FACIES DEVELOPMENT OF THE GALLUP FORMATION

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Recent oil and gas discoveries in sandstone lenses of the Gallup formation or its stratigraphic equivalent in the San Juan Basin have stimulated subsurface exploration in a search for similar stratigraphic traps.

The purpose of this article is to discuss briefly the Gallup formation of upper Cretaceous age and its gradation from a porous massive sandstone on the southwest flank, into a black calcareous shale on the northeast side of the San Juan Basin.

The geographic area included in this discussion as shown on the index map extends from Townships 17 through 27 North and Ranges 1 through 15 West, including parts of McKinley, Rio Arriba, Sandoval and San Juan Counties, New Mexico.

REGIONAL GEOLOGY

The San Juan Basin is a nearly circular structural basin of Tertiary age. There is a sequence of upper Cretaceous marine and continental sediments indicating that the present structural basin was, during Cretaceous times, a portion of the southwest side of a intracratonic basin or epicontinental sea.

The entire upper Cretaceous interval within the San Juan Basin varies from 5000 to 7000 feet in thickness with regional thickening from southeast to northwest. This regional increase of the entire section is the net effect of two separate wedges of sediments.

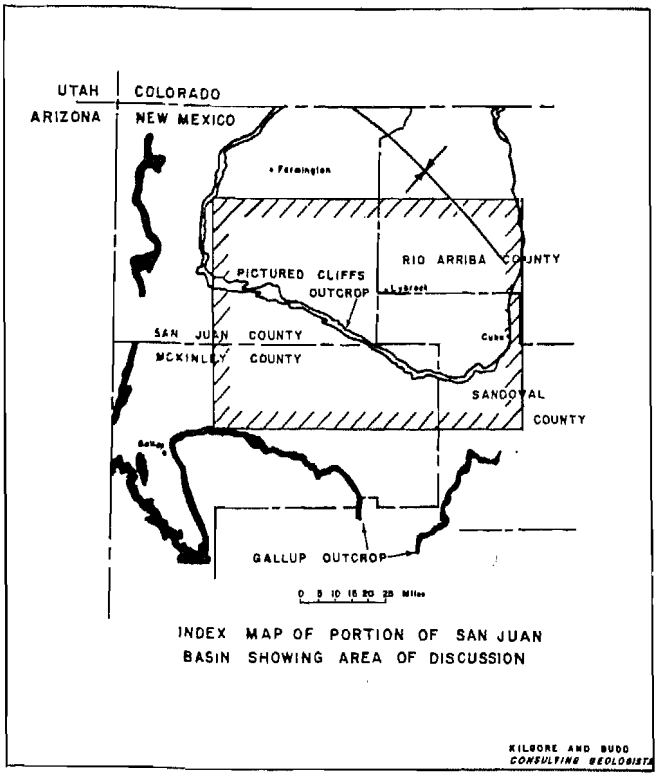
The lower wedge, the interval from the base of the Dakota formation to the top of the Pictured Cliffs sandstone, thickens from notheast to southwest with lithofacies gradation indicating a southwest source for the clastic sediments.

The upper wedge that occupies the interval from the top of the Pictured Cliffs sandstone to the top of the Cretaceous section including primarily the Fruitland and Kirtland formations thickens from southeast to northwest with an indicated source of sediments northwest of the site of deposition.

At the close of lower Cretaceous time, major subsidence caused invasion of epicontinental seas and inundated the Jurassic erosional surface.

After deposition of the basal clastic unit—the Dakota formation—there existed a stable neritic environment with deposition of very fine-grained distal clastic sediments that form the lower members of the Mancos shale. As shown on the accompanying cross sections, these earlier units exhibit little change over broad areas and may be identified and correlated on electrical logs with facility.

This stable environment existed until shortly after the initial deposition of the middle Mancos member (lower 40' of Zone L, composite log). Apparently there was limited uplift in the source area southwest of the Mancos seas. This activity is reflected in the fine-grained clastics that were transported out to sea before they were deposited as thin lenses of calcareous sandstones and siltstones encased in black shale that constitute the calcareous members of the Mancos. Some of these lenses are developed enough to be recognizable on electrical logs and are given the name "Tocito" (Tocito lense of Zone L. composite log).

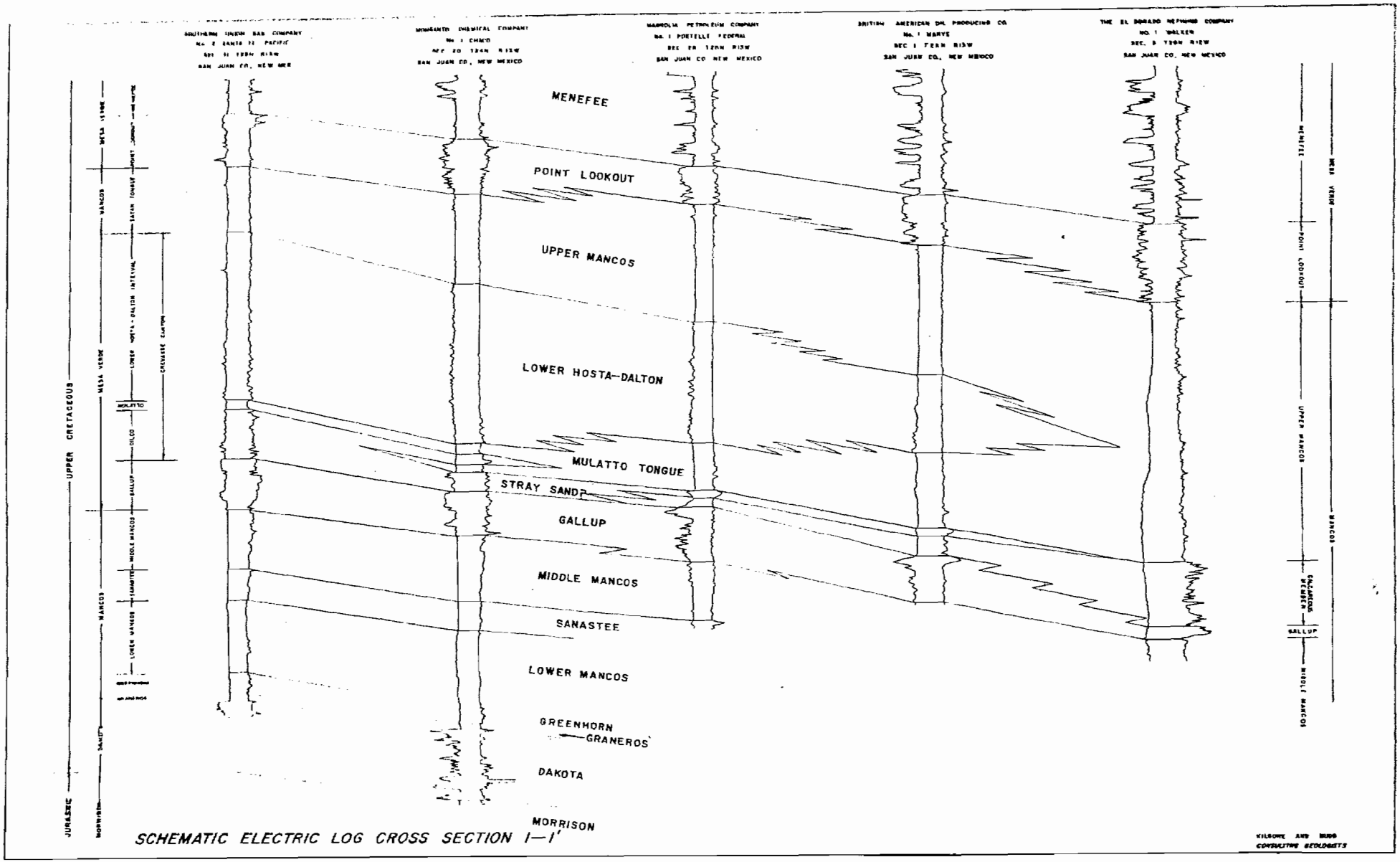


INDEX MAP OF PORTION OF SAN JUAN BASIN SHOWING AREA OF DISCUSSION

There was additional uplift in the southwest that resulted in an influx of medium-grained clastic sediments into the southwestern portion of the Mancos seas. These proximal sediments were deposited in a series of coalescing deltas which constitute the Gallup formation in the southwest part of the San Juan Basin. As these deltas were extended toward the northeast, the Mancos seas withdrew to the proximate position of line A-A' on the accompanying lithofacies map (Plate 2). This line represents the point of maximum regression of the Mancos seas.

The influx of sediments abated and there existed a short period of stability during which a series of sediments were deposited forming the transitional and epineritic facies.

After this short period of stabilization there was a sudden subsidence and the seas transgressed and inundated


SOUTHERN UNION GAS COMPANY
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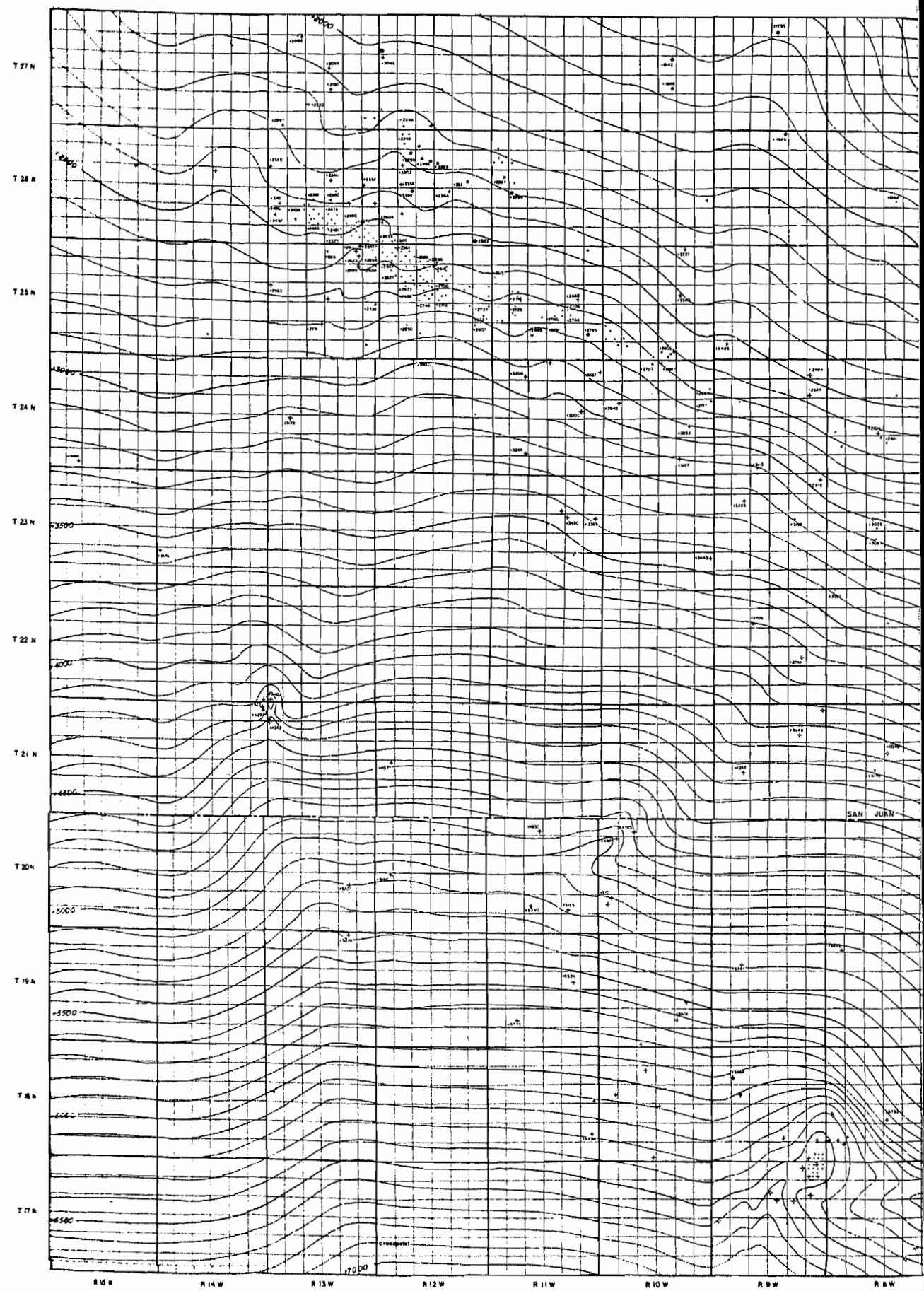
SEC. 31 T28N R13W
SAN JUAN CO., NEW MEX
MONSANTO CHEMICAL COMPANY
No. 1 CHACO
SEC. 20 T24N R13W
SAN JUAN CO., NEW MEXICO
MAGNOLIA PETROLEUM COMPANY
No. 1 PORTELLE FEDERAL
SEC. 28 T28N R13W
SAN JUAN CO. NEW MEXICO
BRITISH AMERICAN OIL PRODUCING CO.
No. 1 MARYS
SEC. 1 T28N R13W
SAN JUAN CO., NEW MEXICO
THE EL DORADO REFINING COMPANY
NO. 1 WALKER
SEC. 8 T30N R16W
SAN JUAN CO., NEW MEXICO
MENEFEE
POINT LOOKOUT
UPPER MANCOS
LOWER HOSTA—DALTON
MULATTO TONGUE
STRAY SAND
GALLUP
MIDDLE MANCOS
SANASTEE
LOWER MANCOS
GREENHORN
GRANEROS
DAKOTA
MORRISON
UPPER CRETACEOUS
JURASSIC
MESA VERDE
MANCOS
DAKOTA
MORRISON
MENEFEE
POINT LOOKOUT
UPPER MANCOS
CALCAREOUS MEMBER
GALLUP
MIDDLE MANCOS
SCHEMATIC ELECTRIC LOG CROSS SECTION I—I'
WILSON AND WOOD
CONSULTING GEOLOGISTS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SOUTH FLANK OF SAN JUAN BASIN

WELLS SHOWN PENETRATED GALLUP SECTION OR ITS EQUIVALENT

SCALE 1" = 2 MILES | BY SAN JUAN REPRODUCTION

STRUCTURE CONTOUR MAP
POINT LOOKOUT SAND STONE
CONTOUR INTERVAL 100'

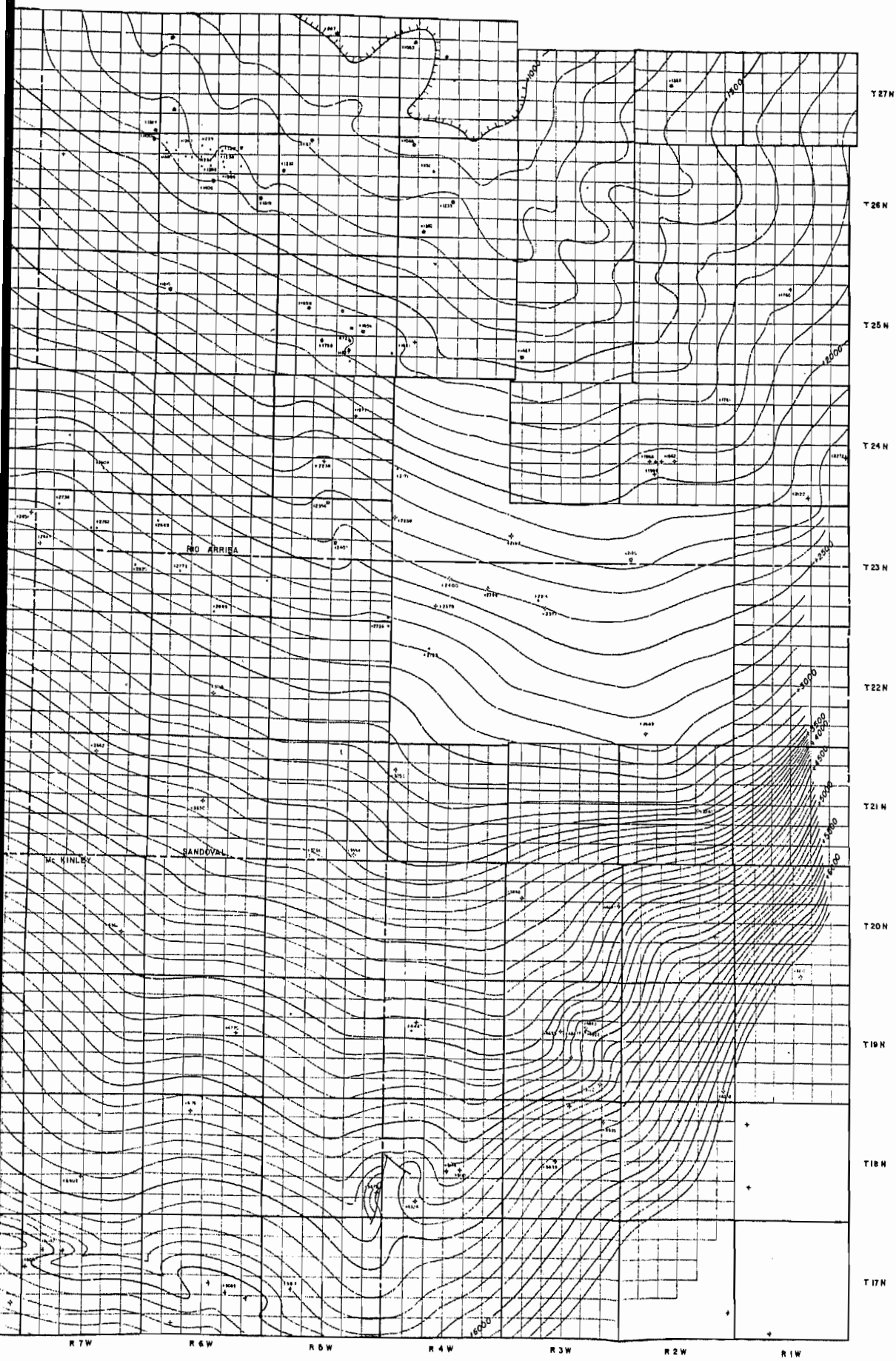


PLATE NO. 1

these deltaic deposits of the Gallup formation.

This was one of the first of a series of cycles consisting of limited uplift in the source area and deposition of medium-grained clastics concurrent with marine regression toward the northeast. These regressions terminated in a short period of stability followed by subsidence with a transgression of the seas over the newly deposited sediments. Thus, the Mesaverde group is composed of a series of formations with their constituent members reflecting these cycles of regression and transgression of the seas. These sediments have their thickest portion on the southwest with attenuated edges in the subsurface (Section 1-1') toward the northeast and in some cases appearing at the surface on the northeast side of the San Juan Basin.

STRATIGRAPHY

The Mesaverde group as defined on the southwest side of the San Juan Basin by Beaumont, Dane and Sears (1956) is as follows:

Mesaverde Group
- Cliff House ss.—(Zone F, composite log).
  - La Ventana tongue
- Menefee fm.—(Zone G, composite log).
  - Allison mbr.
  - Cleary coal mbr.
- Point Lookout ss.—(Upper 130' of Zone H, composite log).
  - Hosta tongue
- Crevasse Canyon fm.—(Zone J, composite log).
  - Gibson coal mbr.
  - Bartlett Barren mbr.
- Dalton ss. mbr.
  - Dilco coal mbr.
- Gallup fm.—(Zone K, composite log).

This Group totals more than 2400 feet in thickness at its maximum development on the southwest side of the San Juan Basin. As previously discussed, the different formations in this group undergo lithofacies gradation along with rapid thinning toward the northeast.

The older formations of the Mesaverde group exhibit this lateral gradation and northeast thinning to a greater extent than the younger formations. In particular, the Gallup and Crevasse Canyon formations thin northeastward and are eventually replaced by members of the Mancos shale.

As Bozanic (1955) has demonstrated and as is shown on accompanying cross sections, Nos. 1-1', 2-2' and 3-3', the Gallup formation (Zone K, composite log) and the lower part of the Crevasse Canyon formation (lower 200' of Zone J, composite log) grade into the Niobrara member of the Mancos shale at the approximate position of line D-D' on the accompanying lithofacies map (Plate 2). The upper members of the Crevasse Canyon formation (upper 400' of Zone J, composite log) are replaced by the upper member of the Mancos shale.

In all probability the entire Mesaverde group thins and eventually disappears so that at some point the overlying Lewis shale is in direct contact with the underlying Mancos shale (Silver, 1950). This feature probably took place northeast of the northeast limits of the Mesaverde outcrop in the San Juan Basin and has been removed by erosion.

STRUCTURE

The San Juan Basin is an asymmetrical syncline with a moderately dipping northeast flank and gently dipping southwest flank. The axis extends in a northwest-southeast direction as shown on the index map. The southwest flank dips approximately 100 feet to the mile and is a remarkably uniform example of regional homoclinal dips. At the south edge of the area under discussion, approaching the Zuni uplift, there is some local folding and faulting. Basically, however, the general area is one of very regular, monotonous, north and northeastward dips into the center of the basin.

The structure contour map, Plate No. 1, is contoured on top of the Point Lookout sandstone (upper 130' Zone H, composite log) which the writer has found to be the lowest, fairly consistent horizon in the Mesaverde group that offers sufficient control for mapping.

GALLUP FORMATION

The sediments that comprise the Gallup formation were deposited in a regressing marine sea. It is possible to divide the Gallup into several distinct facies. From southwest to northeast the following facies may be recognized: the deltaic facies, the transitional facies, the epineritic facies and the infraneritic facies.

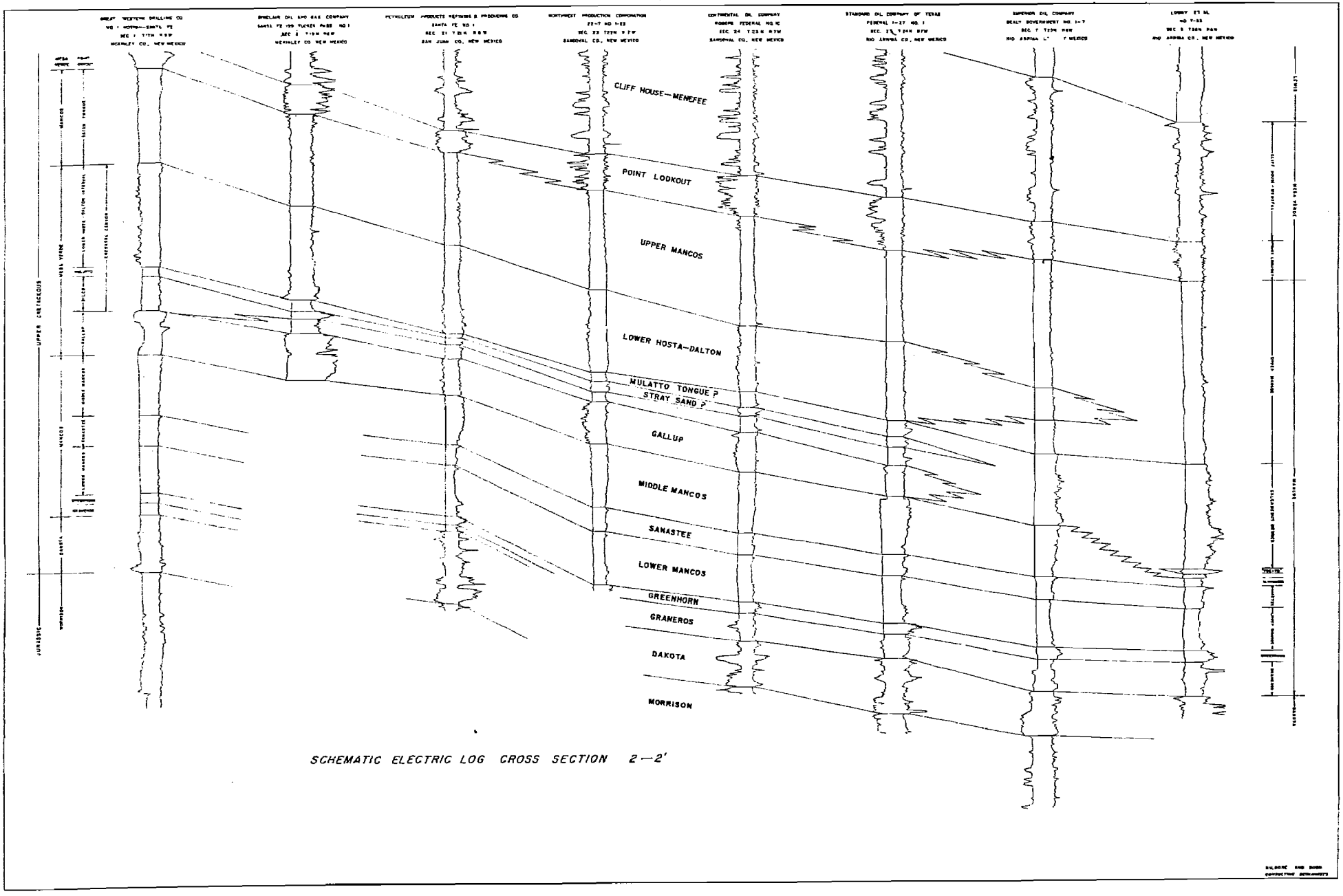
Deltaic Facies

The deltaic facies extends from the Gallup outcrop at the southwest side of the San Juan Basin northeast to the approximate position of line A-A'. This facies represents a series of coalescing deltas deposited from newly activated highlands to the southwest. The sediments comprising this facies of the Gallup are a series of massive, lenticular, medium-grained, locally crossbedded, subangular to subrounded, clean, fairly well sorted, porous and permeable quartz sandstones. Surface water has entered these porous sandstone beds at the outcrop and migrated down-dip saturating the porous rocks of this facies.

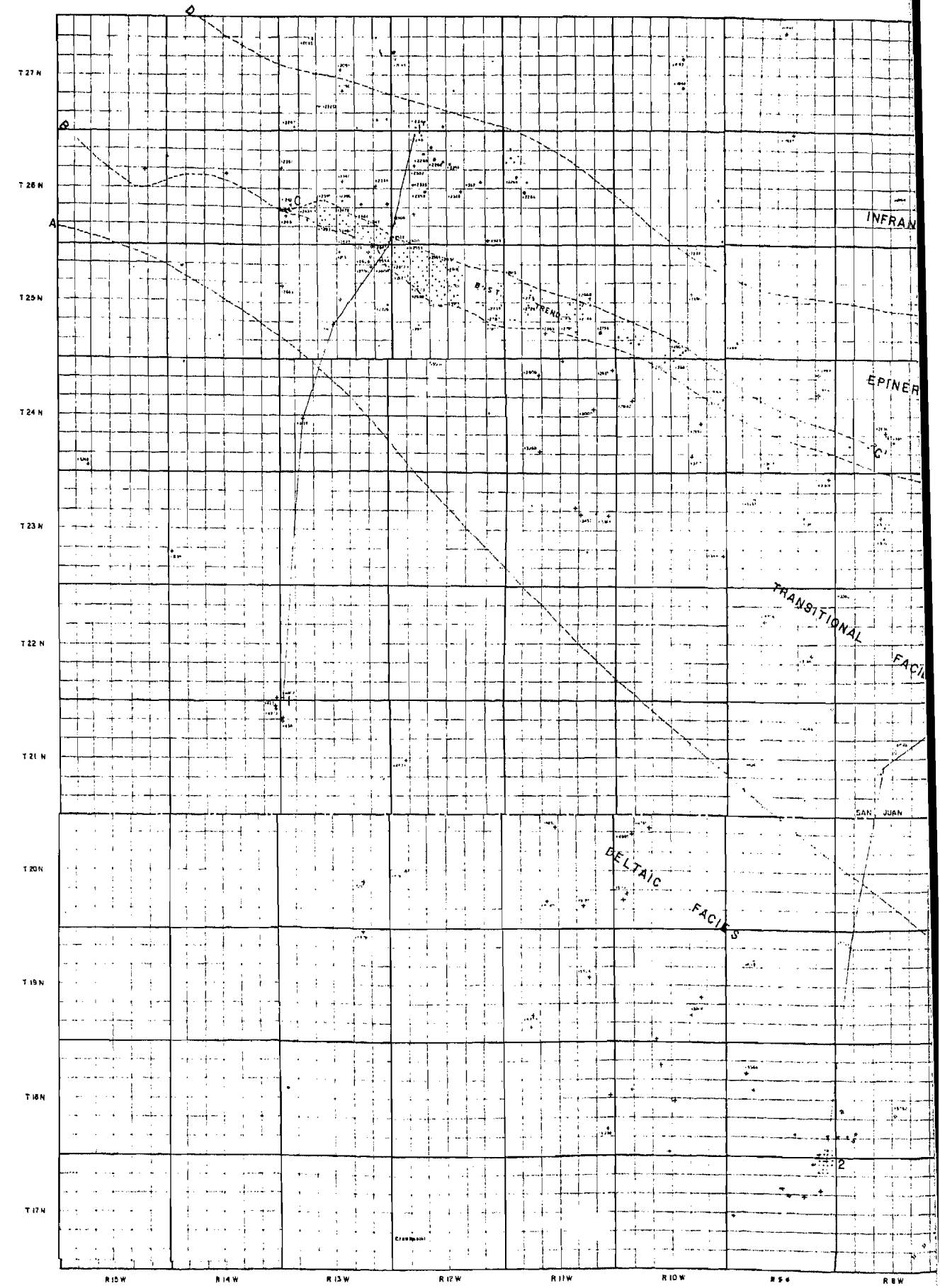
These sandstone lenses have favorable porosity and permeability and provide excellent reservoir beds for the accumulation of oil and gas if some type of trap exists. In this particular facies of the Gallup, structural closure is the critical single feature in oil and gas accumulation.

Transitional Facies

Immediately north of and adjacent to the deltaic is the transitional facies. Including the littoral and very near shore environments of the Gallup seas, this facies, as indicated between lines A-A' and B-B' on the accompanying



SCHEMATIC ELECTRIC LOG CROSS SECTION 2—2'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SAN JUAN
DELTAIC
FACIES
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PLATE N

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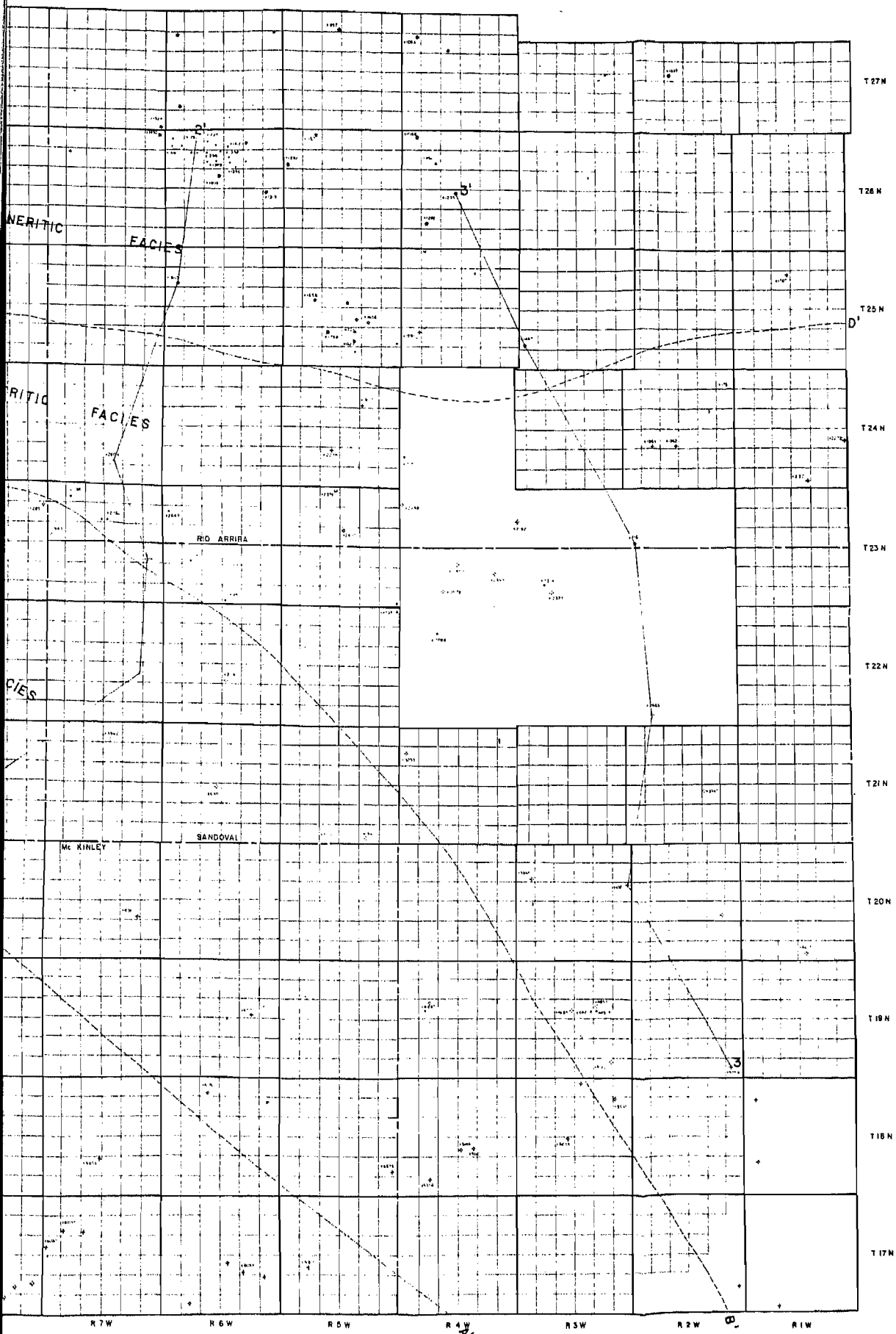
SOUTH FLANK OF SAN JUAN BASIN

WELLS SHOWN PENETRATED GALLUP SECTION OR ITS EQUIVALENT

SCALE 1" = 2 MILES

FACIES MAP OF THE GALLUP FORMATION

1—1' CROSS SECTION LINE



NO. 2

lithofacies map, represents deposition in tidal flats, swamps, near shore and shallow marine environments. Sediments deposited here vary from clay to coarse-grained fragments with the finer particles predominating.

The lithology in this zone consists of a series of interbedded, black, carbonaceous, fossiliferous shales with siltstones and medium- to fine-grained sandstones. Abundant carbonized plant fragments and the primary structure of cores from this zone are indicative of a near shore, shallow water, occasionally turbulent environment. Slump fabric is common. Shale inclusions in sandstone and sandstone inclusions in shale are indicative of reworking processes. Thin sandstone and shale laminations, in some cases deformed both by post depositional wave action and diagenitic compaction, indicate shallow water environment.

Normally, the porous sandstone lenses are saturated with water ranging from fresh to slightly sulfurous. Apparently these lenses are in communication with the deltaic facies so that fresh water has encroached down-dip and saturated these sandstone beds. Conversely, oil and gas generated in the black, carbonaceous shales and siltstones have migrated up-dip and have lost too the atmosphere unless stopped by structural and/or stratigraphic entrapment.

In the transitional facies intercommunication of these sandstone beds lessens the possibility of stratigraphic accumulations of oil and gas. Oil and gas exploration should be directed toward structurally-controlled accumulations.

Epineritic Facies

Adjacent to and immediately northeast of the transitional facies, between lines B-B' and D-D' of the Gallup formation, is the epineritic facies as defined by Krumbein and Sloss (1951). The proximal sediments in this zone are true marine deposits, farther removed from the source area than the deltaic and transitional facies; yet, in the shallower nearshore portion of an epicontinental neritic environment.

Sediments deposited in this environment reveal the effect of further transportation and winnowing of the seas. They range from clay-size particles to coarse-grained sand fragments; however, as in the case of the transitional facies, the finer particles predominate.

The lithology of this zone consists of argillaceous siltstones and fine-grained argillaceous sandstones with thin streaks of black, carbonaceous, fossiliferous shale. Locally, slump fabric may be observed together with some evidence of reworking; however, not to the extent observed in the transitional facies. These rocks are relatively impermeable. The surface waters that encroached down-dip from the Gallup outcrop through the massive sandstones into the interfingering sandstone lenses of the transitional facies have not invaded this facies. The connate water in the more porous members of this zone is salty. Frequently the sandstone and siltstone units of this facies are saturated with oil and/or gas. Hydrocarbons have been trapped essentially in or near the source beds due to the impermeable nature of the rocks.

Bisti field is in this particular facies of the Gallup. The Bisti trend consists of a number of porous, permeable sandstone lenses encased in relatively impermeable siltstones and shales.

The sand grains comprising these sandstone lenses are a heterogenous mixture of varied size quartz fragments with usually minor quantities of accessory minerals such as: calcite, feldspar, chlorite, sericite, chalcedony, glauconite, zircon, garnet, tourmaline, hematite, limonite, pyrite, ilmenite, magnetite and clay minerals, indicative of a granitic source.

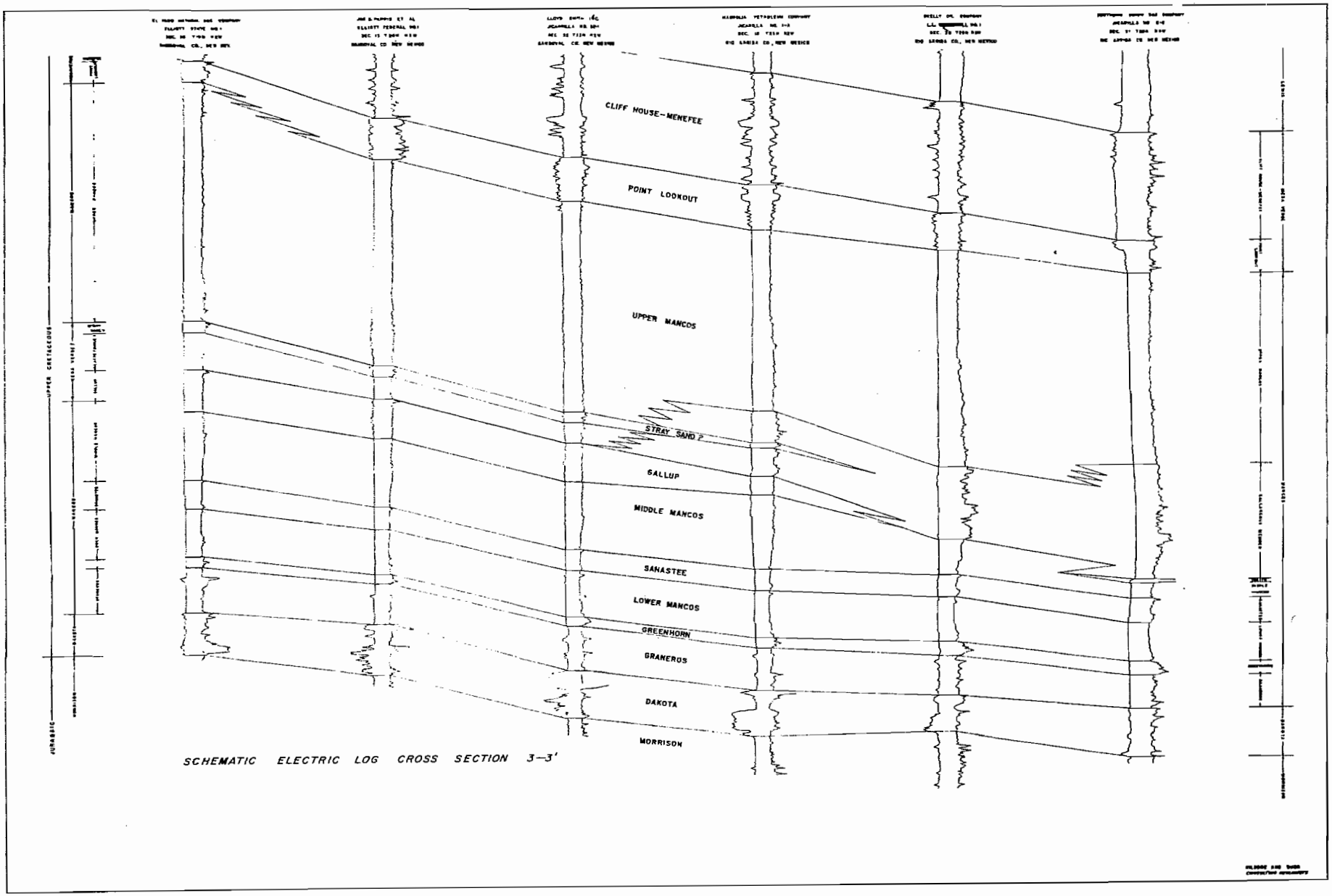
These sandstone lenses have indicated by sieve analysis from a number of cores (Pritchett, 1957) that the average grain size of the producing zone is appreciably larger than the average size of the sediment comprising the remainder of this zone. Apparently, the intergranular porosity of Bisti field is not a simple result of winnowing action by submarine currents removing the clay and silty-size fragments leaving the larger fragments as relatively clean, porous sandstone lenses. Instead, the productive sandstones are composed of fragments similar in size to the sediments of the deltaic facies which have been introduced into the area. These deposits have been called offshore sandbars by Tompkins (1957). The writer has looked for primary structures, such as cross-bedding and other indications of a sandbar subject to subaerial erosion. None were apparent. It is the writer's opinion, however, that the depositional environment and mechanics were bar-like in nature.

These sediments grade downward in size toward the southeast along the trend. There is an appreciable thinning of these sandstone lenses in the same southeast direction.

Examination of the accompanying lithofacies map reveals that on the north end of Bisti Field, the deltaic facies is closer to the sandstone lenses of Bisti trend than at any other part. This proximity, together with the southeast thinning and graduation of sand grains, suggest the following mechanics for deposition of the productive sandstone lenses now constituting the Bisti trend.

The area in which the beach facies closely aproaches the Bisti trend probably represents the entrance into the sea of a locally major drainage system. The sediments dumped at this point were distributed by long-shore currents moving in a southeast direction. Due to the sorting action of the current, the fragments were strewn along the sea floor with the fine fragments being carried farther before deposition.

Thus, the Bisti trend appears to be a special case wherein larger-than-average sediments were deposited in this neritic environment due to a combination of abnormal supply and current action. There are other linear, sand-bar lenses of sandstone and sandy siltstone in this facies. So



SCHEMATIC ELECTRIC LOG CROSS SECTION 3–3'

far all have been saturated with oil or gas. These lenses are parallel or en echelon with Bisti trend; however, none have the size or permeability of Bisti field.

Current oil exploration is directed toward drilling on trend with these local porous lenses on the theory that additional sandstone lenses have a better mathematical probability of occurring there than between trends. However, this exploration is in its initial phase and the degree of success is yet difficult to determine.

Infraneritic Facies

This facies represents deposition of distal sediments in the quiet, relatively shallow Mancos seas. The sediments are fine- to very fine-grained and form the shales of the lower part of the calcareous member of the Mancos. These shales are black, carbonaceous, fossiliferous, hard, dense and silty with few very thin to hair-line laminae of calcareous sandstone or siltstone. The bedding is normally very delicate and even, indicative of deposition below wave base.

In this section of carbonaceous shales, small lenticular bodies of medium- to fine-grained sandstone are frequently found. These porous lenses are commonly oil saturated and referred to as the "Tocito lenses," although they are discontinuous and occupy slightly varying stratigraphic positions.

These sandstone lenses occur sporadically throughout the entire calcareous member of the Mancos shale section; however, with greater frequency near the base.

They are genetically related to the Gallup formation in the sense that they were derived from the same source and are lithologically similar. However, the writer questions the validity of applying the name Gallup to them as they generally occupy a lower stratigraphic position in the Mancos.

SUMMARY

The Gallup formation of the Mesaverde group is a wedge-shaped section of clastics derived from the highlands southwest of the site of deposition. Rejuvenation of the highlands and marine regression to the northeast resulted in the deposition of a section of sediments that reflect the various environments. On the basis of these different environments the Gallup is divisible into facies, named in a northeast direction; the deltaic facies, the transitional facies, the epineritic facies and the infraneritic facies.

The deltaic facies consists of massive, porous crossbedded sandstones with minor shale stringers, normally saturated with fresh to brackish water. In this facies, structural closure is the prime requisite for oil and gas accumulation.

North east of the deltaic facies is the transitional facies represented by interbedded siltstones and fine-grained sandstones with minor quantities of shale. The members of this section are also saturated with fresh to slightly brackish water. in this facies, as in the deltaic facies, structural closure is required for oil and gas accumulation.

Northeast of the transitional facies is the epineritic facies consisting of nearshore and offshore marine sediments, represented by siltstone and shales with local sandstone lenses. Some of these lenses are a result of winnowing action by submarine currents that remove the finer particles leaving permeable sandstone reservoirs. The Bisti trend appears to have been a special case, combining estuarine source with longshore current distribution. Porous lenses in this facies are partially saturated with oil and may be produced if permeability exits or can be created by sand- or oil-fracturing treatment. Permeable lenses may occur at random in this facies with, the writer believes, the mathematical probability of occurrence being higher on the nearshore or southwest margin.

Infraneritic facies as indicated by the writer represents the deposition of sediments in the deeper portions of the Mancos seas that were relatively unaffected by the influx of Gallup sediments and accompanying marine regression. Rocks comprising this facies are black, carbonaceous, calcareous, fossiliferous shales with local lenses of porous sandstone or siltstone, partially saturated with oil or gas. The lenses are called "Tocito", although this term is controversial and does not conform with accepted stratigraphic nomenclature requirements. Porosity and permeability developments are requisites for commercial oil and gas accumulations in this facies.

CONCLUSIONS

The sandstone lenses in the epineritic and infraneritic facies of the Gallup formation or its stratigraphic equivalents in the San Juan Basin act as oil and gas traps. Bisti trend includes some of the thickest and best developed of such lenses and represents a special case. The writer feels that exploration for similar development should be along strike with Bisti field on the southwest margin of the epineritic facies and if possible in an area where a seaward extension of the deltaic facies indicates entrance of a major drainage system.

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