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PROGRESS REPORT ON GAMMA-RAY LOGGING ACTIVITIES

By
Sherman S. Comstock

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PROGRESS REPORT ON GAMMA-RAY LOGGING ACTIVITIES

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PROGRESS REPORT ON

GAMMA-RAY LOGGING ACTIVITIES

ABSTRACT

An evaluation is made of radioactivity logging as applied to exploration drilling on the Colorado Plateau. The compilation of data gives a preliminary insight into the possibilities of the technique being applied. A comparison has also been made of the results obtained by the logging units of the U. S. Geological Survey, The Texas Company, and the Colorado Exploration Branch.

The work performed by the Commission has demonstrated that it is possible to utilize a gamma-ray log for geologic interpretation and for obtaining approximate assay values. Gamma-ray logging is a definite aid to exploratory drilling in detecting radioactivity anomalies and providing an accurate geologic log. Extensive application of this technique may reduce the over-all cost of drilling through reduction of the amount of coring required and make possible a close coordination of geologic planning with the drilling operation.

Operational logging and experimentation have proved that equipment now being used by the Colorado Exploration Branch provides satisfactory operation in the following respects: (1) provides sufficient sensitivity,

(2) gives a linear response, (3) reproduces a log when re-runs are made in the same hole several days apart and under dissimilar weather conditions; (4) produces a log in which the statistical fluctuations do not affect the interpretation, and (5) has an adequate range of sensitivity scales. It has been demonstrated that a single logging unit, with provision for field maintenance, can log the total footage being drilled on a project today.

It is concluded that a complete gamma-ray logging service will be a decided asset to the exploration drilling program.

INTRODUCTION

Types of equipment.

The Atomic Energy Commission's program for radioactivity logging of drill holes includes the work of three groups: (1) the U. S. Geological Survey, working with Commission funds; (2) The Texas Company, working under contract with the Commission; and (3) the Commission's Colorado Exploration Branch. Fundamentally, the equipment used by all of these organizations is similar in principle and components, each consisting of a surface unit and a subsurface unit. The surface unit contains a power supply, electronic circuits, page recorder, and winch with cable, which are mounted in a conventional, four-wheel-drive vehicle. The subsurface unit consists of a Geiger tube and an amplifier enclosed in a metal cylindrical housing which is attached to the end of the logging cable. The subsurface unit is lowered into a drill hole and the variations in gamma-ray intensity are recorded as the probe is withdrawn from the hole at a constant speed.

Reference will be made throughout this report to the name used to designate each particular unit. "Barnaby" is applied to the equipment designed by the U. S. Geological Survey. "Raschol" is used by The Texas Company for its device, the term representing an abbreviation of the phrase "radioactivity survey core hole logging". To distinguish from Barnaby and Raschol, the name "Batskoy" has been adopted by the Colorado Exploration Branch to designate its own particular logging unit, which was fabricated under contract with Geophysical Measurements Corporation, Tulsa, Oklahoma.

EXPERIMENTAL WORK

Experimental work has been performed to determine the dependability of the Batskoy unit and also to compare the logs obtained from Barnaby, Raschol and Batskoy. During the month of March 1951, a group of ten drill holes at the Blanding, Utah, project was logged by each of these units, providing a direct comparison of the logs produced by each (Plates 6 and 7). Experimental work to determine the dependability and optimum operating procedures of the Batskoy unit has been conducted coincident with operational logging at the Lukachukai No. 1 and Cove Mesa drilling projects.

Preparation of geologic logs.

General discussion. Before the utility of a gamma-ray logging program can be evaluated, the extent to which geology and stratigraphy can be interpreted from a log must be determined. A proper interpretation of a radioactivity log identifies types of rocks and their thickness. Interpretation involves a consideration of geologic as well as drill-hole conditions, and is dependent upon a knowledge of local stratigraphy.

The geologic strip log is the main source of information for estimating ore reserves and determining possible geologic controls. A geologic strip log as developed by the geologist in the field is rightfully to be considered as a true representation of the core recovered. However, when the core recovery is below average, the geologist must infer that the core represents the lithology of the hole and that core recovery was uniform throughout a run. Furthermore, even though a standardized procedure is being used by field geologists to describe lithology, it has been noted that there are variations in the geologic information recorded when the drill core is observed by different geologists.

In contrast to the geologic strip log, the radioactivity log is an accurate depth-measuring device which obtains an impartial record of variations in gamma-ray emission throughout the entire drill hole. A gamma-ray record can be utilized to construct a complete geologic log; and in areas where core drilling is difficult, it is a valuable aid to the field geologist in constructing a usable log.

Selection of proper settings. The instrument settings of logging speed, time constant, and sensitivity scale control the characteristic appearance of the gamma-ray curve produced. From previous geologic study of core, the significant features helpful to exploration drilling are known to be sandstone, red to brown claystone, and grey claystone. Settings must be selected to provide requisite definition of these units at an optimum logging speed.

A geologic strip log (Plate 2) constructed in the field describes in detail the above-mentioned facies changes.

Since it was first necessary to determine what constitutes useful information from the core, the experimental work in the Blanding district, Utah, was directed toward obtaining a gamma-ray log from which the maximum amount of information could be interpreted. The selected settings were a logging speed of three feet per minute, a six-second time constant, and an X20 scale (Plate 1). Plate 1 illustrates the logs produced by using different combinations of settings. It was observed that if only the major lithologic facies were to be interpreted, a considerably faster logging speed with a shorter time constant could be used.

The intensity of gamma radiation affecting the subsurface unit in a drill hole is not constant, owing to the variations in the number of atoms that happen to disintegrate in a given moment. These change variations are known as statistical fluctuations and produce very large variations in the intensity of gamma rays during extremely small time intervals. The effect of such changes in intensity becomes progressively smaller when averaged over a longer time interval. The time constant is a part of the electronic circuit designed to average the variations in intensity over a definite time interval. An increase in the sensitivity scale without changing the time constant or logging speed increases the size of the statistical fluctuation by an amount in proportion to the ratio of sensitivity scales used. Reducing the logging speed does not change the amplitude of the statistical fluctuations, but causes them to occur more frequently in the same vertical distance on the log. It is necessary, therefore, in a study of geologic interpretation to determine the most desirable combination of time constant, sensitivity scale, and logging speed to produce a log which gives good definition with small statistical fluctuations.

Procedure for interpretation. To interpret a log correctly in terms of geology it must be possible to determine the major lithologic breaks accurately and interpret what these individual units mean in terms of lithology. The clean break between lithologic units is represented on the graph by a characteristically sloping transition. The length of the measuring device (effective length of the counter) is the primary cause for this type of representation. A counter actually is seeing that portion of the hole opposite it, and in the case of a clean lithologic break it is in effect recording radiation from two entirely different rock types. Regardless of the amplitude of the break, the midpoint or center of the changing intensity value indicates the position of the contact. Gradational changes are represented on the graph by a gradational slope and not a definite sharp break. If the graph shows a break in which the maximum intensity is not a sharp point but holds the maximum value, then the unit being logged has a greater width than the effective length of the counter.

A standard procedure should be followed in utilizing the gamma-ray log for geologic purposes. It is necessary, particularly in a new area, to have core information from several reference drill holes. The first step in interpretation is to separate the major rock units. The term "major unit" is used in this report to represent a section of a drill hole which is bounded by definite changes in radiation intensity. A breakdown of major units is illustrated on Plate 2, with numbers placed to the left of the geologic column in increasing order from the surface down. Interpretation of intensity changes within a major unit (Plate 2) entails a greater knowledge and experience with local stratigraphy. Acquiring such knowledge and experience is a cumulative understanding developed by using the logs as a functional part of a drilling project.

Experience has shown that the following rock types can be considered as major units: (1) sandstone, (2) red-brown mudstone or claystone, (3) greyish mudstone or claystone, (4) interbedded mudstone, sandstone and siltstone. These units can be well defined from a gamma-ray log both as to position and thickness of the unit.

Detection of radioactivity anomalies.

Determination of assay values. A major objective of gamma-ray logging is to determine in place a uranium assay in terms of radiation intensity. Determination of this relationship would enable the field geologist to obtain an assay value in terms of equivalent percent U_3O_8 directly from the gamma-ray log. This would be a definite advantage because the project geologist would have assay values immediately available from which to plan further drilling and from which to make periodic ore reserve calculations. At present, there is a time lapse of a week or two weeks between field sampling and return of assay results to the field.

A program is now being planned to establish the relationship between gamma-ray intensity and equivalent percent U_3O_8 so that assay data will be available on future drilling projects. The method to be employed will consist of diamond core drilling about twelve holes in a known mineralized area and then by using a larger-diameter calyx drill piloted by the original diamond drill holes, an annular core will be obtained through the mineralized horizon. The drill holes will be logged before the calyx drilling is done. A comparison can then be made of radiation intensity recorded in the diamond-drill hole and the uranium content of the calyx core, which is actually the mineralization that has supplied the radiation measured by the Geiger probe.

Stability of Batskoy.

The term "stability" describes the ability of a logging instrument to reproduce a graph of a drill hole during successive logging runs in the same hole. This is one of the fundamental problems which needs to be resolved if dependable results are to be obtained from drill-hole logging. To test the Batskoy equipment, the same drill hole was logged at different times of the day, several days separating the runs, and under different climatic conditions. Plate 8 illustrates the stability of the equipment in reproducing a drill-hole log, both as to amplitude and position of intensity variations.

Supplemental data for low core recovery.

Gamma-ray logs can be used as supplemental information to correct the geologic strip log from core and verify the presence and position of mineralization. Plate 3 illustrates the advantage of having a gamma-ray log in areas where core recovery is low. The geologic strip log has been traced directly from the field log. A corrected geologic log constructed by taking into consideration the geologic strip log, the percent core recovery and the gamma-ray log of the hole is also shown. Mineralization was confirmed between 162.5 and 167.5 feet. No core had been recovered from this zone and consequently had not been recorded on the geologic strip log.

Geologic interpretation on widespaced drilling.

A preliminary attempt at interpreting geology directly from a gamma-ray log is illustrated on Plate 4. Field locations of the holes are shown on the accompanying index map. Core recovery in the Blanding area was well above 90 percent, which afforded a good opportunity for comparing gamma-ray logs with geologic logs prepared from the core. This illustration is not intended to show correlation between holes, but it is a first attempt to prepare a geologic log from a gamma-ray log. This experiment was performed in the Grand Junction office according to the procedure described below.

1. An index map and each gamma-ray log were traced.

2. Drill holes 570, 555, 542, 530 and 520 were chosen as reference holes. The geologic logs from gamma-ray interpretation (GRI) were developed for these particular holes by cross-comparison of both the geologic strip core logs (GSLC) and the gamma-ray logs.

3. The interpretation of gamma-ray logs of 576, 562, 548, 536 and 524 was made by comparison with the geologic logs of reference holes to the north and south. As an example, the GRI for hole 548 was developed by referring to drill holes 555 and 542.

4. After the preliminary work above, geology was interpreted for holes 576, 562, 548, 536 and 524. After a comparison was made, the geologic strip log from core was traced to the right of the GRI.

In constructing the geologic log from the gamma-ray log, no distinction is made between sandstone and siltstone, and the percentage of included mudstone has been shown as an irregular line corresponding to the variations in intensity recorded by the logging unit.

As has been stated previously, to interpret geology properly from gamma-ray logs of non-cored holes, a certain number of cored reference holes should be available. The maximum number of reference holes necessary and the maximum spacing of the reference holes will be determined by field experience. The interpretation of the logs on Plate 4 has been influenced by the wide spacing of the reference holes, but it is of interest to note the detail which may be realized from gamma-ray interpretation.

Comparison of logs by Barnaby, Raschol and Batskoy.

Plate 7 is a visual comparison of the records produced by the logging units of the U. S. Geological Survey, The Texas Company, and the Colorado Exploration Branch. The instrument settings, type of recorder and recorder paper, vertical scale, character of the graph produced, and scale values of radiation intensity are shown.

The radioactivity logs produced by Batskoy and Raschol (Plate 6) are very similar, especially from the standpoint of interpretation. The amplitudes are relatively the same in counts per minute, which means that the sensitivity of the counters and performance of the equipment is about the same. The one disadvantage observed by the writer in the stability of the Raschol logs was the pronounced variations in statistical fluctuations (Plate 6) even when a drill hole was logged three times in succession. The major geologic features were still definite, but the minor changes were obscured.

APPLICATION OF GAMMA-RAY LOGS

General discussion.

The purpose of research with Batskoy equipment has been to establish the applicability of a gamma-ray logging program to exploration and its economic significance. Of immediate importance to any drilling program are the assay values for ore reserve calculations. Assaying by radiometric hole logging is a prompt method of securing this information.

Wagon-drilling operation.

A wagon-drilling project without a gamma-ray unit is dependent upon drill hole cuttings for information as to geology and mineralization (Plate 5). The varying time lag of the cuttings from the time of cutting until they reach the surface introduces a source of error in the sampling procedure. An overlapping or intermingling of different rock types occurs, which adds to the difficulty of interpretation. One of the most useful aspects of a radioactivity log is its ability to measure accurately this time lag. When a sample log is plotted against a gamma-ray log, the time lag is immediately apparent. The radioactivity log shows accurately the depths of various lithologic breaks, whereas the sample cuttings fail to reveal the exact depth. Samples from cuttings can very well be contaminated from cavings higher up in the hole, and the true character of the rock penetrated may be obscured. The gamma-ray log will not be noticeably affected by the annular space of the drill hole.

Core-drilling operation.

A main objective of gamma-ray logging is to avoid the necessity of coring on a majority of the drill holes. A certain number of the holes should be cored to serve as reference holes for checking the gamma-ray interpretation. Such reference holes will be the initial wide spaced drilling for structural data. By comparison and study of gamma-ray logs and core, geologic data can be recorded for use in interpreting non-cored holes.

At present, the drilling project in the Blanding district, Utah, has found that The Texas Company (Raschol) logs give useful supplemental information to the core-drilling project. The logs are being referred to as a guide to sampling the core. Location of the top and bottom limits of mineralization is considerably more definite than checking core with a hand counter, which has appreciably lower sensitivity. Whenever core recovery is below average, the actual character of the lost core does not have to be inferred from the core recovered, but can be confirmed from the gamma-ray log. Very weak anomalies which cannot be detected by a hand counter are apparent from a gamma-ray log.

OPERATING DATA

Lukachukai drilling project.

Drilling began on September 25, 1950, and terminated on February 2, 1951. The Batskoy unit began actively logging drill holes about November 1, 1950. The summary below is for the entire drilling period.

Total footage drilled	49,944.5
Total number of drill holes	322
Total footage of gamma-ray logs	29,259.3

Total number of holes - gamma-ray.	195
Total number of shifts - gamma-ray	50
Average footage per shift	585.2
Total shifts - vehicle maintenance	8.5
Total shifts - repair and maintenance of Batskoy equipment	8.0
Average number of holes per 8 hours logging time . . .	3.9

It was necessary for the field operator on this project to travel to and from four separate drilling areas. More time was necessary in traveling from one mesa to another than would be normal on a project in which the drilling was confined to only one area. Of the total number of holes drilled, 95.7 percent of the holes on Mesa I, 77.1 percent of the holes on Mesa II, 8.8 percent of the holes on Mesa III, and 6.2 percent of the holes on Mesa IV were radiometrically logged.

During the last month of the project, wagon-drilling was tried on the Nakai Chee Begay property, Red Rock area, and on Cove Mesa. Of the total 556.2 feet drilled on the Begay claim, 52.4 percent was radiometrically logged. On Cove Mesa, radiometric logs of the entire 629 feet drilled were obtained.

Blanding district, Utah.

The following summary is for a period of three weeks, which was directly of an experimental nature.

Total number of logs	63
Total footage	7,609.2
Total number of shifts on logging.	12
Average holes per shift	5.25
Average footage per shift	634.1

Cove Mesa, Arizona.

The Cove Mesa project employs two wagon drills and one core drill operating one shift per day. The tabulation below covers the period March 19 through April 21, 1951.

Total number of holes drilled	179
Total number of holes logged - Batskoy.	152
Total footage drilled	13,371.5
Total footage logged - Batskoy.	10,153.7
Hours logging time in the field	119
Average footage per 8 hours logging time.	682.6
Mineralized holes	54

EQUIPMENT

Batskoy.

The Commission, by contract with Geophysical Measurements Corporation during the latter part of May 1950, specified that the equipment should clearly indicate radiation intensity changes of 5 microroentgens per hour applied stepwise. This was considered necessary to be able to interpret lithologic changes, as well as to obtain an assay of the mineralized zone. The Batskoy unit arrived in Grand Junction on October 10, 1950, and was first used on the Lukachukai drilling project (northeast Arizona) from October 14, 1950, until the termination of drilling on January 25, 1951. A period of three weeks was spent at Blanding obtaining experimental data, and Batskoy was then transferred to the wagon-drilling project at Cove Mesa, northeast Arizona. A second Batskoy unit should be available about the first of August 1951.

Description. The Batskoy logging equipment is installed in a four-wheel-drive Willys-Overland Jeep station wagon. Power supply for the electronic equipment and winch motor is a 115-volt, 2000-watt generator, which is mounted on the front of the jeep, and driven by the jeep engine. An electric winch with a drum approximately 14 inches in diameter and 11 inches wide is mounted inside the jeep and is driven by an electronically controlled variable-speed electric motor rated at 1/2 horsepower. The drum can carry 1000 feet of 0.19-inch cable. A 7/8-inch subsurface probe containing a self-quenching Geiger tube, pulse amplifier, and high-voltage supply is attached to the cable; the subsurface unit is entirely waterproof. An amplifying unit containing an oscilloscope and an integrator are mounted on a metal panel inside the jeep. The controls for changing the sensitivity, time constant, and logging speed are mounted on the front of the metal panel. Sensitivity scales are 0-10, 0-30, 0-60, 0-100, 0-200, and 0-400 microroentgens per hour (gammas from uranium in equilibrium). It was upon the recommendation of the National Bureau of Standards and the Commission that scale values in microroentgens per hour were adopted, since microroentgens per hour and percent uranium are measures of conditions in nature and can be correlated from place to place. In contrast, counts per minute is a characteristic of a particular instrument and will vary depending upon the instrument sensitivity. A time constant of 1, 1.5, 2, 3, 4, 6, 8, 10, 15, 20, 30, 40, 60, and 80 seconds can be used. Logging speed can be varied from less than one foot to about 60 feet per minute. A tripod with sheave wheel is used for guiding the cable into the hole. The sheave wheel is a measuring wheel which is synchronized with the drive of a Speedomax paper recorder. Variations in radiation intensity are recorded as the probe is withdrawn from the hole at a constant speed.

The purpose of having the high-voltage power supply (threshold voltage to the counter) in the subsurface probe is that a single conductor cable of much smaller diameter, and also greater strength, can be used. All voltage for the pulse transmitter and the threshold voltage for the counter are developed in the subsurface probe from an input of 60 volts at 400 cycles.

To check the zero point of the recorder, the gain control is turned to zero. In effect, this stops the pulses from entering the integrator circuit and results in a zero reading on the output d-c. ammeter of the integrator circuit. It is the d-c. output from the integrator circuit that drives the Speedomax recorder. A check on the zero point of the recorder can be made either on the surface or in a drill hole.

Calibration check. A radium standard, enclosed in a stainless-steel housing, is used daily to check the performance of the logging equipment. The source is a sealed pyrex ampoule containing 50 micrograms of radium dissolved in a solution containing two percent barium chloride and five percent by weight of hydrogen chloride.

The procedure for checking the equipment for normal operation is as follows: (1) operate the recorder against time; (2) place the subsurface probe with K-type counter on the ground and make a graph showing the radiation of the surface at that particular time; (3) place the radium standard 108 inches from the center of the K-type counter while the recorder is still making a graph. For normal results, a 5-microroentgen stepwise break will be produced. The radium standard should have its long dimension parallel to that of the counter.

Maintenance and alterations. The first alteration was to increase the multiplier scales (sensitivity) from X1, X3, X10 to X1, X3, X6, X10, X20, X40. It was found that the X10 scale was too sensitive to produce a log which could be interpreted with ease. Later additional capacitors were added to the time constant circuit to increase the selections of time constants. Originally, the time constants were 10, 15, 20, 30, 40, 50, 60, 80 seconds. The change made possible the use of these time constants plus 1, 1.5, 2, 3, 4, 5, 6, 8 seconds. The time constants of 1 through 8 seconds are within the most desirable range. A wire-wound potentiometer was installed on the motor speed control to increase the range of the speed control rheostat at the lower logging speeds. This allows for a more accurate setting of logging speeds such as are being used by the Commission.

Several changes were made in the motor-control circuit so that logging speeds at less than one foot per minute could be used. During the last week of April 1951, a change was made in 400-cycle power supply. To increase the input voltage to 60 volts, the resistance in the input to the 400-cycle power supply was reduced. These alterations adapted it in the Batskoy surface equipment for the particular purpose for which it is being used.

The subsurface unit consists of a pulse transmitter, high-voltage supply for the counter, and the counter. The counters used are the type-K (12-in. effective length), type-L (3-in. effective length), and type-R (1-in. effective length).

The pulse transmitter and K-counter have met the specifications for producing a log for geologic interpretation. The K-counter has been in use for periods of several months without a noticeable change in the character of the log produced. A pulse transmitter was replaced because logs on the same hole did not repeat well, which suggested poor voltage regulation in the pulse transmitter.

From time to time, the type-L and type-R counters have ceased to function under higher radiation. This problem has caused concern to both the Commission and Geophysical Measurements Corporation. A situation existed in which a counter would not function in the field, yet when it was checked at Tulsa, by Geophysical Measurements it operated perfectly. A type-L counter was first used on the Lukachukai drilling project and would operate for several weeks. This counter was replaced by the type-Rcounter, which was given a field trial at Blanding. Results corresponded until the counter entered the ore zone.

The only difference between field operation and laboratory conditions at Tulsa was in temperature. It was then recalled that whenever the counters had failed to function, the weather had been coldest. Chilling these counters in the laboratory verified that they were affected by a lowering of temperature when under high radiation. This problem has been remedied by a change in design, and, in the opinion of Geophysical Measurements Corporation, the characteristics of the counters will now be unaffected by temperature variation.

From the mechanical standpoint, the chief difficulty has been with the drive assembly from the jeep motor to the alternator. A U-joint connecting shaft and a dog clutch were the original assembly. The dog-clutch pulley assembly was used to engage and disengage the drive shaft to the alternator. Because the jeep engine was not rigidly mounted, misalignment of the shaft to the alternator resulted. Whenever the engine was driving the alternator a thrusting force was impressed on the U-joint assembly. This thrusting, coupled with rotational force and vibration caused the U-joints to wear unevenly. The dog clutch assembly also needed replacement. A power take-off has been installed off the transmission of the jeep and will drive the alternator without being affected by the vibration of the engine.

Barnaby.

The Barnaby unit produces a log on an Easterline Angus recorder.

The recorder paper has a curvilinear base line for the horizontal dimension (Plate 7), and the vertical scale is 3/4 inch equals 2 feet. Because of the vertical scale and the characteristic shape of the Barnaby logs, it is difficult to make a quick visual comparison with a Batskoy or Raschol log, both of which are rectilinear logs on a vertical scale of 1 inch equals 10 feet.

In general, Barnaby has been developed solely as an instrument for locating mineralized zones, and arriving at an assay value in terms of grade and thickness. As stated by Mr. Kenneth G. Bell, of the U. S. Geological Survey, the gamma-ray logs by the Barnaby unit at Blanding were "obtained by using a probe suitable for making a quantitative determination of equivalent uranium between the limits of 0.05 percent and 2.50 percent; but that they were not directly comparable with a high efficiency probe, and at a lower logging speed, with the objective of indicating on a qualitative basis gamma-ray intensities originating from within the individual members of a sequence of sedimentary strata". Plate 7 illustrates a part of drill hole B530 with logs from Batskoy, Raschol and Barnaby. The maximum radiometric assay from core sampled was 0.02 percent U_3O_8. For a complete understanding of the operation of the Barnaby equipment, reference should be made to the Trace Elements Investigation Report No. 87 (unclassified).

Raschol.

The Texas Company's logging unit is mounted in a universal jeep and consists of an integrator panel, a high-voltage supply for the subsurface unit , a winch driven by a constant-speed motor, a General Electric page recorder, and a subsurface unit comprising a Geiger counter and a pulse amplifier which are enclosed in a brass tube of approximate one-inch outside diameter.

The logging speed is controlled by a constant-speed motor and a variable gear train connected to the winch. A change is made in the setting of the variable gear train whenever the logging cable begins a new wrap on the drum, to maintain a constant logging speed.

The subsurface high-voltage supply is located in the surface equipment. To assure the operator that the zero point of the recorder is true, the threshold voltage to the Geiger tube can be switched off. With this arrangement the recorder zero point can be checked before starting a logging run (bottom of hole) and on completing a run (at the surface).

CONCLUSIONS

Based on present information, the following conclusions seem warranted:

1. Gamma-ray logs can be interpreted to provide geologic logs.
2. Geologic interpretation from gamma-ray logs is a definite

improvement over geologic strip logs from a wagon-drilling project or from low-recovery core drilling.

3. Correlation of the major features is more apparent from a gamma-ray log than from visual inspection of core.
4. A radioactivity log is a dependable measurement of depth and thickness of mineralization and lithology.
5. It has been accepted that a radiometric assay from a gamma-ray log will provide a representative assay. Experimental work is needed to establish the relationship between equivalent percent U_3O_8 and the scale value in counts per minute.
6. Gamma-ray logging when coordinated with the drilling program can provide a direct method of planning the location of drill holes.

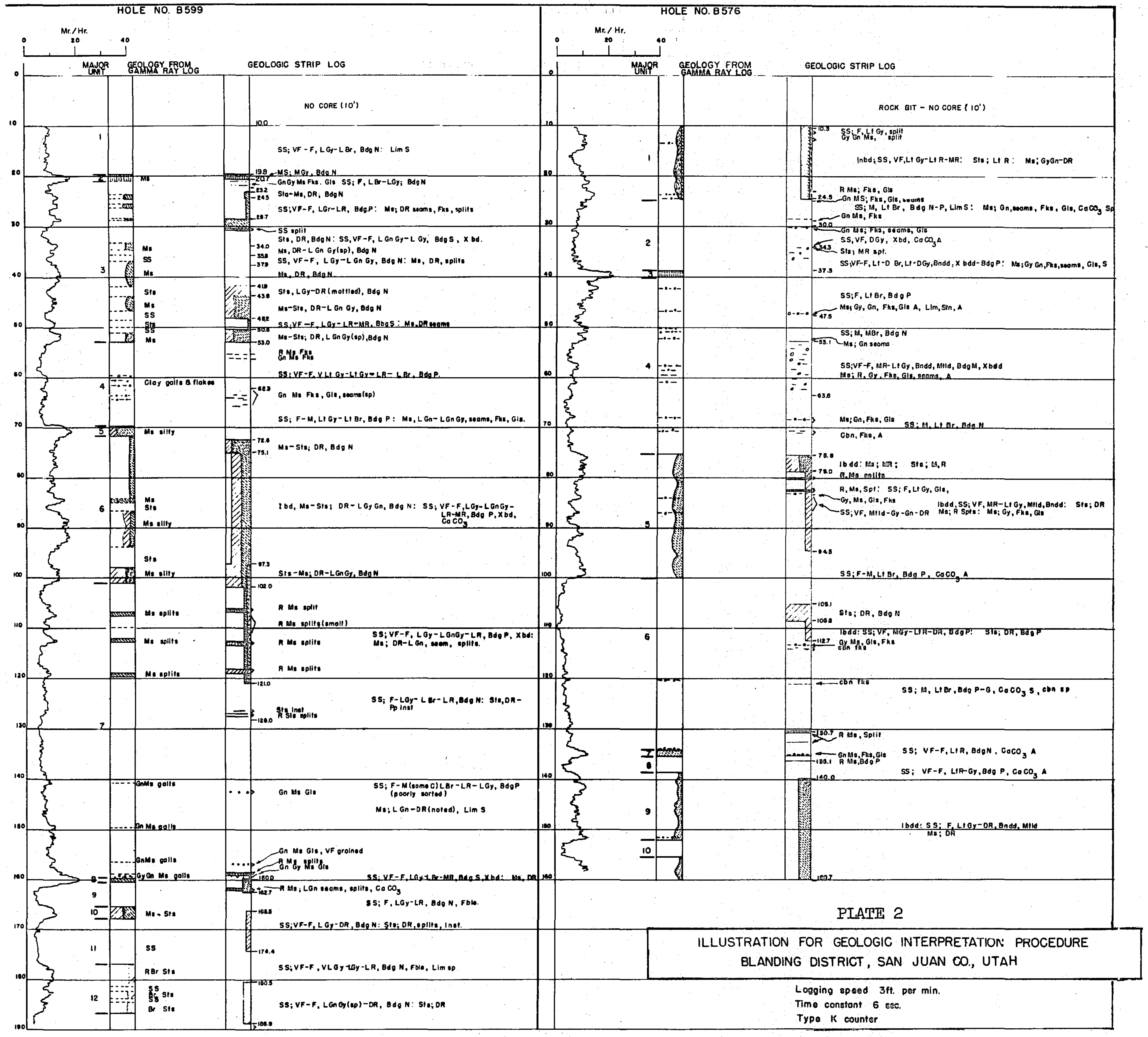


PLATE 2

ILLUSTRATION FOR GEOLOGIC INTERPRETATION PROCEDURE
BLANDING DISTRICT, SAN JUAN CO., UTAH

BATSKOY GRAPHS FOR SELECTION OF PROPER SETTINGS
BLANDING DISTRICT, SAN JUAN CO, UTAH
HOLE NO. 562

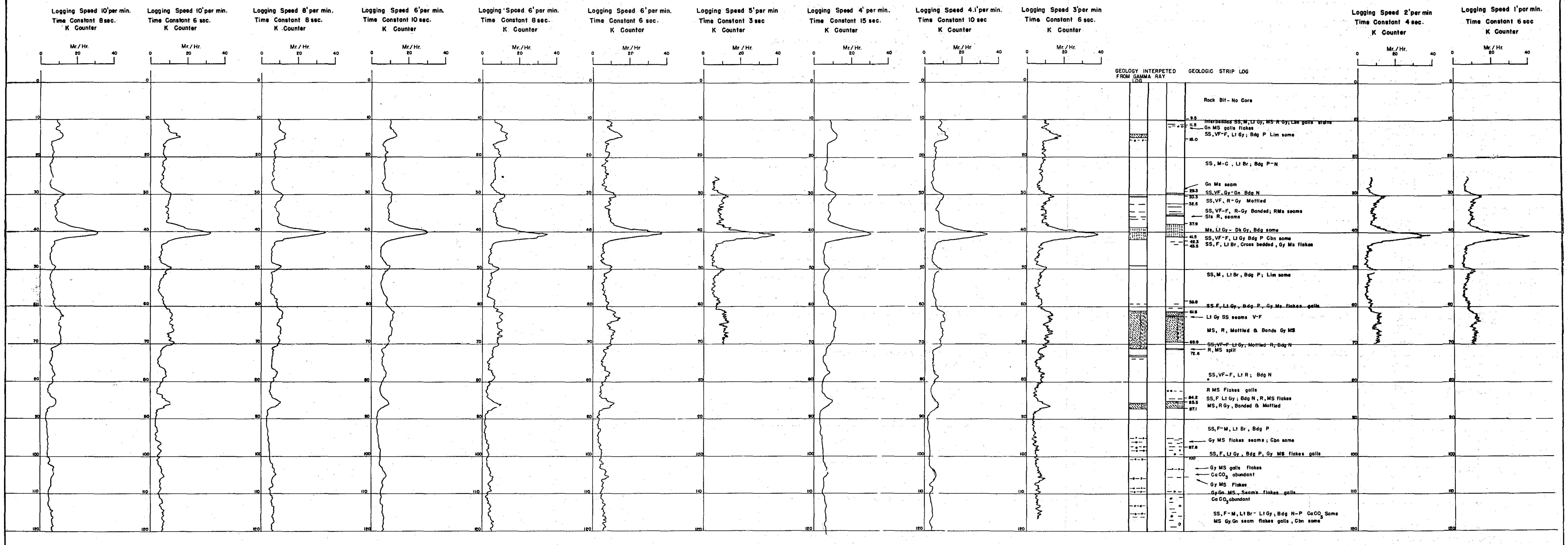


PLATE 1

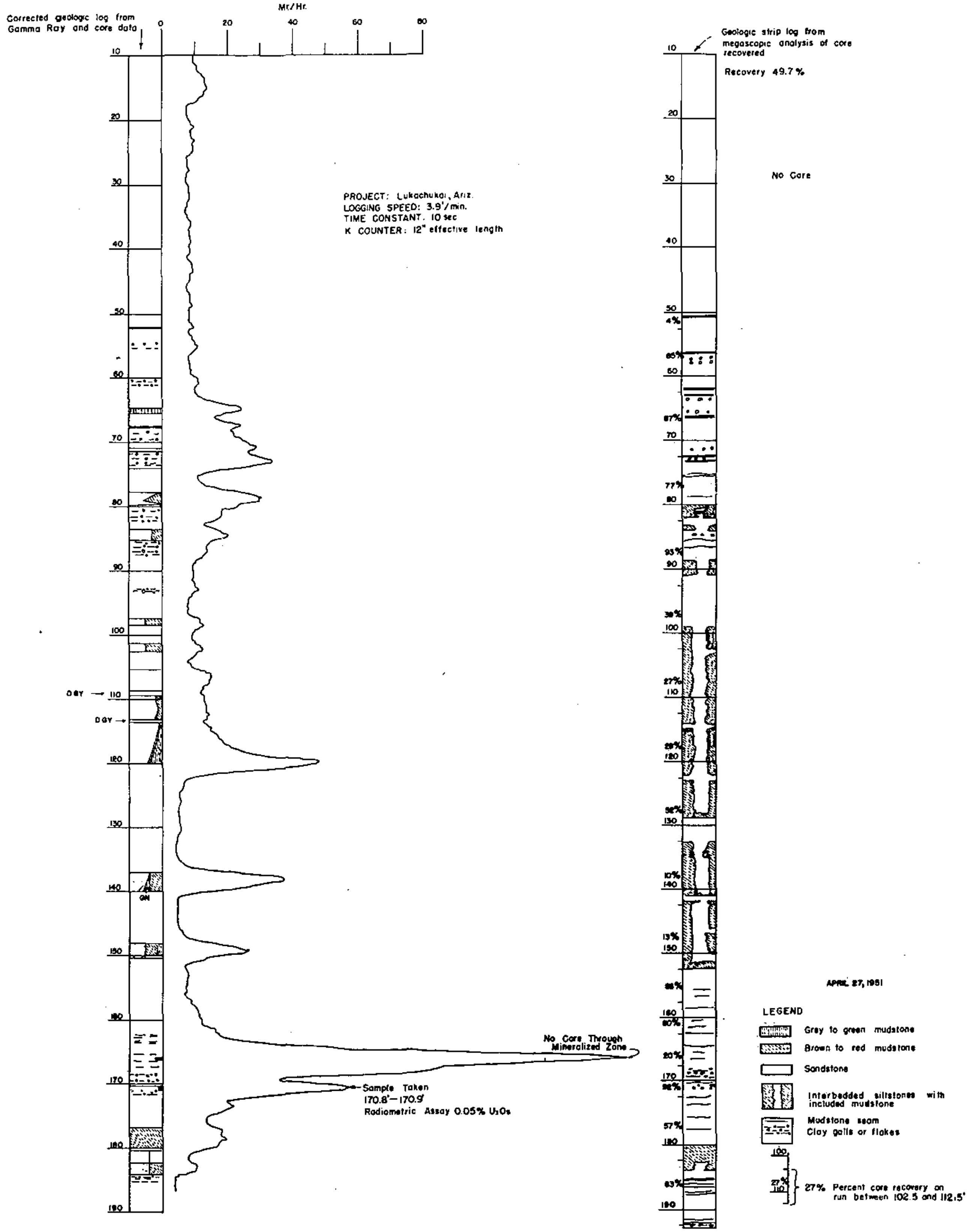
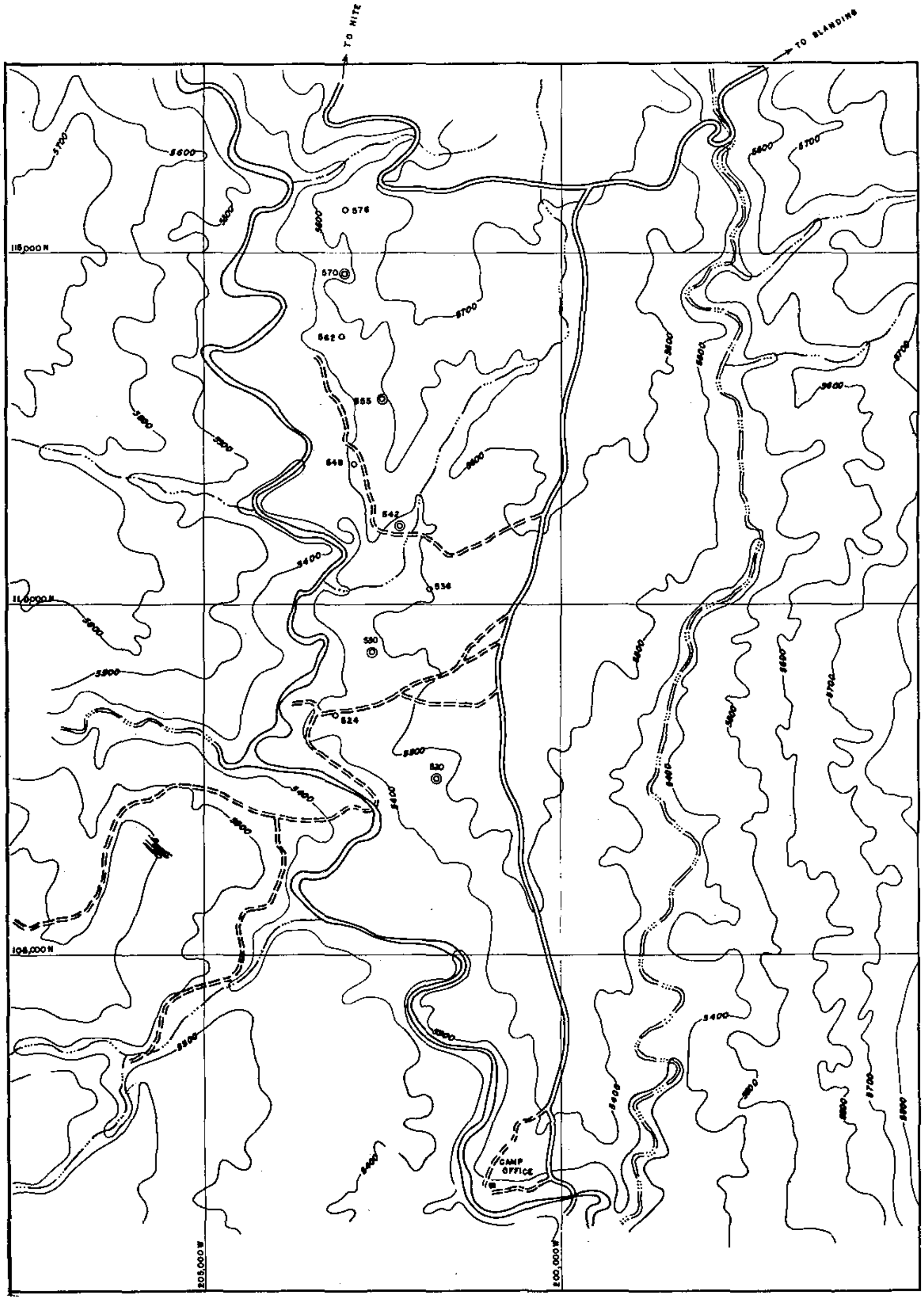


PLATE 3

ILLUSTRATING 1. CORRECTED GEOLOGIC LOG
2. MINERALIZATION NOT CORED



INDEX MAP OF DRILLING AREA

PLATE 4
(See facing page for legend.)

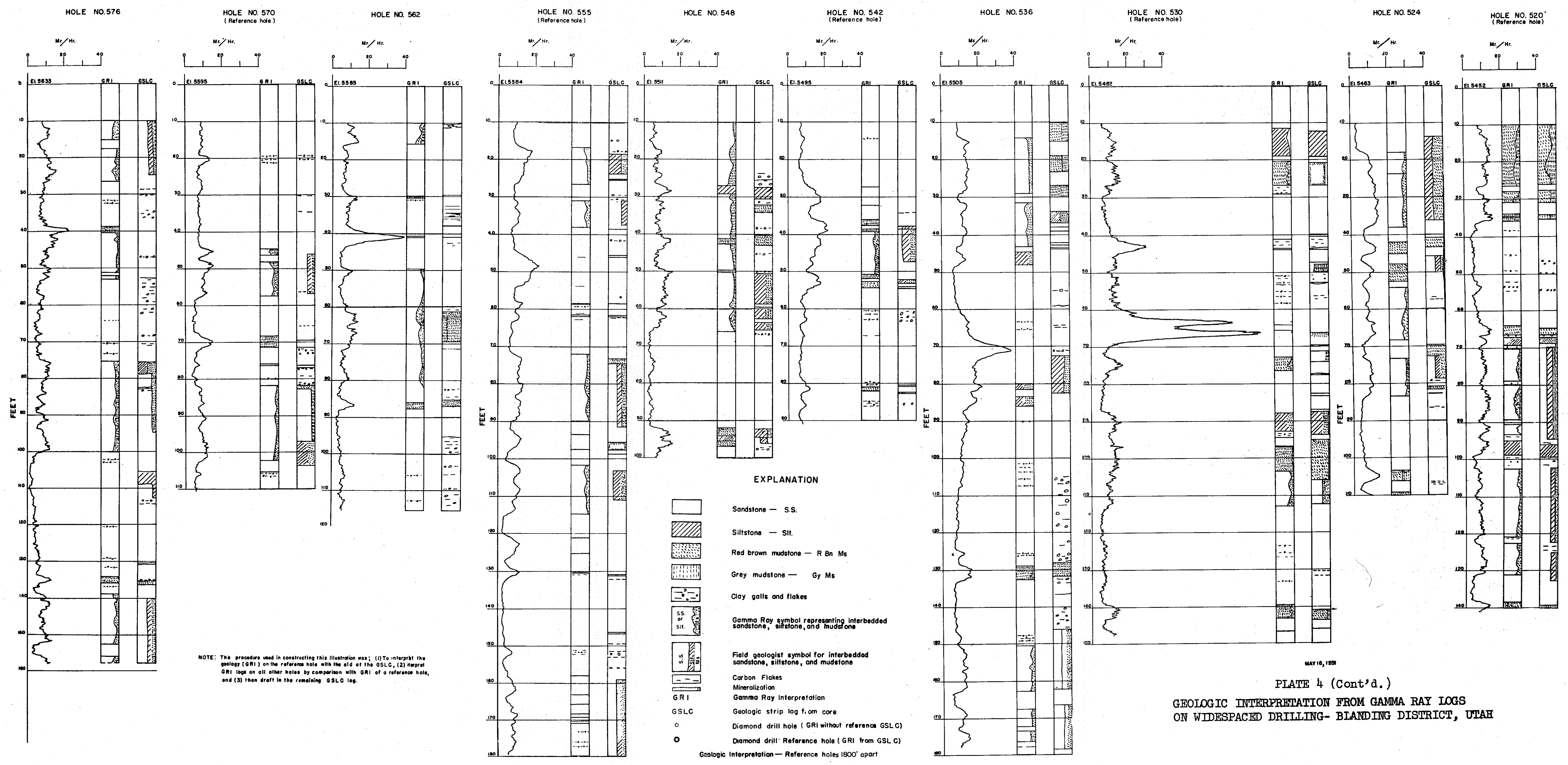
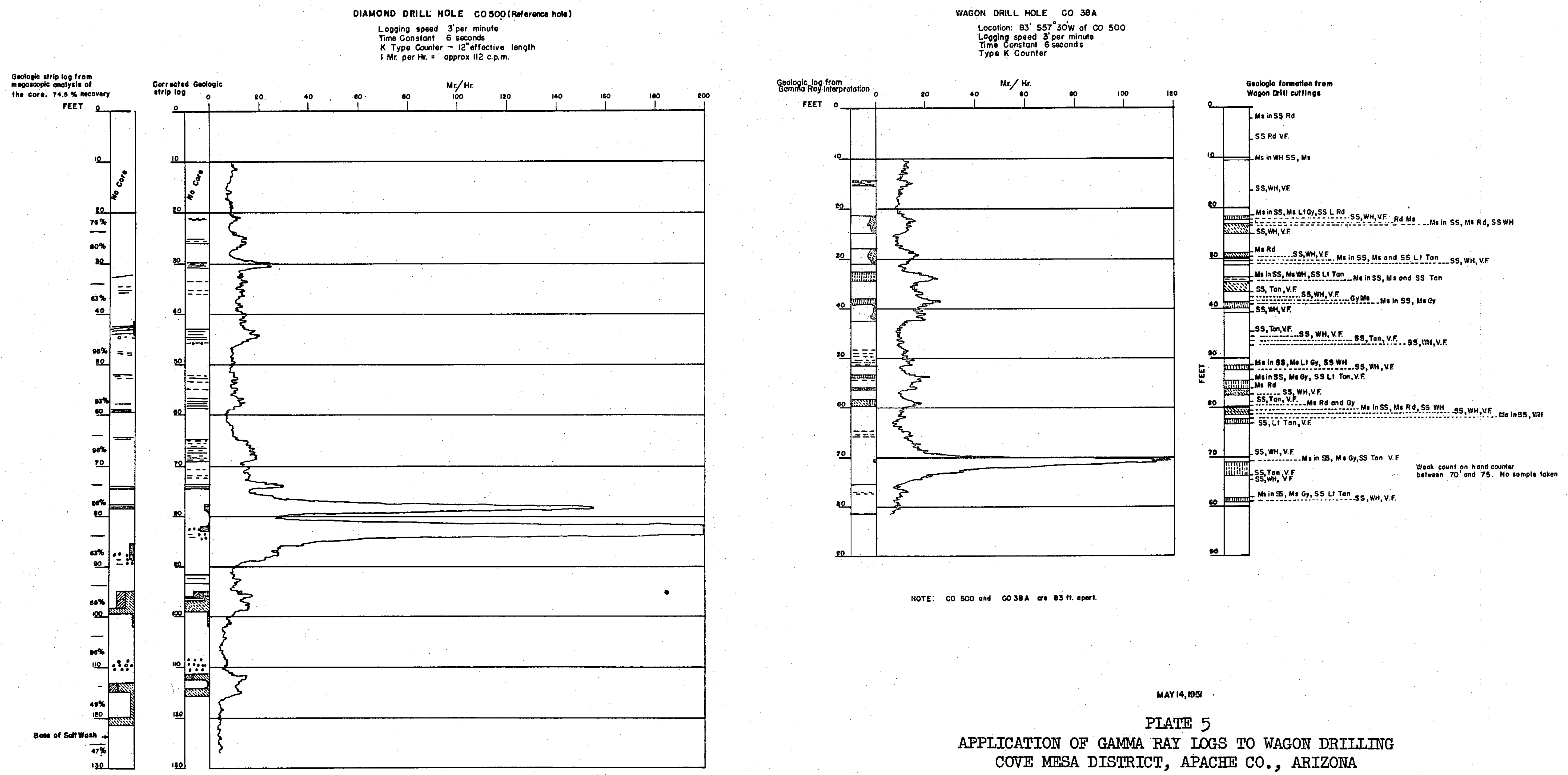


PLATE 4 (Cont'd.)

GEOLOGIC INTERPRETATION FROM GAMMA RAY LOGS ON WIDESPACED DRILLING- BLANDING DISTRICT, UTAH



MAY 14, 1951

PLATE 5
APPLICATION OF GAMMA RAY LOGS TO WAGON DRILLING
COVE MESA DISTRICT, APACHE CO., ARIZONA

COMPARISON OF GAMMA RAY LOGS
BLANDING DISTRICT, SAN JUAN CO., UTAH

Drill Hole B-562

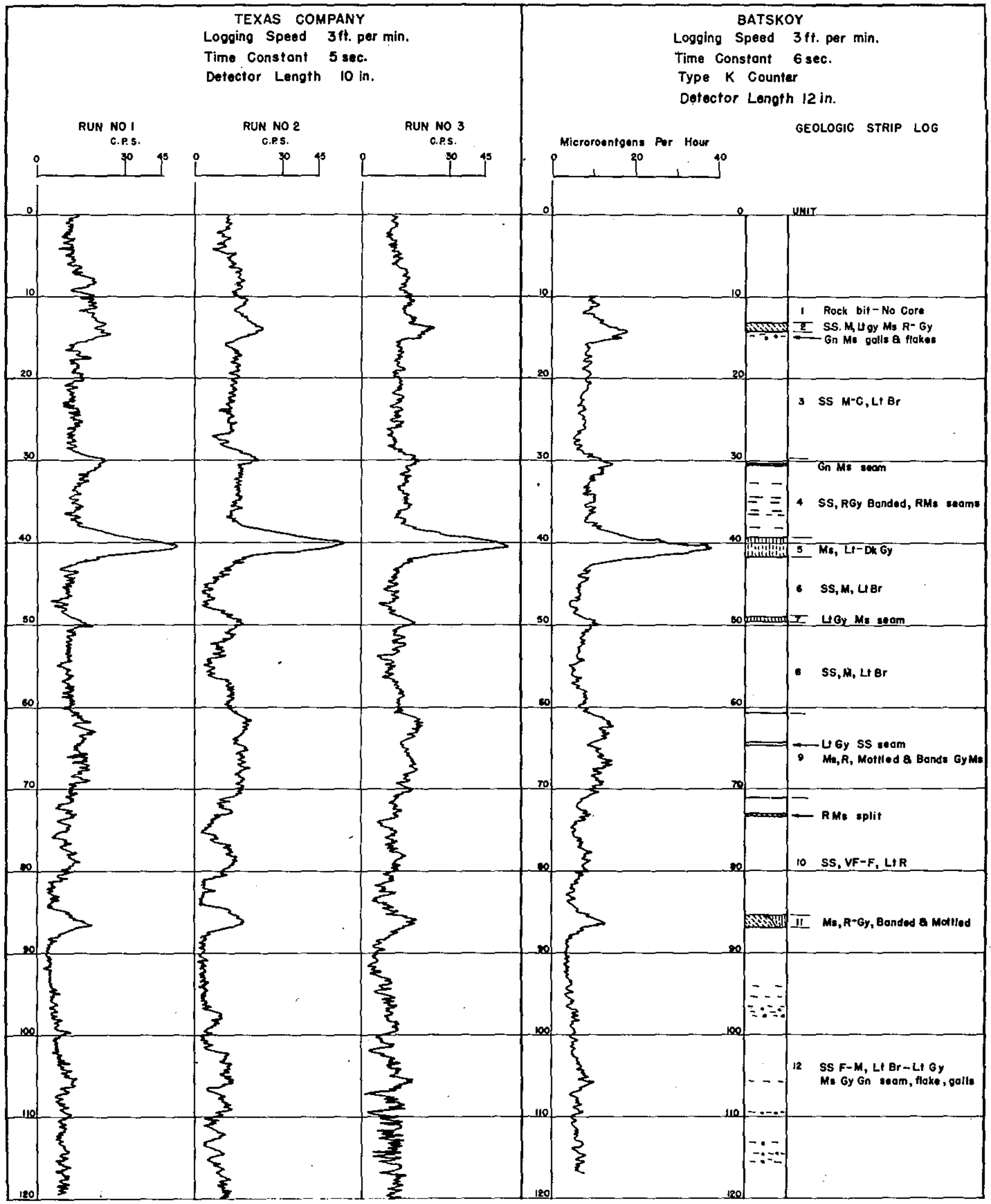
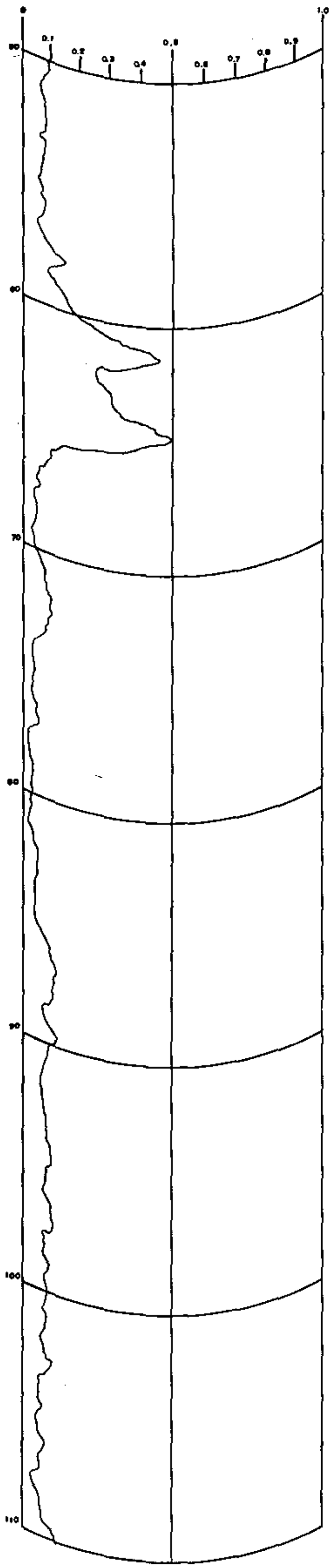


PLATE 6

BARNABY

Logging speed 5ft per min.
Multiplier scale (c.p.m.) X1000
Esterline — Angus Recorder
Paper width as shown below

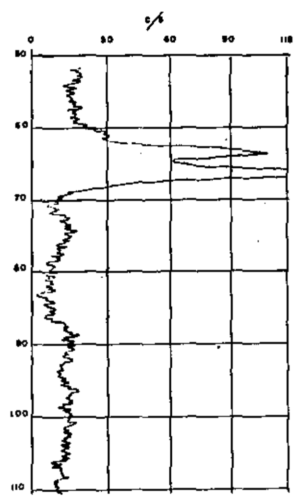


MAY 8, 1951

PLATE 7
COMPARISON LOGS -- DRILL HOLE 530
BLANDING DISTRICT, SAN JUAN CO., UTAH

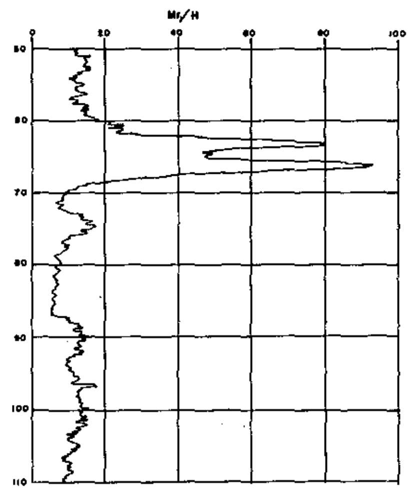
THE TEXAS COMPANY

Logging speed 3ft per min.
Sensitivity scale X1
Time constant 5 sec.
Detector: 1" dia. 10" long
G-E recorder—paper width $3\frac{1}{2}$"

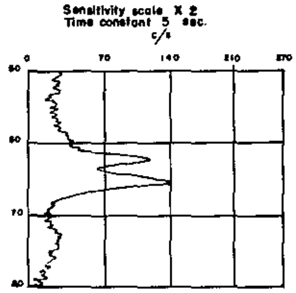


BATSKOY

Logging speed 3ft per min.
Time constant 4 sec.
K counter—Length 12"
Speedomax Recorder — 10" paper width

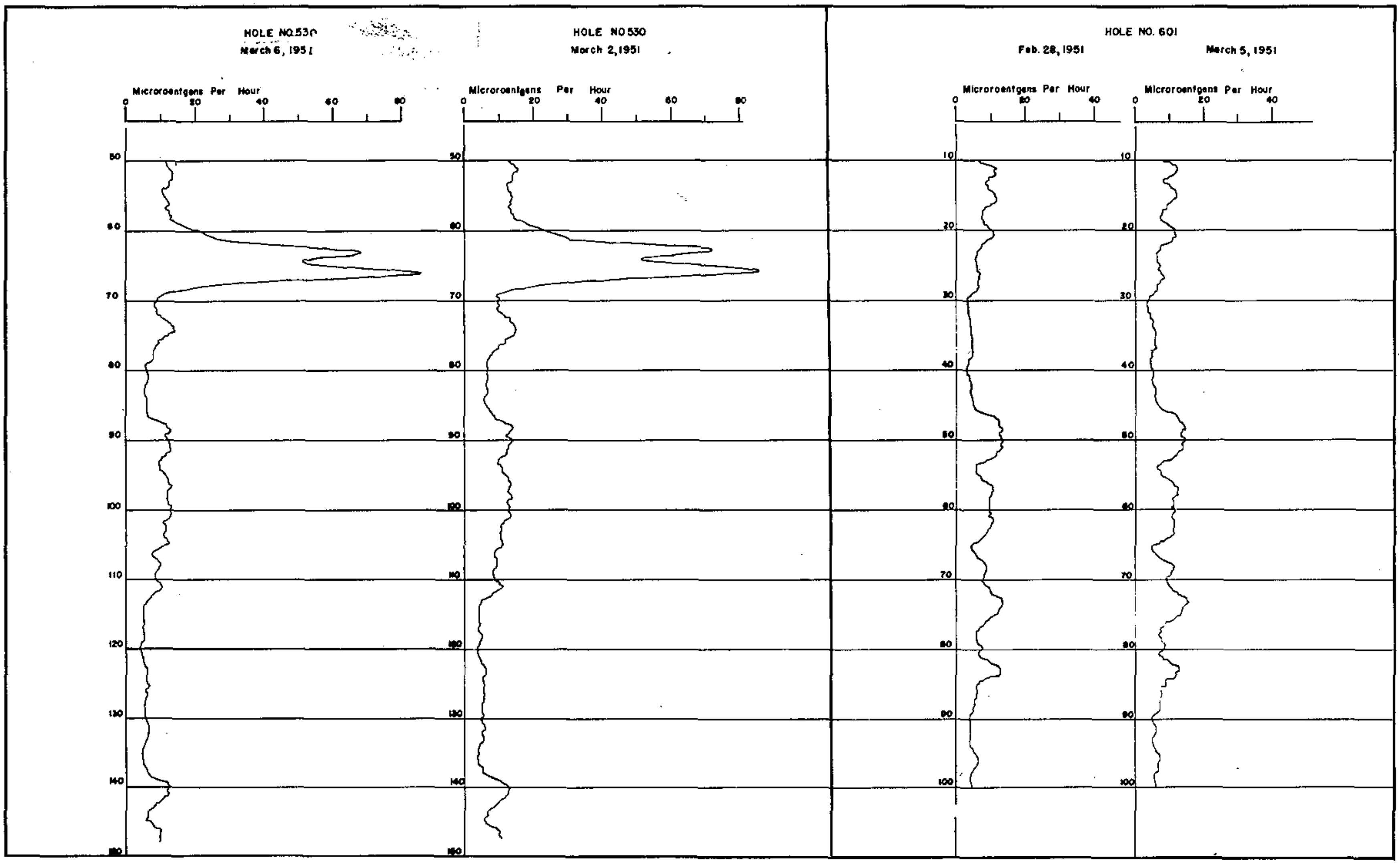


Sensitivity scale X 2
Time constant 5 sec.



COMPARISON OF BATSKOY LOGS
BLANDING DISTRICT, SAN JUAN CO., UTAH

Logging speed 4 ft. per min.
Time constant 10 sec.
Type K counter



NOTE: These logs illustrate the ability of the equipment to repeat when the holes are logged several days apart.

PLATE 8