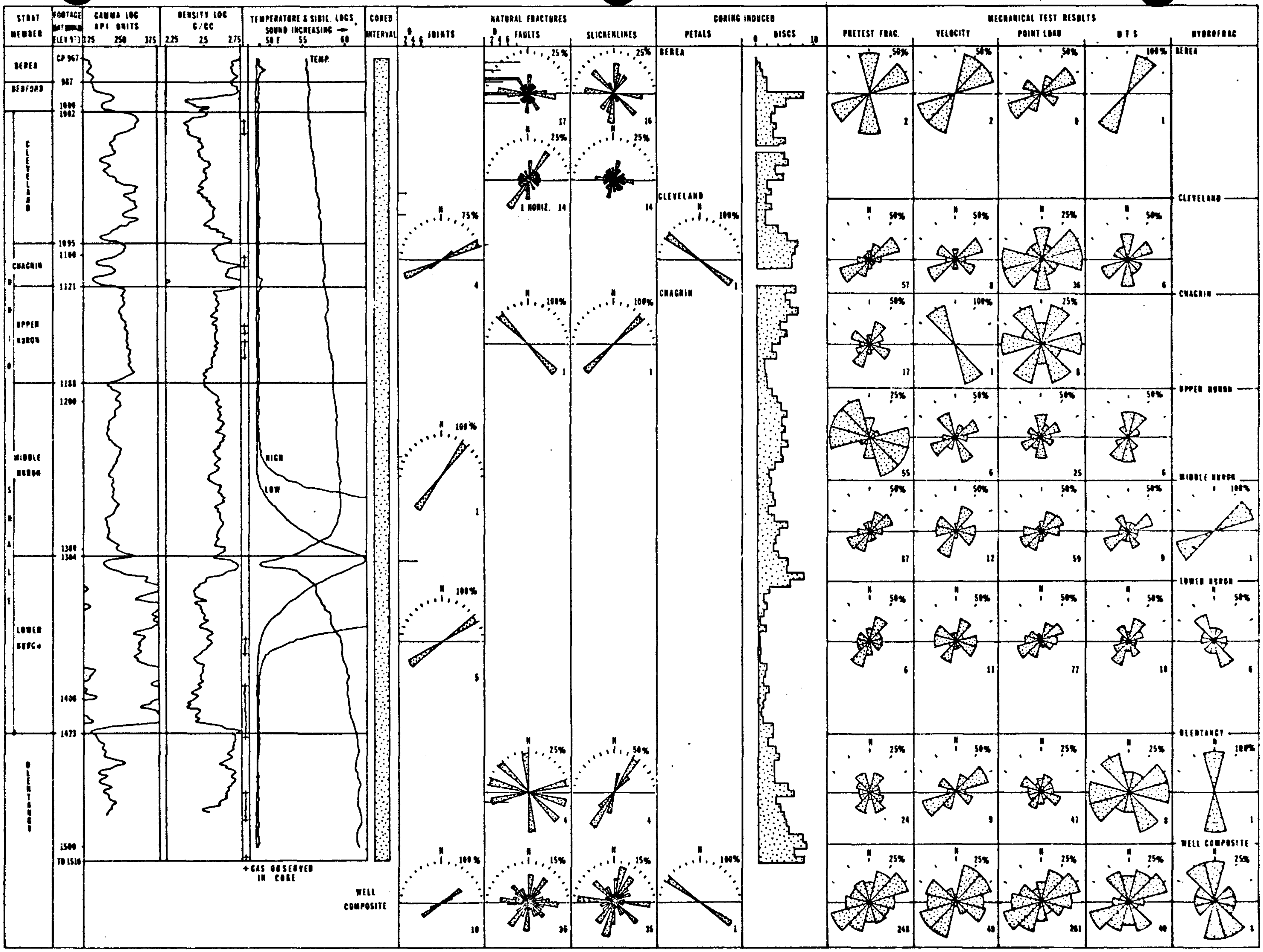


FIGURE 3

LOCATION OF THE EGSP-KENTUCKY #4 WELL,
JOHNSON COUNTY, KENTUCKY



"D" DISTRIBUTION OF FRACTURES.

FIGURE E.G.S.P. KENTUCKY 4 WELL SUMMARY.

CLIFFS MINERALS INC

EGSP-MICHIGAN #1

FORMATION THICKNESSES

Formation	Depth	Thickness	Depths Cored
Antrim Shale	914'-1,318'	404'	1,290'-1,318'
Traverse Group	1,318'-T.D.	---	1,318'-1,393'

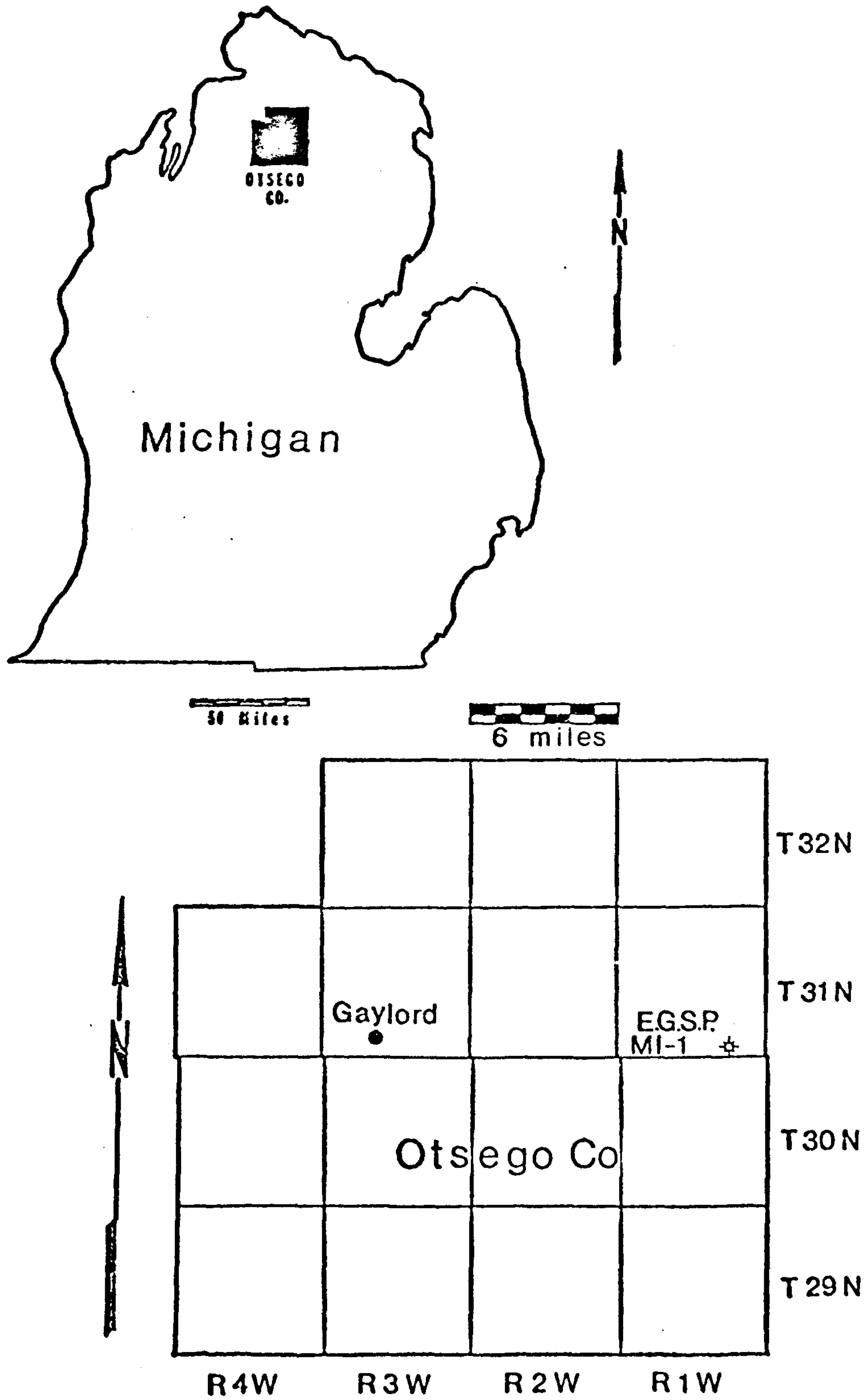


FIGURE 3

LOCATION OF THE EGSP-MICHIGAN #1 WELL

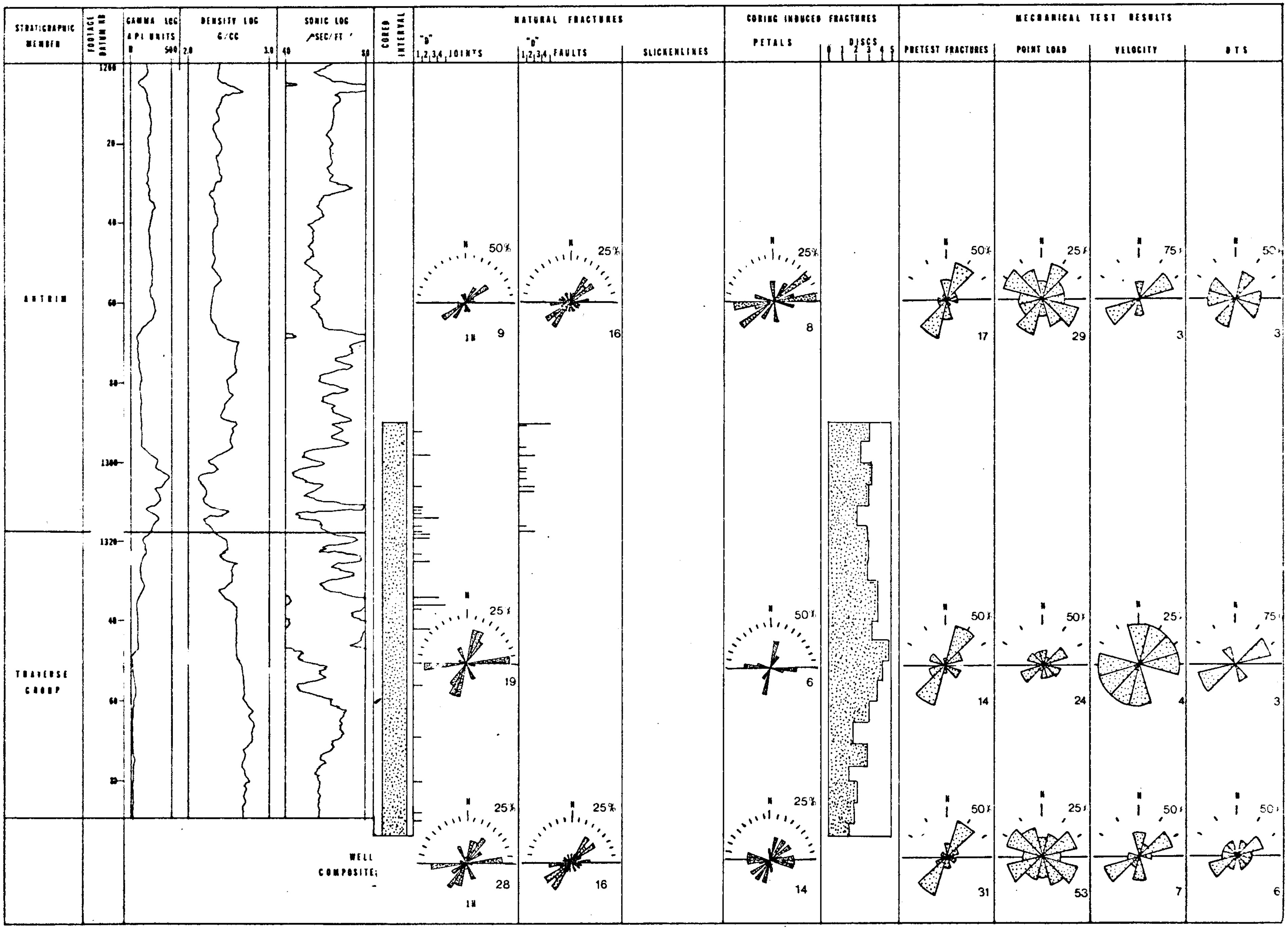


FIGURE EGSP MICHIGAN 1 WELL SUMMARY

"D" — DISTRIBUTION OF FRACTURES
"H" — HORIZONTAL

CLIFFS MINERALS, INC

EGSP-MICHIGAN #2

FORMATION THICKNESSES

Formation	Depth	Thickness	Depths Cored
Sunbury Shale	1,082' -1,092'	10'	----
Bedford Shale	1,092' -1,228'	136'	----
Antrim Shale:			
Unit 6	1,228' -1,244'(?)	16'	----
Unit 5	1,244'(?)-1,290'	46'	----
Unit 4	1,290' -1,450'	160'	1,435'-1,450'
Unit 3	1,450' -1,477'	27'	1,450'-1,477'
Unit 2	1,477' -1,518'	41'	1,477'-1,518'
Unit 1A	1,518' -1,559'	41'	1,518'-1,559'
Unit 1B	1,559' -1,602'	43'	1,559'-1,602'
Unit 1C	1,602' -1,623'	21'	1,602'-1,623'
Traverse Group	1,623' -T.D.	---	1,623'-1,684'

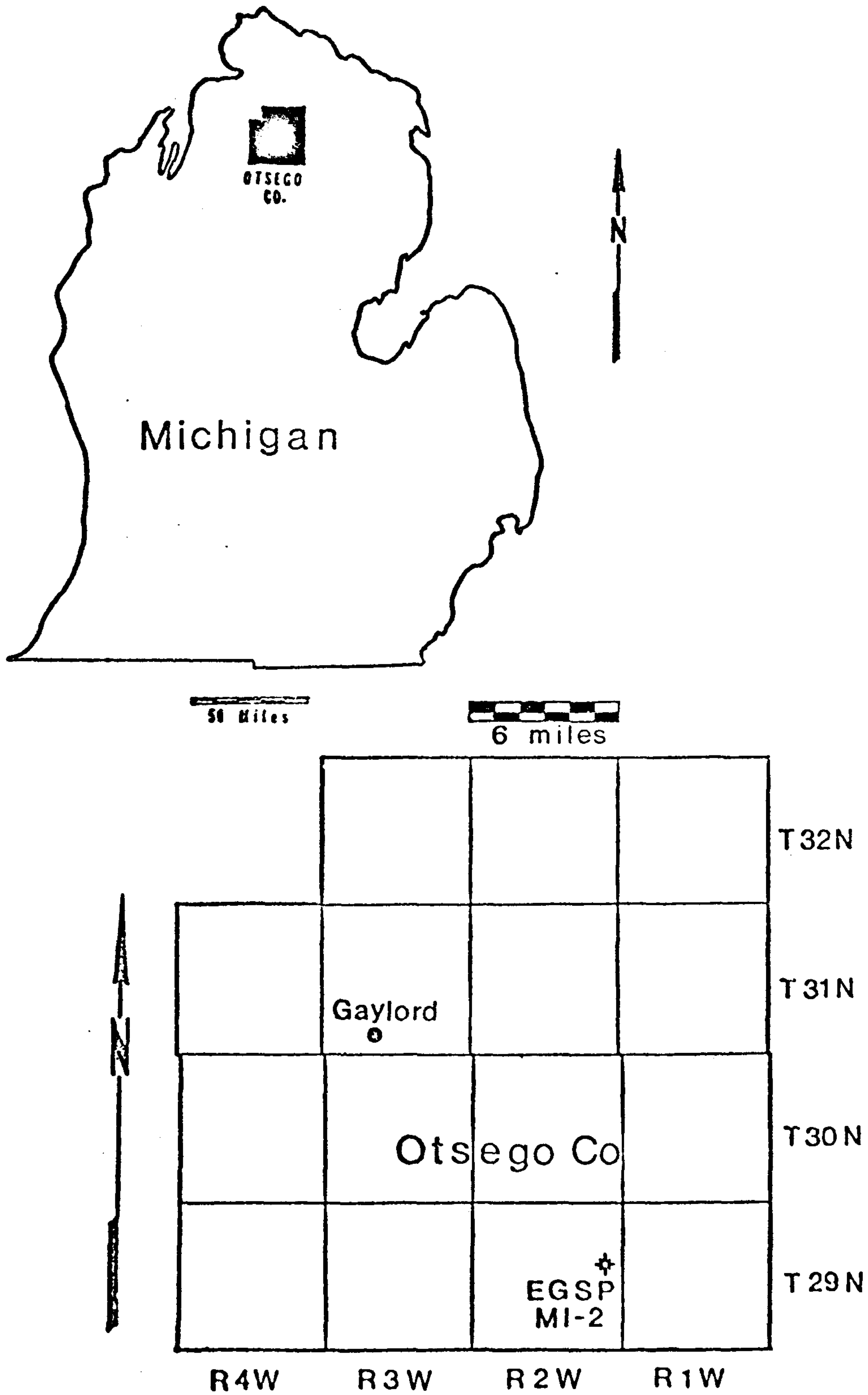
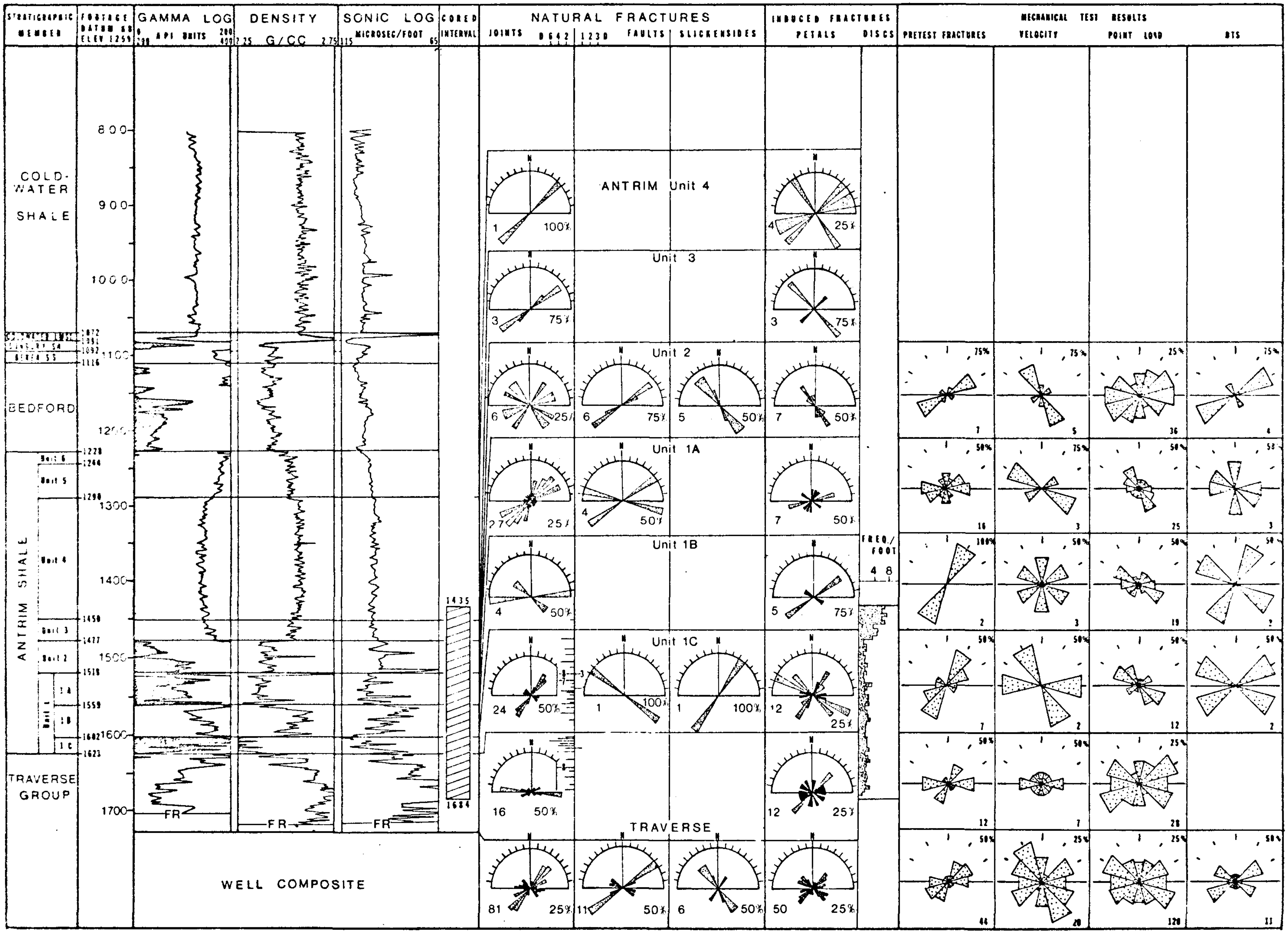


FIGURE 3

LOCATION OF THE EGSP-MICHIGAN #2 WELL



EGSP MICHIGAN 2 Well Summary

DOW CHEMICAL WELL #100

FORMATION THICKNESSES

Formation	Depths	Depths Cored	Cored Intervals Received
Sunbury Shale	818'- 946'	820'- 946'	820'- 862' 880'- 894' 915'- 946'
Berea Sandstone	946'-1,030'	946'-1,030'	946'-1,030'
Bedford Shale	1,030'-1,170'	1,030'-1,150' 1,160'-1,170'	1,030'-1,146' -----
False Antrim Shale	1,170'-1,209'	1,170'-1,209'	-----
Antrim Shale:			
Unit 6	1,209'-1,240'	1,209'-1,240'	-----
Unit 5	1,240'-1,268'	1,240'-1,268'	-----
Unit 4	1,268'-1,303'	1,268'-1,303'	-----
Unit 3	1,303'-1,340'	1,303'-1,340'	-----
Unit 2	1,340'-1,358'	1,340'-1,358'	-----
Unit 1A	1,358'-1,394'	1,358'-1,394'	-----
Unit 1B	1,394'-1,410'	1,394'-1,410'	-----
Unit 1C	1,410'-1,429'	1,410'-1,429'	-----
Traverse Formation	1,429'-1,850'	1,429'-1,476'	-----
Dundee Limestone	1,850'-2,055'	2,000'-2,055'	2,000'-2,015' 2,022'-2,055'
Detroit River Group	2,055'-TD	2,055'-2,059'	2,055'-2,057'

DOW CHEMICAL WELL #103

FORMATION THICKNESSES

Formation	Depths	Depths Cored	Cored Intervals Received
False Antrim Shale	1,155'-1,194'	1,177'-1,194'	1,177'-1,186' 1,191'-1,194'
Antrim Shale:			
Unit 6	1,194'-1,220'	1,194'-1,220'	1,194'-1,200' 1,202'-1,203' 1,204'-1,211' 1,216'-1,218' 1,219'-1,220'
Unit 5	1,220'-1,251'	1,220'-1,251'	1,220'-1,238' 1,241'-1,251'
Unit 4	1,251'-1,284'	1,251'-1,284'	1,251'-1,284'
Unit 3	1,284'-1,322'	1,284'-1,322'	1,284'-1,316' 1,318'-1,322'
Unit 2	1,322'-1,344'	1,322'-1,344'	1,322'-1,344'
Unit 1A	1,344'-TD	1,344'-1,368'	1,344'-1,364' 1,365'-1,368'

DOW CHEMICAL WELL #205

FORMATION THICKNESSES

Formation	Depths	Depths Cored	Cored Intervals Received
Antrim Shale:			
Unit 1B	1,376'-1,394'	1,383'-1,394'	1,383'-1,394'
Unit 1C	1,394'-1,420'	1,394'-1,420'	1,394'-1,396' 1,401'-1,420'
Traverse Formation	1,420'-TD	1,420'-1,497'	1,420'-1,497'

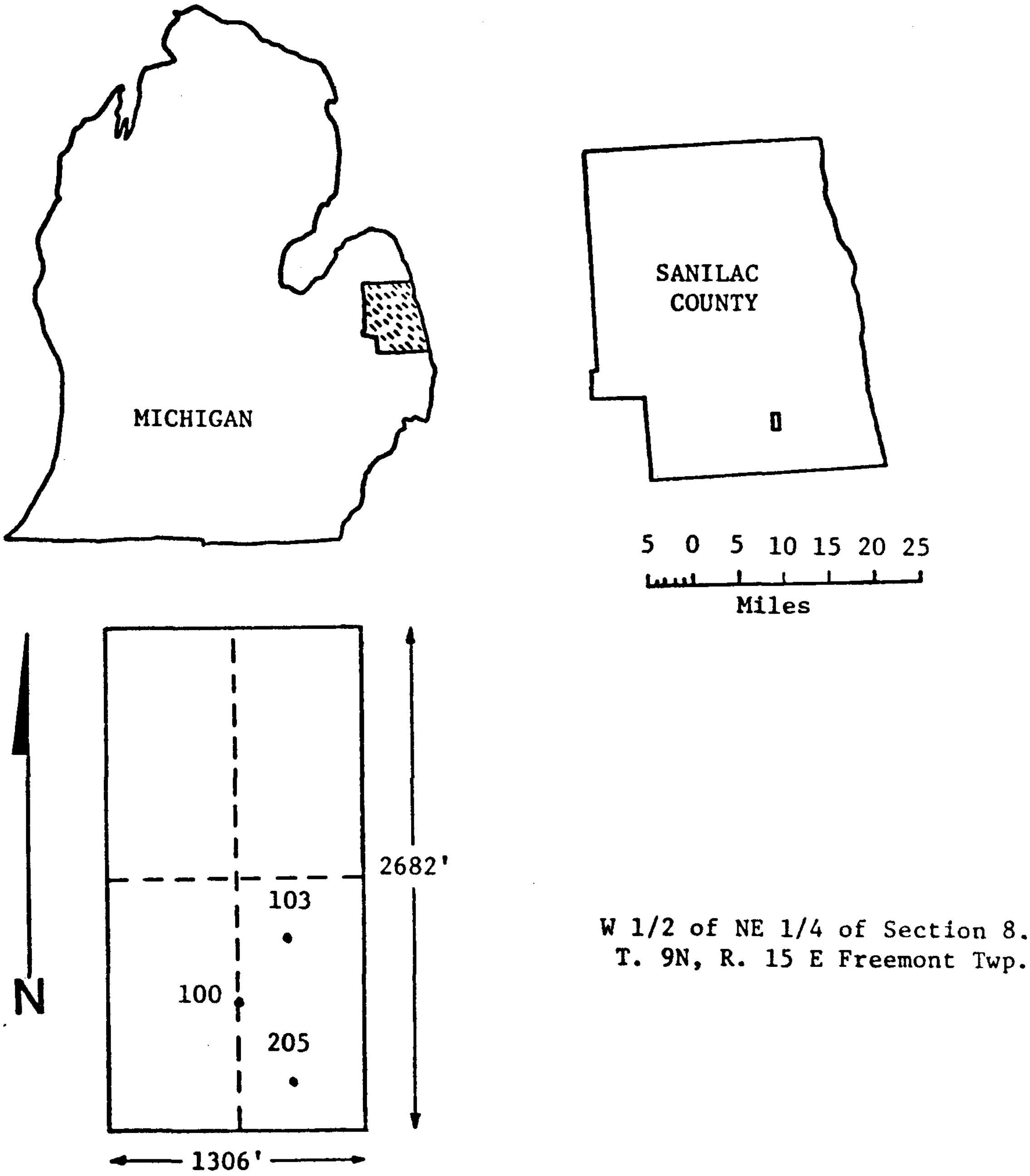


FIGURE 3

LOCATION OF DOW CHEMICAL #100, #103, AND #205 WELLS
SANILAC COUNTY, MICHIGAN

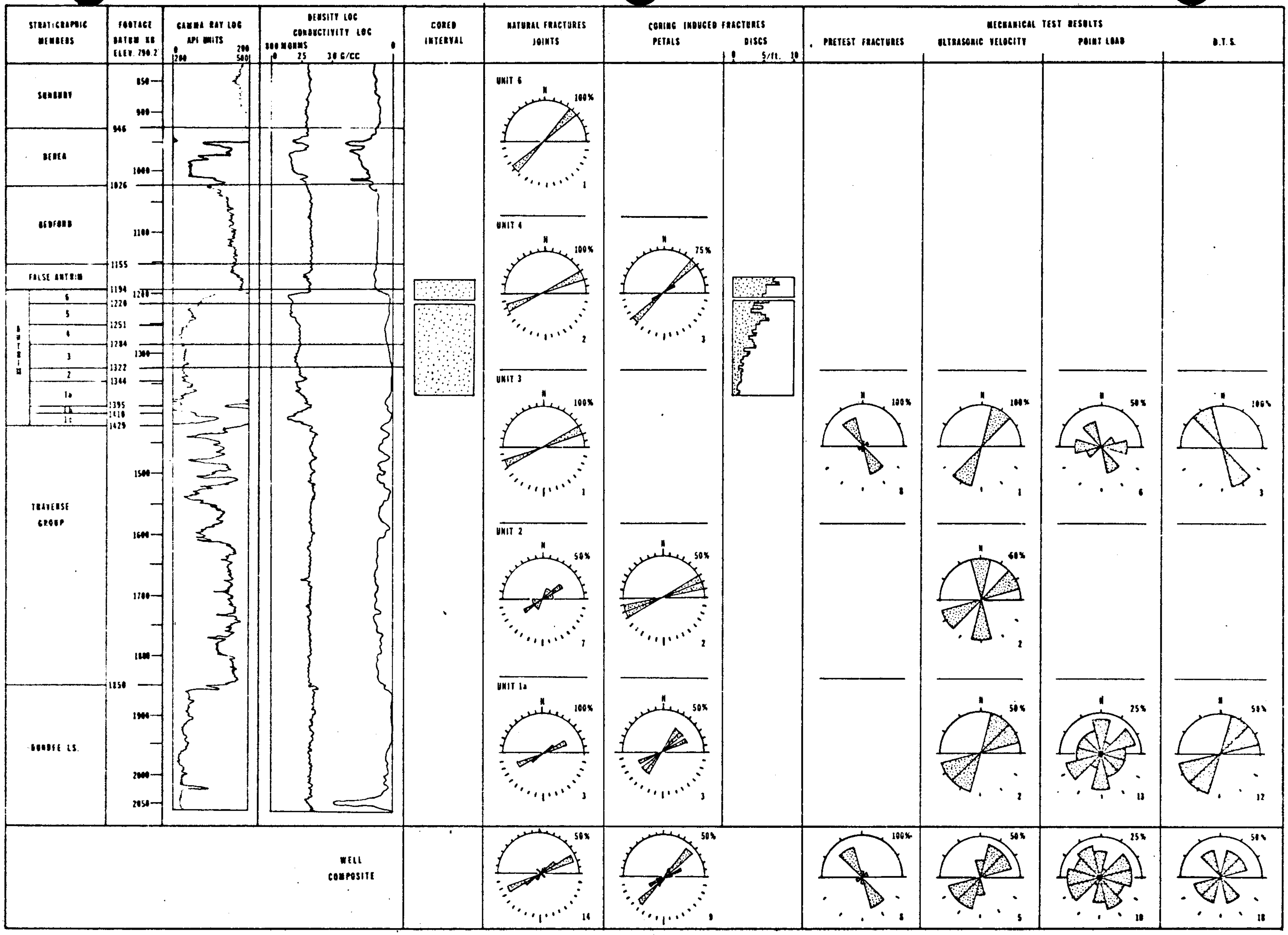


FIGURE DOW CHEMICAL WELL NO. 103

CLIFFS MINERALS, INC

EGSP-NEW YORK #1

FORMATION THICKNESSES

Formation	Depths	Thickness	Depths Cored
Perrysburg Formation:			
Dunkirk Shale	C.P.- 515'	------	370'- 515'
Java Formation:			
Hanover Shale	515'- 984'	469'	515'- 546' 963'- 984'
Pipe Creek Member	984'-1,018'	34'	984'-1,018'
West Falls Formation:			
Angola Shale	1,018'-1,335'	317'	1,018'-1,021' 1,328'-1,335'
Rhinestreet Shale	1,335'-2,345'	1,010'	1,335'-2,345'
Sonyea Formation:			
Cashaqua Shale	2,345'-2,495'	150'	2,345'-2,359' 2,486'-2,495'
Middlesex Shale	2,495'-2,629'	134'	2,495'-2,629'
Genesee Formation:			
West River Shale	2,629'-2,730'	101'	2,629'-2,664' 2,723'-2,730'
Genundewa Limestone	2,730'-2,737'	7'	2,730'-2,737'
Pen Yan Shale	2,737'-2,866'	129'	2,737'-2,866'
Lodi Limestone	2,866'-2,876'	10'	2,866'-2,876'
Geneseo Shale	2,876'-2,924'	48'	2,876'-2,924'
Tully Limestone	2,924'-T.D.	------	2,924'-2,929'

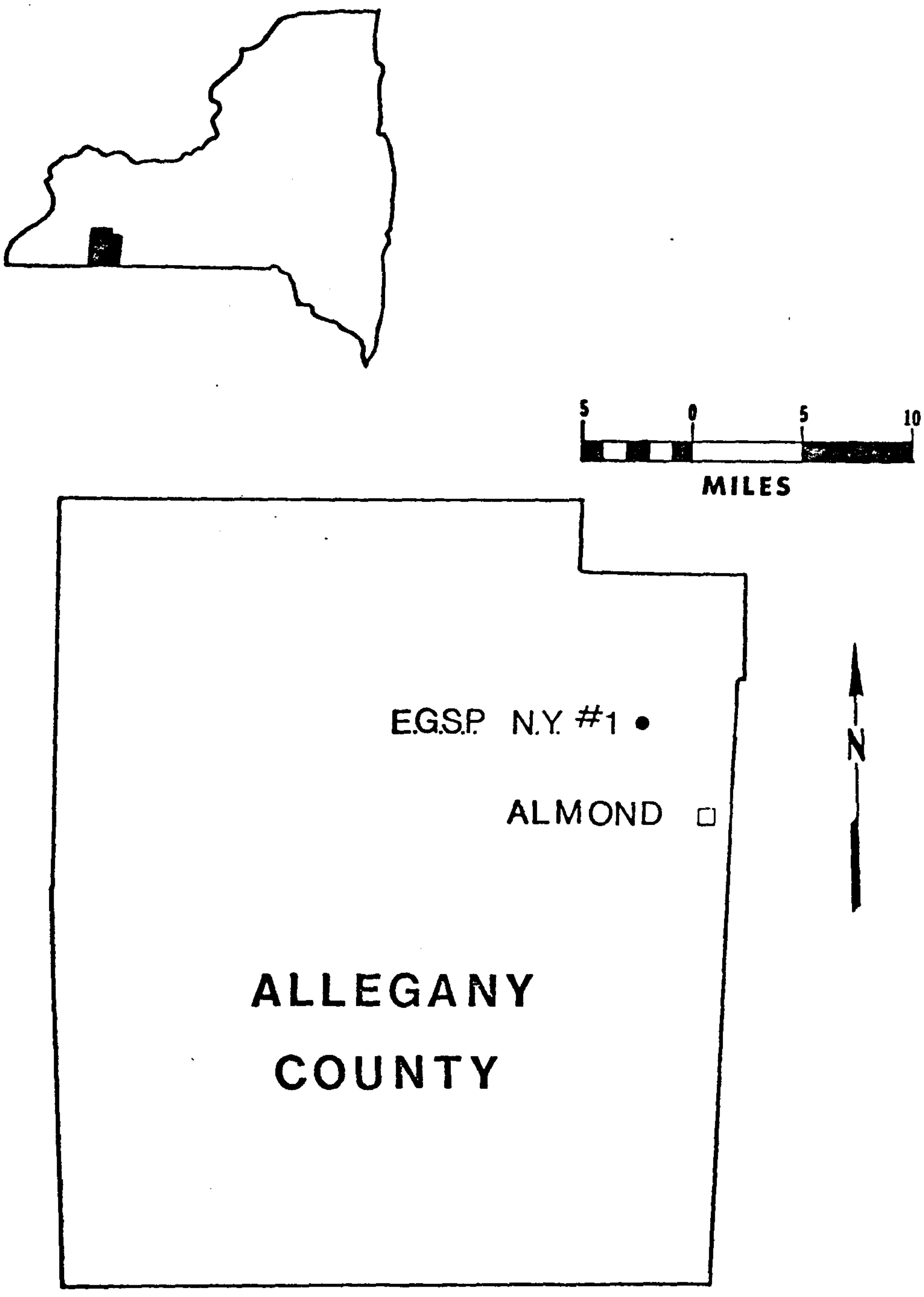


FIGURE 3

LOCATION OF THE EGSP-NEW YORK #1 WELL,
ALLEGANY COUNTY, NEW YORK

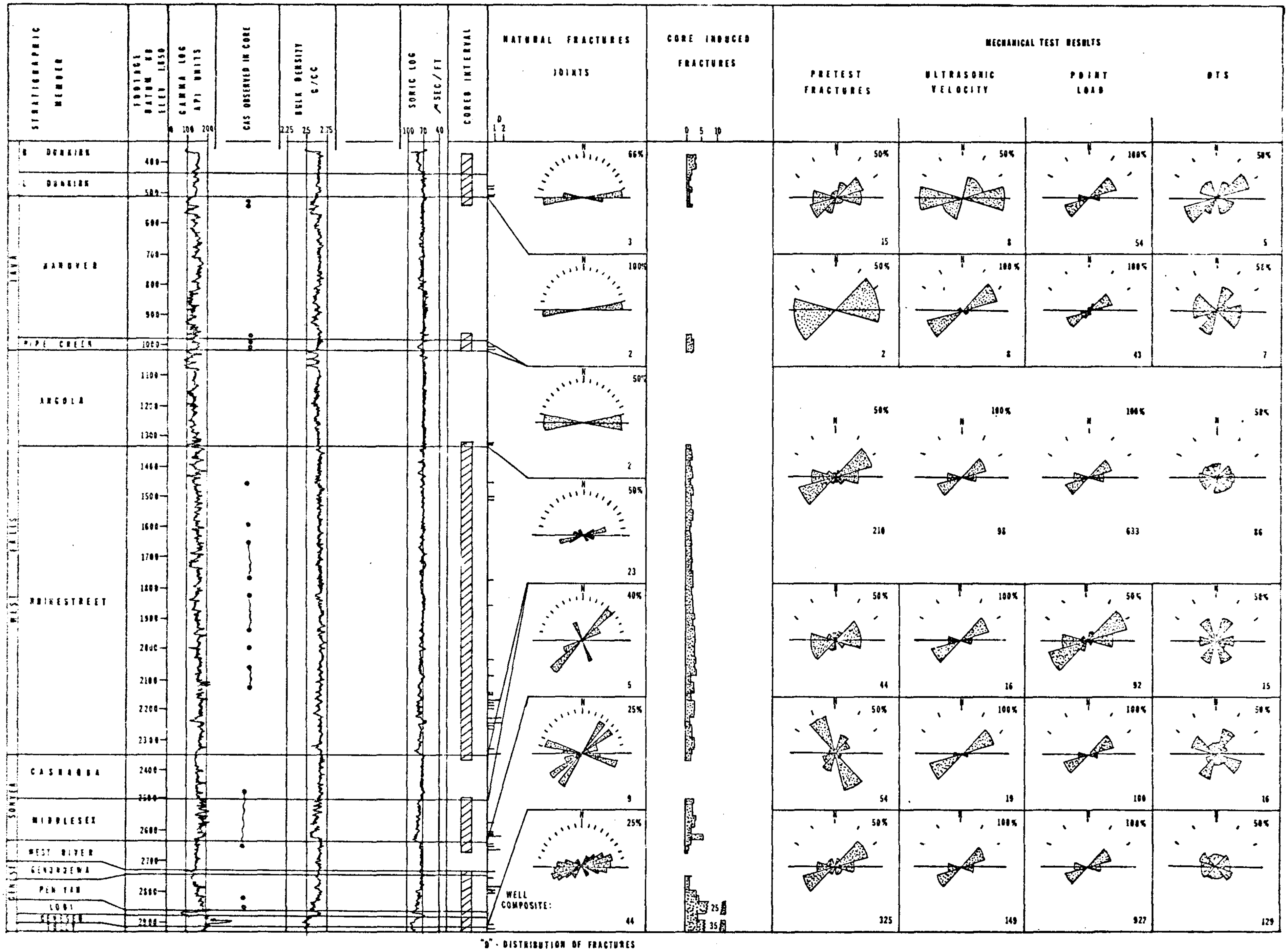


FIGURE EGSP NEW YORK 1 Well Summary

CLIFFS MINERALS, INC.

EGSP-NEW YORK #2

FORMATION THICKNESSES

COULD NOT FOLLOW THE CABLE TOOL BIT WITH THE CORE BARREL.

EGSP-NEW YORK #3

FORMATION THICKNESSES

Formation	Depth	Thickness	Depths Cored
West Falls Formation: Rhinestreet Shale	0'-1,263'+	1,263'+	1,203'-1,263'

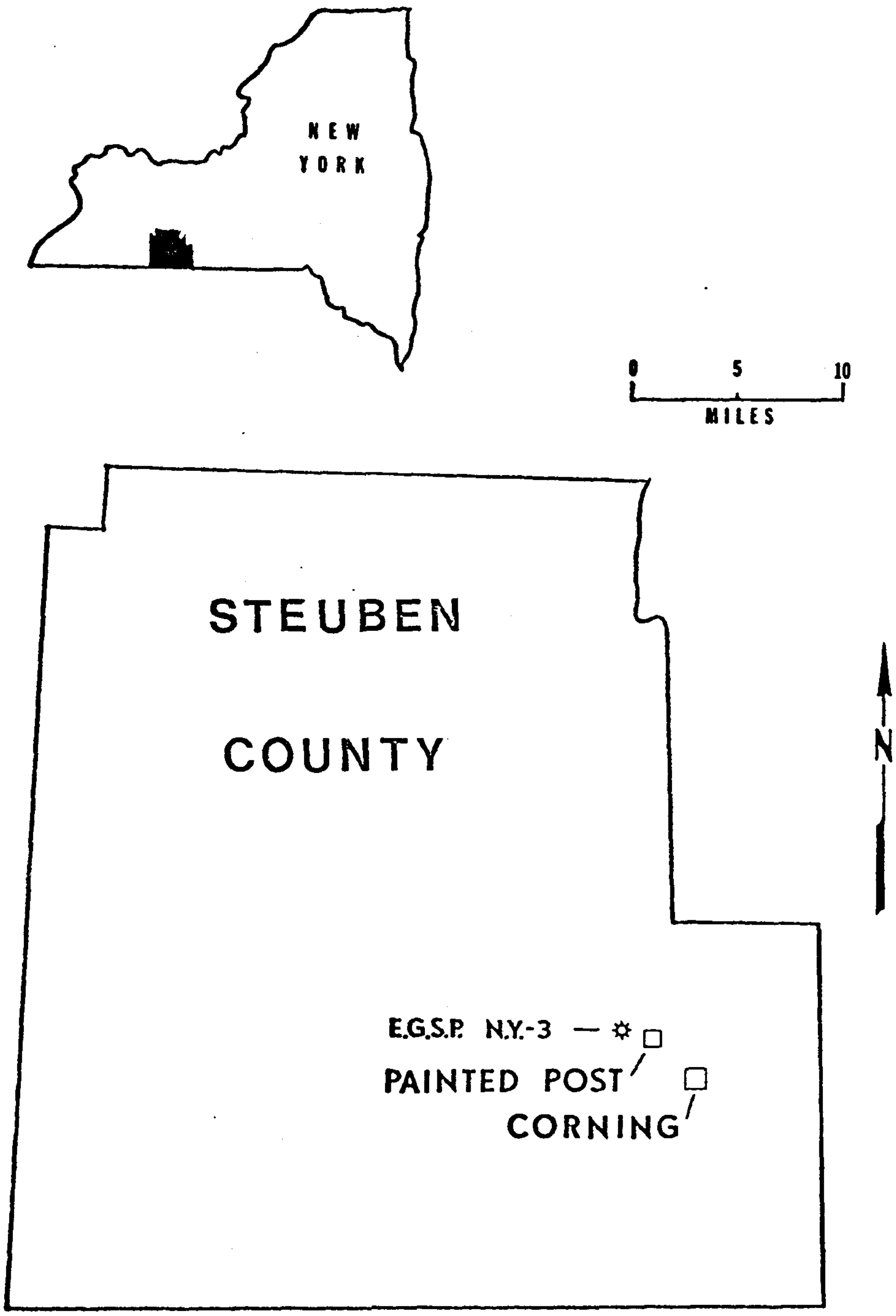


FIGURE 3

LOCATION OF THE EGSP-NEW YORK #3 WELL, STEUBEN COUNTY, NEW YORK

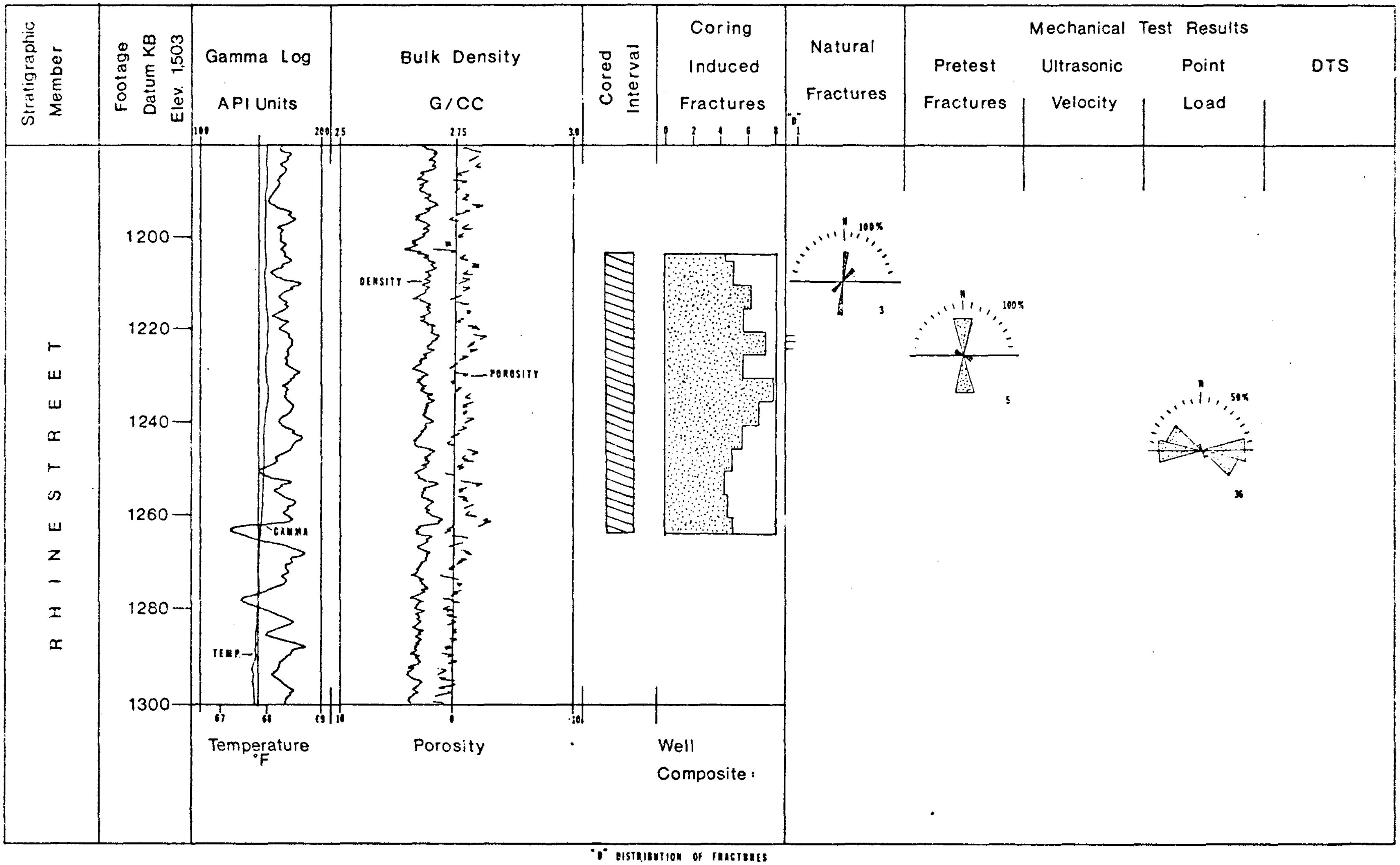


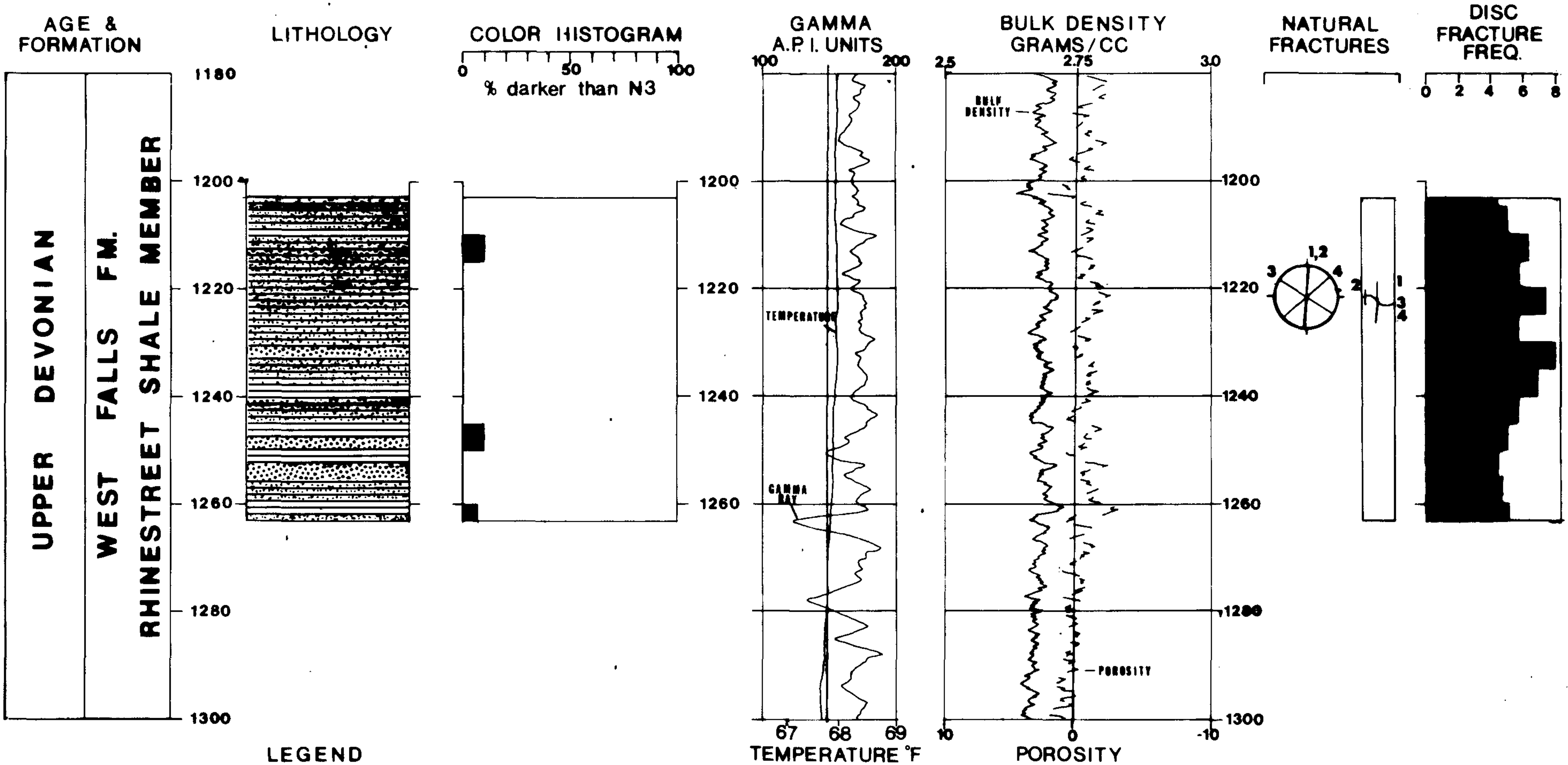
Figure EGSP New York 3 Well Summary

CLIFFS MINERALS INC.

E.G.S.P.-NEW YORK 3, STEUBEN COUNTY

A.P.I. no. 31-003-15382
Well: Ambrose E. Scudder Unit no. 1

Drawn: December, 1980
Drilling Completed: July 26, 1980



LEGEND

MUDSTONE

SILTSTONE

SILTY MUDSTONE

PREPARED BY:

CLIFFS MINERALS, INC.

UNDER CONTRACT NO. DE-AC21-78 MC08199

EGSP-NEW YORK #4

FORMATION THICKNESSES

Formation	Depth	Thickness	Depths Cored
Genesee Formation:			
Geneseo Shale	2,970'-3,080'	110'	2,010'-3,080'
Hamilton Group:			
Tully Limestone	3,080'-3,130'	50'	3,080'-3,084'
Moscow Shale	3,130'-3,270'	140'	--------
Tichenor Limestone	3,270'-3,279'	9'	--------
Ludlowville Shale	3,279'-3,498'	219'	--------
Centerfield Limestone	3,498'-3,508'	10'	--------
Skaneateles Shale	3,508'-3,761'	253'	--------
Stafford Limestone	3,761'-3,780'	19'	--------
Marcellus Shale	3,780'-3,842'	62'	3,790'-3,842'
Onondaga Limestone	3,842'-T.D.	----	3,842'-3,848'

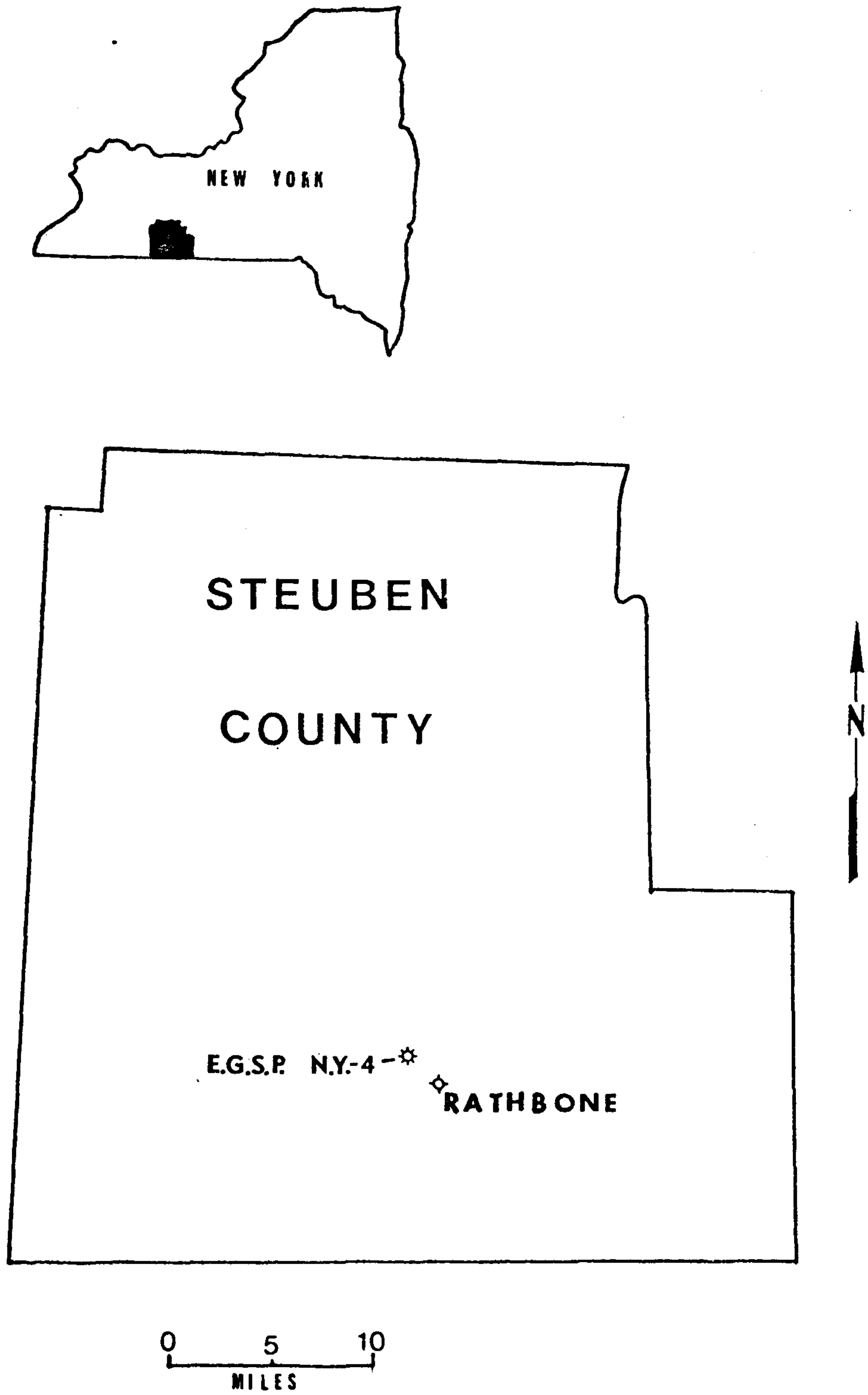
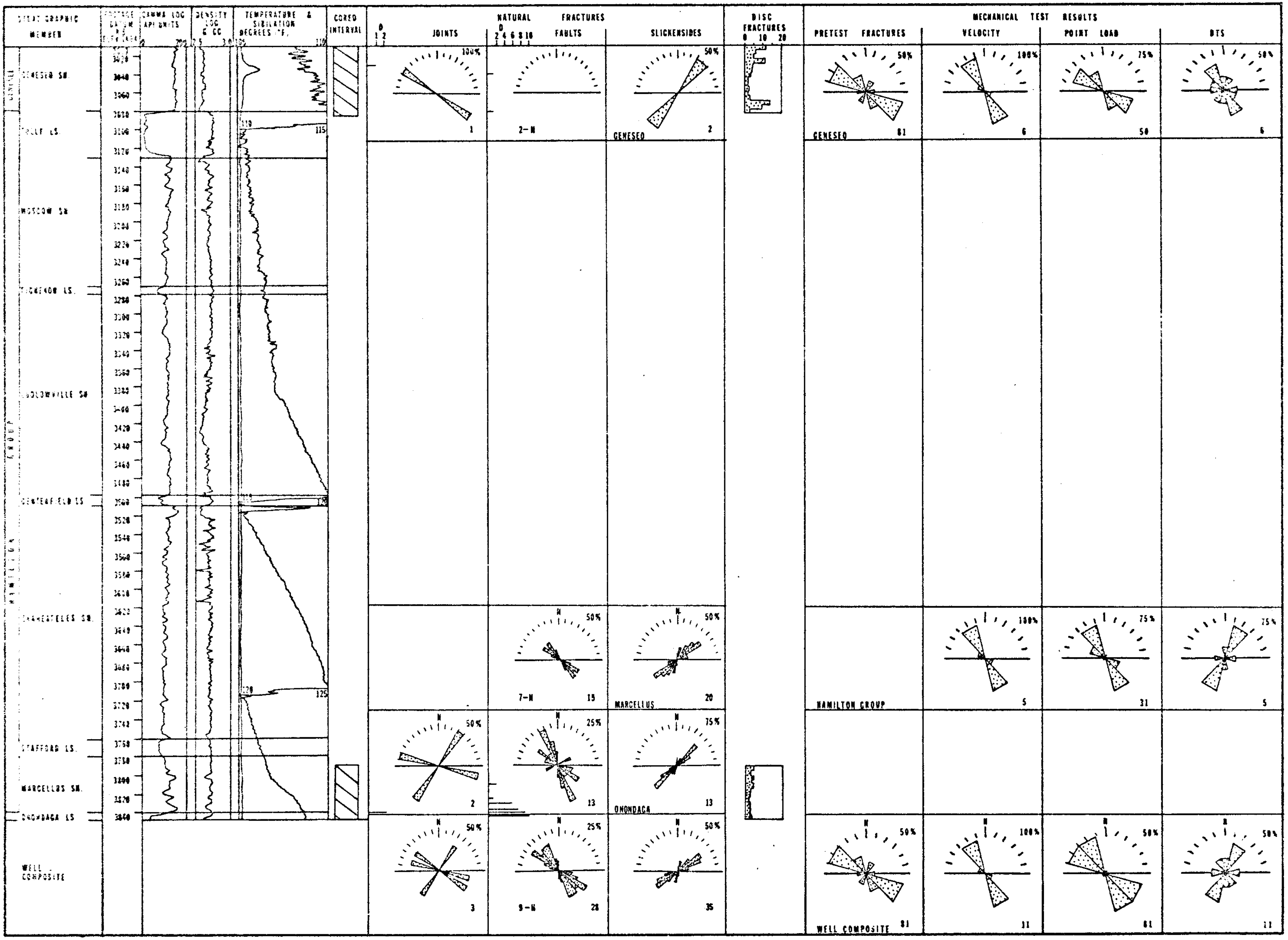


FIGURE 3

LOCATION OF THE EGSP-NEW YORK #4 WELL, STEUBEN COUNTY, NEW YORK



"D": DISTRIBUTION OF FRACTURES
"H": HORIZONTAL

FIGURE E.G.S.P. NEW YORK 4 WELL SUMMARY

CLIFFS MINERALS, INC

EGSP-OHIO #1

FORMATION THICKNESSES

CORE RECOVERED 240 FEET

CORED BY OTHERS

EGSP-OHIO #2

FORMATION THICKNESSES

CORE RECOVERED 224 FEET

CORED BY OTHERS

EGSP-OHIO #3

FORMATION THICKNESSES

Formation	Depths	Thickness	Depths Cored
Bedford Shale	C.P.- 579'	----	562'- 579'
Ohio Shale:			
Cleveland Member	579'- 612'	33'	579'- 612'
Three Lick Bed	612'- 712'	100'	612'- 712'
Huron Shale Member	712'-1,154'	442'	712'-1,154'
Olentangy Shale	1,154'-1,252'	98'	1,154'-1,252'
Onondaga Limestone	1,252'-T.D.	----	1,252'-1,257'

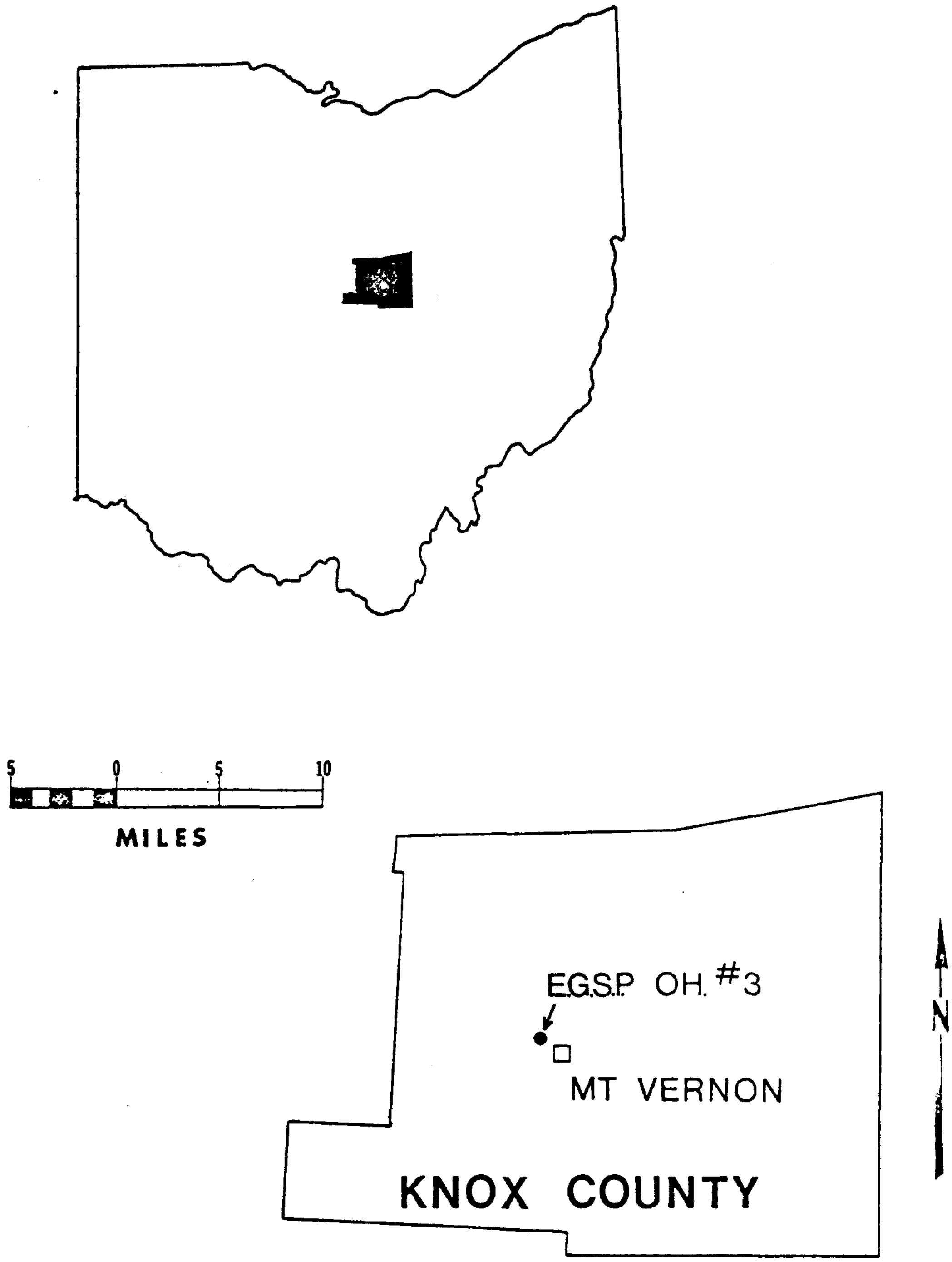


FIGURE 3

LOCATION OF THE EGSP OHIO #3 WELL
KNOX COUNTY, OHIO

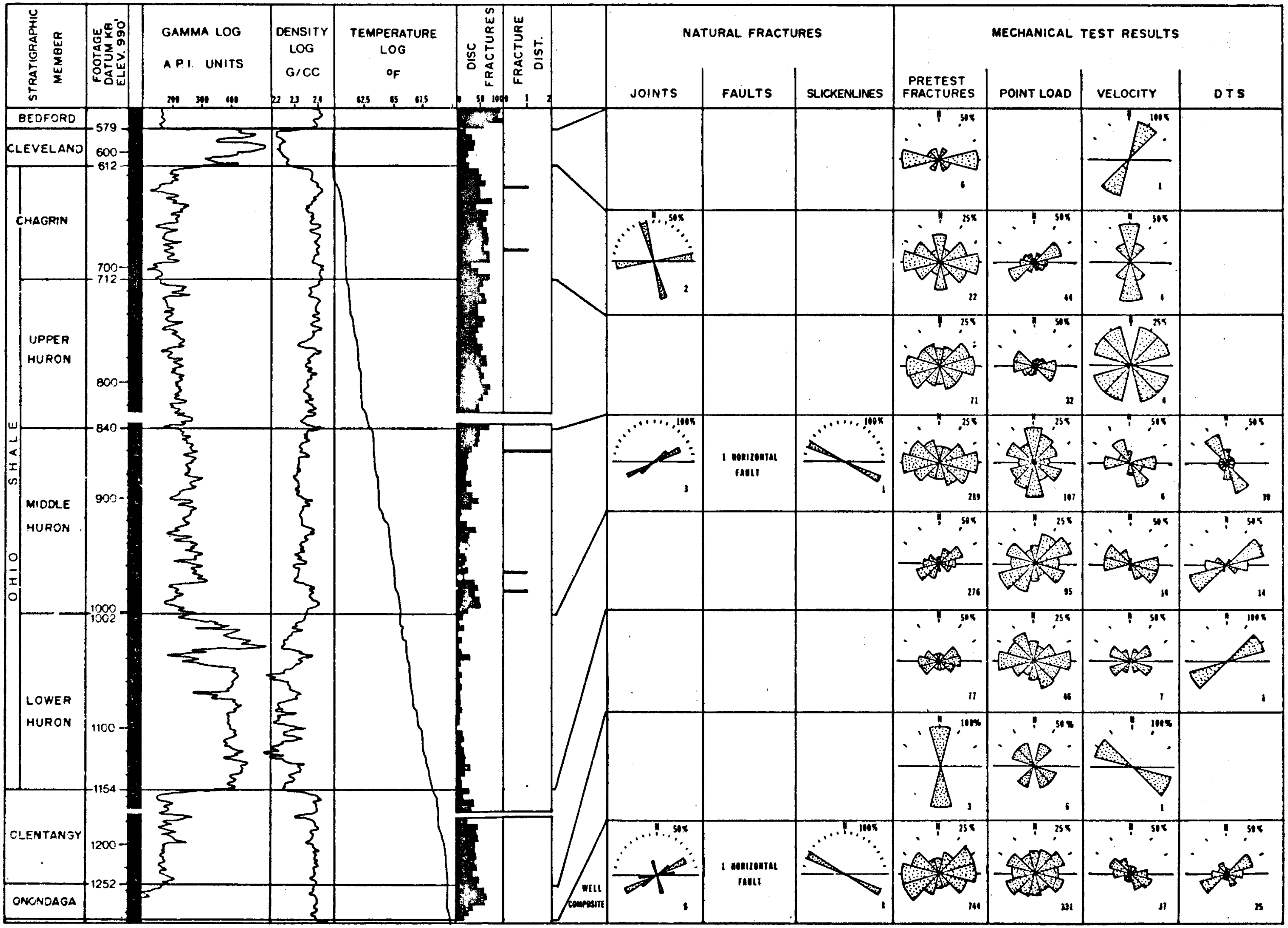


FIGURE E.G.S.P. OHIO 3 WELL SUMMARY.

CLIFFS MINERALS, INC.

EGSP-OHIO #4

FORMATION THICKNESSES

Formation	Depths	Thickness	Depths Cored
Chagrin Shale	*- 838'	----	508'- 566' 746'- 826'
Dunkirk Formation	838'- 862'	24'	838'- 862'
Java Formation:			
Hanover Shale	862'- 969'	107'	862'- 876' 949'- 969'
Pipe Creek Member	969'- 986'	17'	969'- 986'
West Falls Formation:			
Angola Shale	986'-1,060'	74'	986'- 989'
Rhinestreet Shale	1,060'-1,202'	142'	1,069'-1,108' 1,119'-1,159' 1,169'-1,202'
Hamilton Group:			
Tully Limestone	1,202'-1,250'	48'	1,202'-1,209'
Mahantango Shale	1,250'-1,330'	80'	1,309'-1,330'
Marcellus Shale	1,330'-1,360'	30'	1,330'-1,360'
Onondaga Limestone	1,360'-*	----	1,360'-1,386'

* Contact Undetermined

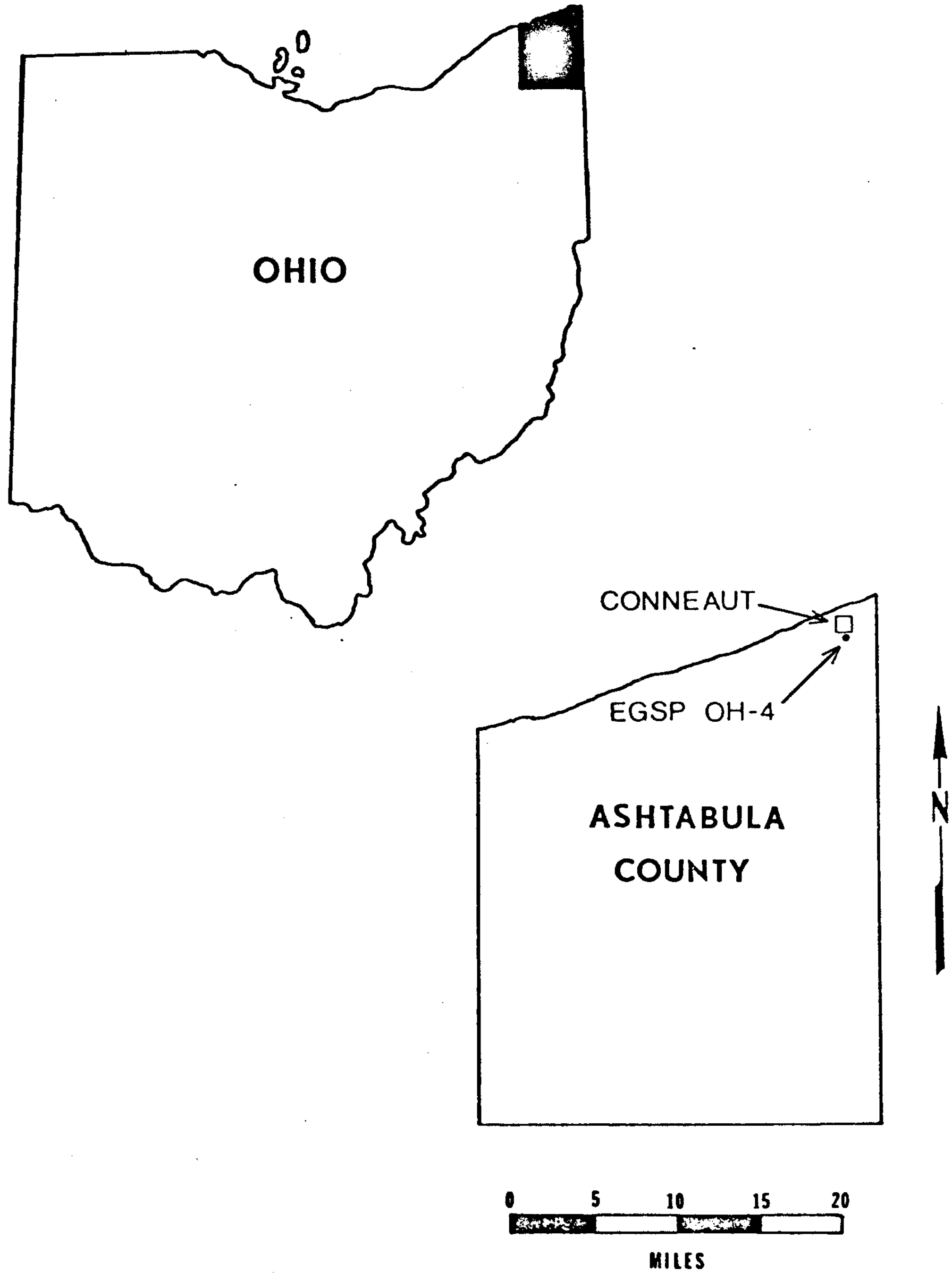
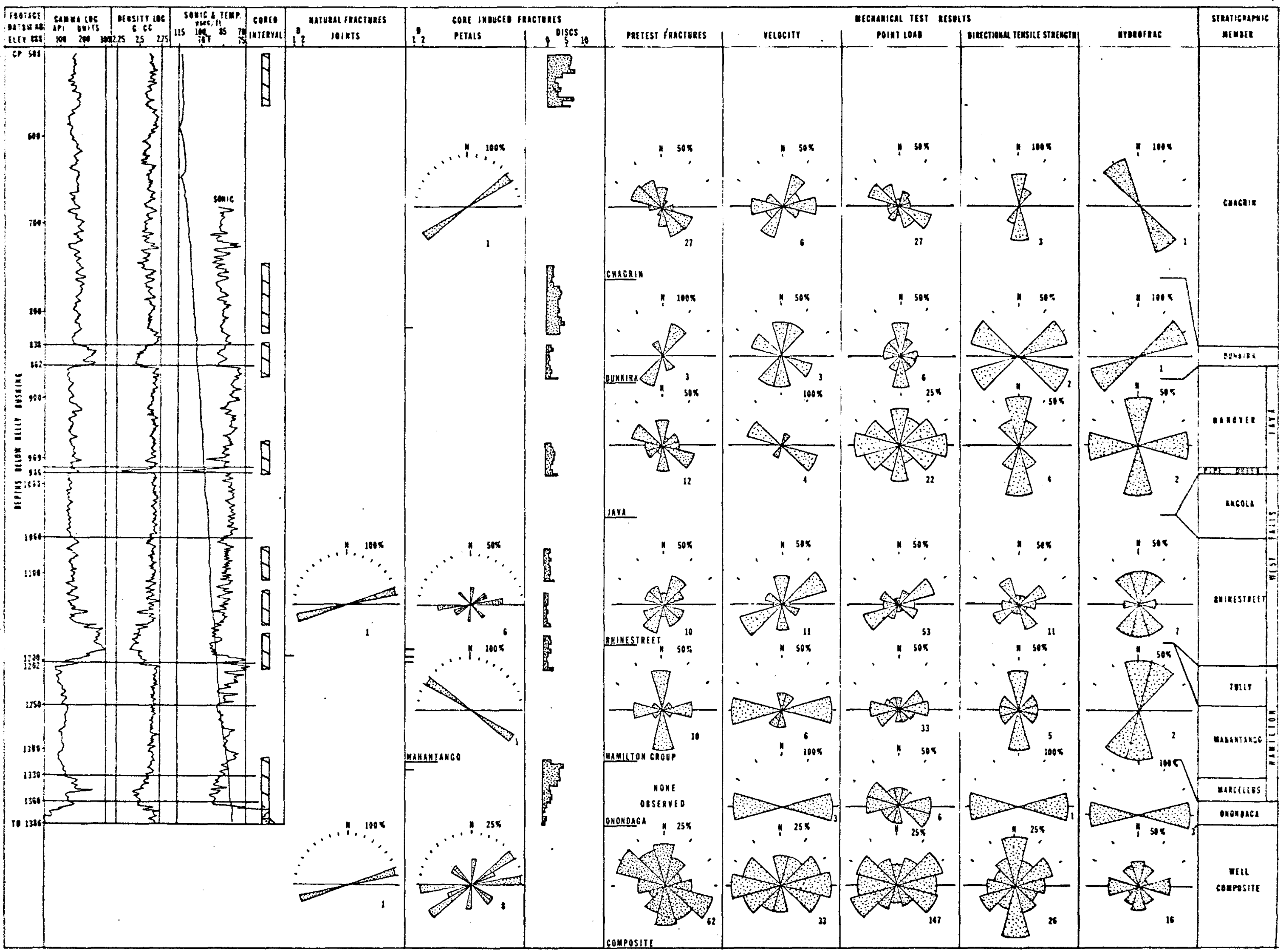


FIGURE 3

LOCATION OF THE EGSP OHIO #4 WELL

ASHTABULA COUNTY, OHIO



"D": DISTRIBUTION OF FRACTURES

FIGURE E.G.S.P OHIO 4 WELL SUMMARY.

CLIFFS MINERALS, INC

EGSP-OHIO #5

FORMATION THICKNESSES

Formation	Depths	Thickness	Depths Cored
Ohio Shale:			
Cleveland Shale	299'- 428'	129'	400'- 428'
Chagrin Shale	428'- 735'	307'	428'- 735'
Huron Shale:			
Upper	735'- 814'	79'	735'- 814'
Middle	814'- 901'	87'	814'- 900'
Lower	901'-1,088'	187'	900'-1,088'
Olentangy Shale:			
Upper	1,088'-1,279'	191'	1,088'-1,279'
Onondaga Limestone	1,279'- *	---	1,279'-1,281'

* Undetermined Contact

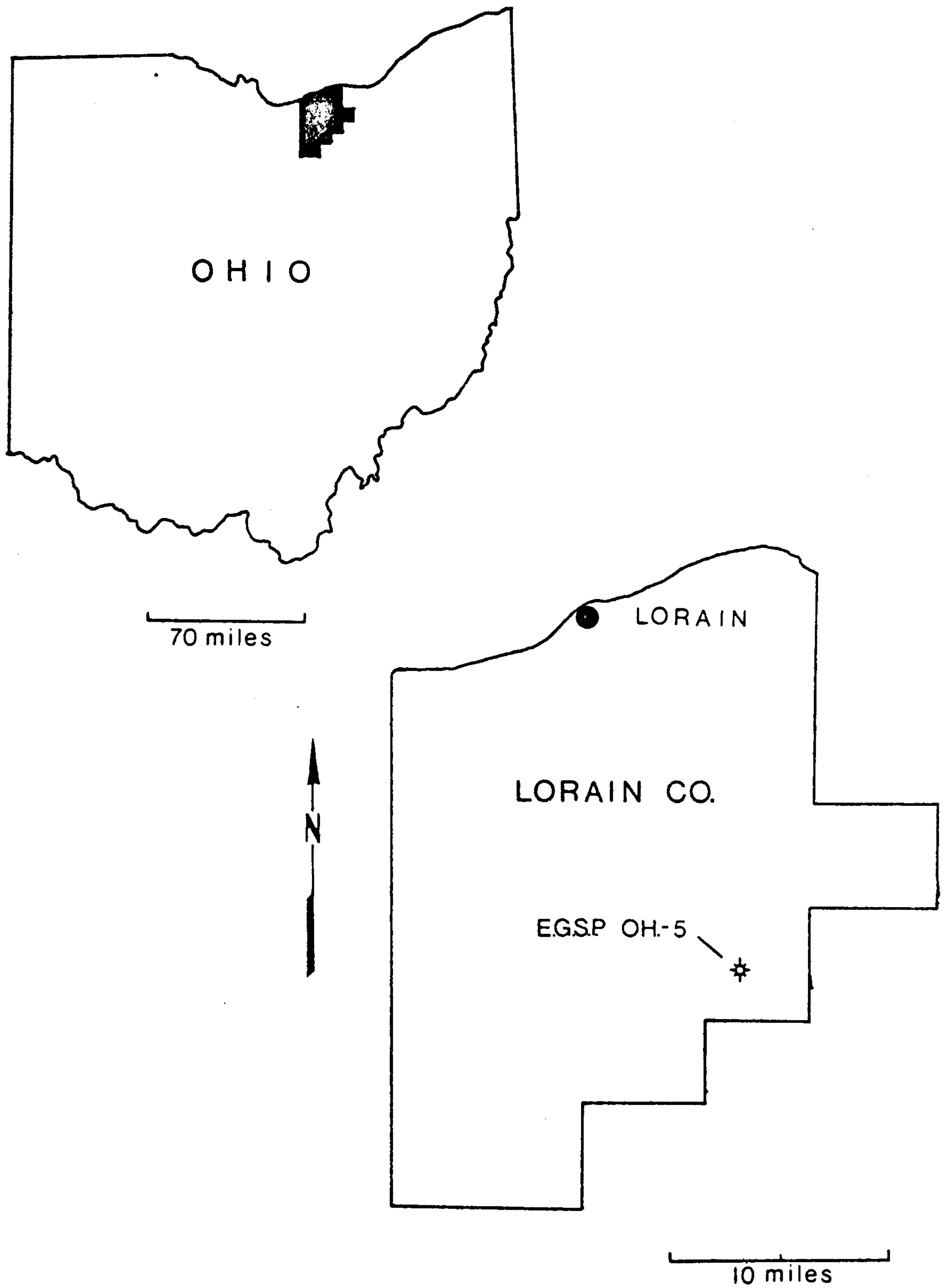


FIGURE 3

LOCATION OF THE EGSP-OHIO #5 WELL
LORAIN COUNTY, OHIO

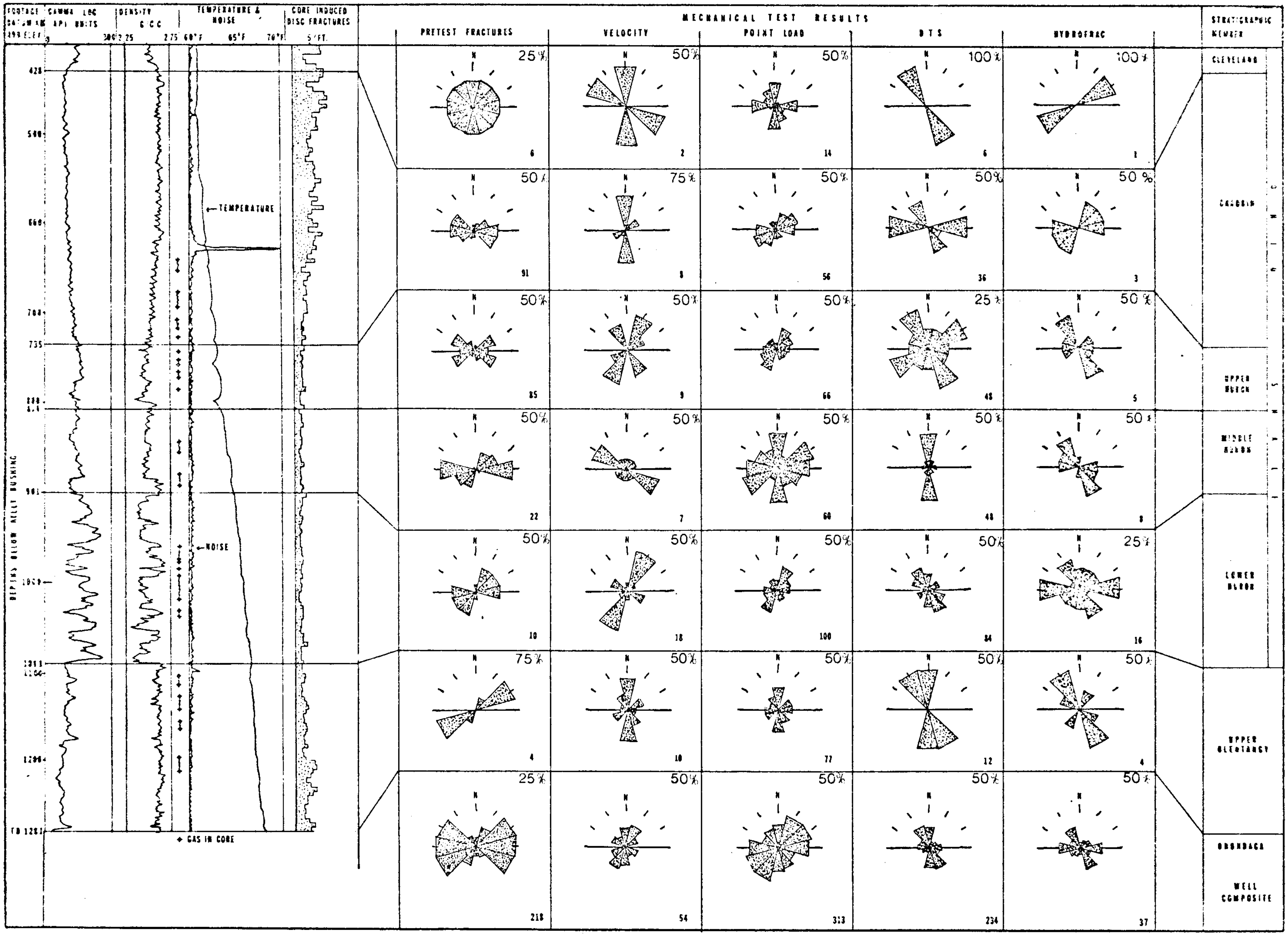


FIGURE E.G.S.P. OHIO 5 WELL SUMMARY

CLIFFS MINERALS, INC

EGSP-OHIO #6-1

FORMATION THICKNESSES

Formation	Depths	Thickness	Depths Cored
Ohio Shale:			
Cleveland Shale	1,770'-1,814'	44'	1,810'-1,814'
Chagrin Shale	1,814'-2,007'	193'	1,814'-1,866'
Huron Shale:			
Upper	~2,007'-2,134'	~127'	-----
Middle	~2,134'-2,318'	~184'	2,310'-2,318'
Lower	2,318'-2,563'	245'	2,318'-2,368' 2,446'-2,501'
Olentangy Shale:			
Upper	2,563'-2,704'	141'	-----
Lower	2,704'-2,791'	87'	-----
Columbus Limestone	2,791'- *	---	-----

* Undetermined Contact

NOTE: Approximated contacts were picked from geophysical logs.

FIGURE 3

LOCATION MAP OF THE EGSP PROJECT AREA
IN GALLIA COUNTY, OHIO

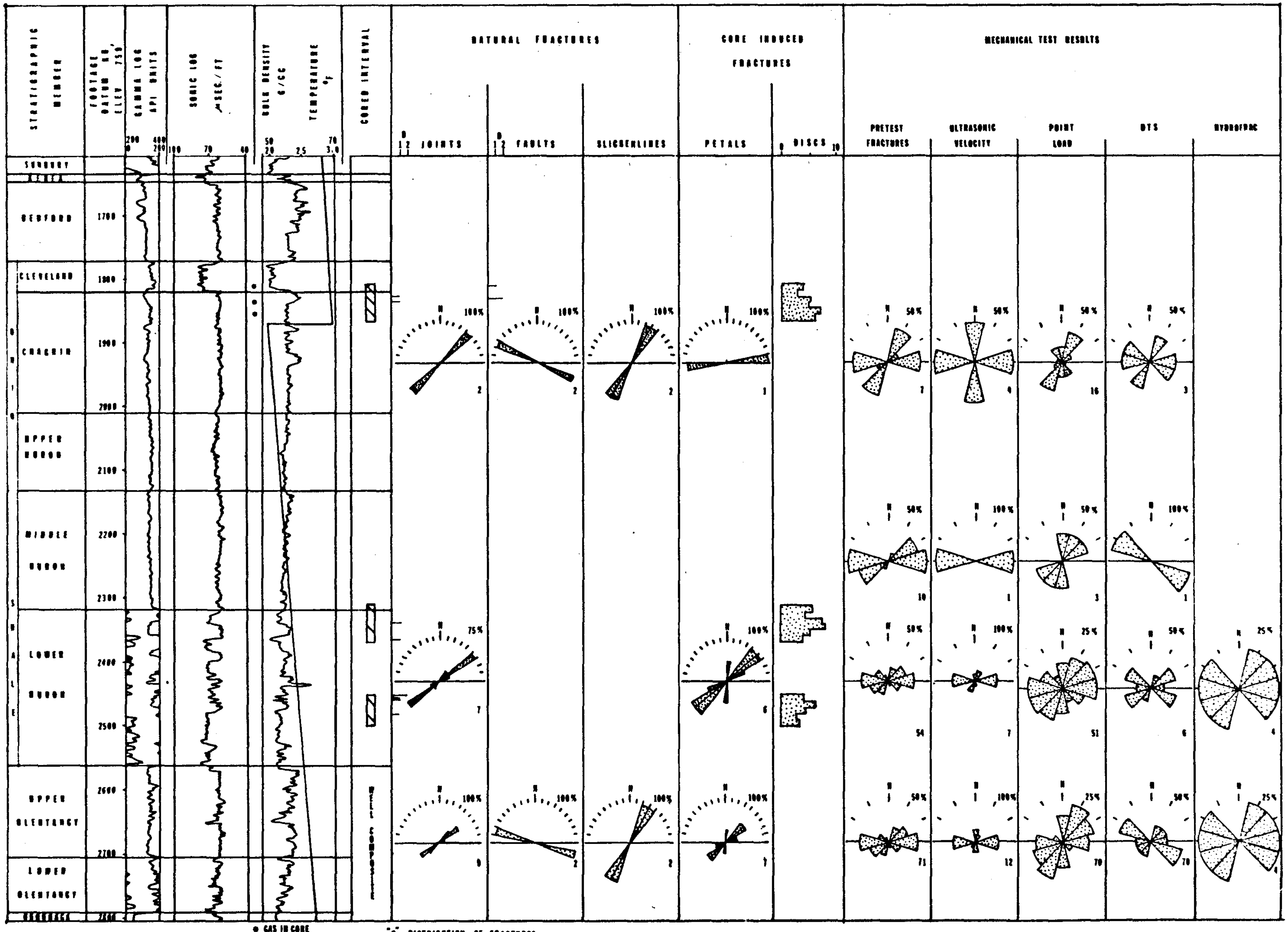


Figure EGSP OHIO 6-1 Well Summary

CLIFFS MINERALS, INC.

EGSP-OHIO #6-2

FORMATION THICKNESSES

Formation	Depths	Thickness	Depths Cored
Bedford Formation	1,608'-1,728'	120'	1,697'-1,728'
Ohio Shale:			
Cleveland Shale	1,728'-1,764'	36'	1,728'-1,755'
Chagrin Shale	1,764'-1,968'	204'	-----
Huron Shale:			
Upper	∿1,968'-2,087'	∿119'	-----
Middle	∿2,087'-2,260'	∿173'	-----
Lower	2,260'-2,498'	238'	2,282'-2,341' 2,418'-2,476'
Olentangy Shale:			
Upper	2,498'-2,634'	136'	-----
Lower	2,634'-2,715'	81'	-----
Columbus Limestone	2,715'- *	----	-----

* Undetermined Contact

NOTE: Approximated contacts were picked from geophysical logs.

FIGURE 3

LOCATION MAP OF THE EGSP PROJECT AREA IN GALLIA COUNTY, OHIO

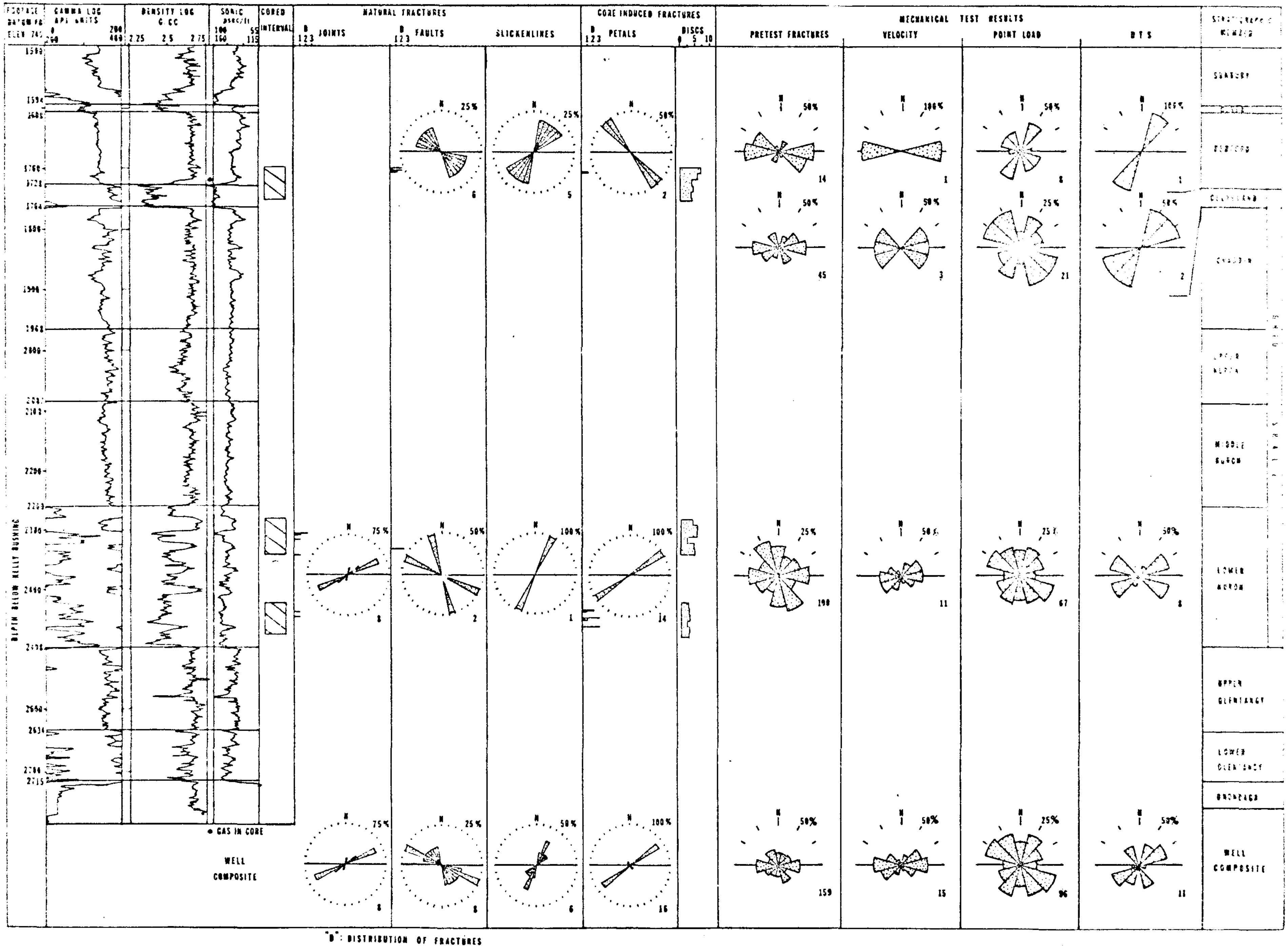


FIGURE E.G.S.P. OHIO 6-2 WELL SUMMARY

CLIFFS MINERALS, INC

EGSP-OHIO #6-3

FORMATION THICKNESSES

Formation	Depths	Thickness	Depths Cored
Bedford Formation	1,890'-2,000'	110'	1,988'-2,000'
Ohio Shale:			
Cleveland Shale	2,000'-2,040'	40'	2,000'-2,040'
Chagrin Shale	2,040'-2,224'	184'	2,040'-2,046'
Huron Shale:			
Upper	~2,224'-2,367'	~143'	-----
Middle	~2,367'-2,546'	~179'	-----
Lower	2,546'-2,791'	245'	2,590'-2,602'
Olentangy Shale:			
Upper	2,791'-2,960'	169'	-----
Lower	2,960'-3,020'	60'	-----
Columbus Limestone	3,020'- *	---	-----

* Undetermined Contact

NOTE: Approximated contacts were picked from geophysical logs.

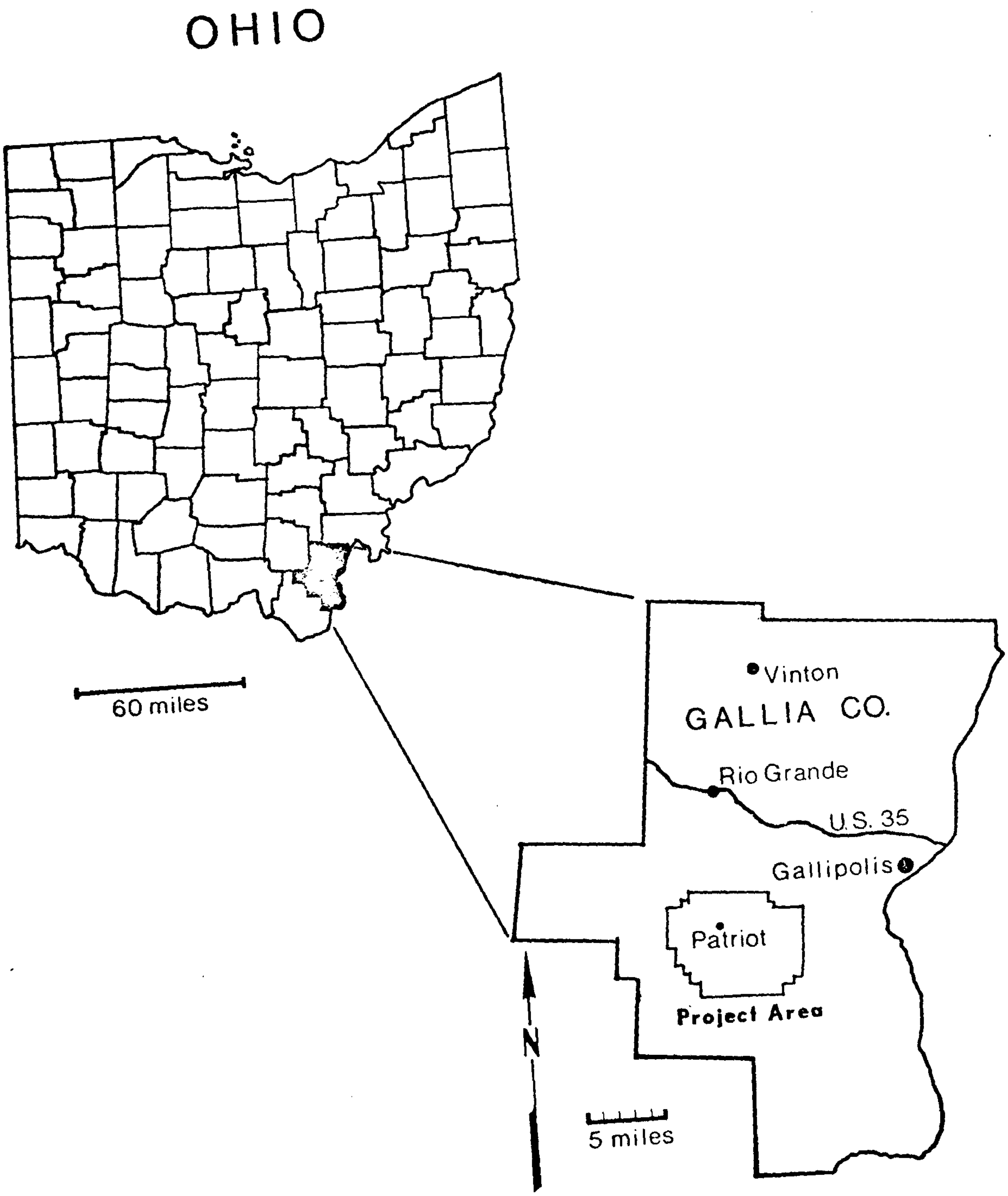


FIGURE 3

LOCATION MAP OF THE EGSP PROJECT AREA IN GALLIA COUNTY, OHIO

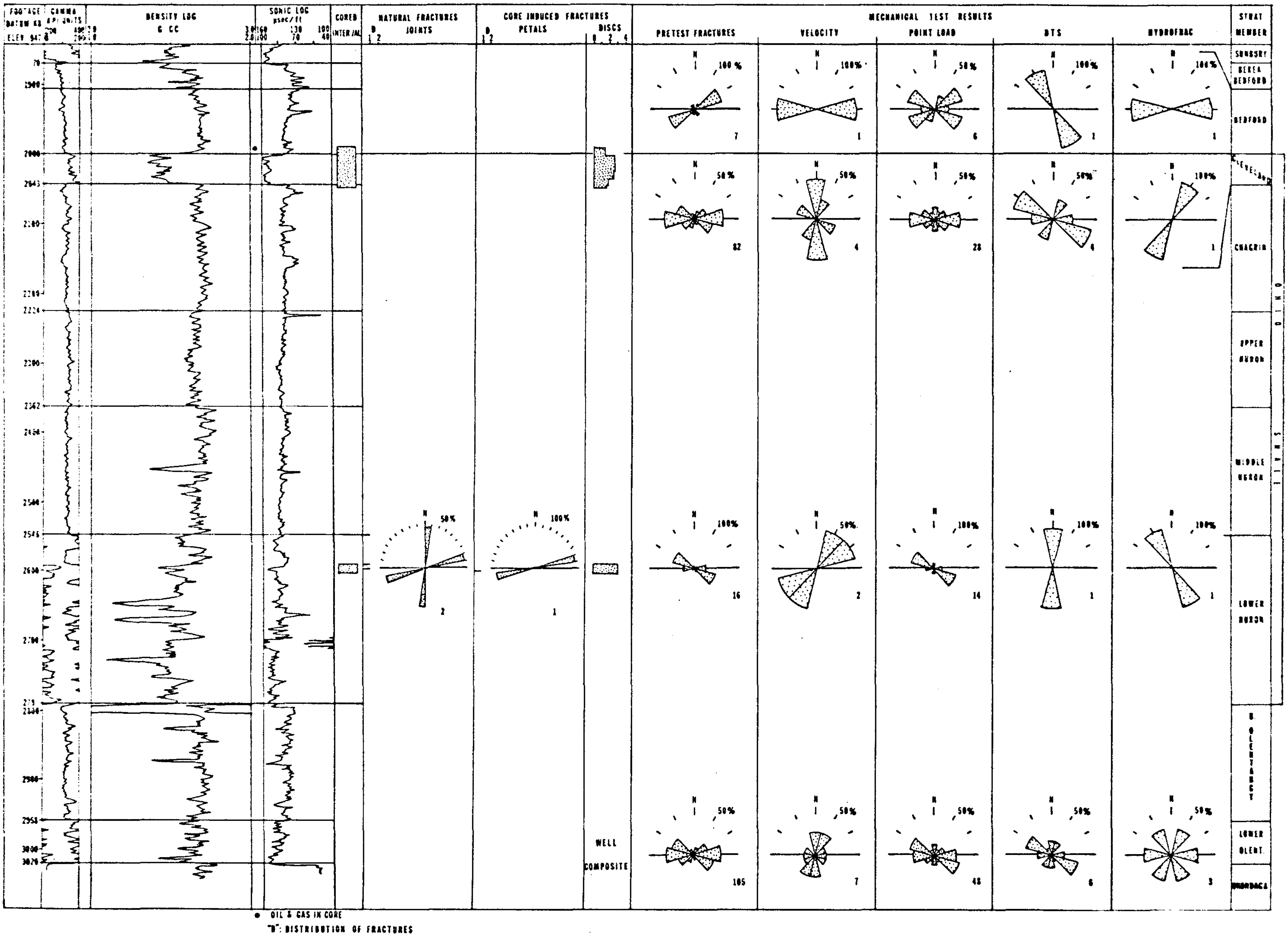


FIGURE E.G.S.P. OHIO 6-3 WELL SUMMARY.

CLIFFS MINERALS, INC

EGSP-OHIO #6-4

FORMATION THICKNESSES

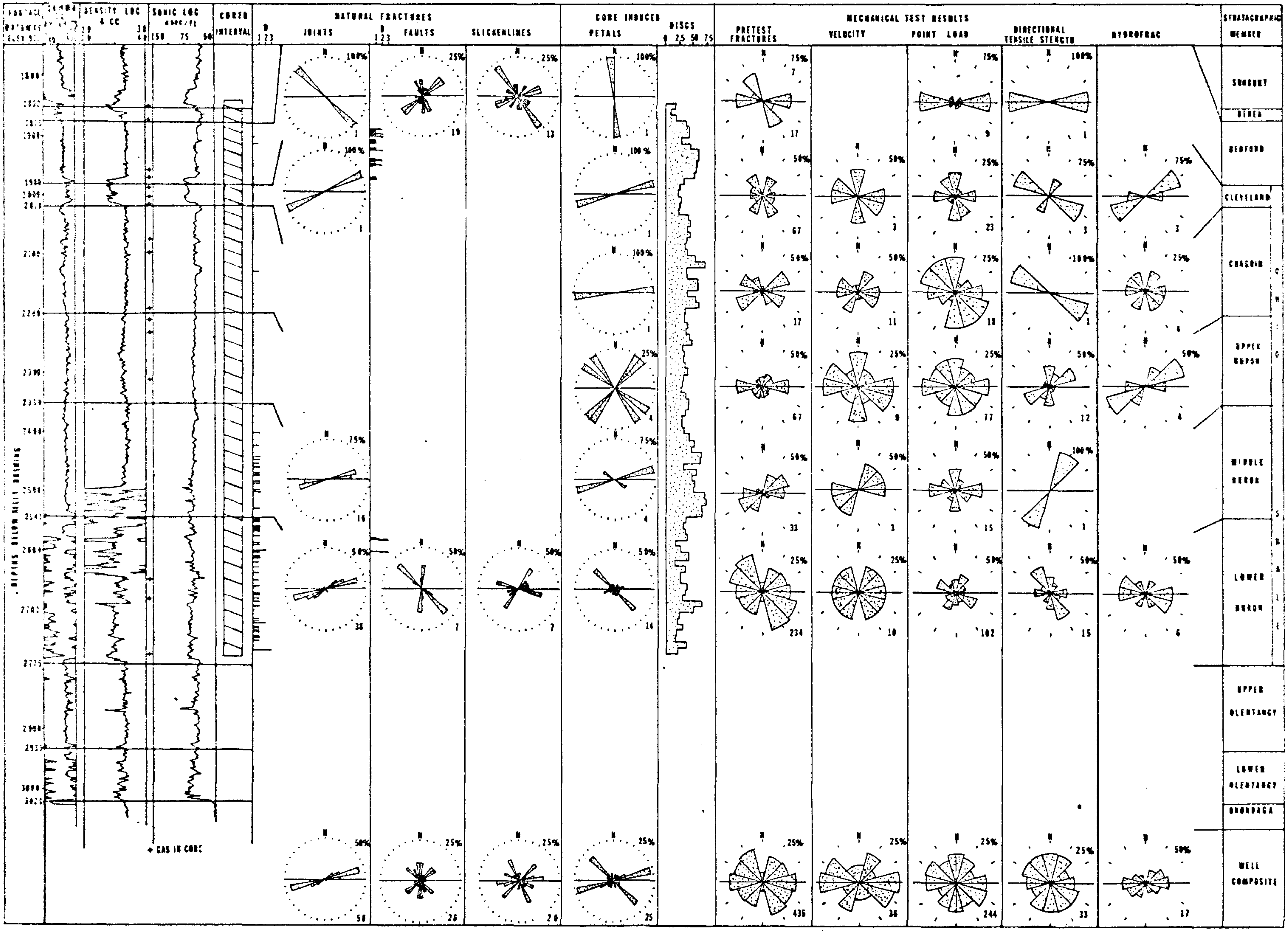
Formation	Depths	Thickness	Depths Cored
Sunbury Shale	1,825'-1,852'	27'	1,840'-1,852'
Berea Sandstone	1,852'-1,875'	23'	1,852'-1,875'
Bedford Formation	1,875'-1,980'	105'	1,875'-1,980'
Ohio Shale:			
Cleveland Shale	1,980'-2,018'	38'	1,980'-2,018'
Chagrin Shale	2,018'-2,200'	182'	2,018'-2,200'
Huron Shale:			
Upper	∿2,200'-2,350'	∿150'	2,200'-2,350'
Middle	∿2,350'-2,543'	∿193'	2,350'-2,543'
Lower	2,543'-2,790'	247'	2,543'-2,775'
Olentangy Shale:			
Upper	2,790'-2,933'	143'	-----
Lower	2,933'-3,020'	87'	-----
Columbus Limestone	3,020'- *	---	-----

* Undetermined Contact

NOTE: Approximated contacts were picked from geophysical logs.

FIGURE 3

LOCATION MAP OF THE EGSP PROJECT AREA
IN GALLIA COUNTY, OHIO



"D": DISTRIBUTION OF FRACTURES

FIGURE E.G.S.P. OHIO 6/4 WELL SUMMARY.

EGSP-OHIO #6-5

FORMATION THICKNESSES

Formation	Depths	Thickness	Depths Cored
Bedford Formation	1,555'-1,678'	123'	1,660'-1,678'
Ohio Shale:			
Cleveland Shale	1,678'-1,714'	36'	1,678'-1,714'
Chagrin Shale	1,714'-1,900'	186'	1,714'-1,718'
Huron Shale:			
Upper	∿1,900'-2,034'	∿134'	1,940'-1,998'
Middle	∿2,034'-2,206'	∿172'	-----
Lower	2,206'-2,446'	240'	2,440'-2,446'
Olentangy Shale:			
Upper	2,446'-2,582'	136'	2,446'-2,493'
Lower	2,582'-2,664'	82'	-----
Columbus Limestone	2,664'- *	---	-----

* Undetermined Contact

NOTE: Approximated contacts were picked from geophysical logs.

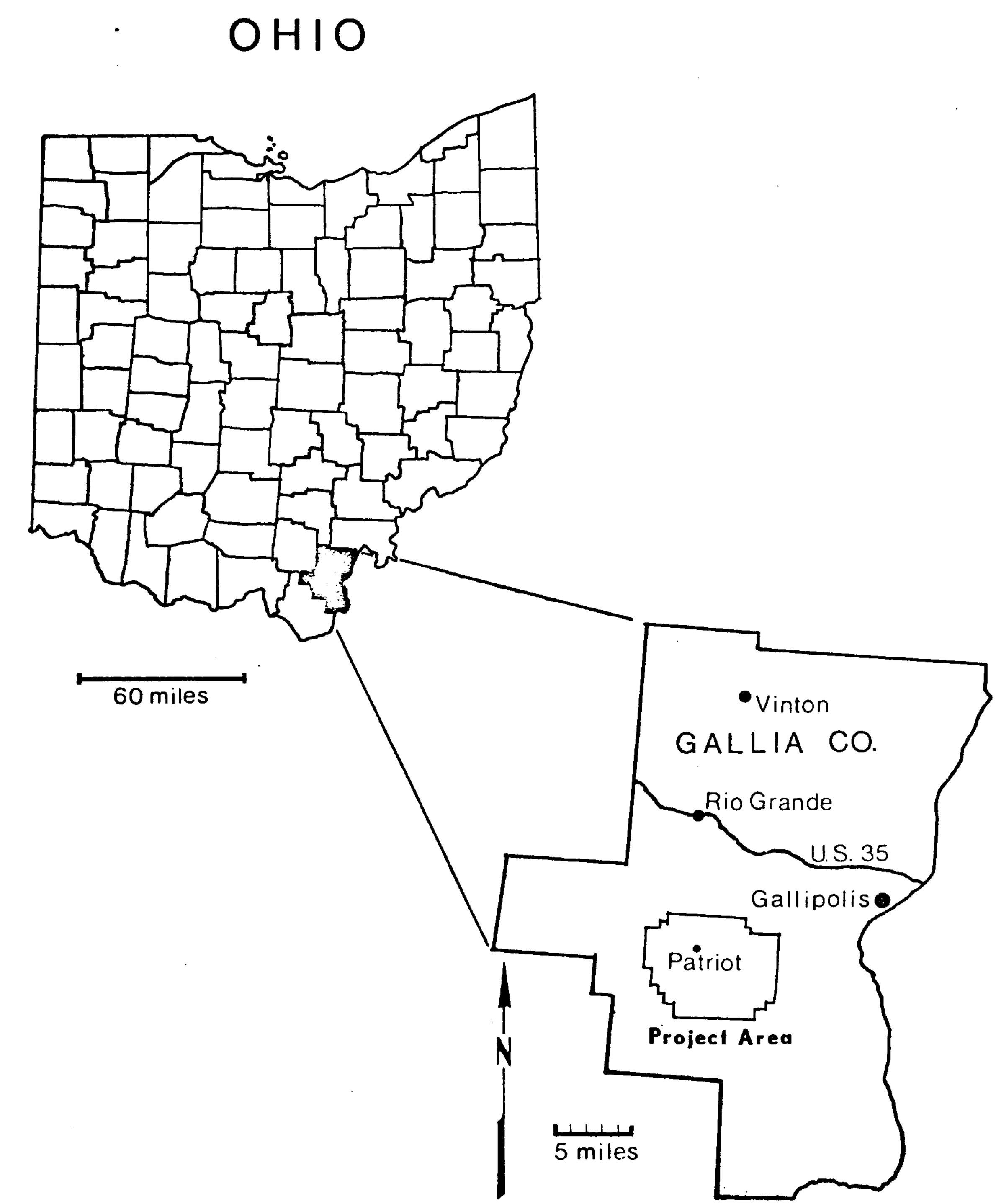


FIGURE 3

LOCATION MAP OF THE EGSP PROJECT AREA
IN GALLIA COUNTY, OHIO

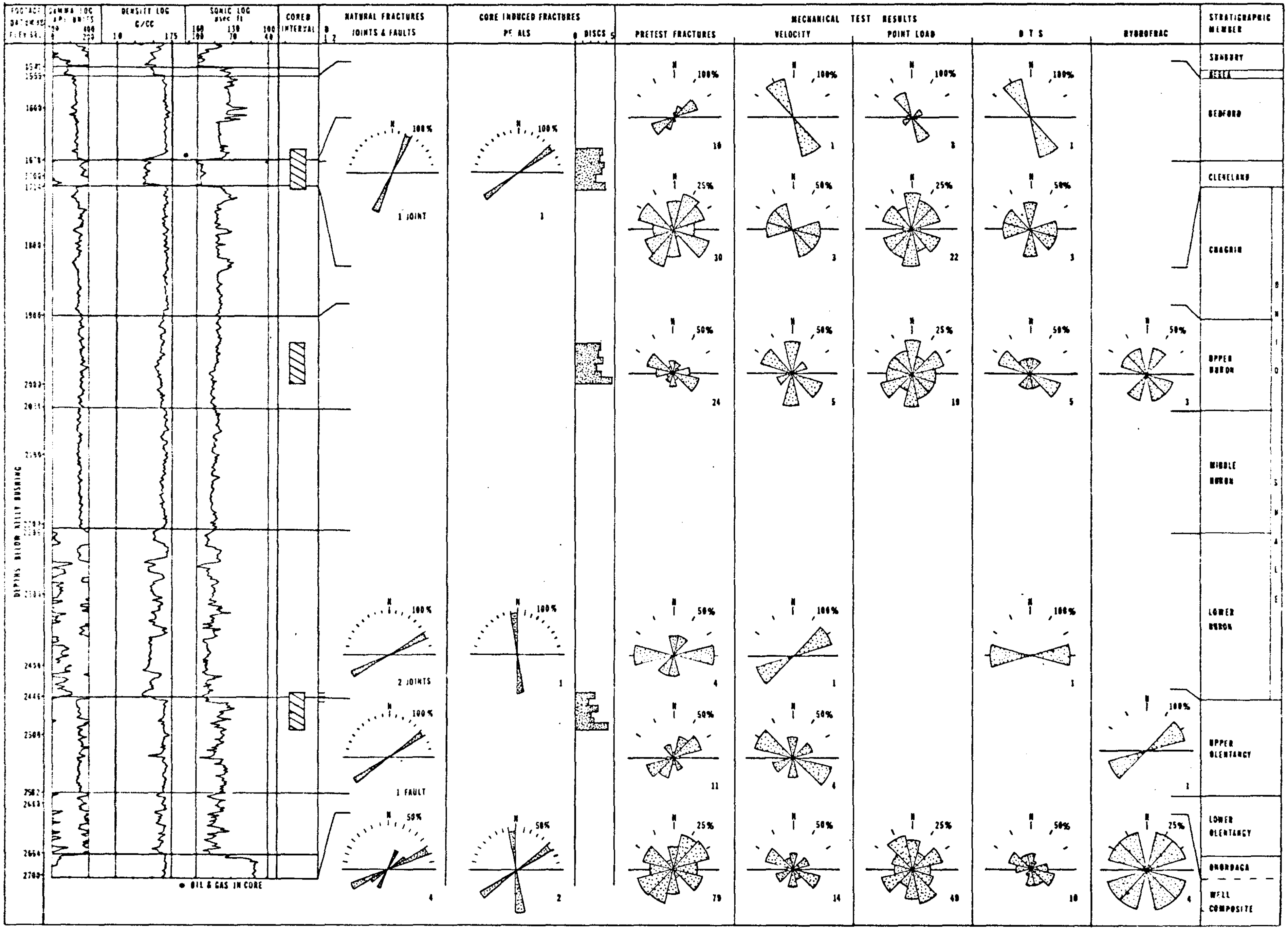


FIGURE E.G.S.P. OHIO 6-5 WELL SUMMARY.

"D": DISTRIBUTION OF FRACTURES

CLIFFS MINERALS, INC

EGSP-OHIO #7

FORMATION THICKNESSES

Formation	Depth	Thickness	Depths Cored
Ohio Shale:			
Chagrin Shale Member	CP-1,558'	---	1,500'-1,558'
Chagrin-Huron Shale Member (Intertongued)	1,558'-1,729'	171'	1,558'-1,729'
Huron Shale Member	1,729'-2,152'	423'	1,729'-2,152'
Java Formation:			
Hanover Shale Member	2,152'-2,284'	132'	2,152'-2,284'
Pipecreek Member	2,284'-2,298'	14'	2,284'-2,298'
West Falls Formation:			
Angola Shale Member	2,298'-2,490'	192'	2,298'-2,490'
Rhinestreet Shale Member	2,490'-2,584'	94'	2,490'-2,584'
Hamilton Group:			
Tichenor Limestone	2,584'-2,589'	5'	2,584'-2,589'
Mahantango Formation	2,589'-2,672'	83'	2,589'-2,672'
Marcellus Formation	2,672'-2,708'	36'	2,672'-2,708'
Onondaga Group:			
Delaware Limestone	2,708'-TD	---	2,708'-2,710'

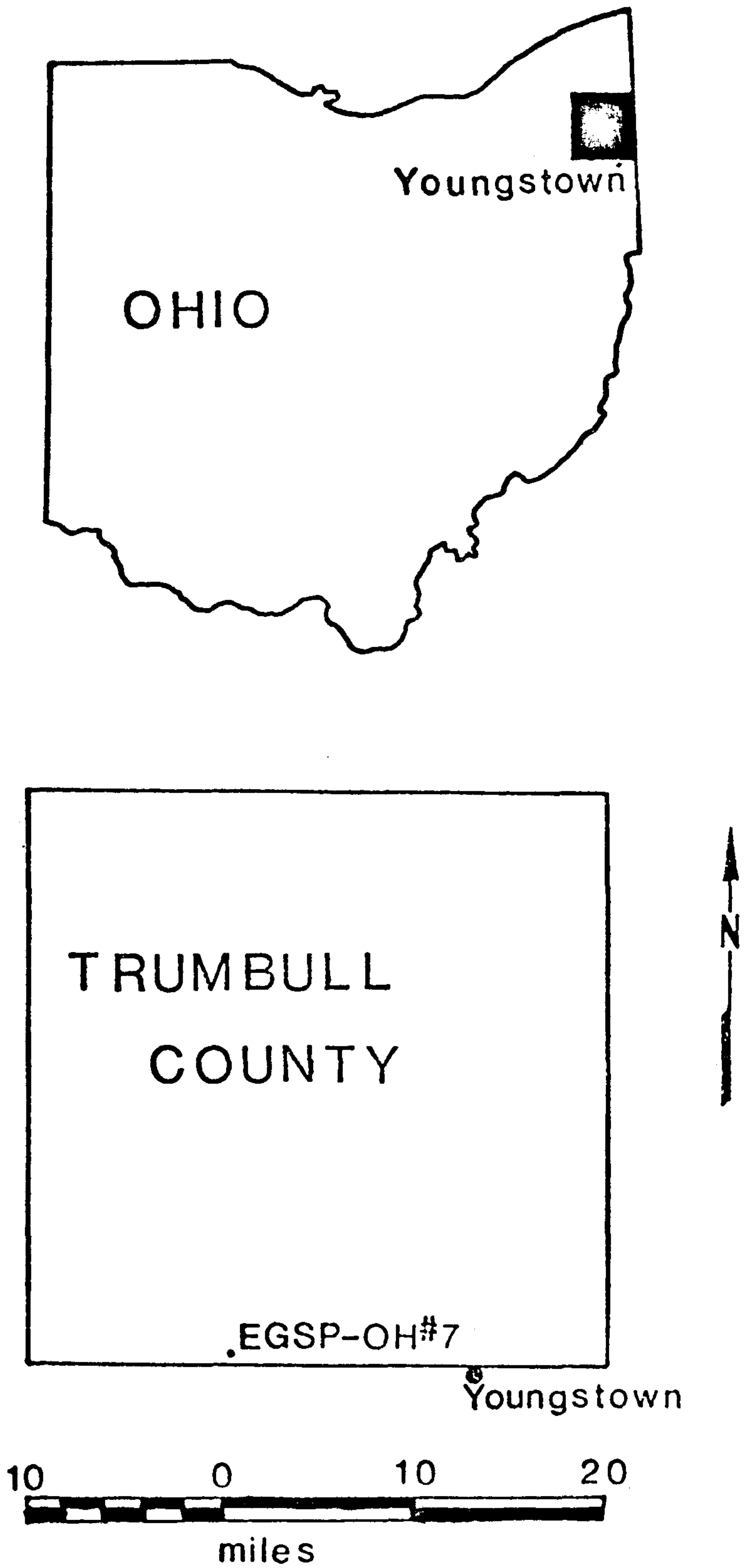
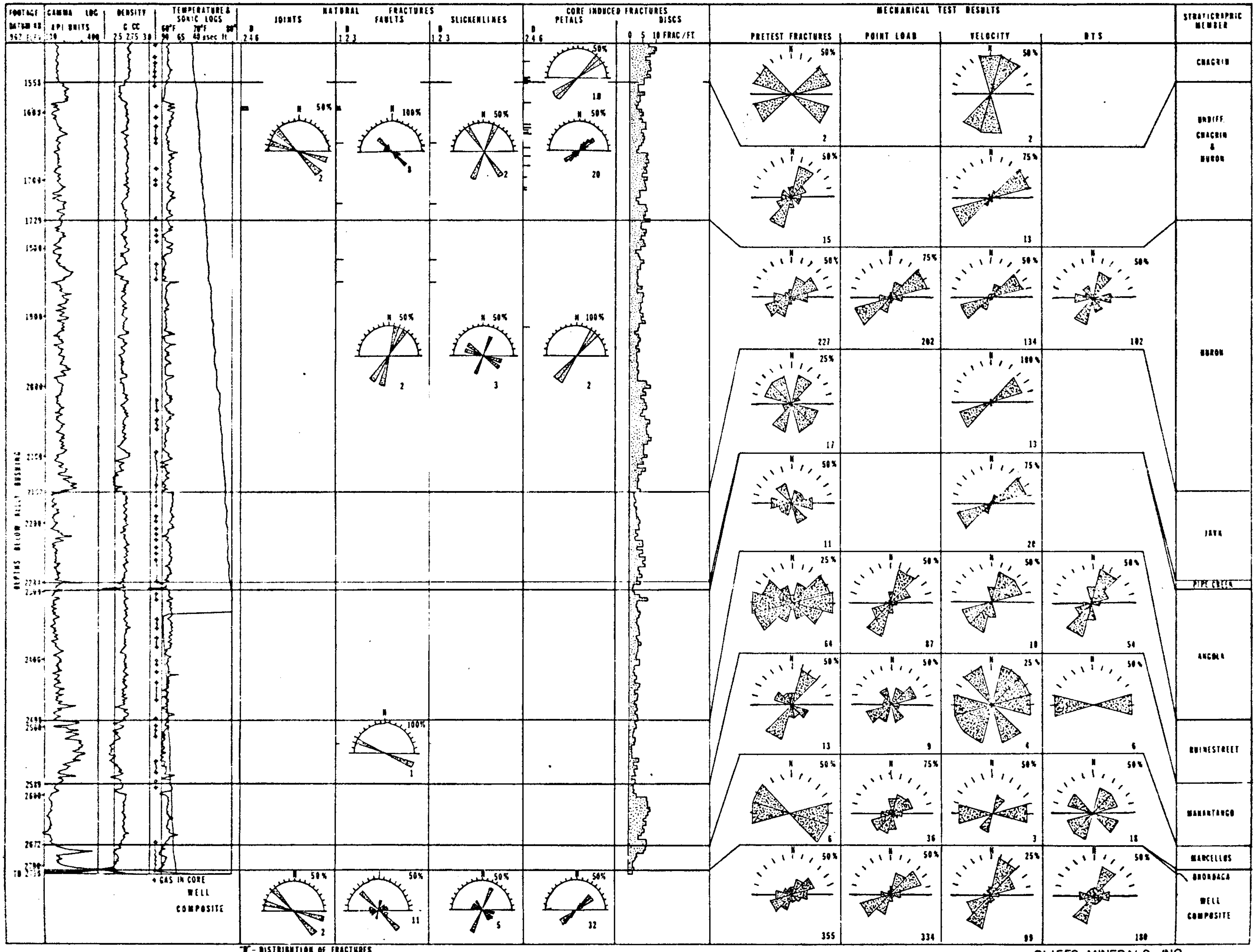


FIGURE 3

LOCATION OF THE EGSP-OHIO #7 WELL
TRUMBULL COUNTY, OHIO



CLIFFS MINERALS, INC.

FIGURE EGSP OHIO 7 WELL SUMMARY

EGSP-OHIO #8

FORMATION THICKNESSES

Formation	Depth	Thickness	Depths Cored
Ohio Shale:			
Chagrin Shale Member	CP-2,842'	---	1,750'-2,087'
Huron Shale Member	2,842'-3,477'	635'	3,085'-3,477'
Java Formation:			
Hanover Shale Member	3,477'-3,600'	123'	3,477'-3,600'
Pipe Creek Member	3,600'-3,624'	24'	3,600'-3,624'
West Falls Formation:			
Angola Shale Member	3,624'-3,864'	240'	3,624'-3,864'
Rhinestreet Shale Member	3,864'-4,097'	233'	3,864'-4,097'
Hamilton Group:			
Mahantango Formation	4,097'-4,140'	43'	4,097'-4,140'
Marcellus Formation	4,140'-4,148'	8'	4,140'-4,148'
Onondaga Group:			
Delaware Limestone	4,148'-TD	---	4,148'-4,151'

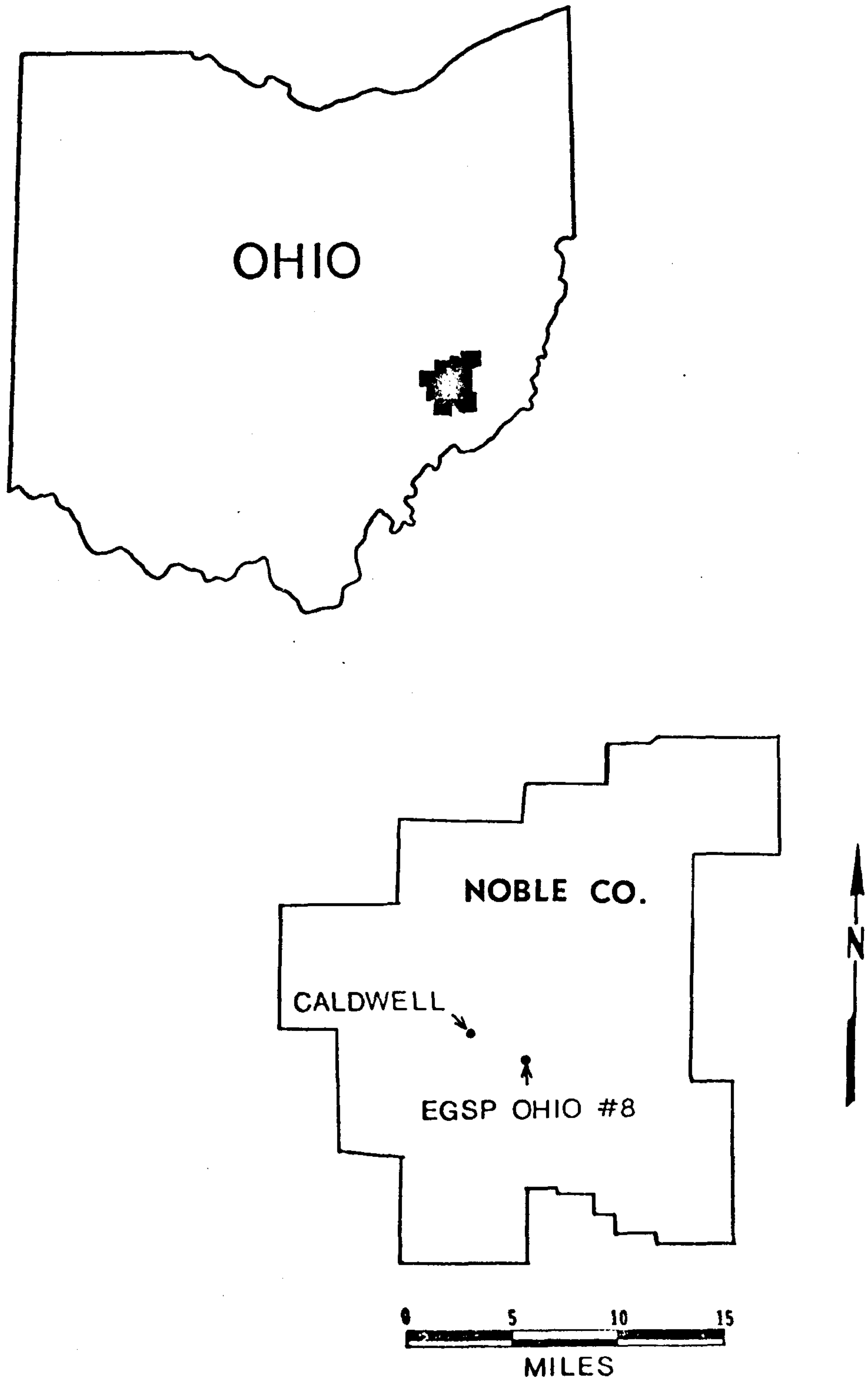
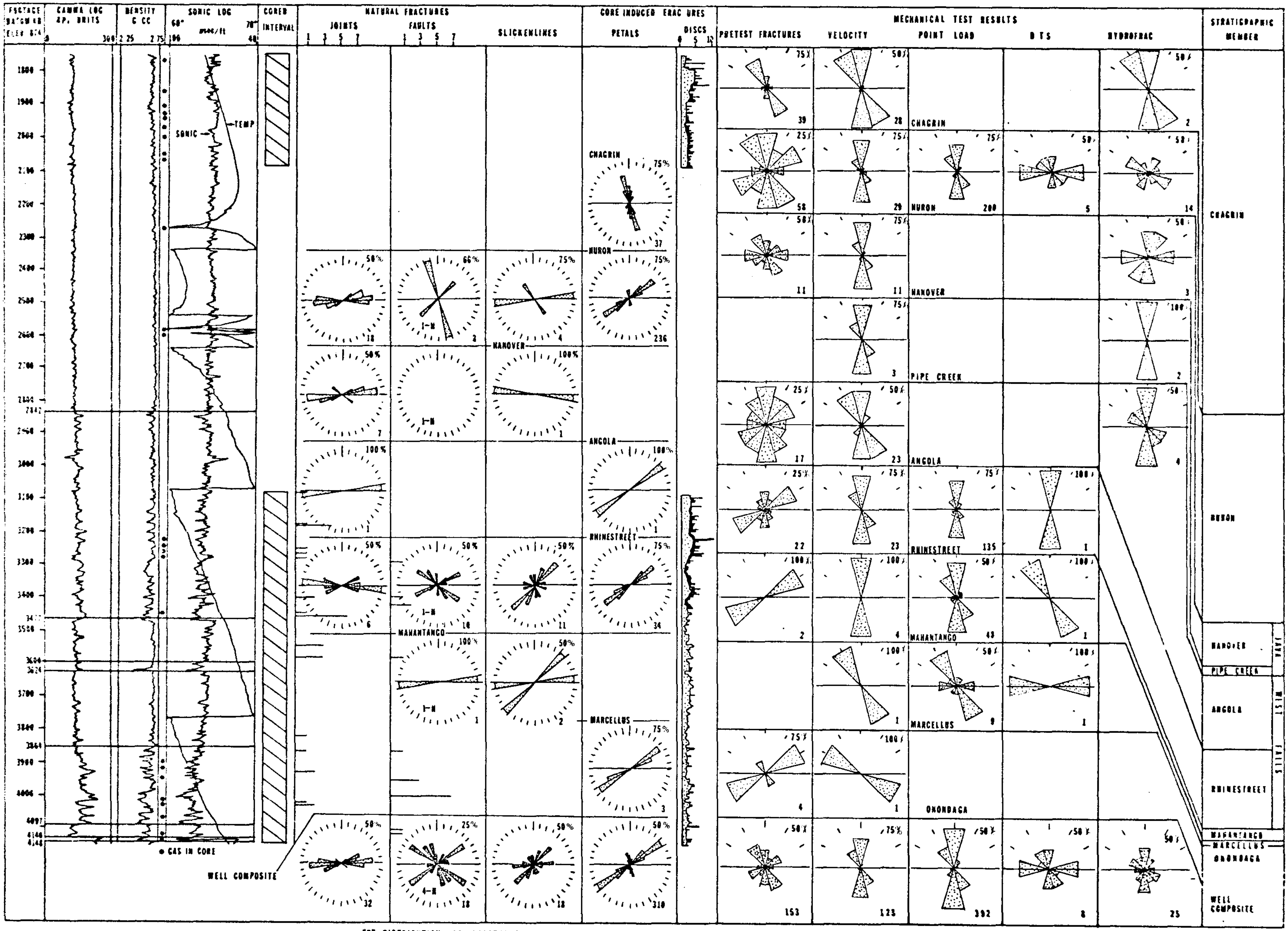


FIGURE 3

LOCATION OF THE EGSP-OHIO #8 WELL, NOBLE COUNTY



"D": DISTRIBUTION OF FRACTURES

H: HORIZONTAL

FIGURE E.G.S.P. OHIO 8 WELL SUMMARY

CLIFFS MINERALS INC.

EGSP-OHIO #9

FORMATION THICKNESSES

Formation	Depth	Thickness	Depths Cored
Ohio Shale:			
Middle Huron Shale Member	CP-2,994'	---	2,914'-2,994'
Lower Huron Shale Member	2,994'-3,394'	400'	2,994'-3,372'

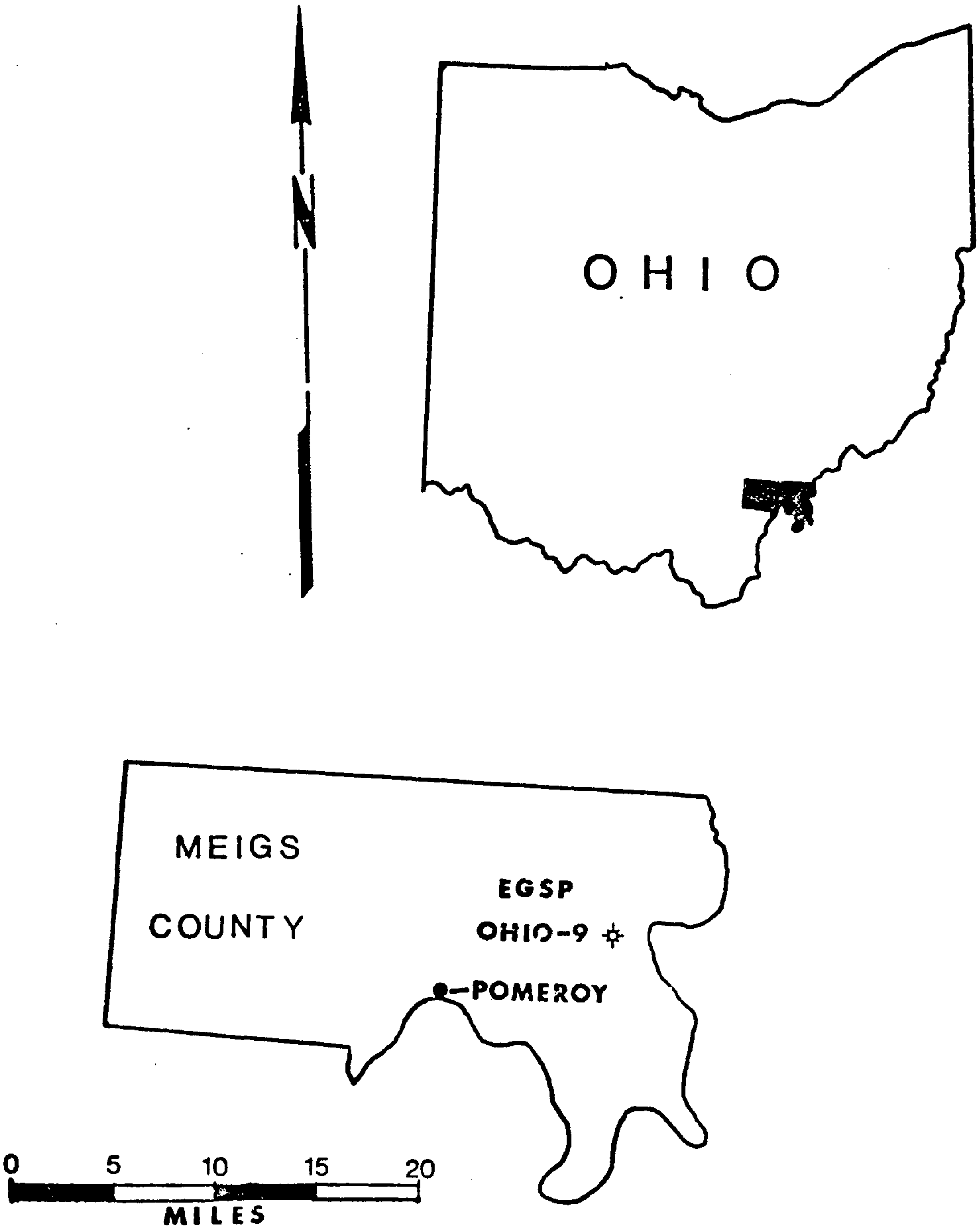


FIGURE 3

LOCATION OF THE EGSP-OHIO #9 WELL, MEIGS COUNTY, OHIO

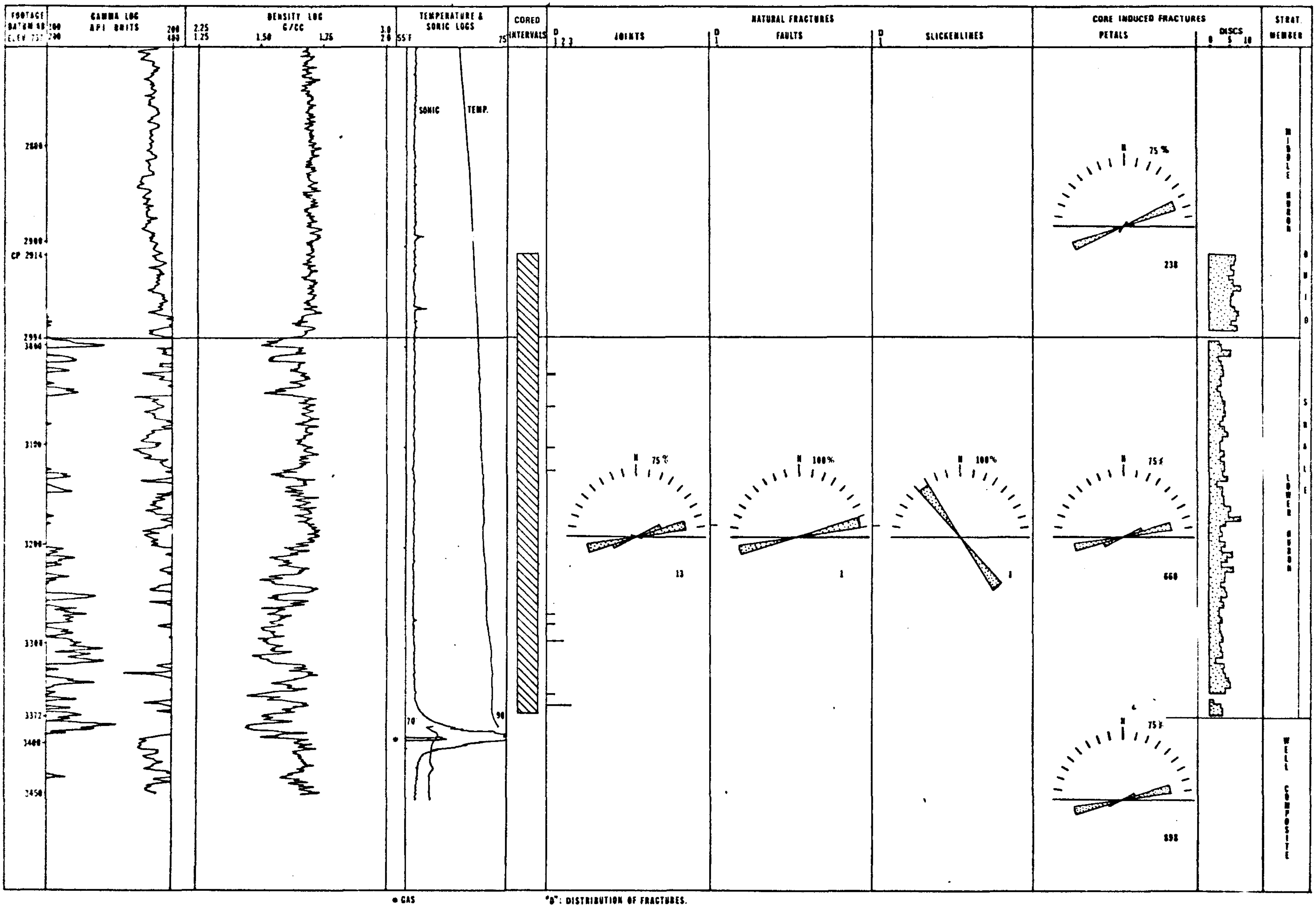


FIGURE E.G.S.P. OHIO 9 WELL SUMMARY.

CLIFFS MINERALS, INC.

EGSP-PENNSYLVANIA #1

FORMATION THICKNESSES

Formation	Depths	Thickness	Depths Cored
West Falls Formation:			
Angola Shale	C.P.-3,485.3'	----	3,470.0'-3,485.3'
Rhinestreet Shale	3,485.3'-4,371.0'	885.7'	3,485.3'-3,528.0'
Sonyea Formation:			
Cashaqua Shale	4,371.0'-4,486.0'	115.0'	----------
Middlesex Shale	4,486.0'-4,553.0'	67.0'	4,530.0'-4,553.0'
Genesee Formation:			
Undifferentiated	4,553.0'-4,734.0'	181.0'	4,553.0'-4,734.0'
Geneseo Shale	4,734.0'-4,768.0'	34.0'	4,734.0'-4,768.0'
Hamilton Group:			
Moscow Shale	4,768.0'-4,808.7'	40.7'	4,768.0'-4,808.7'
Ludlowville Shale	4,808.7'-5,101.0'	292.3'	4,808.7'-5,101.0'
Skaneateles Shale	5,101.0'-5,176.0'	75.0'	5,101.0'-5,176.0'
Marcellus Shale	5,176.0'-T.D.	-----	5,176.0'-5,213.0'

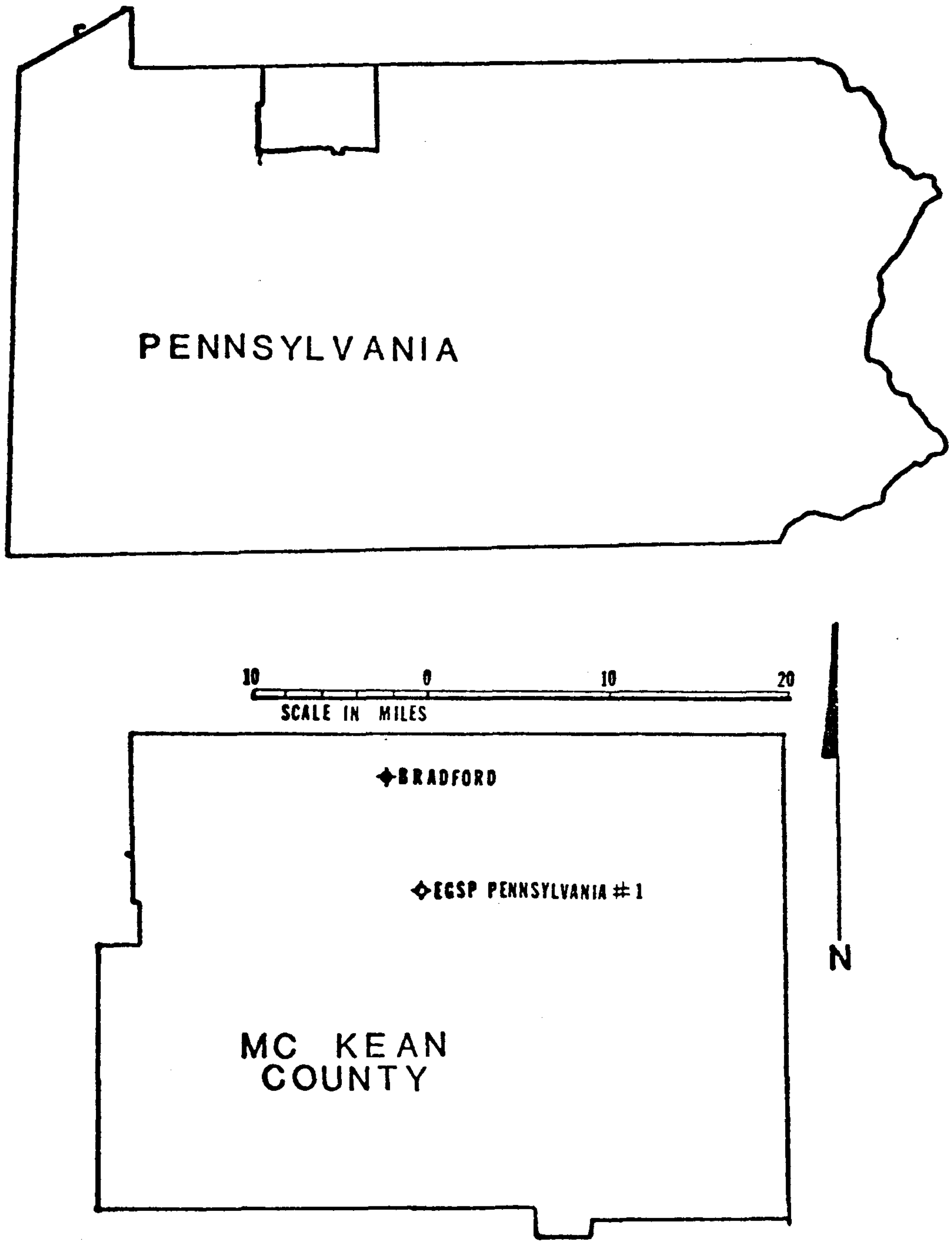


FIGURE 3

LOCATION OF THE EGSP-PENNSYLVANIA #1 WELL, MCKEAN COUNTY, PENNSYLVANIA

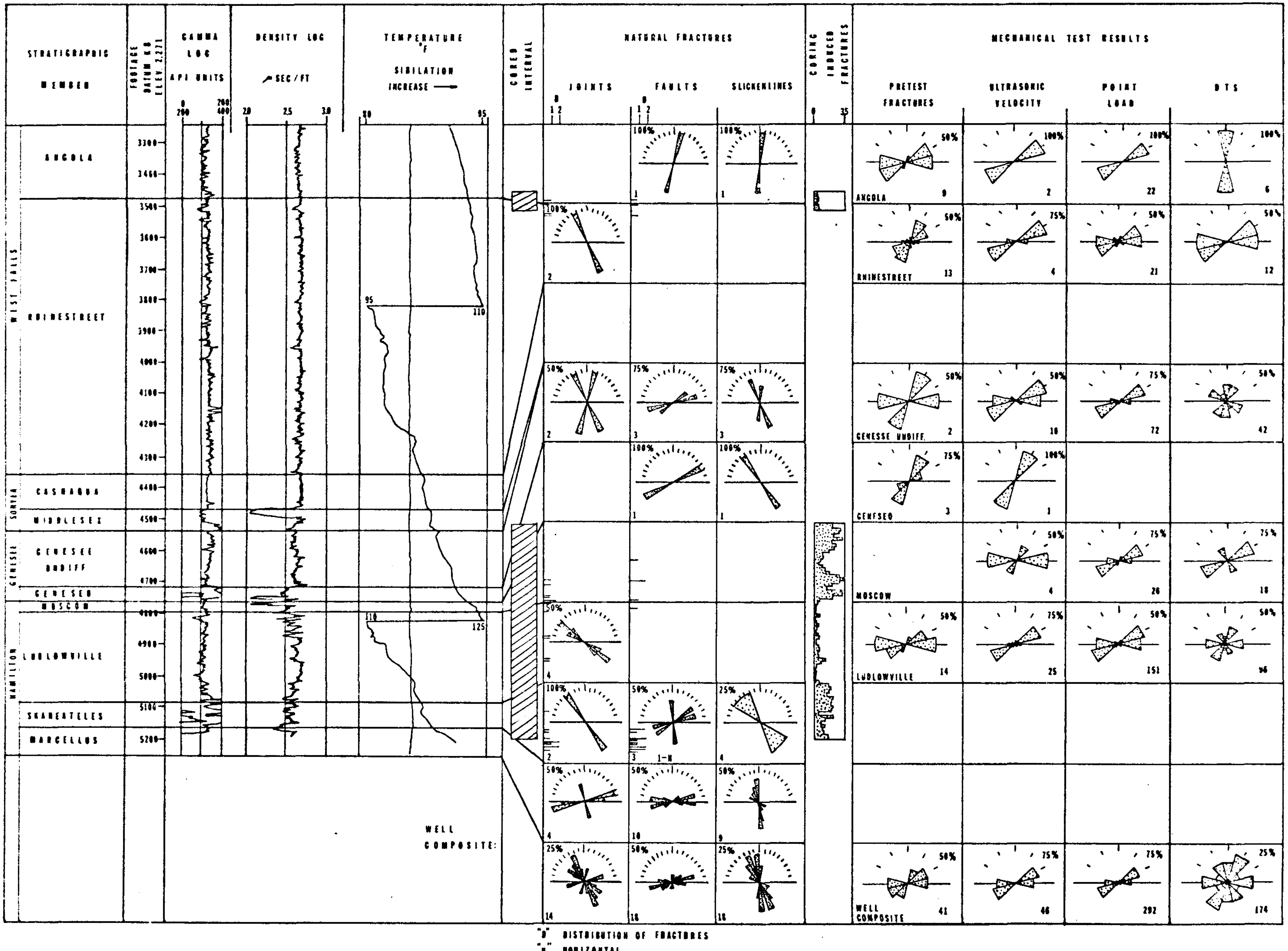


FIGURE EGSP PENNSYLVANIA 1 WELL SUMMARY

CLIFFS MINERALS, INC

EGSP-PENNSYLVANIA #2

FORMATION THICKNESSES

Formation	Depths	Thickness	Depths Cored
Harrel Formation:			
Undifferentiated	C.P. -7,061'	----	6,951'-7,061'
Burkett Shale	7,061' -7,084'	23'	7,061'-7,084'
Hamilton Group:			
Tully Limestone	7,084' -7,144'	60'	7,084'-7,144'
Mahantango Shale	7,144' -7,332'	188'	7,144'-7,332'
Marcellus Shale	7,332' -7,496'(?)	164'	7,332'-7,496'
Onondaga Limestone	7,496'(?)-*	----	7,496'-7,496.2'

* Contact Undetermined

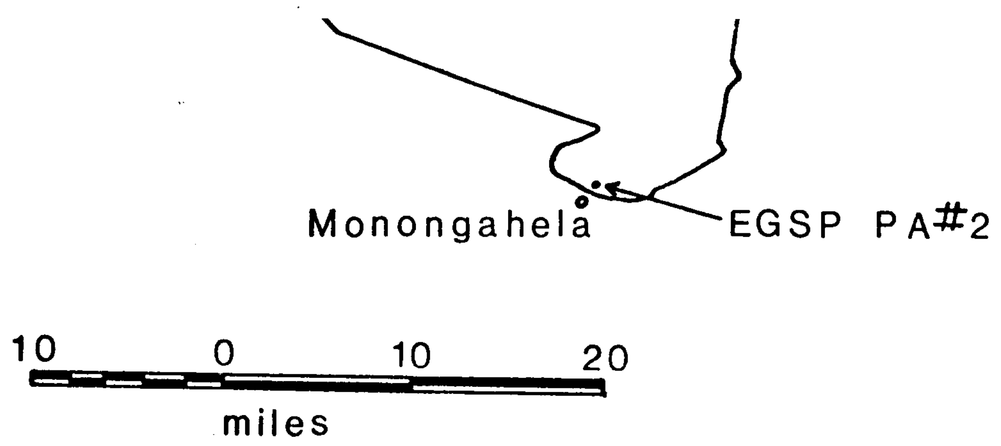


FIGURE 3

LOCATION OF THE EGSP PENNSYLVANIA #2 WELL IN ALLEGHENY COUNTY, PENNSYLVANIA

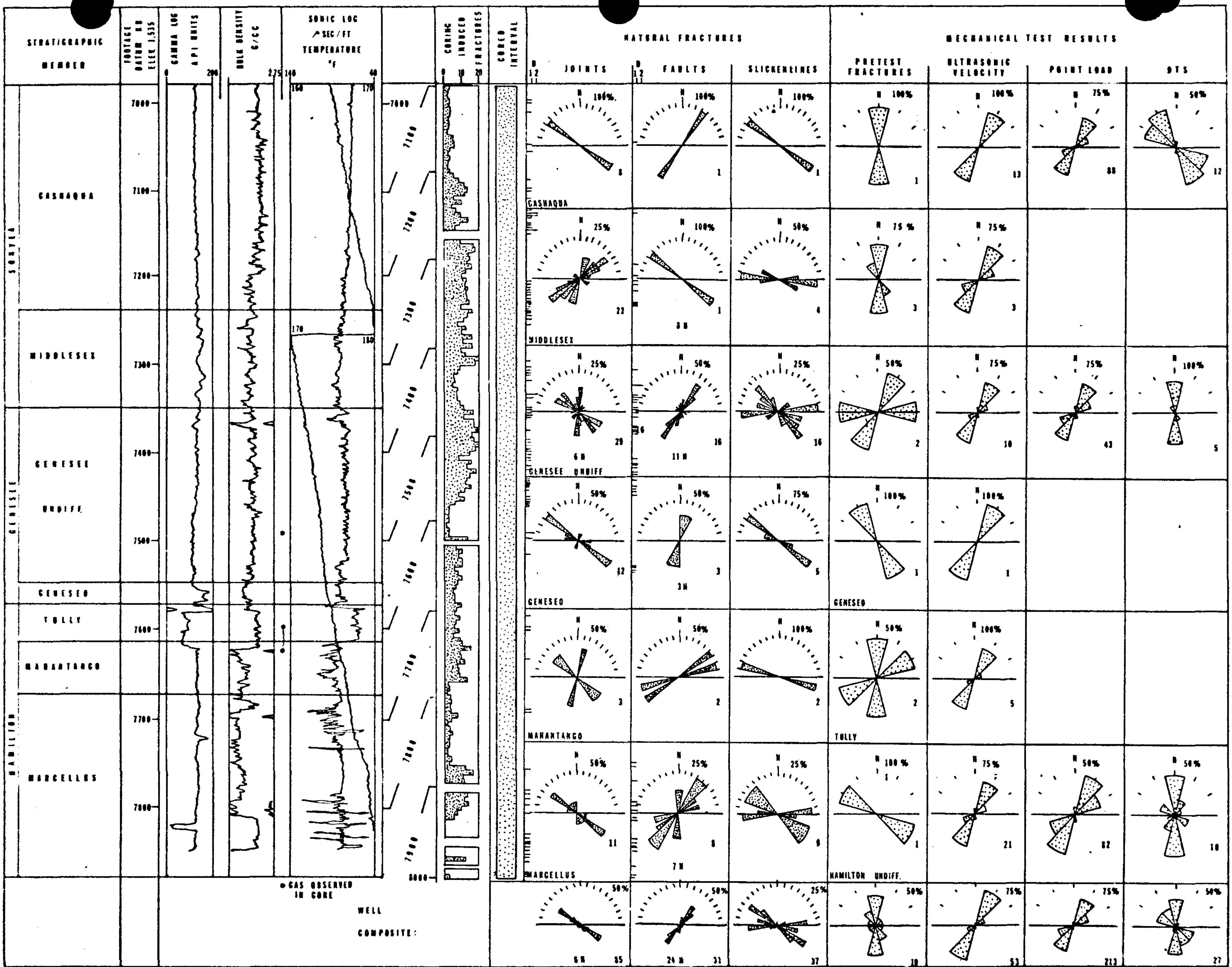


FIGURE EGSP PENNSYLVANIA 4 WELL SUMMARY

"D" DISTRIBUTION OF FRACTURES
"H" HORIZONTAL

CLIFFS MINERALS, INC

EGSP-PENNSYLVANIA #5

FORMATION THICKNESSES

Formation	Depth	Thickness	Depths Cored
West Falls Formation:			
Rhinestreet Shale Member	C.P.- 3,846.0'	324.0'	3,522.0'-3,846.0'
Sonyea Formation:			
Cashaqua Shale Member	3,846.0'- 3,909.0'	63.0'	3,846.0'-3,909.0'
Middlesex Shale Member	3,909.0'- 3,925.0'	16.0'	3,909.0'-3,925.0'
Genesee Formation:			
Undifferentiated	3,925.0'- 3,967.7'	42.7'	3,925.0'-3,967.7'
Geneseo Shale Member	3,967.7'- 3,975.4'	7.7'	3,967.7'-3,975.4'
Hamilton Group:			
Tully Limestone	3,975.4'- 3,979.1'	3.7'	3,975.4'-3,979.1'
Mahantango Shale	3,979.1'-∿4,113.0'	133.9'	3,979.1'-4,113.0'
Marcellus Shale	∿4,113.0'- 4,124.5'	11.5'	4,113.0'-4,124.5'
Onondaga Limestone	4,124.5'-T.D.	1.3'	4,124.5'-4,125.8'

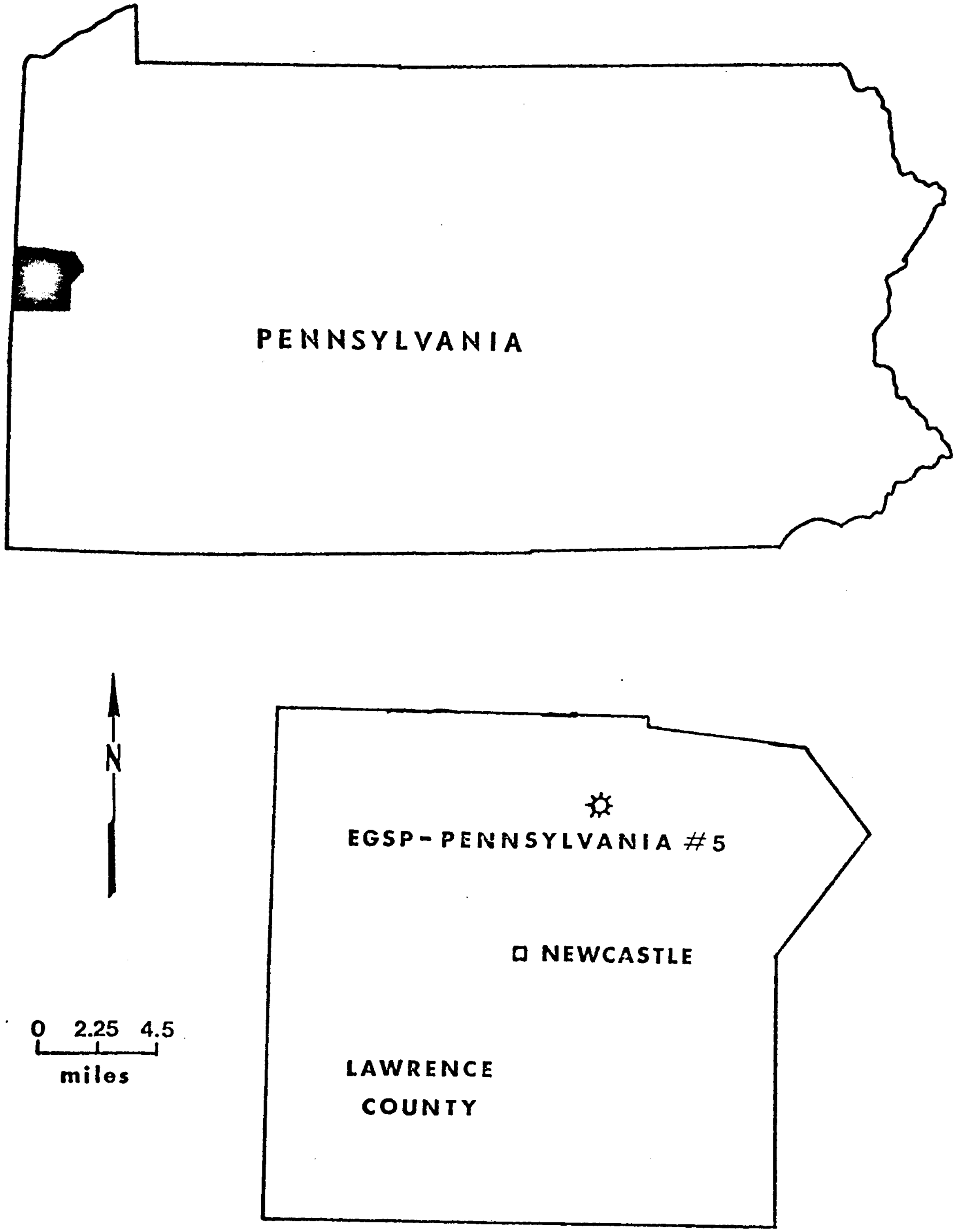


FIGURE 3

LOCATION OF THE EGSP-PENNSYLVANIA #5 WELL, LAWRENCE COUNTY, PENNSYLVANIA

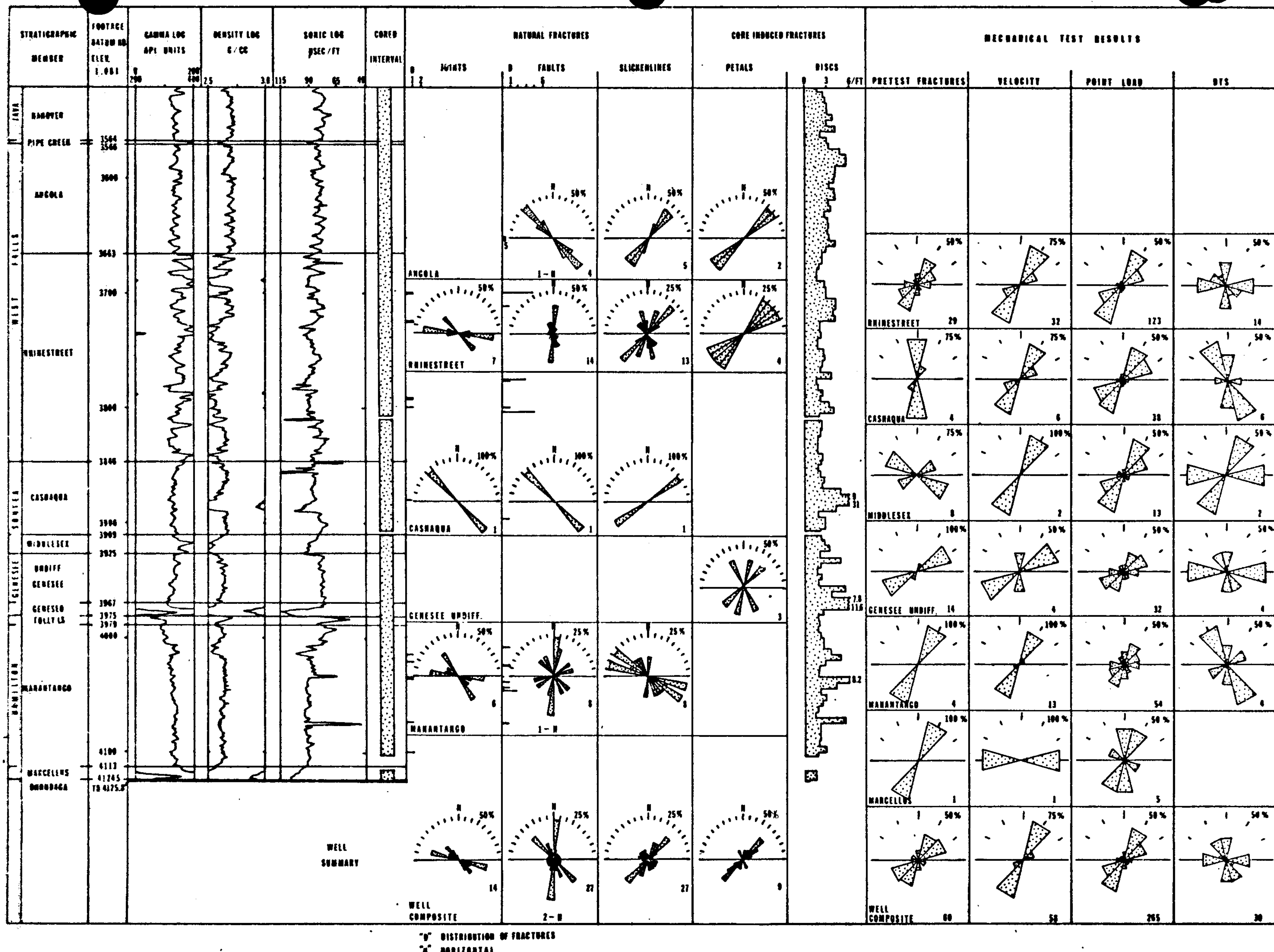


FIGURE E.G.S.P. PENNSYLVANIA 5 WELL SUMMARY.

CLIFFS MINERALS, INC.

EGSP-TENNESSEE #9

FORMATION THICKNESSES

Formation	Depth	Thickness	Depths Cored
Ohio Shale:			
Sunbury-Cleveland Member	1,134'-1,236'	102'	1,167'-1,219'
Chagrin Member	1,236'-1,418'	182'	-----
Huron Member:			
Upper	1,418'-1,502'	84'	-----
Middle	1,502'-1,632'	130'	1,610'-1,632'
Lower	1,632'-1,734'	102'	1,632'-1,734'
Olentangy Shale:			
Upper	1,734'-1,834'	100'	1,734'-1,739' 1,820'-1,834'
West Falls Formation:			
Rhinestreet Member	1,834'-1,856'	22'	1,834'-1,856'
Wildcat Valley Sandstone	1,856'-*	----	1,856'-1,865'

* Contact Undetermined

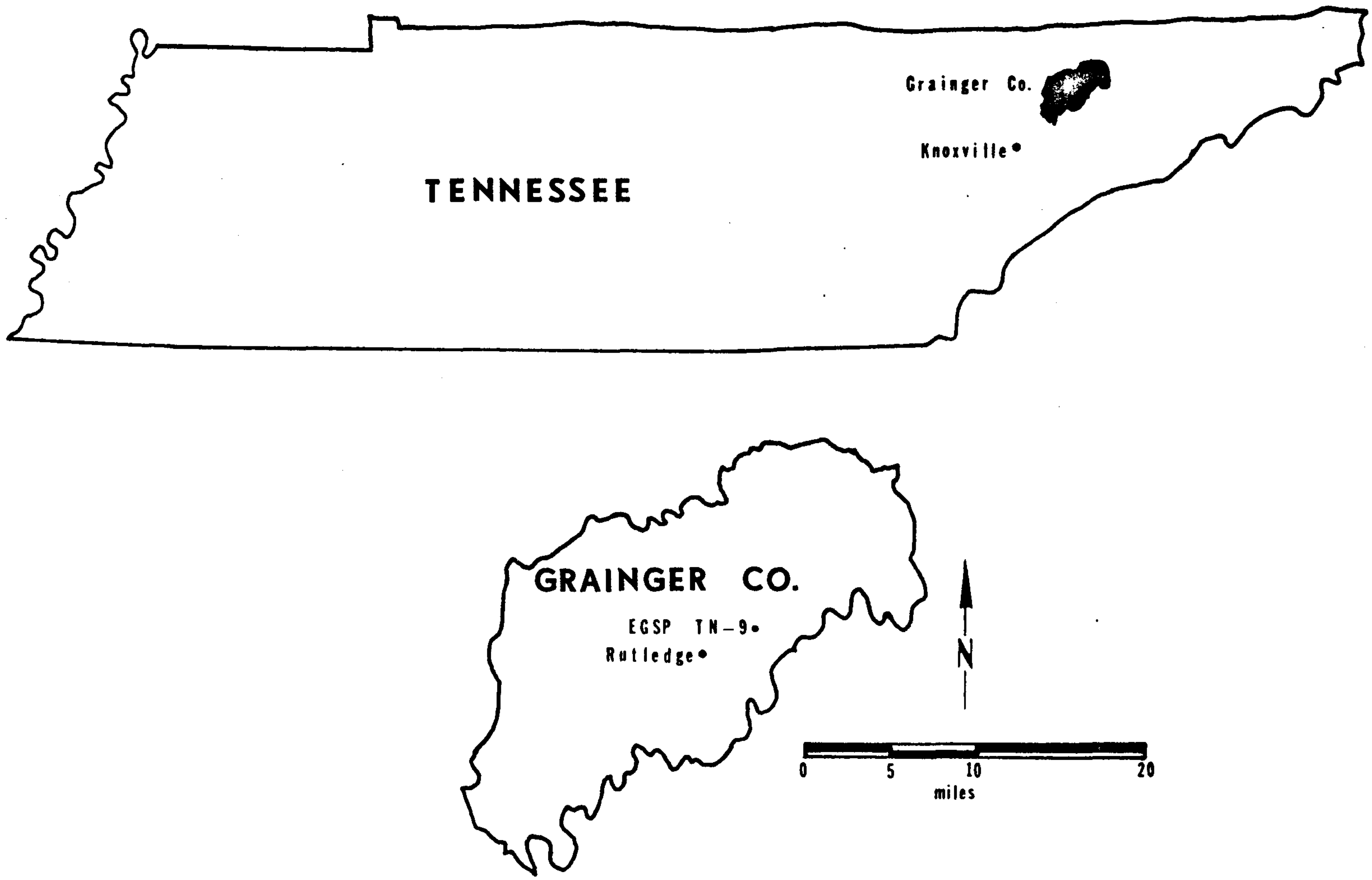
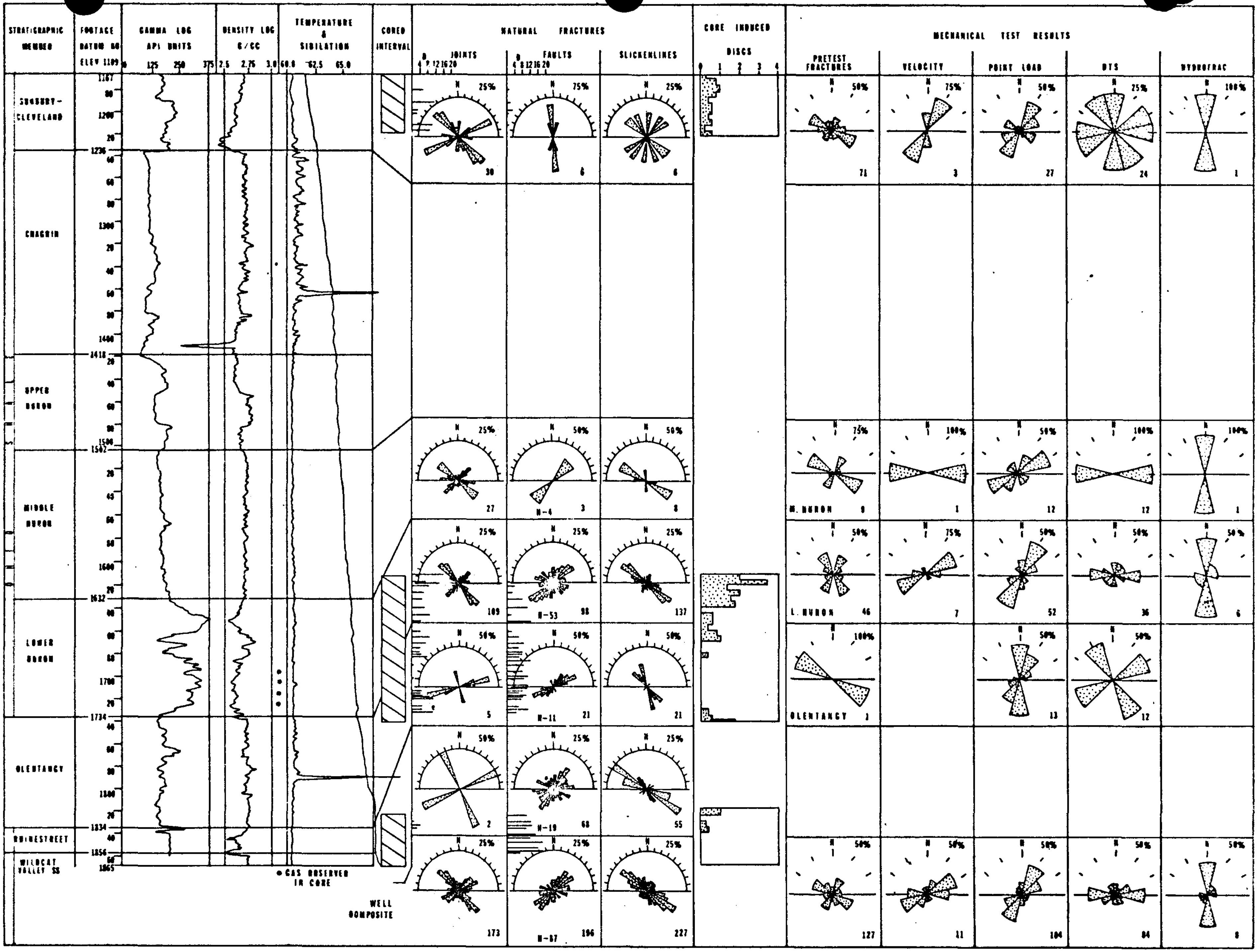


FIGURE 3

LOCATION OF THE EGSP TN #9 WELL IN GRAINGER COUNTY, TENNESSEE



"D": DISTRIBUTION OF FRACTURES
"H": HORIZONTAL FRACTURES

FIGURE EGSP-TENNESSEE #9 WELL SUMMARY

CLIFFS MINERALS, INC

EGSP-WEST VIRGINIA #1

FORMATION THICKNESSES

CORE RECOVERED 287 FEET

DONE BY OTHERS

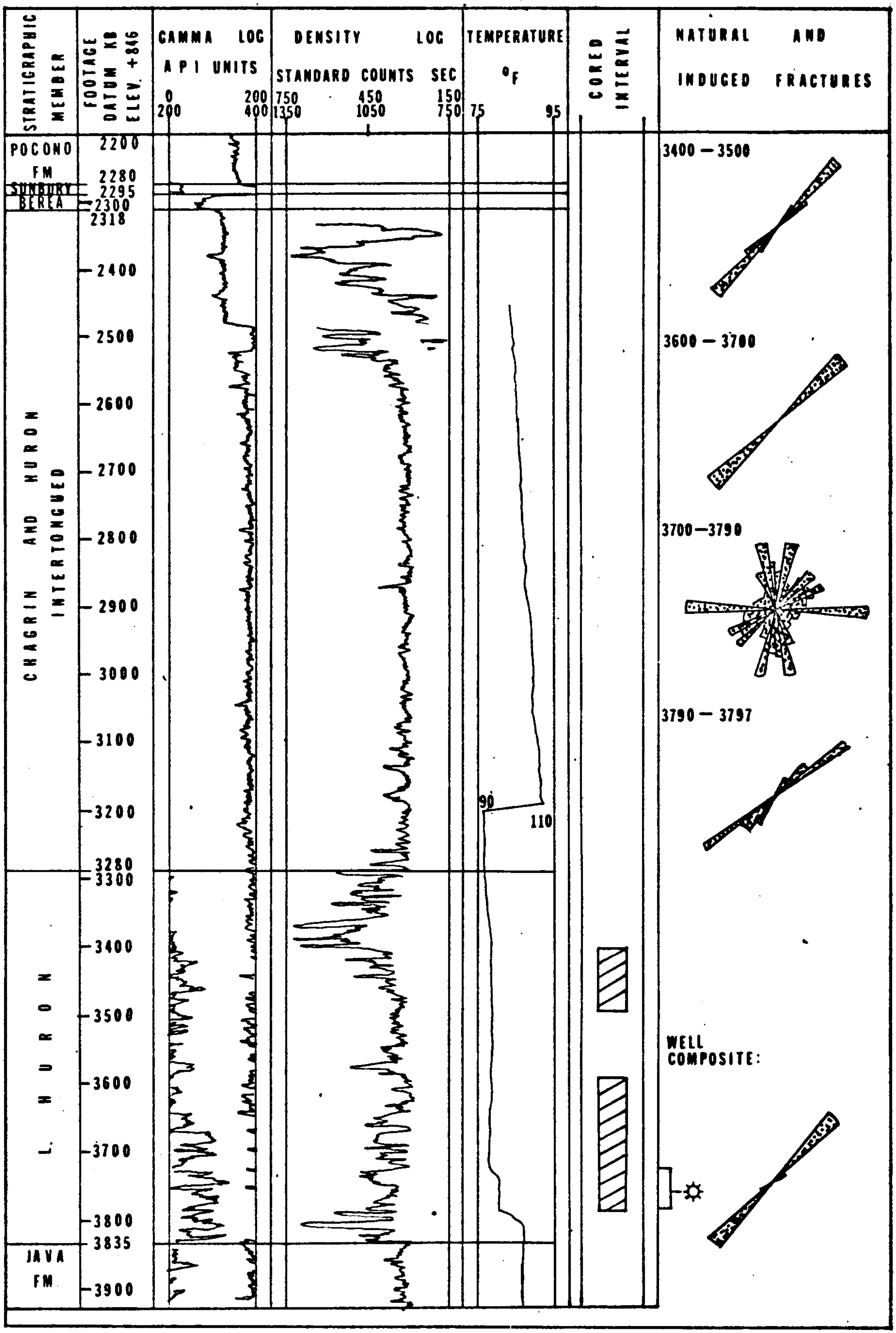


FIGURE E.G.S.P WEST VIRGINIA 1 WELL SUMMARY

EGSP-WEST VIRGINIA #2

FORMATION THICKNESSES

CORE RECOVERED 470 FEET

DONE BY OTHERS

EGSP-WEST VIRGINIA #3

FORMATION THICKNESSES

CORE RECOVERED 1,308 FEET

DONE BY OTHERS

EGSP-WEST VIRGINIA #4

FORMATION THICKNESSES

CORE RECOVERED 614 FEET

DONE BY OTHERS

EGSP-WEST VIRGINIA #5

FORMATION THICKNESSES

Formation	Depth	Thickness	Depths Cored
Chagrin Shale	2,668'-2,722'	54'	2,668'-2,722'
Ohio Shale:			
Huron Shale Member	2,722'-3,040'	318'	2,722'-3,040'
Java Formation:			
Hanover Shale	3,040'-3,128'	88'	3,040'-3,128'
Pipe Creek Member	3,128'-3,148'	20'	3,128'-3,148'
West Falls Formation:			
Angola Shale Member	3,148'-3,308'	160'	3,148'-3,308'
Rhinestreet Shale Member	3,308'-3,373'	65'	3,308'-3,373'
Hamilton Group	3,373'-3,392'	19'	3,373'-3,392'
Onondaga Limestone	3,392'-3,406'	+14'	3,392'-3,406'

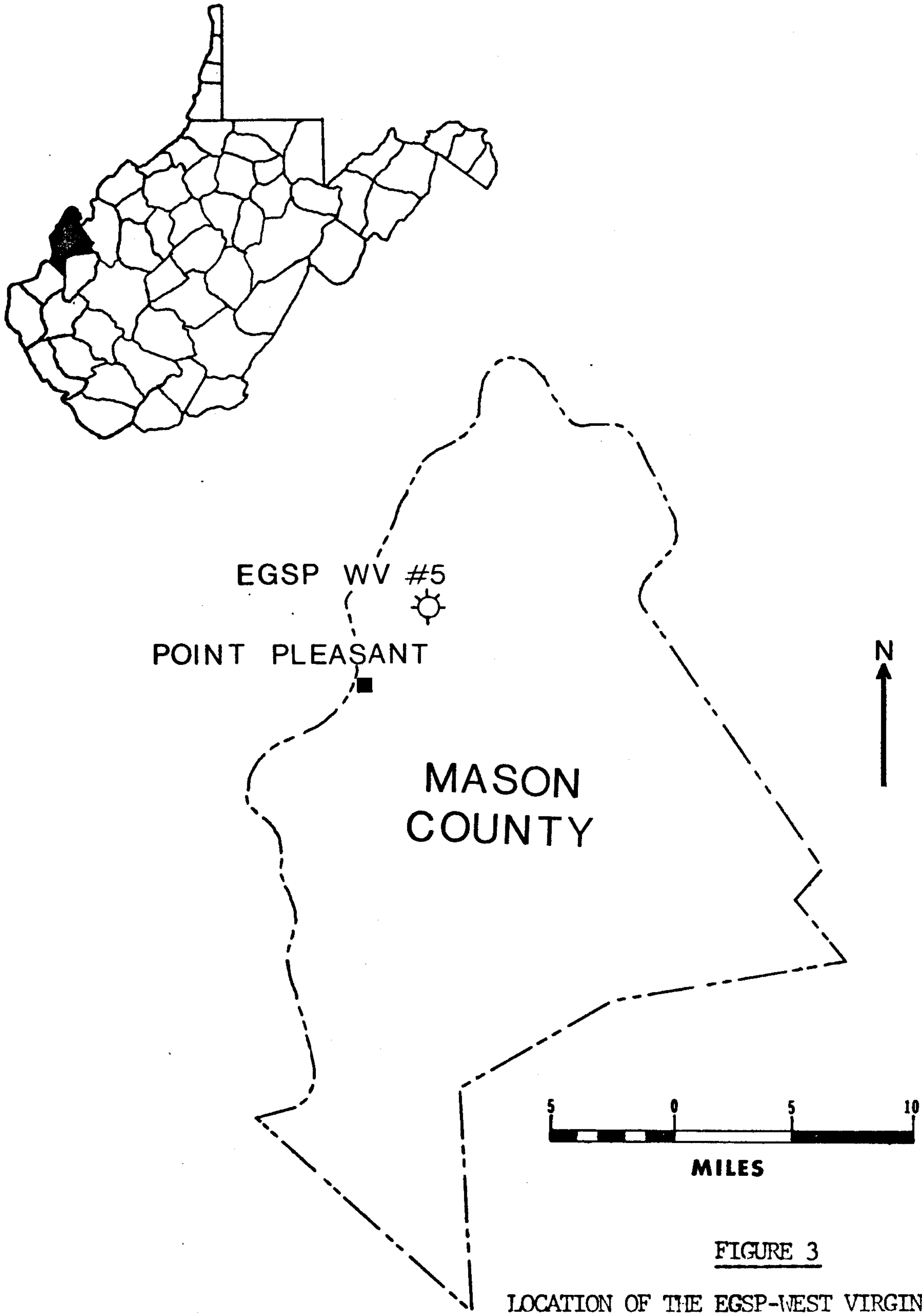


FIGURE 3

LOCATION OF THE EGSP-WEST VIRGINIA #5 WELL, MASON COUNTY, WEST VIRGINIA

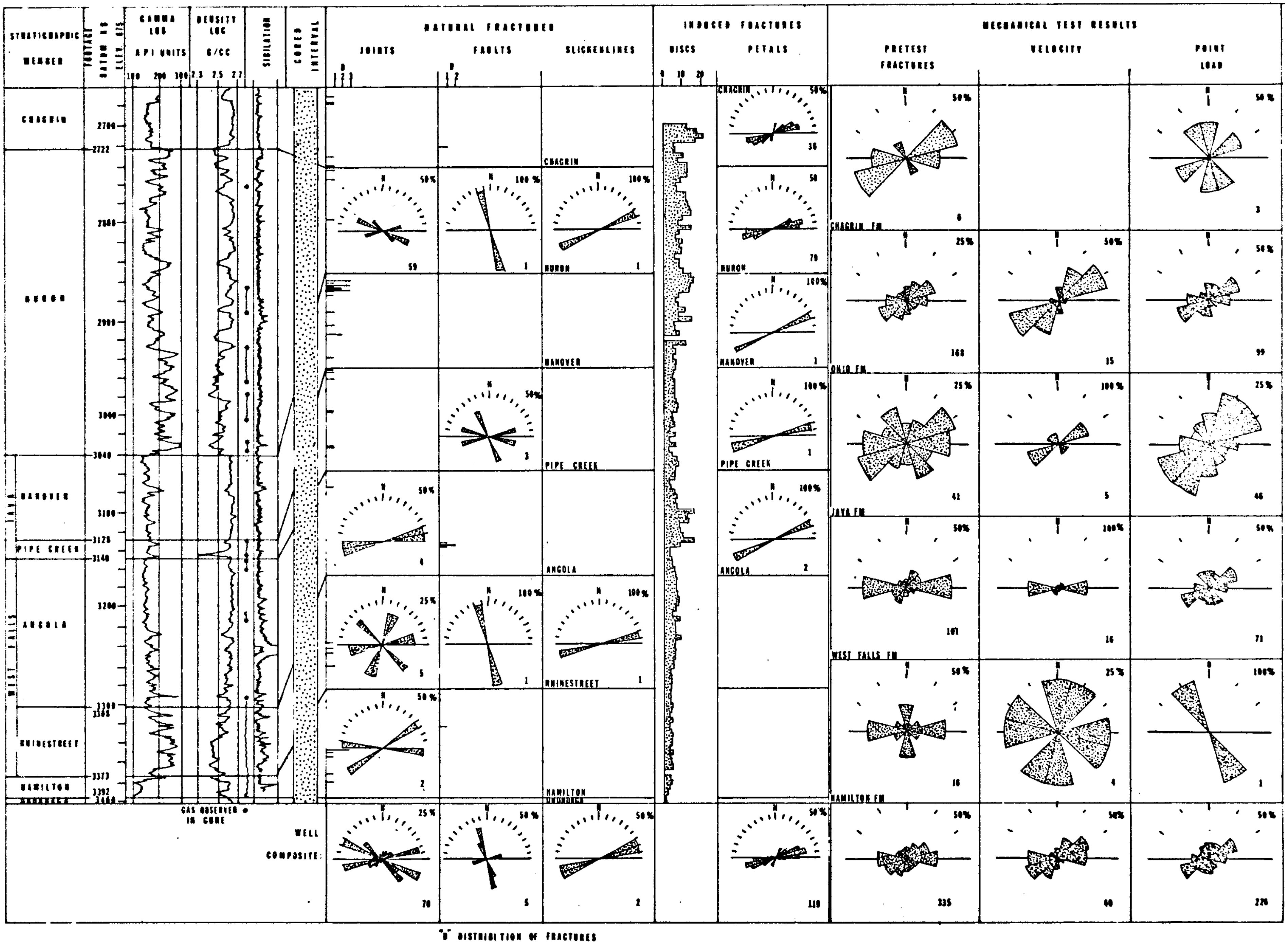


FIGURE EGSP WEST VIRGINIA 5 WELL SUMMARY

CLIFFS MINERALS, INC

EGSP-WEST VIRGINIA #6

FORMATION THICKNESSES

Formation	Depths	Thickness	Depths Cored
Tully Limestone	*-7,231'	----	7,169'-7,231'
Mahantango Shale	7,231'-7,396'	165'	7,231'-7,396'
Marcellus Shale	7,396'-7,500'	104'	7,396'-7,500'
Onondaga Limestone	7,500'-*	----	7,500'-7,518'

* Contact Undetermined

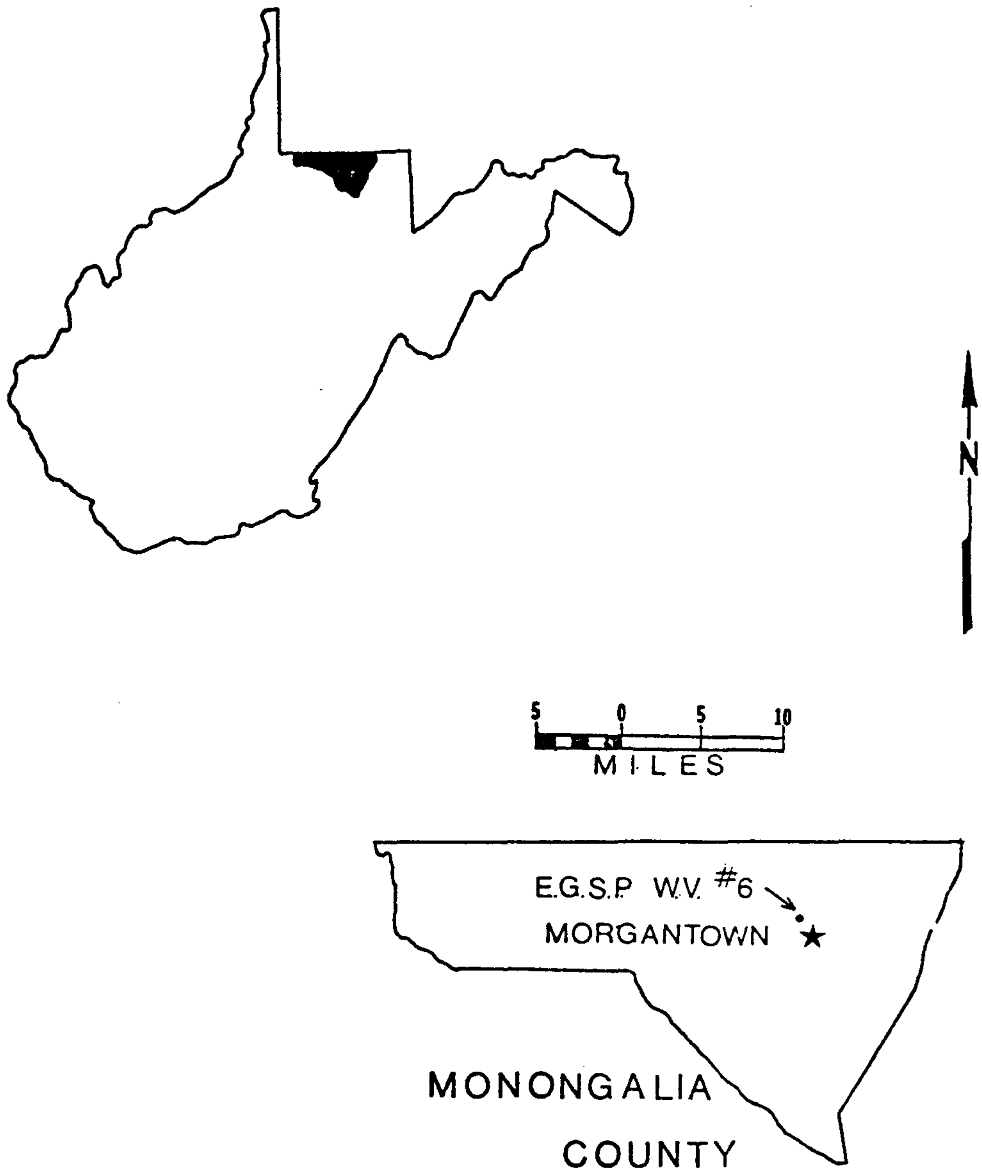
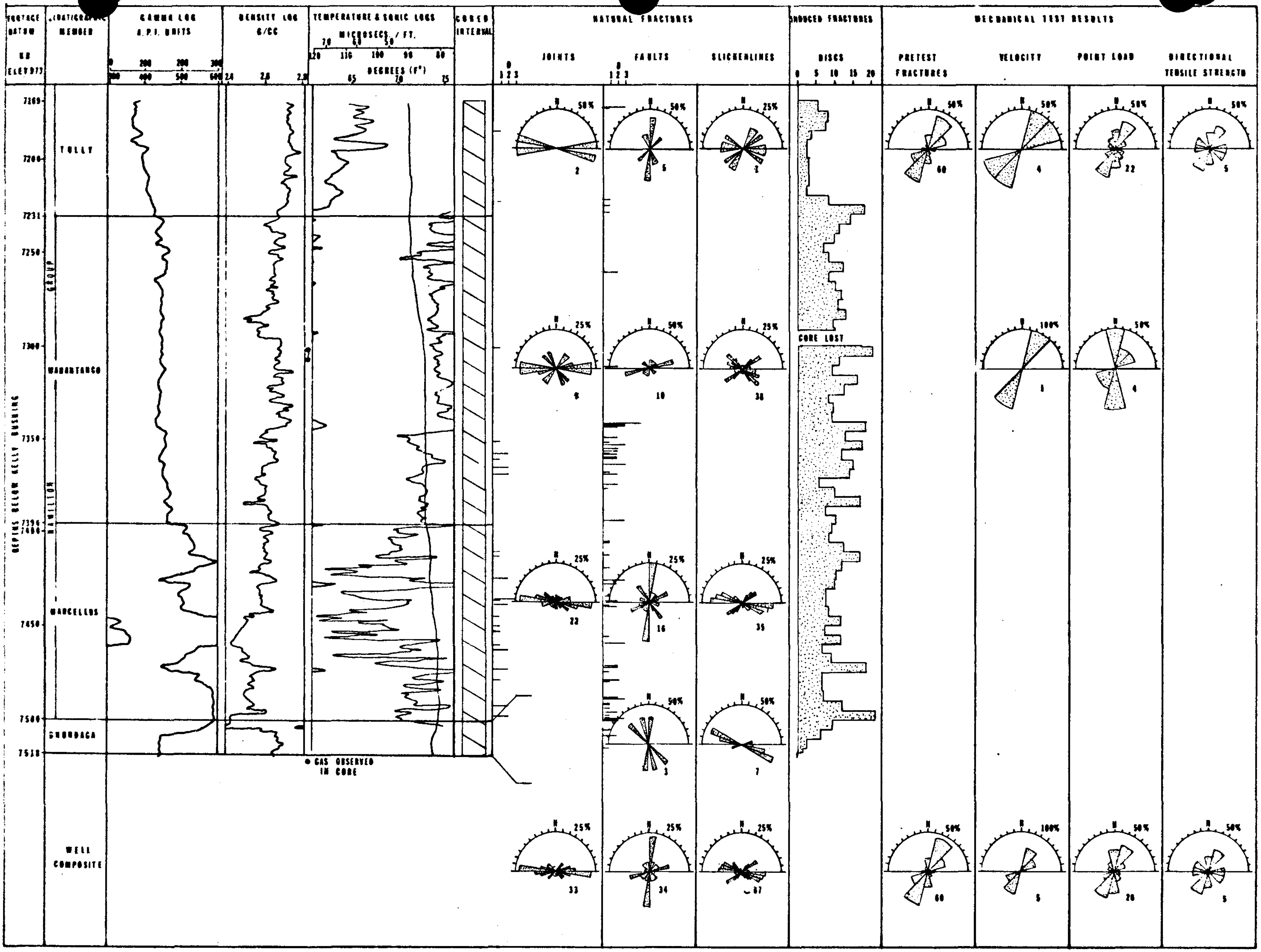


FIGURE 3

LOCATION OF THE EGSP WEST VIRGINIA #6 WELL
IN MONONGALIA COUNTY, WEST VIRGINIA



"N": DISTRIBUTION OF FRACTURES

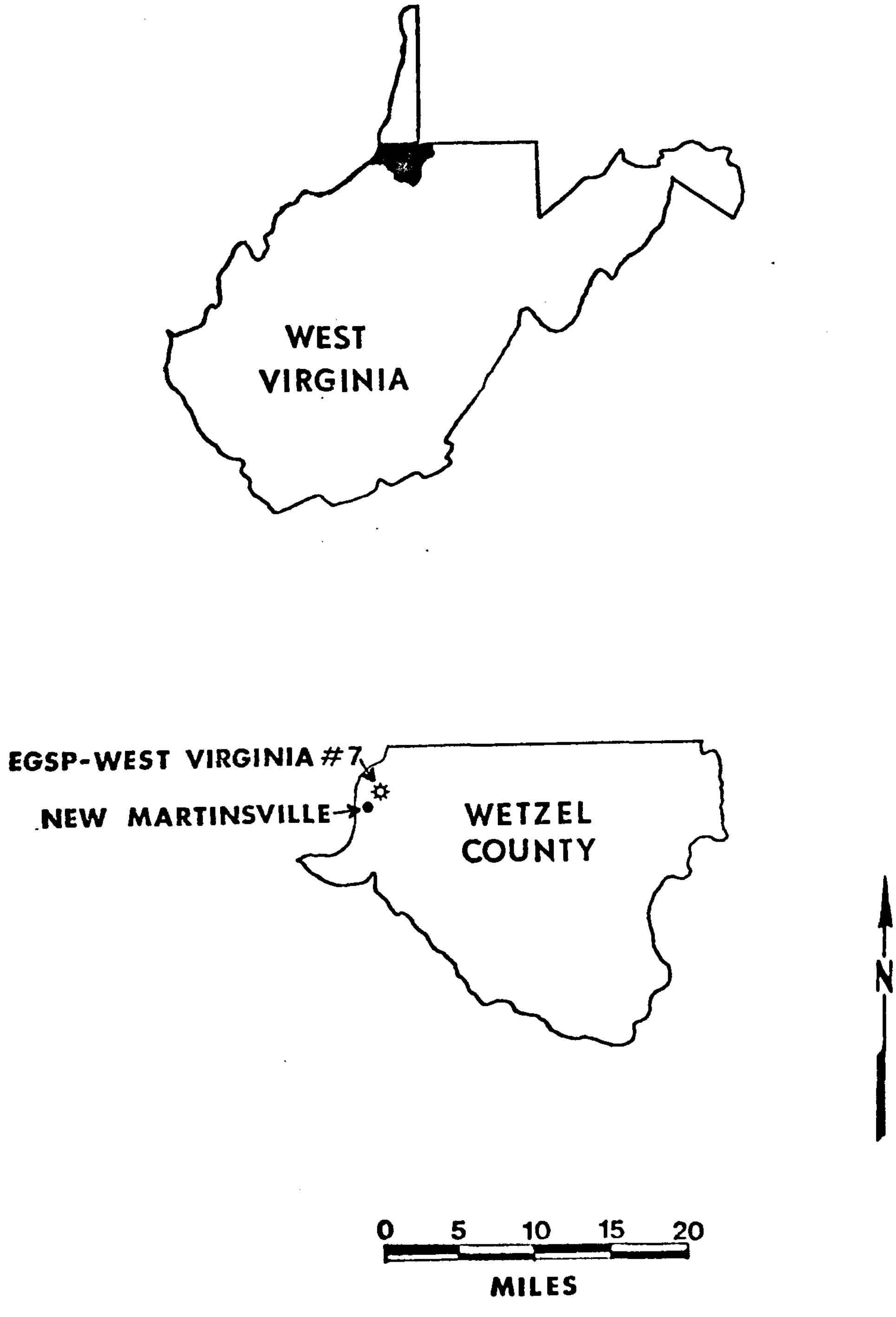
FIGURE E.G.S.P. WEST VIRGINIA 6 WELL SUMMARY

CLIFFS MINERALS, INC.

EGSP-WEST VIRGINIA #7

FORMATION THICKNESSES

Formation	Depths	Thickness	Depths Cored
West Falls Formation:			
Rhinestreet Shale Member	C.P.-6,313'	----	6,102'-6,313'
Sonyea Formation:			
Cashaqua Shale Member	6,313'-6,403'	90'	6,313'-6,403'
Middlesex Shale Member	6,403'-6,430'	27'	6,403'-6,430'
Genesee Formation:			
Undifferentiated	6,430'-6,488'	58'	6,430'-6,488'
Geneseo Shale Member	6,488'-6,513'	25'	6,488'-6,513'
Hamilton Group:			
Mahantango Shale	6,513'-6,568'	55'	6,513'-6,568'
Marcellus Shale	6,568'-6,625'	57'	6,568'-6,625'
Onondaga Limestone	6,625'-T.D.	----	6,625'-6,635'



LOCATION OF THE EGSP-WEST VIRGINIA #7 WELL, WETZEL COUNTY, WEST VIRGINIA

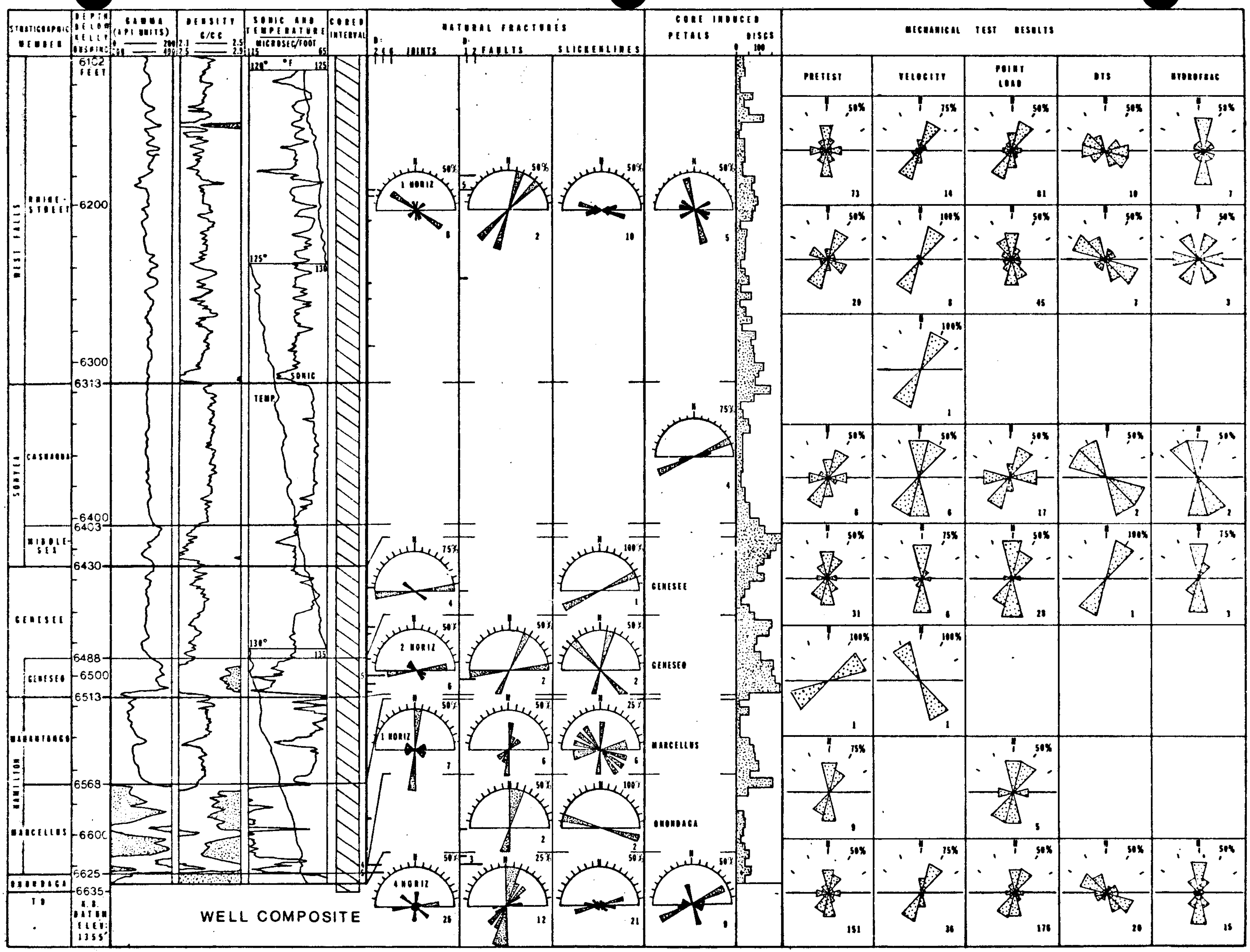


FIGURE EGSP-West Virginia #7 Well Summary D=FRACTURE DISTRIBUTION CLIFFS MINERALS, INC

5.0 REFERENCES

Byrer, C. W. and C. A. Komar, 1977. Field and Laboratory Procedures for Orientated Core Analysis of Devonian Shales, U.S. DOE, ERDA, Morgantown, West Virginia.

Dean, C. S., 1978-1980, personal communications, U.S. DOE, METC, Morgantown, West Virginia.

Dunham, R. J., 1962. Classification of Carbonate Rocks According to Depositional Texture: in W. E. Ham (Ed.), pp. 108-121, AAPG, Tulsa, Oklahoma.

Evans, M., 1980. Fractures in Oriented Devonian Shale Core from the Appalachian Basin, unpublished Master's Thesis, Vol. 1, UGR #259.

Geological Society of America, 1948. Rock Color Chart: Geological Society of America, Boulder, Colorado.

Gruy Federal, Inc., 1978-1980. Various Preliminary Reports, U.S. DOE, METC, Morgantown, West Virginia.

Kulander, B. R., et al., 1977. Fractographic Logging for Determination of Precore and Core-Induced Fractures, Nicholas Combs No. 7239 Well, Hazard, Kentucky: U.S. Department of Energy, MERC/CR-7713, Morgantown, West Virginia.

Ragan, D. M., 1968. Structural Geology, An Introduction to Geometrical Techniques: Second Edition, John Wiley and Sons, Inc., New York, New York.

Renton, J., 1980. Geochemical Analysis of Selected Samples in the EGSP-Tennessee #9: unpublished report, West Virginia Economic and Geologic Survey, Morgantown, West Virginia.

Shoemaker, R., 1978-1981, personal communications, Department of Geology, West Virginia University, Morgantown, West Virginia.

APPENDIX A

TABULATION OF REPORTS PREPARED BY CLIFFS MINERALS, INC.

Of the cores retrieved during the life of the project, Cliffs Minerals, Inc. retrieved approximately 1/2. The following list shows which ones were done by Cliffs and reports prepared.

TABULATION OF CORES RETRIEVED AND REPORTS PREPARED BY CLIFFS MINERALS, INC.

EGSP #	County	Feet Retrieved	Year Cored	Reports Prepared
MI #1	Otsego Co.	103.0	1980	Phase I, Phase II, Phase III
MI #2	Otsego Co.	249.0	1980	Phase I, Phase II, Phase III
IL #5	Wayne Co.	278.0	1979	No Reports - IGS Handled Core - Cliffs Sampled
NY #1	Allegany Co.	1,551.2	1978	Report of Field Operations, Phase II, Phase III
NY #2	Allegany Co.	----	1980	Phase I, No Phase II or Phase III - No Core
NY #3	Steuben Co.	60.2	1980	Phase I, Phase II, Phase III
NY #4	Steuben Co.	132.5	1980	Phase I, Phase II, Phase III
PA #1	McKean Co.	736.3	1980	Phase I, Phase II, Phase III
PA #2	Allegheny Co.	542.9	1979	Phase I, Phase II, Phase III
PA #3	Erie Co.	392.4	1979	Phase I, Phase II, Phase III
PA #4	Indiana Co.	892.8	1979	Phase I, Phase II, Phase III
PA #5	Lawrence Co.	586.5	1979	Phase I, Phase II, Phase III

EGSP #	County	Feet Retrieved	Year Cored	Reports Prepared
WV #5	Mason Co.	648.0	1977	No Field Report-WVGS Handled Core-Phase II, III
WV #6	Monongalia Co.	350.0	1978	No Field Report-WVGS Handled Core-Phase II, III
WV #7	Wetzel Co.	533.5	1978	Report of Field Operations, Phase II, Phase III
OH #3	Knox Co.	679.8	1979	Report of Field Operations, Phase II, Phase III
OH #4	Ashtabula Co.	435.2	1979	Phase I, Phase II, Phase III
OH #5	Lorain Co.	880.7	1979	Phase I, Phase II, Phase III
OH #6-1	Gallia Co.	169.8	1979	
OH #6-2	Gallia Co.	175.5	1979	
OH #6-3	Gallia Co.	69.7	1979	Combined Phase I, Phase II, Phase III Reports
OH #6-4	Gallia Co.	933.3	1979	
OH #6-5	Gallia Co.	174.8	1979	
OH #7	Trumbull Co.	1,210.4	1979	Phase I, Phase II, Phase III
OH #8	Noble Co.	1,346.0	1980	Phase I, Phase II, Phase III
OH #9	Meigs Co.	458.0	1981	Phase I, Phase II, No Phase III
KY #4	Johnson Co.	510.0	1978	Report of Field Operations, Phase II, Phase III
TN #1	Clairbourn Co.	245.0	1978	No Reports - Tennessee GS Handled Core
TN #2	Clairbourn Co.	106.0	1978	No Reports - Tennessee GS Handled Core

EGSP #	County	Feet Retrieved	Year Cored	Reports Prepared
TN #3	Hancock Co.	751.0	1978	No Reports - Tennessee GS Handled Core
TN #4	Hawkins Co.	1,516.0	1978	No Reports - Tennessee GS Handled Core
TN #5	Hawkins Co.	200.0	1978	No Reports - Tennessee GS Handled Core
TN #6	Hawkins Co.	650.0	1978	No Reports - Tennessee GS Handled Core
TN #7	Hawkins Co.	750.0	1978	No Reports - Tennessee GS Handled Core
TN #8	Hawkins Co.	-----	1978	No Reports - No Core
TN #9	Grainger Co.	216.8	1979	Phase I, Phase II, Phase III

APPENDIX B

TABULATION OF REPORTS NOT PREPARED BY CLIFFS MINERALS, INC.

TABULATION OF CORES NOT RETRIEVED AND REPORTS NOT PREPARED BY CLIFFS MINERALS, INC.

EGSP #	County	Reports Prepared
IL #1	Effingham Co.	"Evaluation of Devonian Shale Potential in the Illinois Basin (Illinois, Indiana and Western Kentucky)," DOE/METC-124, 1980.
IL #2	Henderson Co.	Same As IL #1
IL #3	Tazewell Co.	Same As IL #1
IL #4	Hardin Co.	Same As IL #1
IN #1	Sullivan Co.	Same As IL #1
IN #2	Clark Co.	Same As IL #1
KY #1	Perry Co.	"Lithologic Description of Core Material from Nicholas Combs No. 7239 Well, Perry County, Kentucky," C. W. Byrer and D. B. Trumbo, MERC/TPR-76/2, May 1976.
KY #2	Christian Co.	Same As IL #1
KY #3	Martin Co.	No Reports.

EGSP #	County	Reports Prepared
OH #1	Carroll Co.	"Lithologic Description of Core Material from Glen Gery #5-745 Well, Rose Township, Carroll County, Ohio," C. W. Byrer and J. J. Rhoades, MERC/TPR-76/6, October 1976.
OH #2	Washington Co.	"Lithologic Description and Analysis of Cored Well #R-109, Washington County, Ohio," Michael K. Vickers, et al., West Virginia Geological Survey, 1978.
VA #1	Wise Co.	No Reports.
WV #1	Jackson Co.	"Lithologic Description of Cored Wells #11940 and #12041 in the Devonian Shale in the Cottageville, West Virginia Area," C. W. Byrer, et al., MERC/TPR-76/7, October 1976.
WV #2	Jackson Co.	Same As WV #1
WV #3	Lincoln Co.	"Prediction of In-Situ Stresses from Directional Properties of Rock Cores for Field Development of Devonian Shales," Syd S. Peng and Seisuke Okubo, West Virginia University, July 1978.
WV #4	Lincoln Co.	"Lithologic Description of Cored Wells #20402 and #20403 in the Devonian Shale in Lincoln County, West Virginia," C. W. Byrer, et al, MERC/TPR-76/9, October 1976.
WV #5	Mason Co.	"Fracture Density and Orientation Study of the Reel Energy #3 D/K Core from Mason County, West Virginia," Mark Evans, West Virginia University, 1978.

APPENDIX C

CORES RETRIEVED BY CLIFFS MINERALS, INC.

EGSP Well No.	County	Date Drilled	Feet Recovered	Participating Company & Well Designation
1978				
NY #1	Allegany	09/78	1,651.2'	NY Natural Gas #6213 (Jo)
WV #7	Wetzel	10/78	533.5'	Mobay Chemical Co., Emch & Pyles Unit #1
KY #4	Johnson	12/78	529.6'	Ashland Oil Co., Skaggs-Kelly Unit #3-RS
IL #4	Hardin	12/78	221.0'	Rector & Stone Drilling Co., Missouri Portland #1
		Total Year	2,935.3'	
1979				
PA #1	McKean	02/79	736.3'	Minard Run Oil Co., Exploration #1
PA #2	Allegheny	03/79	542.9'	C. E. Power Systems, Combustion Engr., Inc. #1
OH #3	Knox	04/79	679.8'	Thurlow Weed & Assoc., Louise Beckholt #1
OH #4	Ashtabula	08/79	435.2'	Monsanto Research/U.S. Steel
OH #5	Lorain	09/79	880.7'	Columbia Gas #20149-T
OH #6-1	Gallia	09/79	169.8'	Mitchell Energy Corp., #1-5
PA #3	Erie	09/79	392.4'	Monsanto Research/PA D.E.R., State Park #1
OH #6-2	Gallia	10/79	175.5'	Mitchell Energy Corp. #1-7
OH #6-3	Gallia	10/79	69.7'	Mitchell Energy Corp. #1-6
OH #7	Trumbull	10/79	1,210.4'	Columbia Gas #20143-T
IL #5	Wayne	10/79	272.4'	Gruy Federal #1 Simpson
PA #4	Indiana	11/79	892.8'	Angerman Gas #1
OH #6-4	Gallia	11/79	933.3'	Mitchell Energy Corp., #1-8
OH #6-5	Gallia	12/79	174.8'	Mitchell Energy Corp., #1-9
PA #5	Lawrence	12/79	586.5'	Peoples Gas Co., Farm #1
		Total Year	8,152.5'	

EGSP Well No.	County	Date Drilled	Feet Recovered	Participating Company & Well Designation
1980				
MI #1	Otsego	01/80	103.0'	Wolverine Gas & Oil 4-40 Club 1-35
TN #9	Grainger	01/80	216.8'	Gruy Federal #1
OH #8	Noble	03/80	1,346.0'	Donahue, Anstey & Morrill, Shockling #1
NY #2	Allegany	06/80	-0-	Joyce Management
NY #3	Steuben	07/80	60.2'	Donahue, Anstey & Morrill, Scudder #1
NY #4	Steuben	07/80	132.5'	Donahue, Anstey & Morrill, Valley Vista View #1
MI #2	Otsego	08/80	249.0'	Murell Welch, Inc. State Chester #1-18
		Total Year	2,107.5'	
1981				
OH #9	Meigs	01/81	458.0'	Columbia Gas #10056-A
		Total Year	458.0'	
		CUMULATIVE TOTAL	13,653.3'	

APPENDIX D

EGSP REPORTS ISSUED

CORE NAME	REPORTS ISSUED		
MI #1	Phase I	Phase II	Phase III
MI #2	Phase I	Phase II	Phase III
IL #1		ILGS Responsibility	
IL #2		ILGS Responsibility	
IL #3		ILGS Responsiblity	
IL #4	Field Report	ILGS Responsibility-Cliffs Only Sampled	
IL #5	Phase I	ILGS Responsibility-Cliffs Only Sampled	
NY #1	Phase I	Phase II	Phase III
NY #2	No Core Retrieved -- No Reports Issued.		
NY #3	Phase I	Phase II	Phase III
NY #4	Phase I	Phase II	Phase III
PA #1	Field Report	Phase II	Phase III
PA #2	Phase I	Phase II	Phase III
PA #3	Phase I	Phase II	Phase III
PA #4	Phase I	Phase II	Phase III
PA #5	Phase I	Phase II	Phase III
WV #1		WVGS Responsibility	
WV #2		WVGS Responsibility	
WV #3		WVGS Responsibility	
WV #4		WVGS Responsibility	
WV #5	WVGS Responsibility	Phase II	Phase III
WV #6	WVGS Responsibility	Phase II	Phase III
WV #7	Phase I	Phase II	Phase III
OH #1		WVGS Responsibility	
OH #2		WVGS Responsibility	
OH #3	Field Report	Phase II	Phase III

CORE NAME	REPORTS ISSUED		
OH #4	Phase I	Phase II	Phase III
OH #5	Phase I	Phase II	Phase III
OH #6-1	Phase I		
OH #6-2	Phase I		
OH #6-3	Phase I	OH #6 Series Phase II	Series Phase III
OH #6-4	Phase I		
OH #6-5	Phase I		
OH #7	Phase I	Phase II	Phase III
OH #8	Phase I	Phase II	Phase III
OH #9	Phase I	Phase II	
KY #1		WVGS Responsibility	
KY #2		WVGS Responsibility	
KY #3		WVGS Responsibility	
KY #4	Field Report	Phase II	Phase III
TN #1		TNGS Responsibility	
TN #2		TNGS Responsibility	
TN #3		TNGS Responsibility	
TN #4		TNGS Responsibility	
TN #5		TNGS Responsibility	
TN #6		TNGS Responsibility	
TN #7		TNGS Responsibility	
TN #8		TNGS Responsibility	
TN #9	Phase I	Phase II	Phase III
VA #1		WVGS Responsibility	
Dow Chemical		Phase II	Phase III
IN #1		ILGS Responsibility	
IN #2		ILGS Responsibility	

U. S. DEPARTMENT OF ENERGY

MORGANTOWN ENERGY TECHNOLOGY CENTER

EASTERN GAS SHALES PROJECT

CLIFFS MINERALS INC.

PREPARED UNDER
CONTRACT NO. DE-AO21-78MC08199

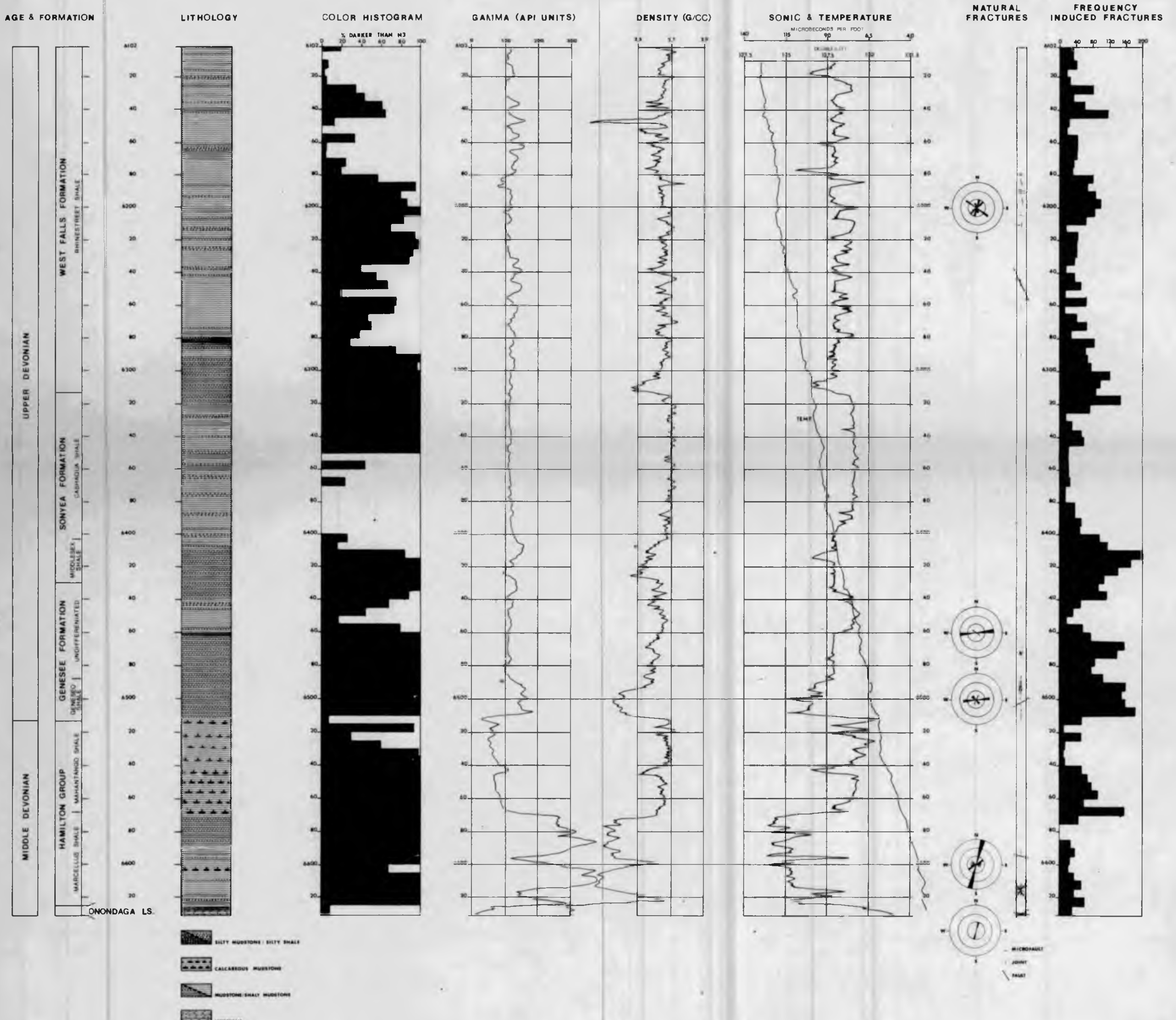
EGSP-WEST VIRGINIA NO. 7, WETZEL CO.

WELL: EMCH & PYLES NO.1

A. P. I. NO.: 47-103-20645

DRILLING COMPLETED: OCTOBER 17, 1978

DRAWN: FEBRUARY 1981



CLIFFS MINERALS INC.

PREPARED UNDER
CONTRACT NO. DE-AC21-78MC08199

U. S. DEPARTMENT OF ENERGY
MORGANTOWN ENERGY TECHNOLOGY CENTER
EASTERN GAS SHALES PROJECT

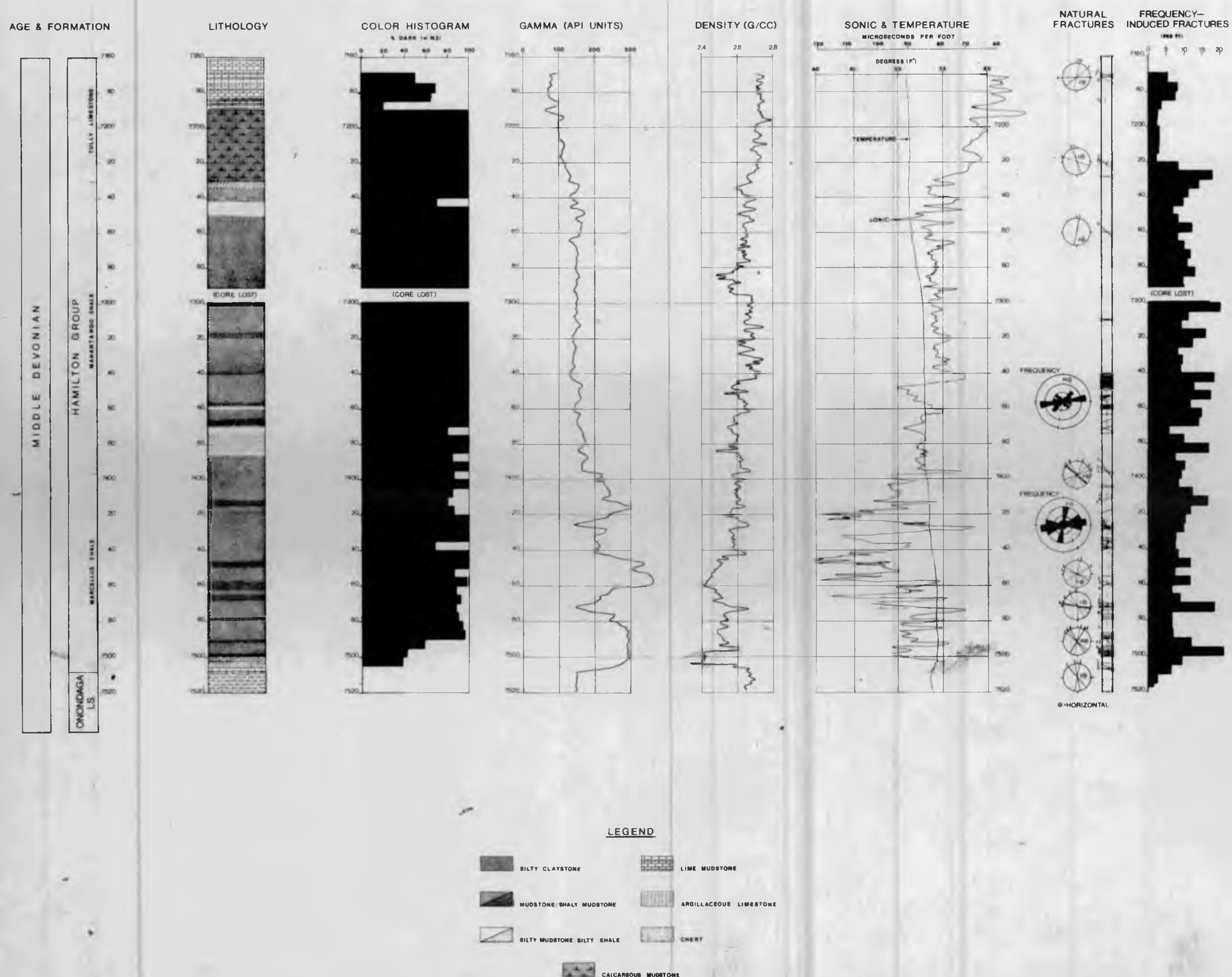
EGSP WV-6, MONON ALIA CO.

WELL M.E.R.C. # 1

A.P.I. NO. 47-061-20370

DRILLING COMPLETED APRIL, 1978

DRAWN JULY, 1979



U. S. DEPARTMENT OF ENERGY

MORGANTOWN ENERGY TECHNOLOGY CENTER

EASTERN GAS SHALES PROJECT

CLIFFS MINERALS INC.

PREPARED UNDER
CONTRACT NO. DE-AC21-78MC08199

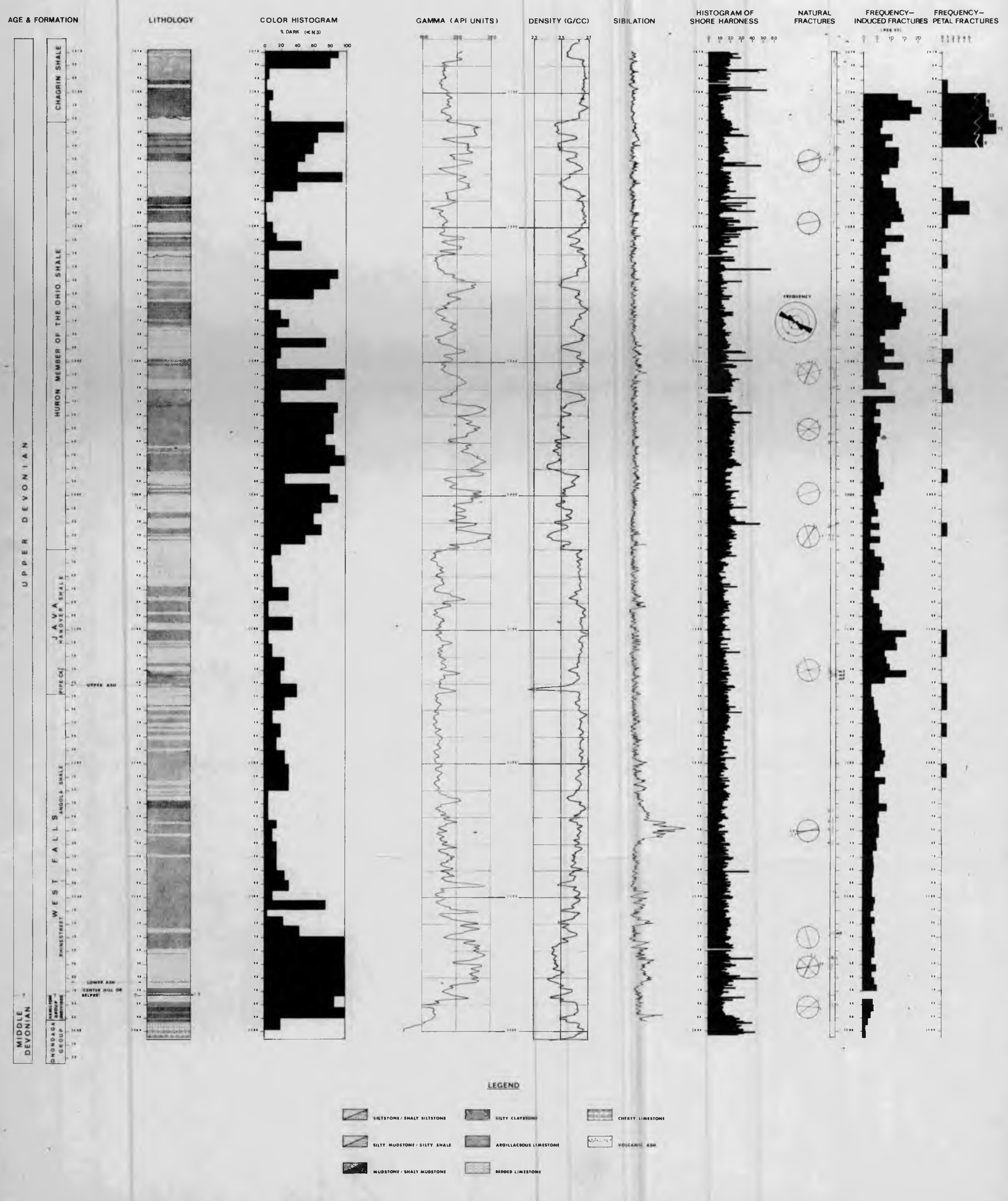
EGSP WV-5, MASON CO.

WELL: D K FARM #3

A.P.I. NO. 47-053-20146

DRILLING COMPLETED: JANUARY 6, 1978

DRAWN: JUNE, 1979



U. S. DEPARTMENT OF ENERGY

MORGANTOWN ENERGY TECHNOLOGY CENTER

EASTERN GAS SHALES PROJECT

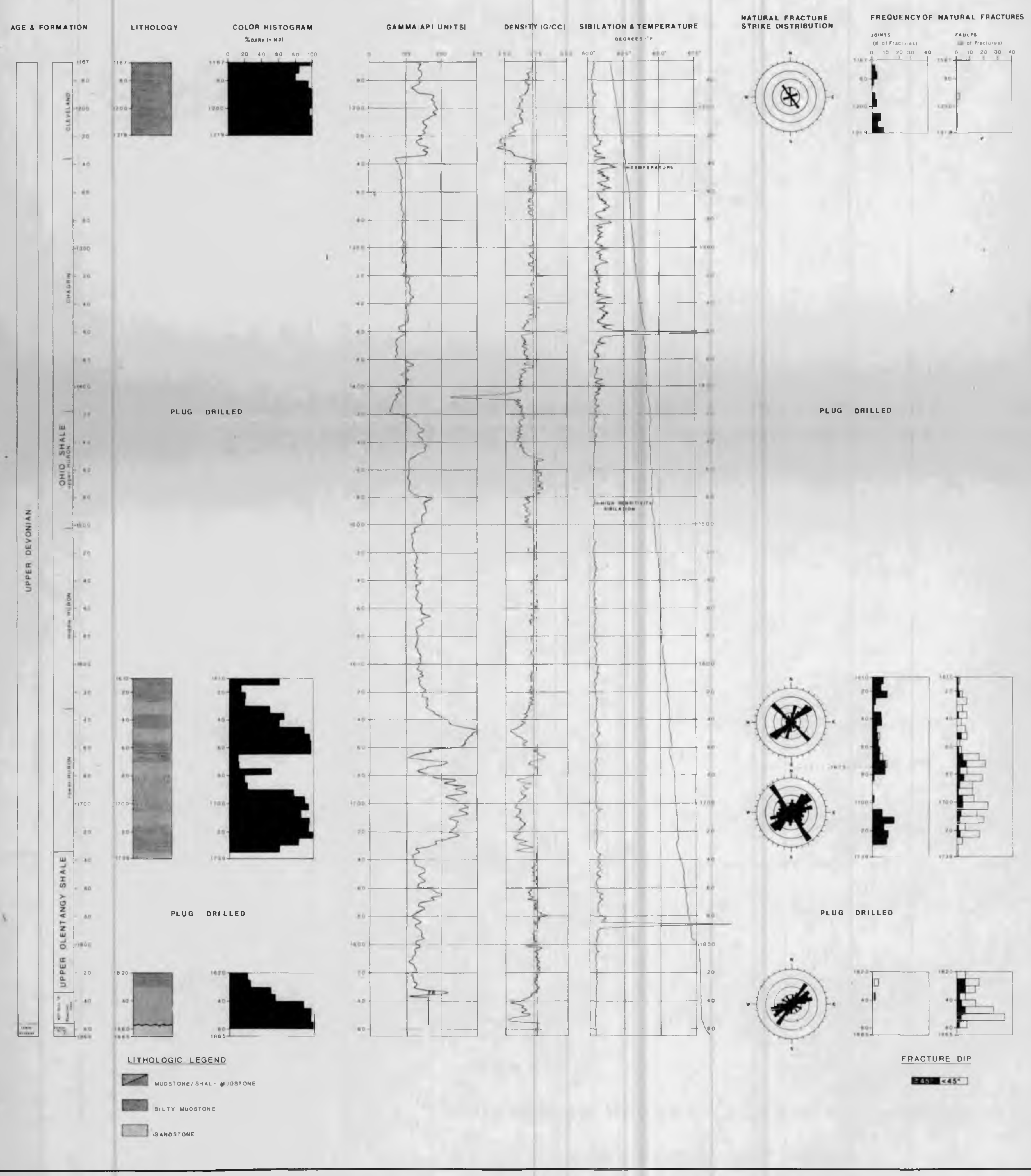
CLIFFS MINERALS INC.

PREPARED UNDER
CONTRACT NO. DE-AC21-78MC08199

EGSP TN-9, GRAINGER CO.

WELL GRUY FEDERAL #1

DRILLING COMPLETED JAN 1, 1980 DRAWN JUNE 1980



U. S. DEPARTMENT OF ENERGY

MORGANTOWN ENERGY TECHNOLOGY CENTER

EASTERN GAS SHALES PROJECT

CLIFFS MINERALS INC.

PREPARED UNDER
CONTRACT NO. DE-AC21-78MC08199

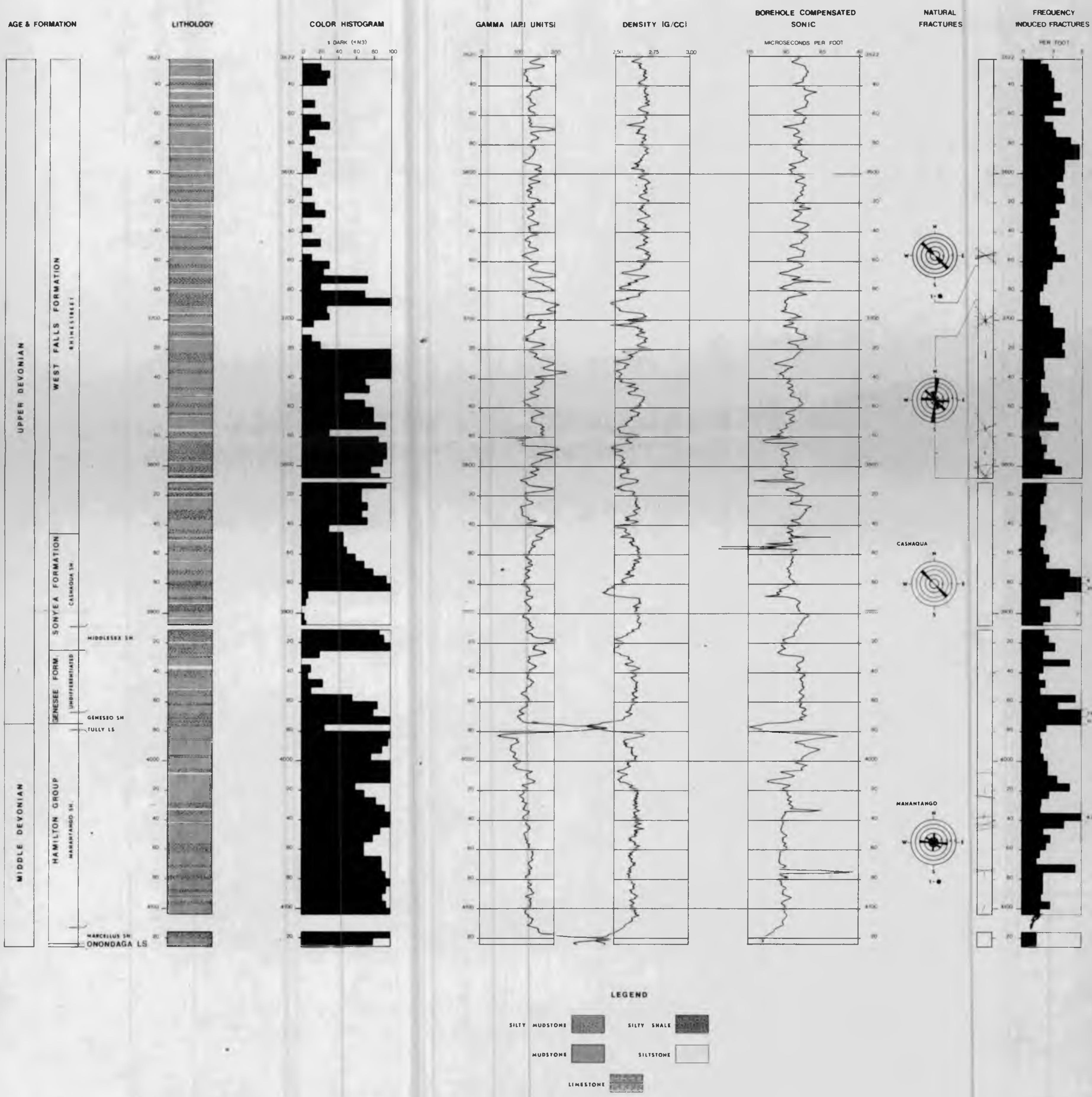
EGSP-PENNSYLVANIA NO. 5, LAWRENCE CO.

WELL: C. SOKEVITZ NO.1

A.P.I. NO. 37-073-20022

DRILLING COMPLETED: DECEMBER 14, 1979

DRAWN: FEBUARY 1981



CLIFFS MINERALS INC.

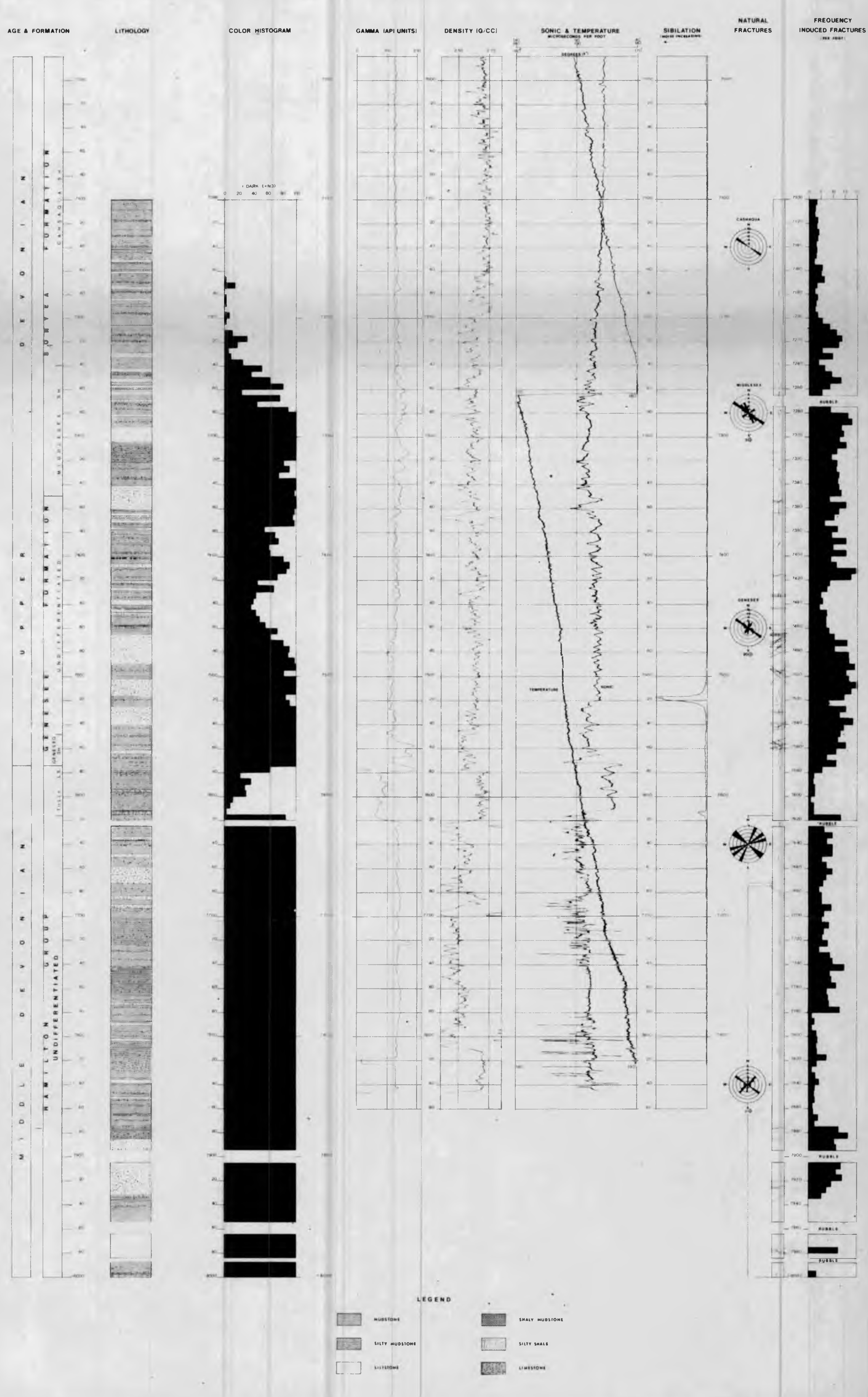
PREPARED UNDER
CONTRACT NO DE AC21 78MC08199

U. S. DEPARTMENT OF ENERGY
MORGANTOWN ENERGY TECHNOLOGY CENTER
EASTERN GAS SHALES PROJECT

EGSP-PENNSYLVANIA NO. 4, INDIANA CO.

WELL: GLENN McCALL #5 | A.P.I. NO. 37-063-25073

DRILLING COMPLETED: NOVEMBER 20, 1979 | DRAWN: FEBUARY 1981



U. S. DEPARTMENT OF ENERGY

MORGANTOWN ENERGY TECHNOLOGY CENTER

EASTERN GAS SHALES PROJECT

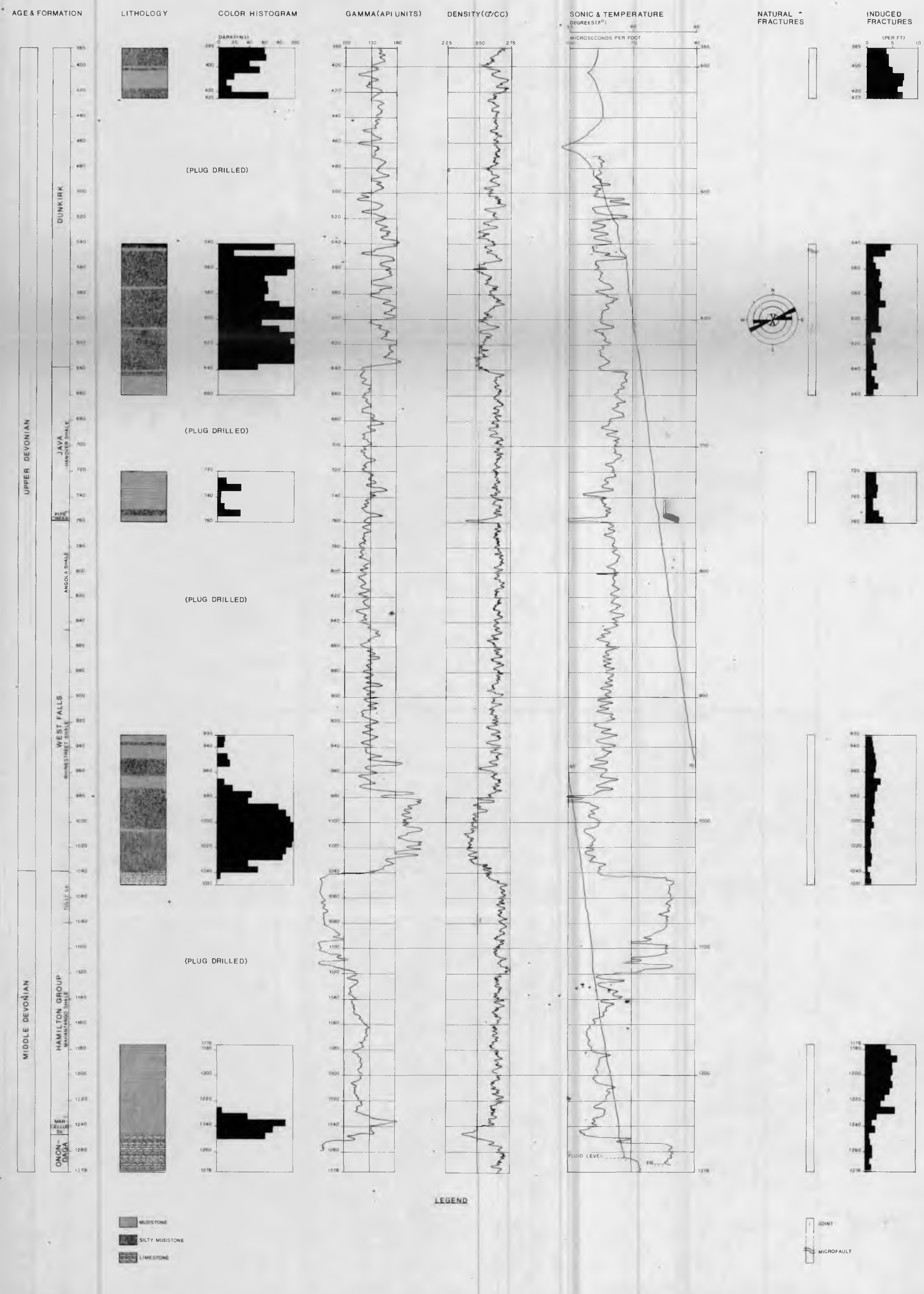
CLIFFS MINERALS INC.

PREPARED UNDER
CONTRACT NO. DE-AC21-78MC08199

EGSP - PENNSYLVANIA 3, ERIE CO.

WELL: PRESQUE ISLE STATE PARK #1 — A.P.I. NO.: 37-049-20846

DRILLING COMPLETED: OCTOBER 1979 — DRAWN: OCTOBER 1980



U. S. DEPARTMENT OF ENERGY
MORGANTOWN ENERGY TECHNOLOGY CENTER
EASTERN GAS SHALES PROJECT

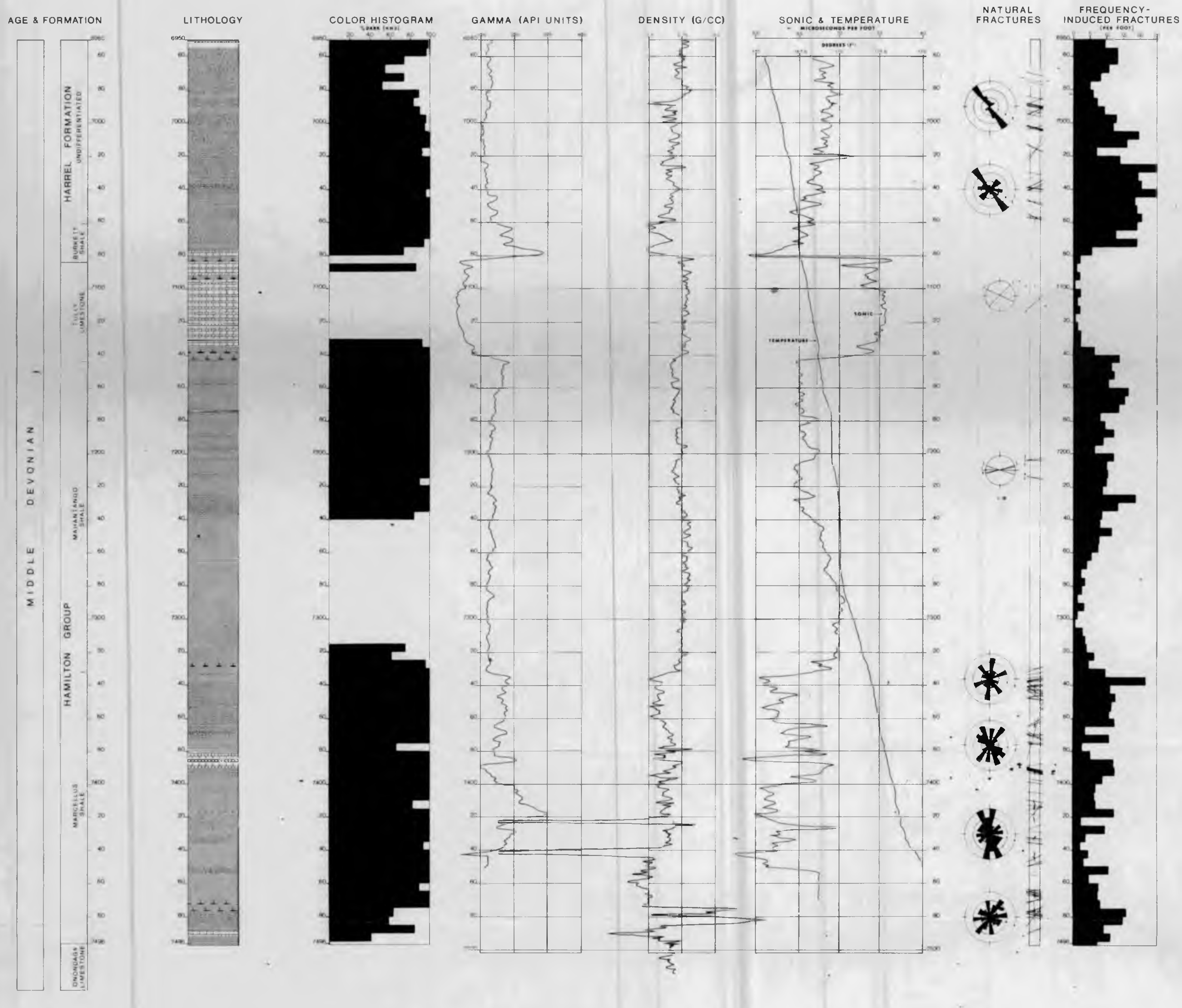
CLIFFS MINERALS INC.

PREPARED UNDER
CONTRACT NO. DE-AC21-78MC08199

EGSP PA-2, ALLEGHENY CO.

WELL: CE #1 | A.P.I. NO.: 37-003-20980

DRILLING COMPLETED: MARCH 1979 | DRAWN: FEBRUARY 1980



LEGEND

MUDSTONE / SHALY MUDSTONE

SILTY MUDSTONE / SILTY SHALE

LIMESTONE

SILTSTONE

CALCAREOUS MUDSTONE

CLIFFS MINERALS INC.

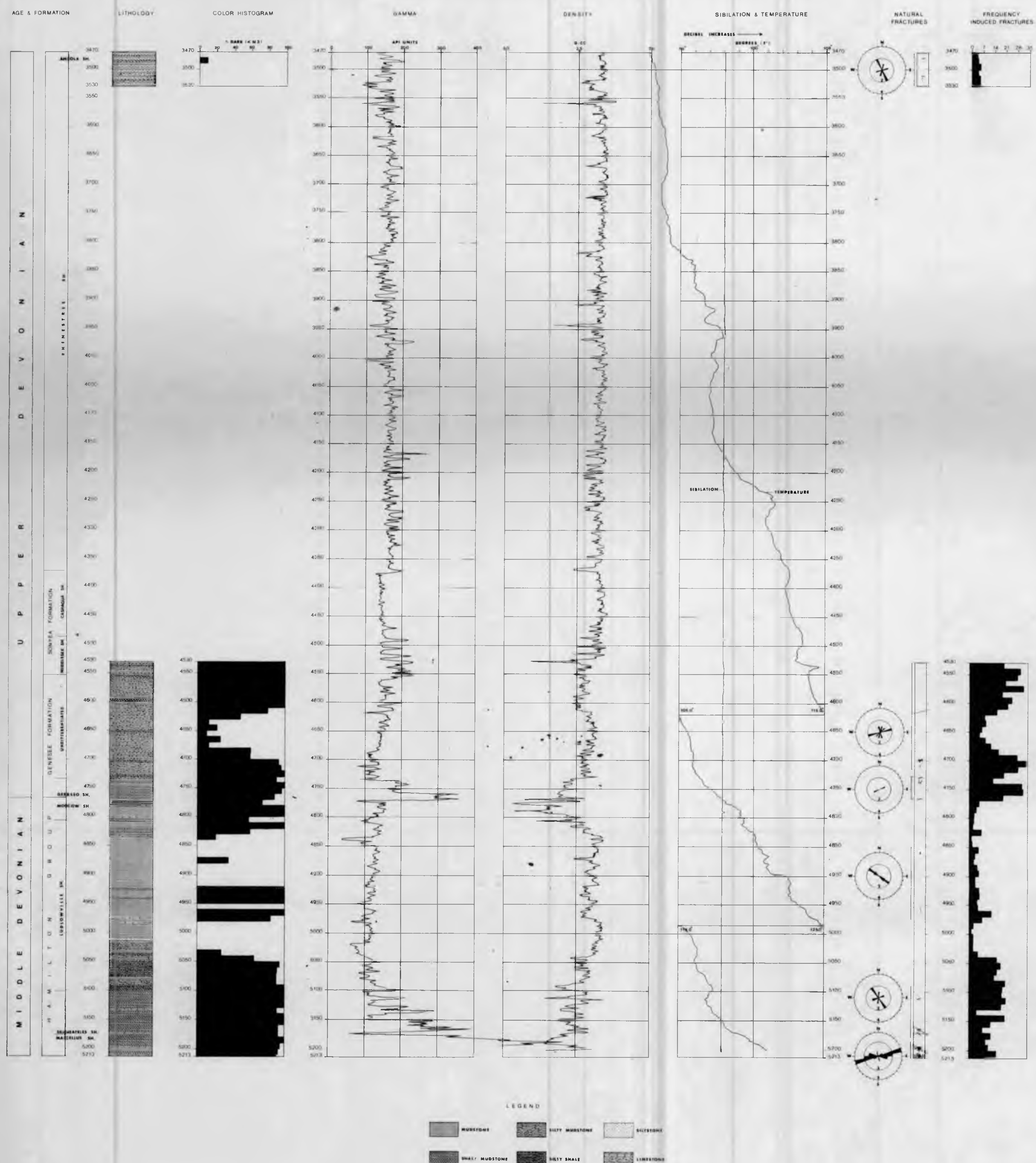
PREPARED UNDER
CONTRACT NO. DE AC21 78MC08199

U. S. DEPARTMENT OF ENERGY
MORGANTOWN ENERGY TECHNOLOGY CENTER
EASTERN GAS SHALES PROJECT

EGSP PA-1, MCKEAN CO.

WELL: M.R. EX #1 — A.P.I. NO. 37-083-37291

DRILLING COMPLETED: FEBRUARY 22, 1979 — DRAWN: MAY, 1981



CLIFFS MINERALS INC.

PREPARED UNDER
CONTRACT NO DE-AC21-78MC08199

U. S. DEPARTMENT OF ENERGY

MORGANTOWN ENERGY TECHNOLOGY CENTER

EASTERN GAS SHALES PROJECT

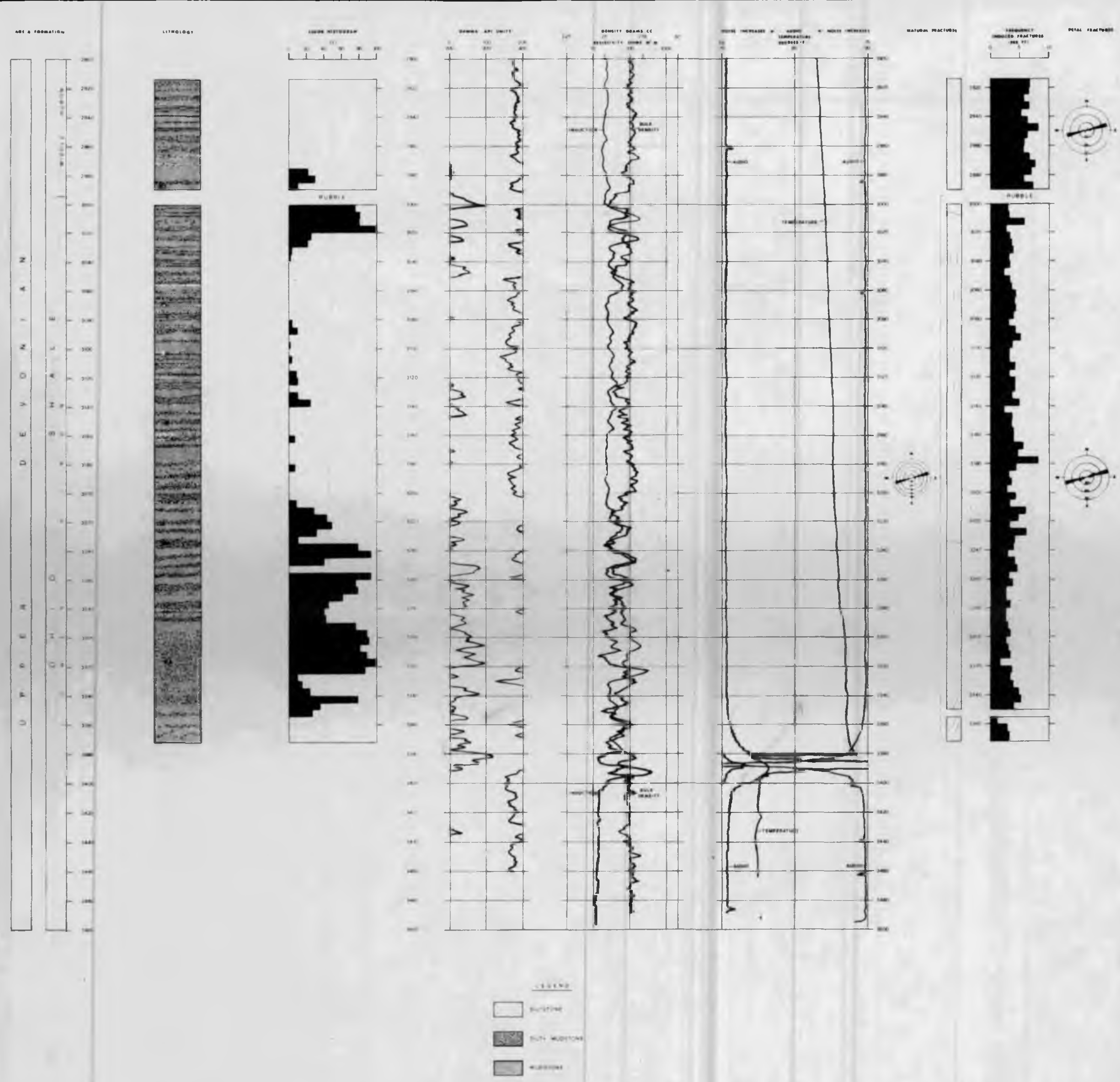
EGSP OH-9, MEIGS CO.

WELL COLUMBIA GAS # 10056-A

A P I NO 34-105-22058

DRILLING COMPLETED FEBRUARY 10 1981

DRAWN MAY 1981



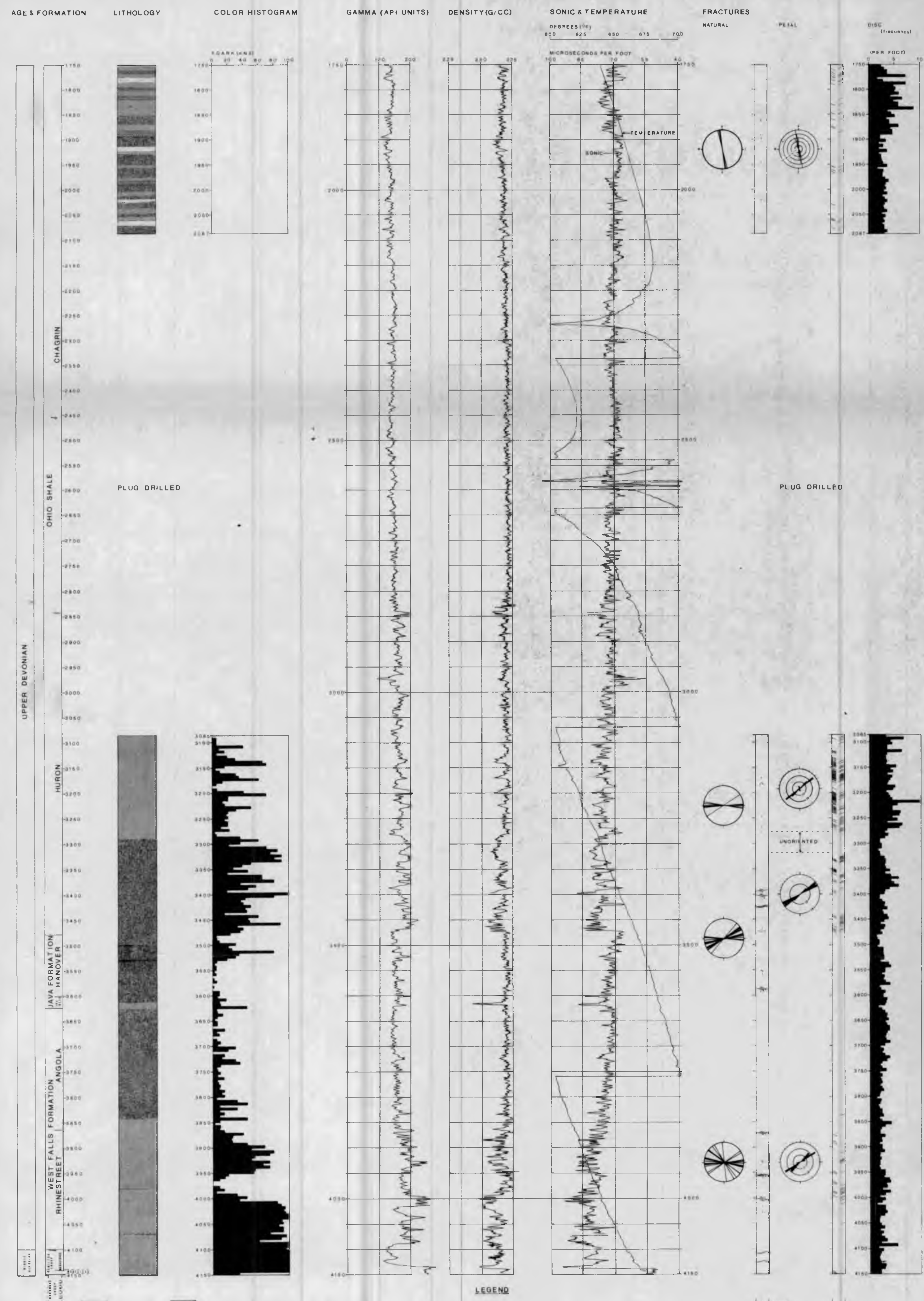
CLIFFS MINERALS INC.

PREPARED UNDER
CONTRACT NO. DE-AC21-78MC08199

U. S. DEPARTMENT OF ENERGY
MORGANTOWN ENERGY TECHNOLOGY CENTER
EASTERN GAS SHALES PROJECT
EGSP-OHIO #8, NOBLE CO.

WELL: SCHOCKLING #1 | A.P.I. NO.: 34-121-22255

DRILLING COMPLETED: MARCH 1980 | DRAWN: OCTOBER 1980



U. S. DEPARTMENT OF ENERGY

MORGANTOWN ENERGY TECHNOLOGY CENTER

EASTERN GAS SHALES PROJECT

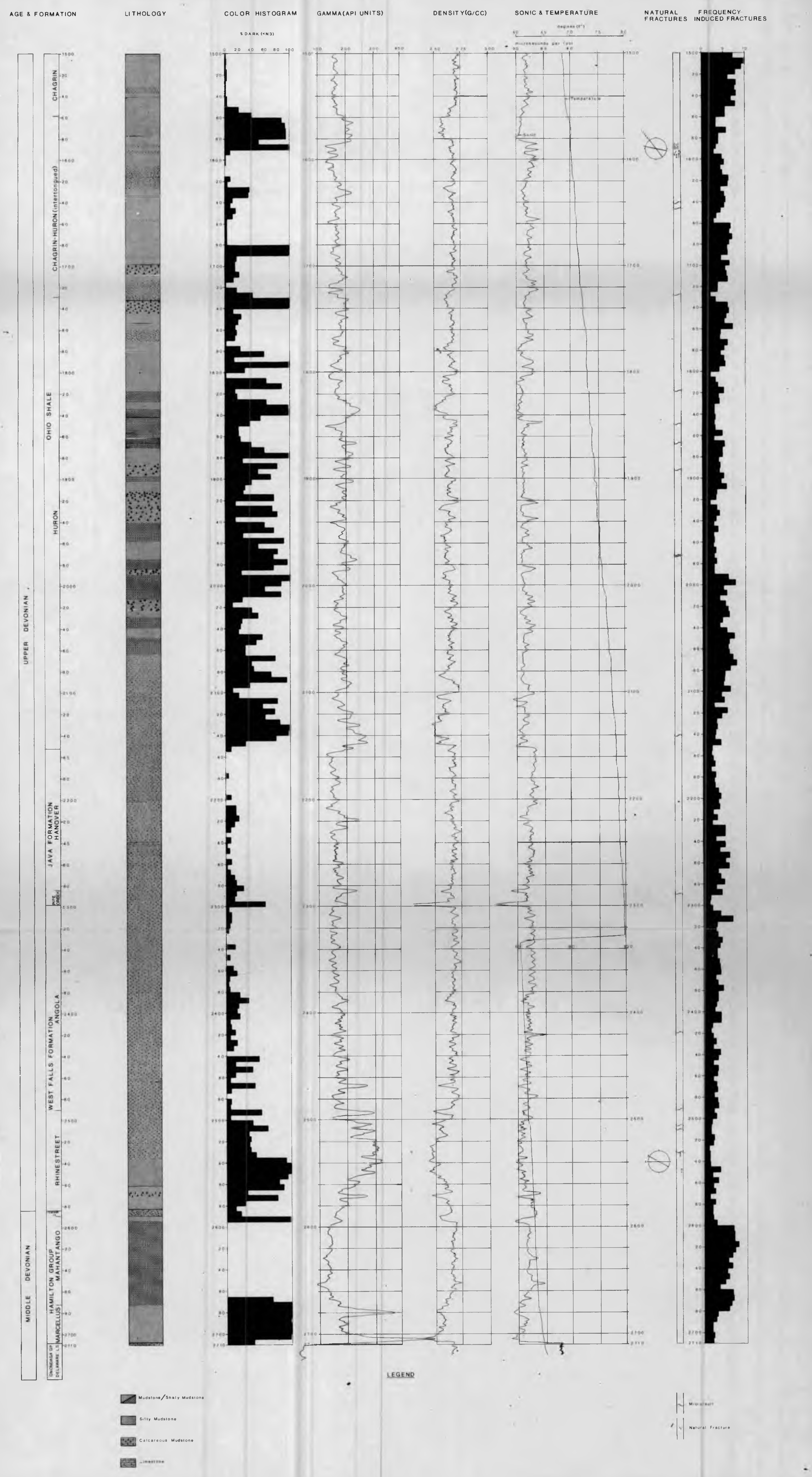
CLIFFS MINERALS INC.

PREPARED UNDER
CONTRACT NO. DE-AC21-78MC08199

EGSP OH-7, TRUMBULL CO.

WELL: OHIO - 7 | API NO.: 34-155-21238

DRILLING COMPLETED OCTOBER 3, 1979 | DRAWN: AUGUST, 1980



CLIFFS MINERALS INC.

PREPARED UNDER
CONTRACT NO. DE-AC21-78MC08199

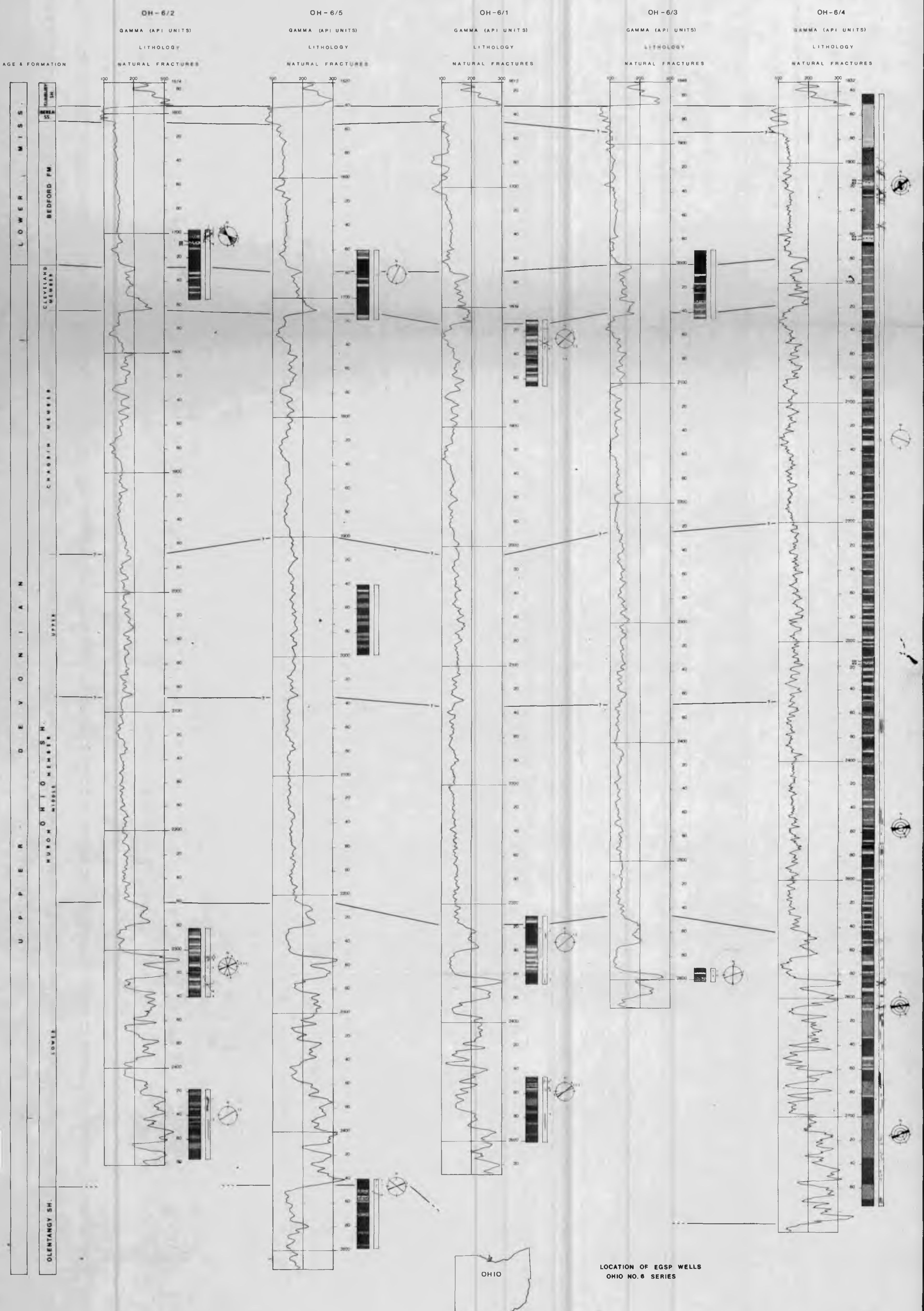
U. S. DEPARTMENT OF ENERGY
MORGANTOWN ENERGY TECHNOLOGY CENTER
EASTERN GAS SHALES PROJECT

EGSP OH-6 SERIES, GALLIA CO.

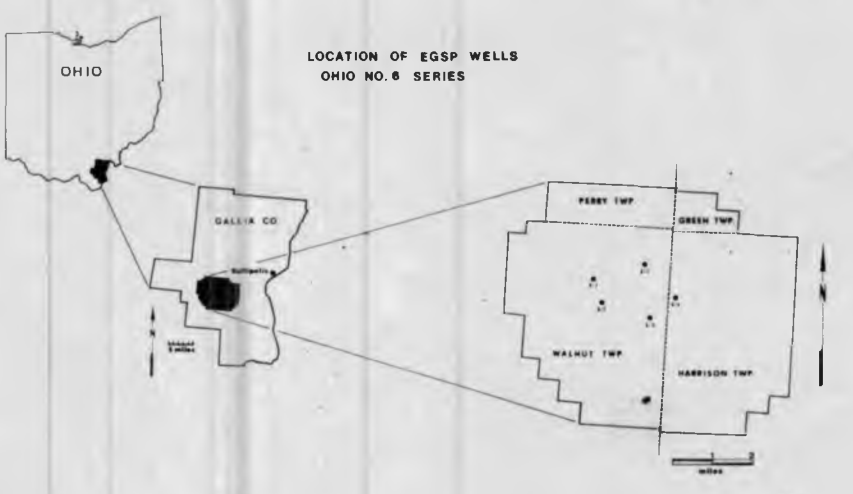
WELL:	A.P.I. NO.:
OH-6/1 (CARPENTER #1-5)	34-053-20482
OH-6/2 (WHITE PRICE NEWBERRY UNIT #1-7)	34-053-20479
OH-6/3 (L. McCOMBS #1-6)	34-053-20474
OH-6/4 (STRAIGHT-WISEMANDLE UNIT #1-8)	34-053-20477
OH-6/5 (M. CARTER #1-9)	34-053-20478

DRILLING COMPLETED: DECEMBER 5, 1979

DRAWN: MAY, 1980



65-69



LOCATION OF EGSP WELLS
OHIO NO. 6 SERIES

LEGEND

MUDSTONE	SILTY MUDSTONE/SILTY SHALE
SHALY MUDSTONE	SILTSTONE
ARGILLACEOUS LIMESTONE	VOLCANIC ASH
SANDSTONE	

CORRELATION DATUM: BASE OF SUNBURY

CLIFFS MINERALS INC.

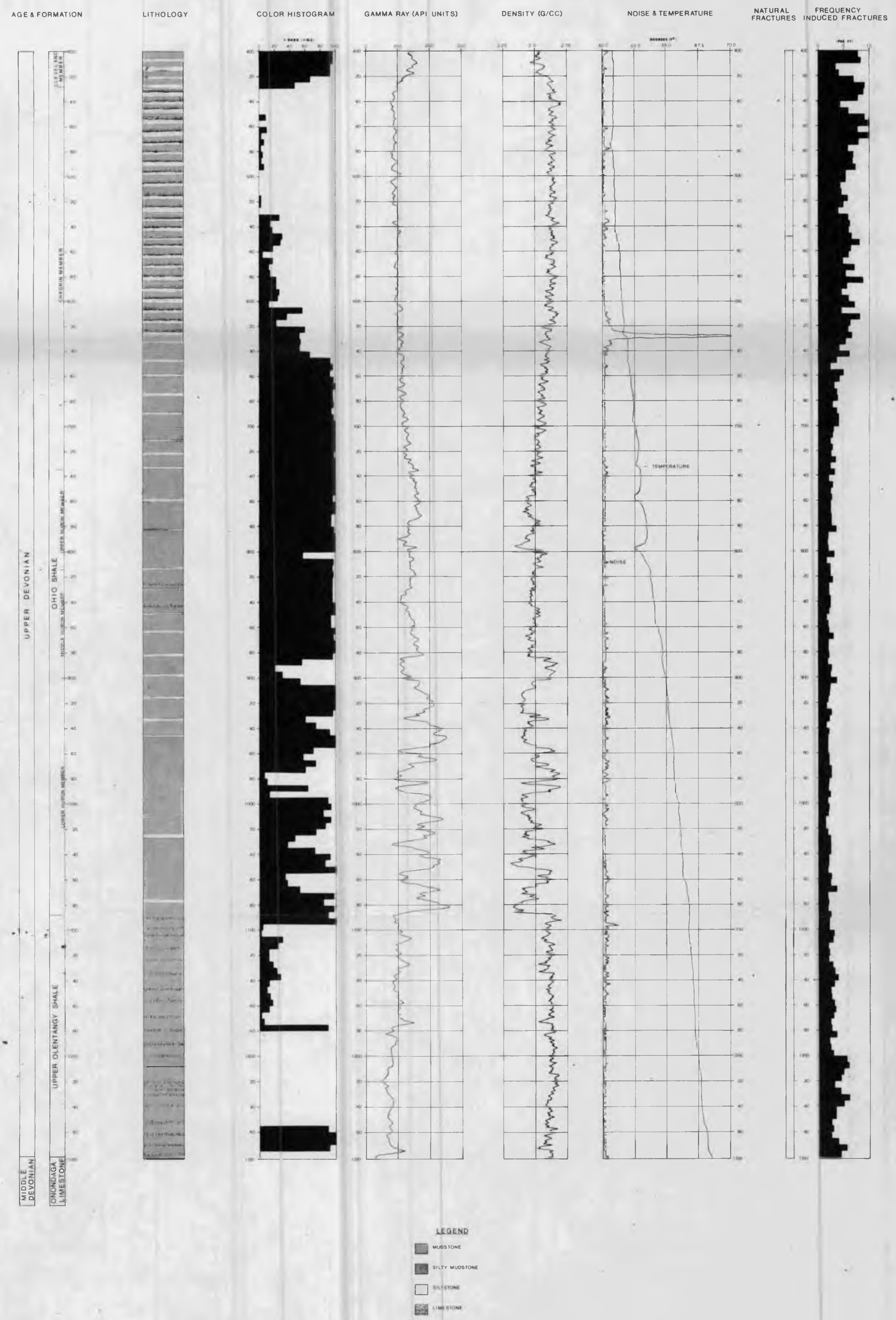
PREPARED UNDER
CONTRACT NO. DE-AC21-78MC08199

U. S. DEPARTMENT OF ENERGY
MORGANTOWN ENERGY TECHNOLOGY CENTER
EASTERN GAS SHALES PROJECT

EGSP OH-5, LORAIN CO

WELL B&R McGUIRE 20149-T | A.P.I. NO 34-093-21103

DRILLING COMPLETED SEPTEMBER 11, 1979 | DRAWN JULY, 1980



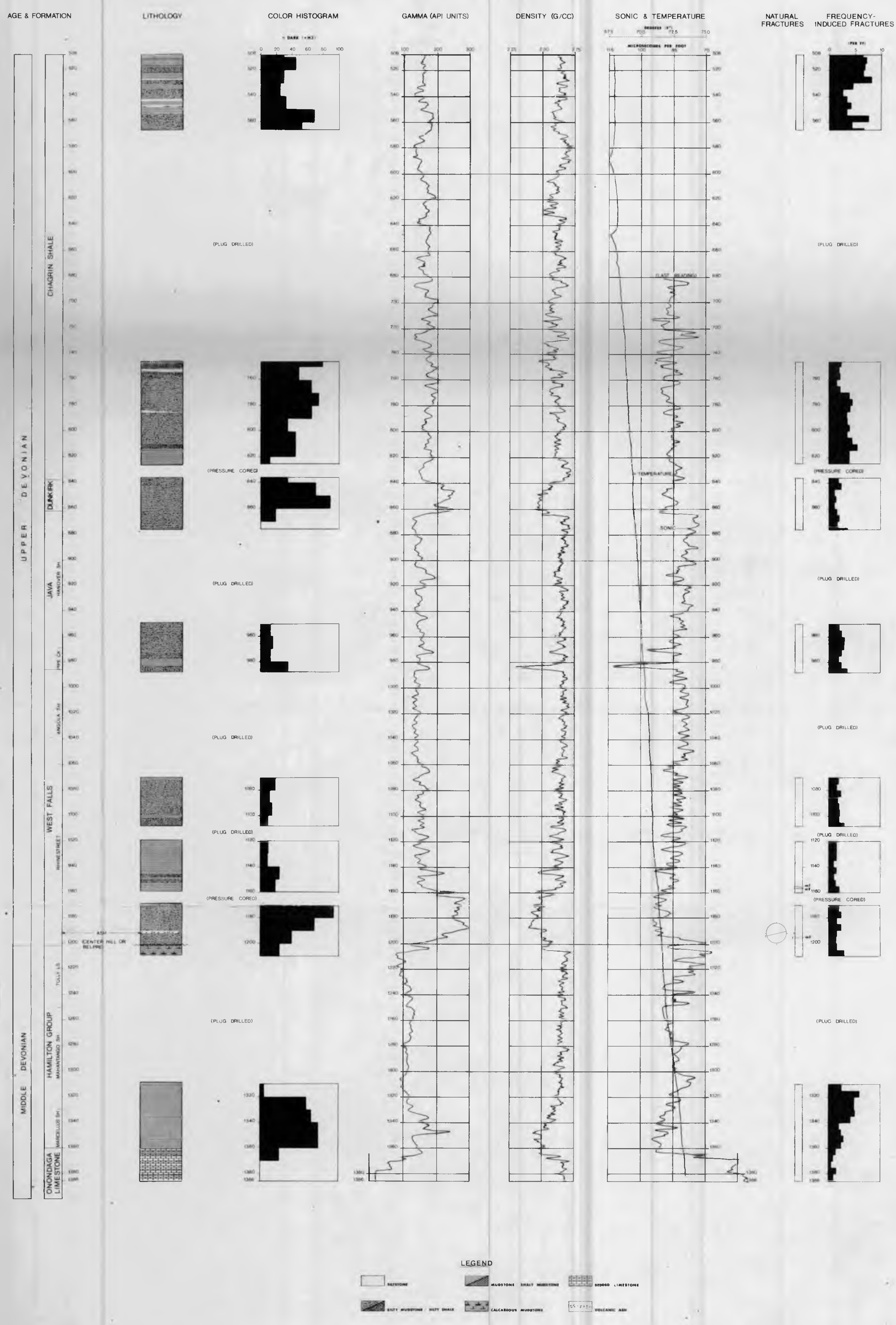
U. S. DEPARTMENT OF ENERGY
MORGANTOWN ENERGY TECHNOLOGY CENTER
EASTERN GAS SHALES PROJECT

CLIFFS MINERALS INC.

PREPARED UNDER
CONTRACT NO. DE-AC21-78MC08199

EGSP OH - 4, ASHTABULA CO.

WELL: OHIO #4
API NO.: 34-007-21087
DRILLING COMPLETED: AUGUST 12, 1979
DRAWN: NOVEMBER, 1979



CLIFFS MINERALS INC.

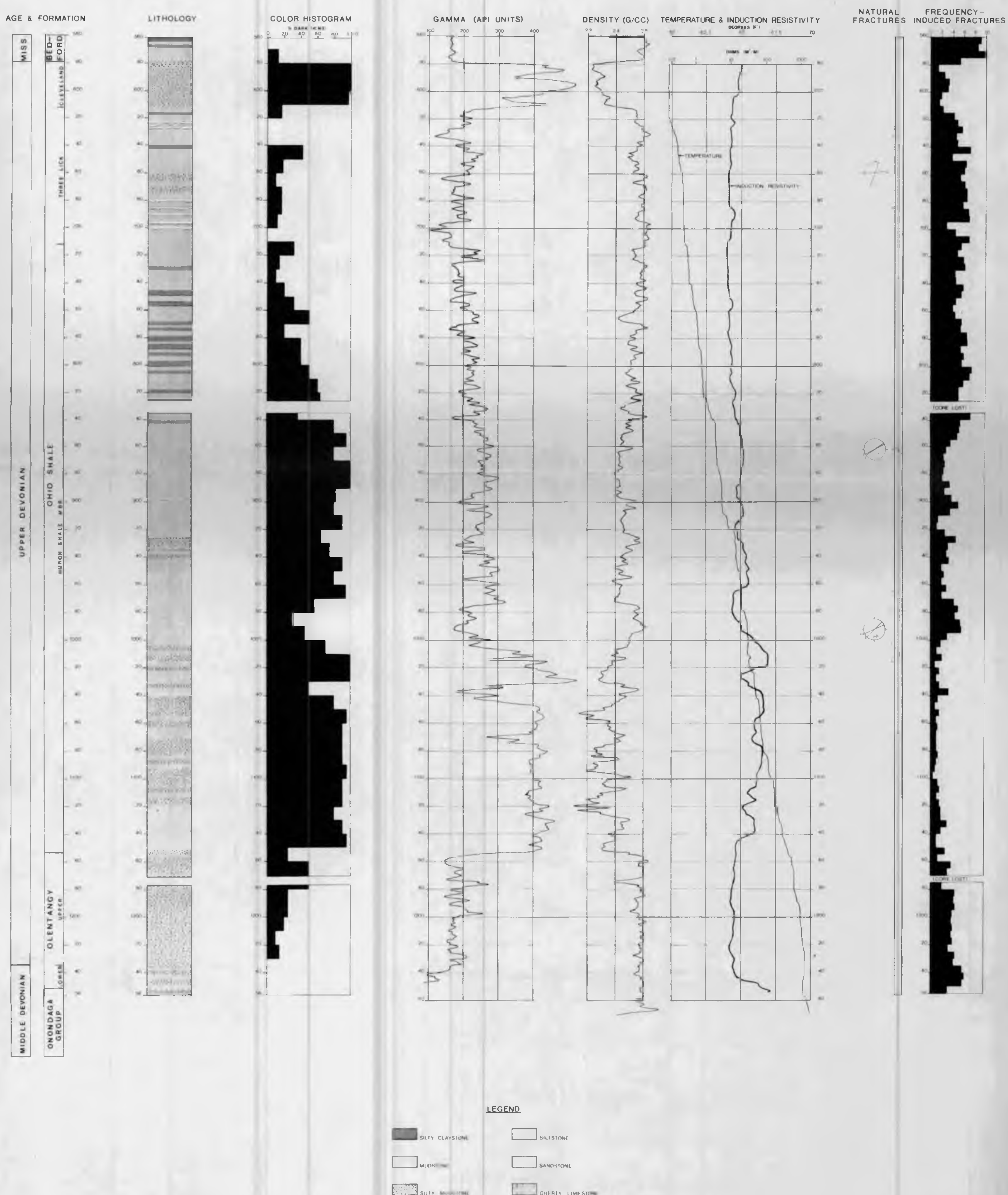
PREPARED UNDER
CONTRACT NO. DE-AC21-78MC08199

U. S. DEPARTMENT OF ENERGY
MORGANTOWN ENERGY TECHNOLOGY CENTER
EASTERN GAS SHALES PROJECT

EGSP OH-3, KNOX CO.

WELL: LOUISE BECKHOLT #1 — A.P.I. NO.: 34-083-22599

DRILLING COMPLETED: APRIL 1979 — DRAWN: JANUARY, 1980



CLIFFS MINERALS INC.

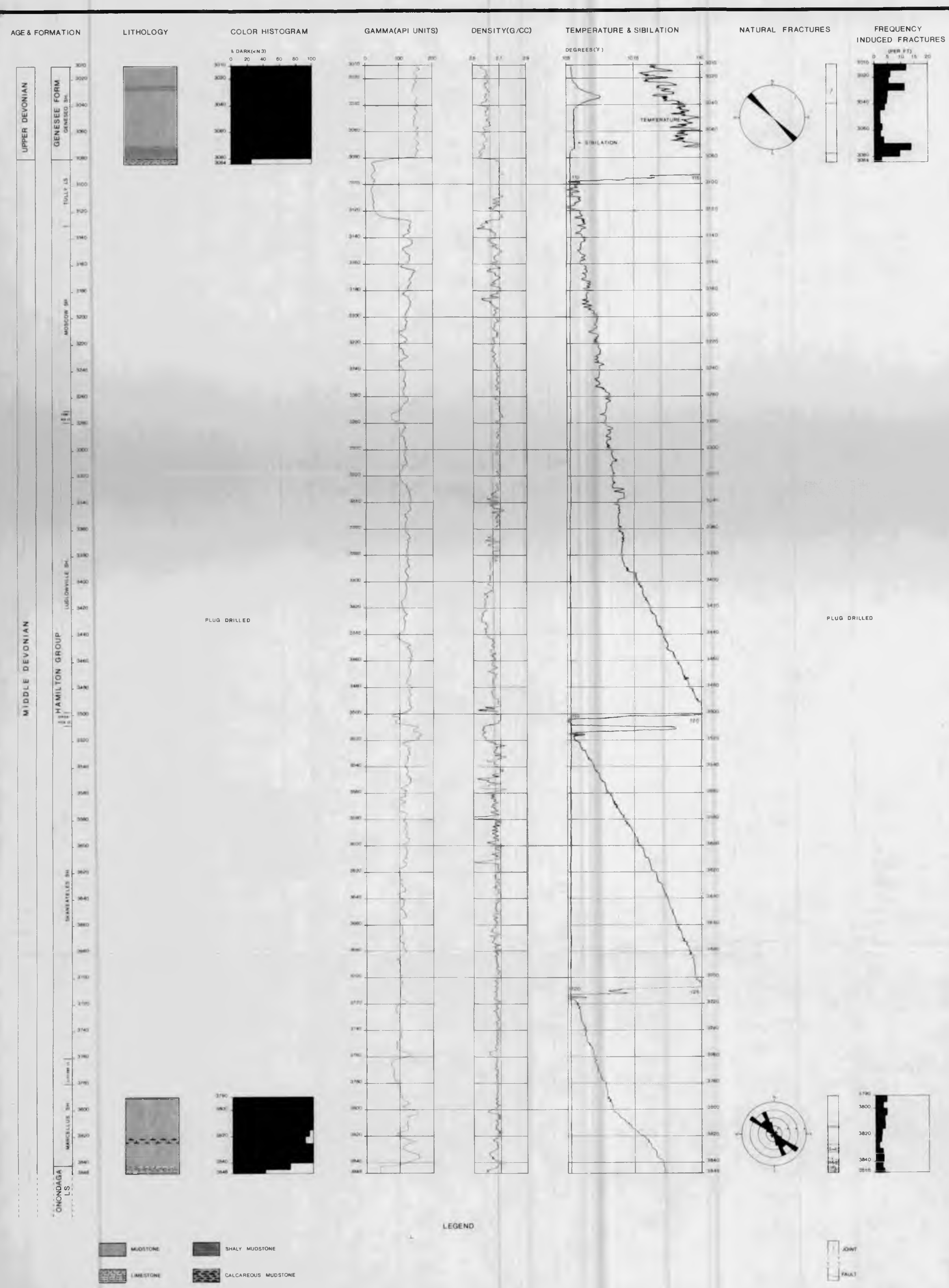
PREPARED UNDER
CONTRACT NO DE-AC21-78MC08199

U. S. DEPARTMENT OF ENERGY
MORGANTOWN ENERGY TECHNOLOGY CENTER
EASTERN GAS SHALES PROJECT

EGSP-NEW YORK 4, STEUBEN CO.

WELL VALLEY VISTA VIEW #1 | A.P.I. NO. 31-010-15268

DRILLING COMPLETED JULY 29, 1980 | DRAWN OCTOBER 1980



U. S. DEPARTMENT OF ENERGY

MORGANTOWN ENERGY TECHNOLOGY CENTER

EASTERN GAS SHALES PROJECT

EGSP - MICHIGAN #2, OTSEGO CO.

CLIFFS MINERALS INC.

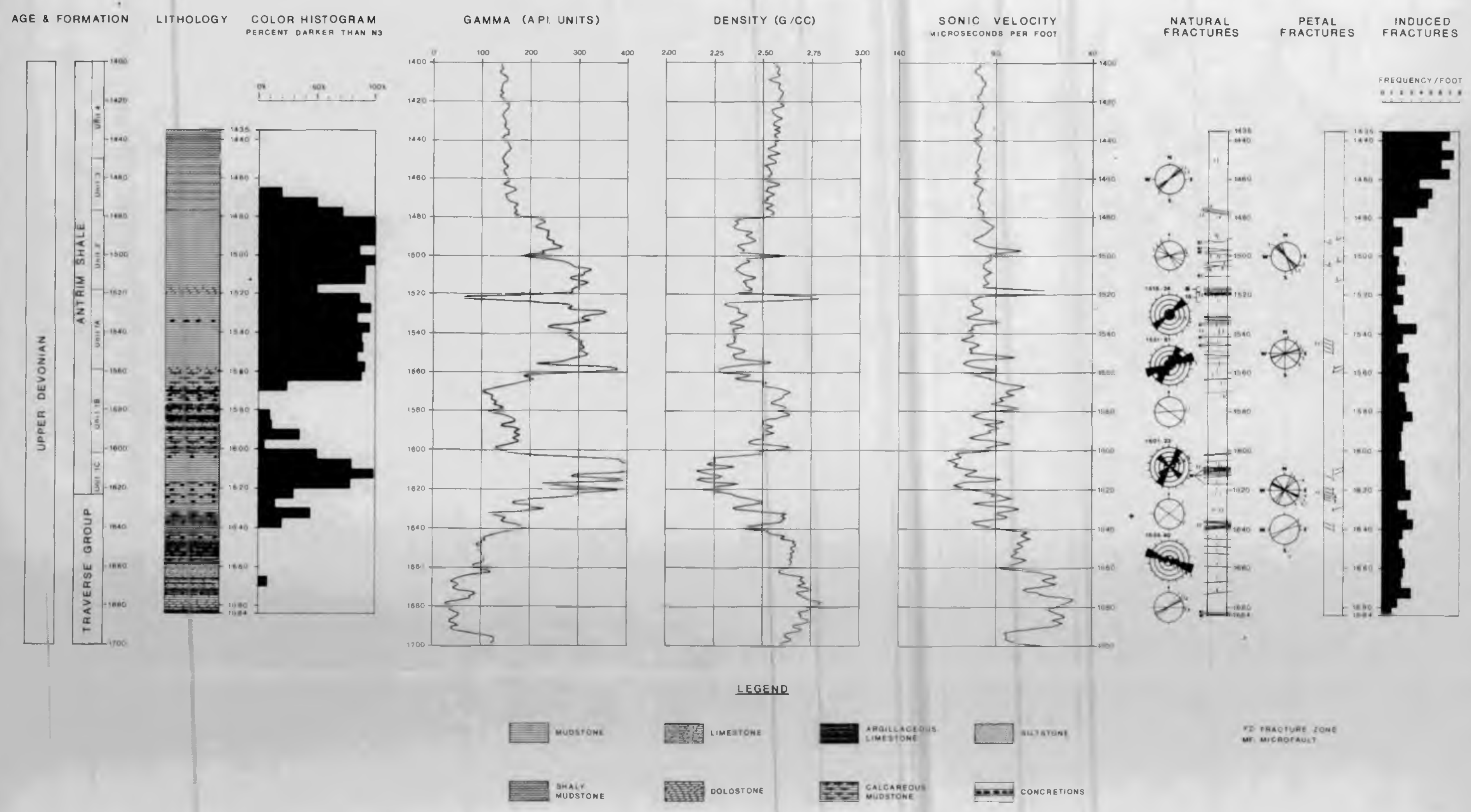
PREPARED UNDER
CONTRACT NO. DE-AC21-78MC08199

WELL: STATE CHESTER NO. 1-18

API NO: 21-137-33875

DRILLING COMPLETED: AUGUST 6, 1980

DRAWN NOVEMBER, 1980



CLIFFS MINERALS INC.

PREPARED UNDER
CONTRACT NO DE-AC21-78MC08199

U. S. DEPARTMENT OF ENERGY

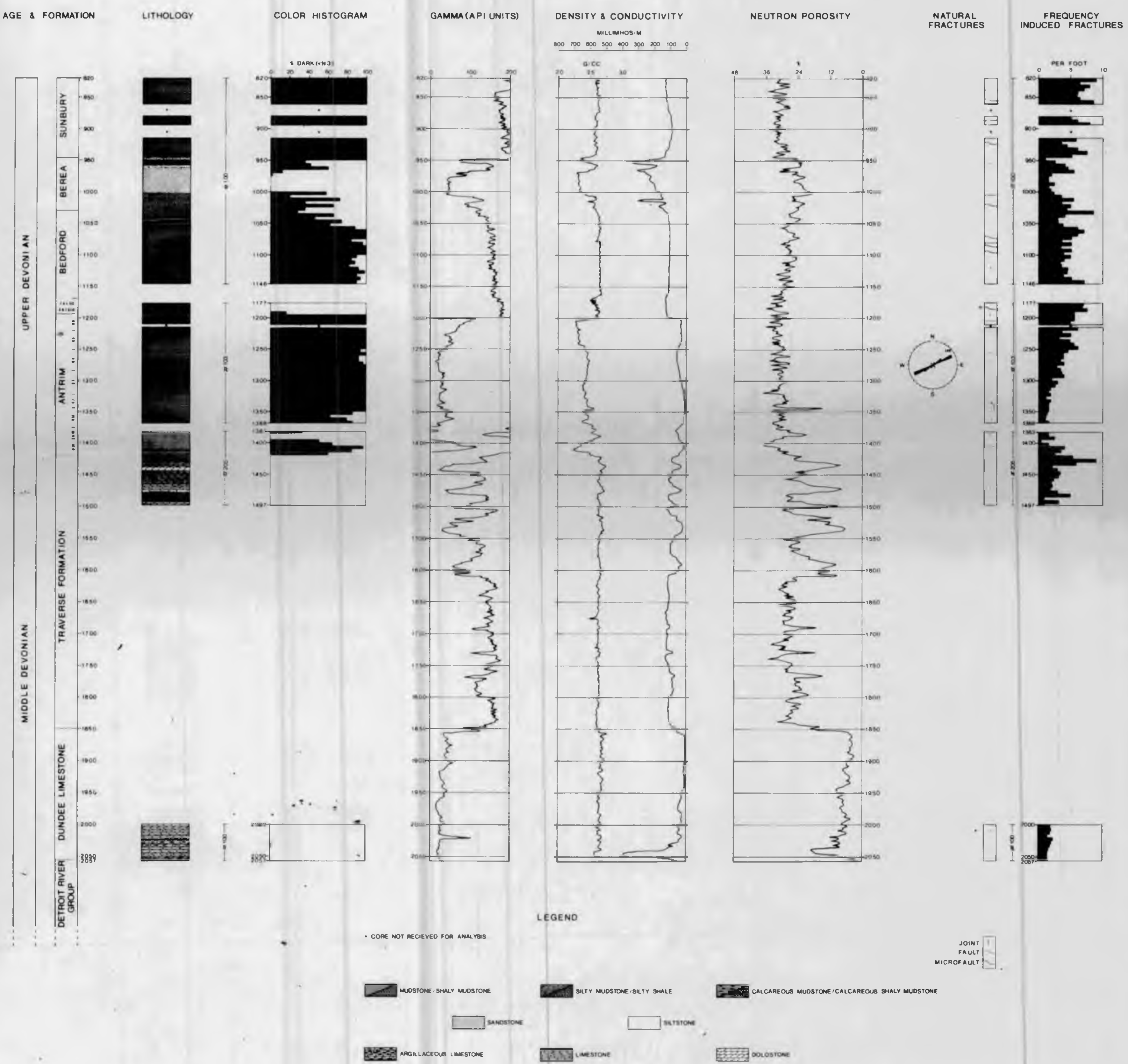
MORGANTOWN ENERGY TECHNOLOGY CENTER

EASTERN GAS SHALES PROJECT

DOE/DOW CHEMICAL #100, #103, & #205 CORES

SANILAC COUNTY, MICHIGAN

DRAWN MAY, 1981



U. S. DEPARTMENT OF ENERGY

MORGANTOWN ENERGY TECHNOLOGY CENTER

EASTERN GAS SHALES PROJECT

CLIFFS MINERALS INC.

PREPARED UNDER
CONTRACT NO. DE-AC21-78MC08199

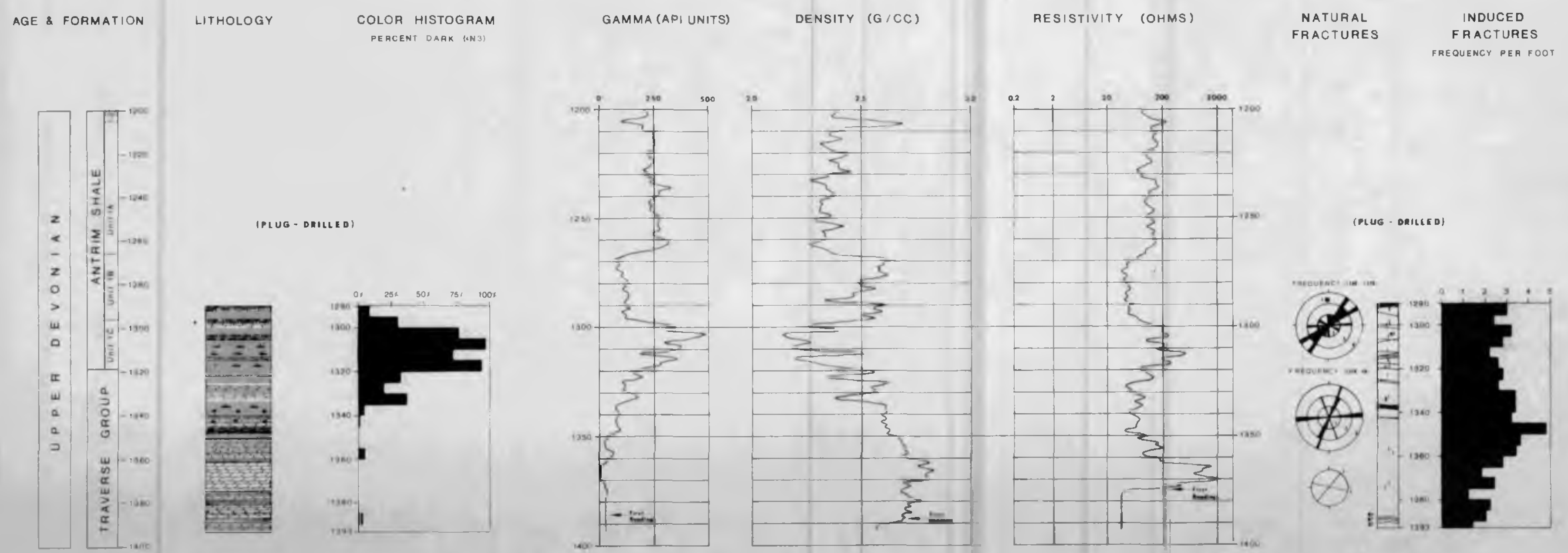
EGSP MI - 1, OTSEGO CO.

WELL: 4-40 CLUB 1-35

A. P. I. NO.: 21-137-33405

DRILLING COMPLETED: JANUARY 9, 1980

DRAWN: AUGUST, 1980



U. S. DEPARTMENT OF ENERGY

MORGANTOWN ENERGY TECHNOLOGY CENTER

EASTERN GAS SHALES PROJECT

CLIFFS MINERALS INC.

PREPARED UNDER
CONTRACT NO. DE-AC21-78MC08199

EGSP KY-4, JOHNSON CO.

WELL: 3-RS

A.P.I. NO.: 16-115-33985

DRILLING COMPLETED: DECEMBER 1978

DRAWN: APRIL 1980