THE COMPOSITION, TEXTURE, STRUCTURE, AND PROBABLE ORIGIN OF THE "GATCHELL" SAND

In Partial Fulfillment of the
Requirements for the Degree
of Master of Science

Louis J. Regan, Jr.
California Institute of Technology
Pasedena, California
June, 1941

ABSTRACT

The purpose of the research has been to gather data on the structural and stratigraphic relations, composition, and texture of the "Gatchell" sand, and to attempt to interpret the conditions of deposition of the sand body in the light of this data. The "Gatchell" is the producing sand of the East Coalinga Extension Oil Field.

Several structure contour maps, an isopach map and two structure sections are presented to show the general structural relations of the "Gatchell". The sand body is thicker on the north than on the south; moreover the rate of eastward thickening is much more rapid in the northern area. The zero isopach, or line of pinch-out of the sand body, is remarkably straight and trends about north-south.

The sand is arkosic, containing between 20-30% feldspar. The feldspar is practically all potash feldspar, orthoclase and microcline being present in subequal amounts. Accessory or heavy minerals are scanty both in number of species and in total amount present. The assemblage is a very stable one, relatively rich in zircon, garnet, and tourmaline. The presence of glaucophane points to a Coast Range origin for at least some of the material. Whether the bulk of the sand was derived from the east or from the west cannot yet be shown.

The sand is very angular and coarse, but very well sorted. It is suggested that the agent transporting and depositing the sand was marine currents. Since the northern sand is older,* it is suggested that the sand body grew from north to south, and that the immediate source of the material may have been on the north.

The internal structure of the sand cannot be shown by bedding, which is lacking, nor by mineral zones, but a generalized picture can be obtained from a consideration of charts showing the median grain size of the sand against depth. A number of these charts are presented in the appendix; it is suggested that in the southern area, at least, "Gatchell" sands transgressed from east to west over Hondo silts. The sand in wells on the west, near the line of pinch-out, is represented in wells on the east by the upper part of the sand body only.

The environment of deposition of the "Gatchell" cannot yet be demonstrated. However, four hypotheses are suggested and discussed, which fit some of the evidence. These hypotheses are (1) the baymouth bar-spit hypothesis (2) the offshore bar hypothesis (3) the shoreface terrace hypothesis and (4) the interfingering hypothesis.

---

*B. Laiming-Oral Communication.

TABLE OF CONTENTS

TABLE OF CONTENTS
(Continued)

THE COMPOSITION, TEXTURE, STRUCTURE, AND PROBABLE ORIGIN OF THE "GATCHELL" SAND

INTRODUCTION

Purpose of the Investigation

The study has been carried out with the hope that detailed knowledge of the composition, internal structure, and stratigraphic and structural relations of the "Gatchell" sand body might lead to an understanding of conditions of deposition, and this in turn to the mode of origin of the sand.

Early in 1938 an Eocene test well was drilled on the East Coalinga anticline, which resulted in the discovery of a new field. The discovery well, drilled by Petroleum Securities Co. on July 1, was completed in an Eocene sand at a depth of 6,908'; since the well was located on the Gatchell lease, the sand is known as the "Gatchell" sand.

Subsequent drilling has outlined the productive area and given data on the nature of the reservoir. The interpretation of this data has led to numerous differences of opinion. Production occurs well down the plunge of the East Coalinga anticline, and is confined to the eastern flank, for the western limit of sand deposition effects closure. The "Gatchell" sand body either lenses out within a short distance or changes to siltstone updip; the abruptness with which this thick sand body disappears westward is very striking. Some of the problems associated with the "Gatchell" are (1) whether the sand is lenticular, or (2) whether the updip pinch-out is a facies change, (3) what position the sand occupies in the Eocene section, and (4) what was the mode of deposition of the sand.

The northern extension of the Coalinga nose area, was discovered by the Amerada Petroleum Corp. in April, 1939 (discovery well S.P.L. Co. no. 7-17, sect. 17, T19S, R16E.) The whole productive area, including both the northern and southern areas, is known as the Coalinga East Extension oil field; the field is 7-8 miles long and only a maximum of a little over a mile wide.

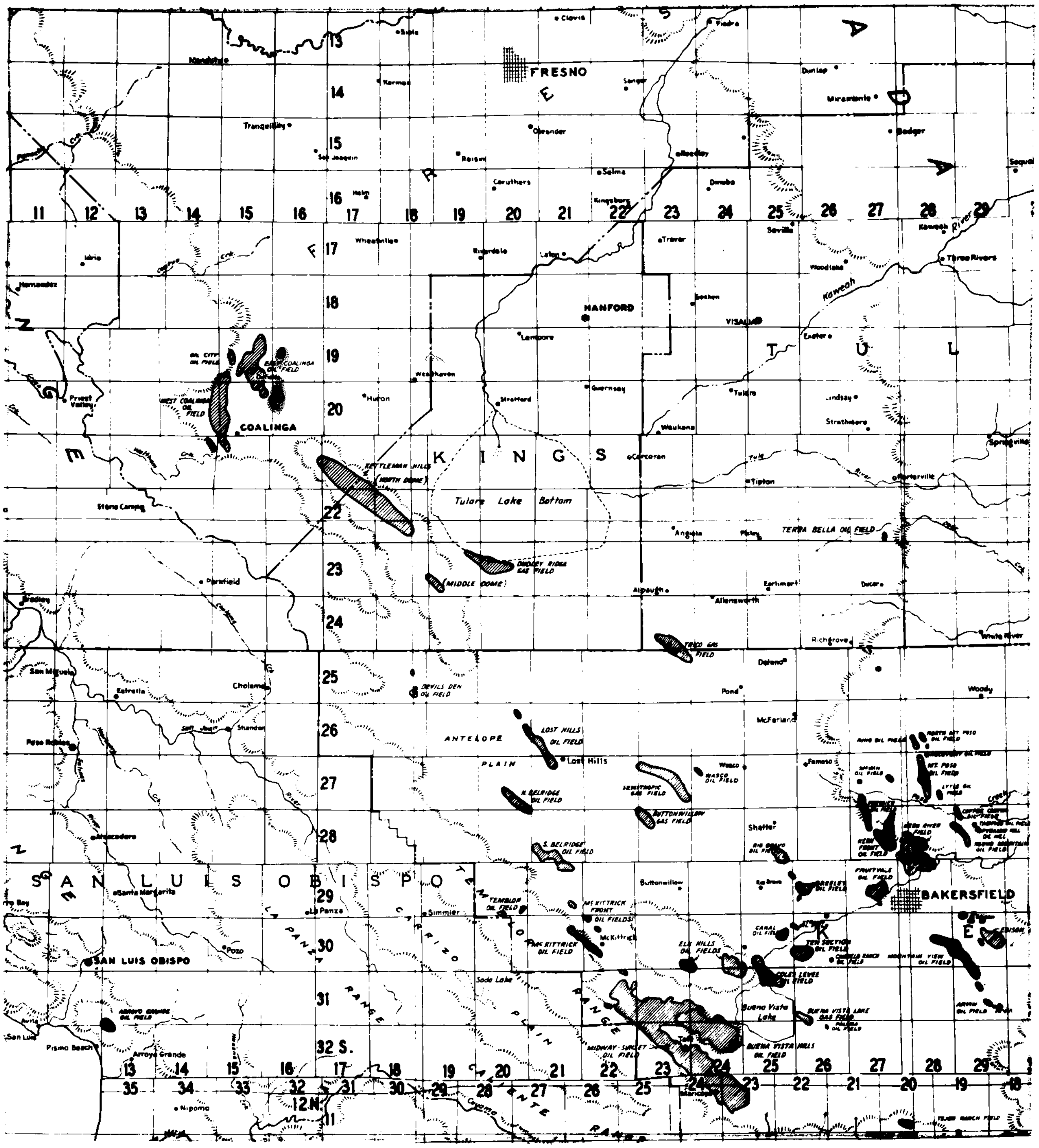
In the study a considerable amount of data has been obtained. Although no definite conclusions regarding the origin of the sand body can yet be reached, nevertheless an examination of available data bearing on the problem is the first step towards its solution. A number of working hypotheses can be set up which fit some of the evidence. Whether one of these hypotheses, or a new one is finally extablished as most likely will depend on acquiring more information from future studies.

This paper is thus an attempt to synthesize what is now known of the "Gatchell". Also, certain lines of approach will be described along which the author hopes to continue the study and ultimately reach a conclusion.

Location of Area

The "Gatchell" sand does not outcrop, and the work has been confined to a study of the sands in cores. The "Gatchell"

INDEX MAP: The red area shows the Location of the East Coalinga Extension Oil Field.



FRESNO
Clovis
Sanger
Kerman
Tranquillity
San Joaquin
Raisin
Caruthers
Selma
Kingsburg
Reedley
Dinuba
Dunlap
Miramonte
Badger
Sequoia
Oleander
Helm
Mendota
Riverdale
Laton
Traver
Seville
Kaweah River
Three Rivers
Woodlake
Goshen
HANFORD
VISALIA
Lemoore
Exeter
Huron
Guernsey
Stratford
Tulare
Lindsay
Strathmore
Waukena
Porterville
Springville
Priest Valley
COALINGA
WEST COALINGA OIL FIELD
EAST COALINGA OIL FIELD
OIL CITY OIL FIELD
KETTLEMAN HILLS (NORTH DOME)
(MIDDLE DOME)
DUDLEY RIDGE GAS FIELD
Tulare Lake Bottom
K I N G S
Corcoran
Tipton
Angiola
Pixley
TERRA BELLA OIL FIELD
Earlimart
Ducor
Alpaugh
Allensworth
Richgrove
White River
TRICO GAS FIELD
Parkfield
Stone Canyon
San Miguel
Estrella
Cholame
Shandon
Paso Robles
Atascadero
DEVILS DEN OIL FIELD
Delano
Pond
Woody
McFarland
ANTELOPE PLAIN
LOST HILLS OIL FIELD
Lost Hills
Wasco
WASCO OIL FIELD
Famoso
SEMITROPIC GAS FIELD
BUTTONWILLOW GAS FIELD
N. BELRIDGE OIL FIELD
S. BELRIDGE OIL FIELD
Shafter
Buttonwillow
S A N   L U I S   O B I S P O
Santa Margarita
La Panza
Simmler
Pozo
SAN LUIS OBISPO
TEMBLOR OIL FIELD
McKITTRICK FRONT OIL FIELDS
McKittrick
McKITTRICK OIL FIELD
ELK HILLS OIL FIELDS
CANAL OIL FIELD
TEN SECTION OIL FIELD
COLES LEVEE OIL FIELD
FRUITVALE OIL FIELD
KERN RIVER OIL FIELD
KERN FRONT OIL FIELD
MOUNTAIN VIEW OIL FIELD
BAKERSFIELD
Edison
Buena Vista Lake
BUENA VISTA LAKE GAS FIELD
BUENA VISTA HILLS OIL FIELD
MIDWAY-SUNSET OIL FIELD
Soda Lake
CARRIZO PLAIN
LA PANZA RANGE
TEMBLOR RANGE
SAN LUIS RANGE
CALIENTE RANGE
ARROYO GRANDE OIL FIELD
San Luis
Pismo Beach
Arroyo Grande
Nipomo
Maricopa
Tulare
Kern

has been cored in wells on the Coalinga nose, in sections 12, 13,24, T20S-R15E; Sections 6,7,8,17,18,19,20, T20S-R16E; in the Amerada area, in sections 17,18,19,20, and 30, T19S-R16E. These sections all lie a few miles N.E. of the town of Coalinga, California.

The town of Coalinga is on the southwest side of the San Joaquin Valley, at the eastern base of the Diablo Range. Immediately north of Coalinga there is a long southeast trending anticlinal mountain, Joaquin Ridge. At the site of the Coalinga East Extension field, which is on the extension of the ridge, the anticline is plunging to the southeast. The continuation of the ridge forms the Kettleman Hills structures to the south. The old Coalinga Field, producing from the Miocene, lies to the west and north of the town. (See Index Map.)

Method of Investigation

As mentioned above, the work has involved the study of subsurface sands in cores. The method of study is outlined below.

A. Structural and Stratigraphic Relations

1. Stratigraphic position and correlation-determined from foraminiferal studies (Data obtained from foraminiferal departments of various operating companies)

2. Relationship to Unconformities
   a. Evidence from cores.
   b. Structure sections based on electrical logs.

3. Areal distribution of Sand Body
   a. Thicknesses encountered in cores.
   b. Data from electric logs.
   c. Isopach and structure contour maps.

B. Mineralogical Composition of Cores

1. Grain counts in thin section and grain slides.

2. Heavy mineral separations and counts.

C. Texture

1. Shape analyses (Sphericity and roundness by the method of Wadell)

2. Grain Size-distribution.
   a. Median grain size, quartiles, sorting are calculated from data obtained by seive analyses.
   b. Areal and vertical size distribution of sand body charted.

D. Internal Structure of Sand Body

1. Study of bedding, parting, etc.

2. Mineral zones.

3. Textural variations-textural zones.

E. Interpretation of Data.

Acknowledgements

Grateful acknowledgements are due to Dr. J.H. Maxon for his continued interest in the problem, for supervision of the work, and for many helpful suggestions. The author also wishes to acknowledge the helpful discussions of some aspects of the problem with Dr. Ian Campbell and Dr. F.D. Bode.

Dr. Hampton Smith, chief geologist for the Texas Co., originally suggested the problem as one worthy of study, and he has given abundantly of his time and much data which has been very useful. Thanks are due also to Dr. H.F. Ashauer and Mr. W.F. Wrath of the Texas field office in Coalinga, whose

cooperation is greatly appreciated.

Thanks are due to the Standard Oil Company, particularly to Mr. C.C. Gester, chief geologist for the company, Dr. W.S.W. Kew, chief of the Los Angeles staff, and to Mr. W.F. Barbat, in charge of the Geological Staff in Taft; to Mr. R.S. Lytle, operator, Mr. R.K. Patterson of the Los Angeles office, and to Mr. F. Taylor of the field office, Coalinga; to the Amerada Petroleum Corporation, and in particular to Mr. D. McCloskey; to the Pure Oil Co., in particular to Mr. H.C.O. Clarke, manager, and to Mr. Norman Thomas, geologist; to the Wilshire Oil Company, and in particular to Mr. Wayne M. Smith, petroleum engineer.

GENERAL GEOLOGY OF THE EOCENE OF THE COALINGA AREA

Before turning to the "Gatchell Sand", it would be well to discuss in a general way the Eocene stratigraphy of the area, and to review briefly the structural history of the Coalinga district, particularily insofar as this history may have effected the deposition of Eocene rocks.

Stratigraphy of the Eocene

The following extracts from a recent paper by White[1] together with the generalized stratigraphic column for the Eocene formations presented below should serve to familiarize the reader with the lithology of the Eocene.

Lodo Formation

"The formation (excluding the Cantua sandstone lens) varies in texture from a claystone to a siltstone. It is gray in color, with bluish to greenish cast; is massive and dense, with a blocky fracture. The formation is commonly glauconitic; and is abundantly foraminiferal."

Cantua sandstone-"The Cantua sandstone makes its appearance in Sec. 10, T16S., R12E., as a lens in the Lodo formation and is traceable to a mile south of Salt Creek where it ends in several tongues. This member separates the Lodo into two other mappable units, the Cerros shale member (lower) and the Arroyo

---

[1] White, R.T. Eocene Yokut Sandstone North of Coalinga, Cal. Bull. A.A.P.G. Vol 24, No. 10, October, 1940

Hondo shale member (upper)." "It is composed mainly of thick beds of massive sandstone in many places with a thin gray silty shale parting ranging from a fraction of an inch to several feet in thickness separating the sandy beds."

"The Lodo formation, 1,130 feet thick at its type locality, varies in thickness from zero at the north and south ends of its exposures, where it is overlapped by the Domengine, to more than 5,000 feet a short distance east of San Carlos Creek. At the latter point the Cantua sandstone member alone has a thickness of approximately 4,500 feet. North and south of this point the Cantua lenses out into shale until it is completely gone a short distance north of Tumey Gulch and south of Salt Creek. The Cantua appears to have been deposited in a structural basin that was subsiding during its deposition, while the areas north and south remained relatively stable. As a result, the sands thinned within a short distance on the flanks of the basin and finally graded laterally into shale."

Yokut Sandstone

"The upper part of the Yokut sandstone is predominantly white, medium to very fine-grained, clean and well sorted with an extremely small precentage of dark minerals. It grades downward into sandstone that is gray to pinkish gray due to the presence of carbonaceous material."

"The upper contact of the Lodo and its Arroyo Hondo shale member with the overlying Yokut sandstone is gradational and in places this change from shale to sand is so gradational that the contact between the two must be drawn arbitrarily. In the north and south ends of the area the Yokut is completely overlapped by the Domengine sandstone which progressively overlaps the whole of the Lodo to rest on the Moreno." "The Yokut sandstone varies from zero to 305 feet in thickness."

Domengine Sandstone

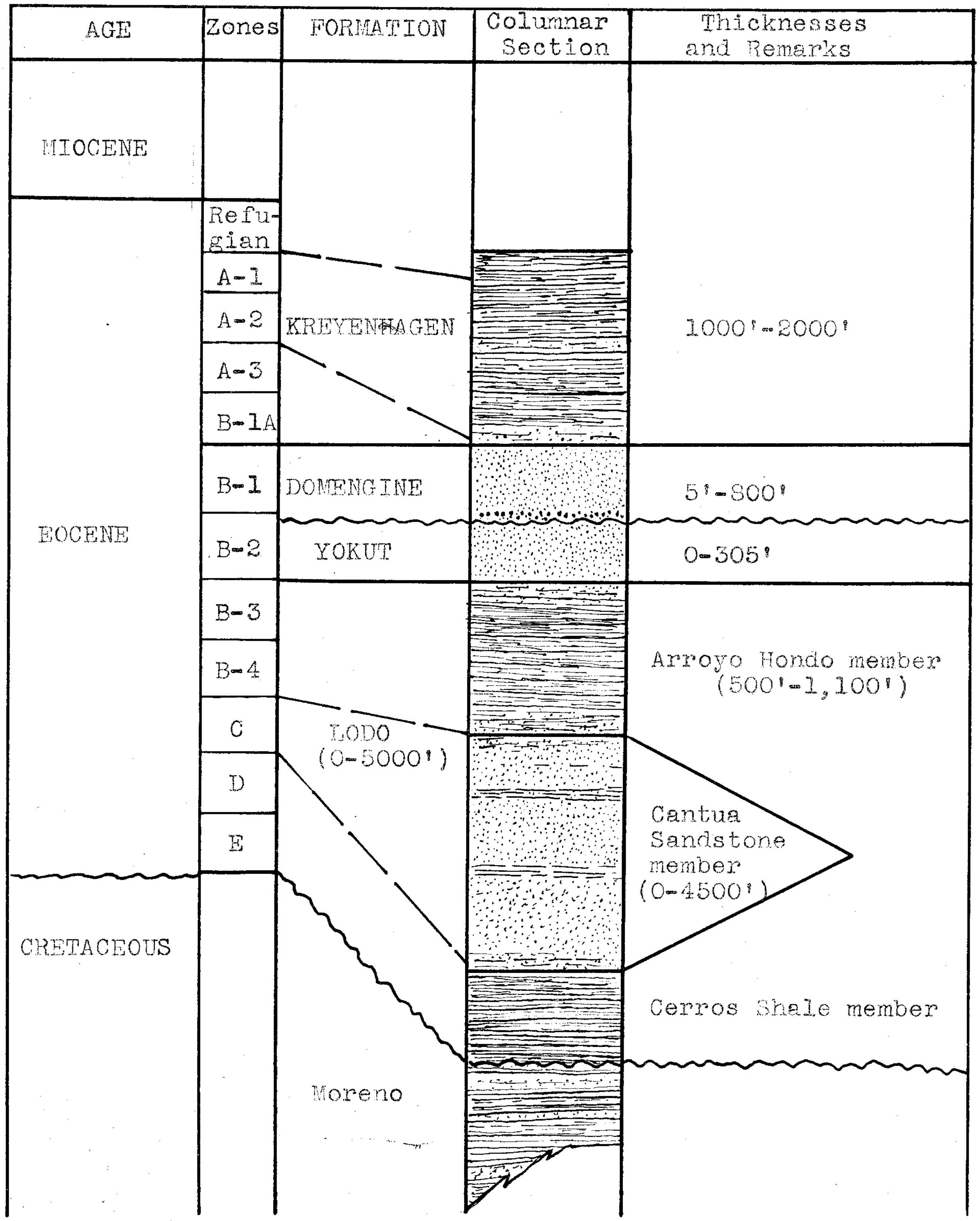
"From the N.W. ¼, Sec. 36, T19S, R14E, northward almost to Domengine Creek, the Domengine is divisible roughly into two units. The lower of these two units is composed of a sand, gray to buff-colored with here and there a purplish cast, fine to medium-grained with scattered grit, and gritty to pebbly and fossiliferous at base. The upper unit is composed of a silty to clayey shale, green-gray; a few fine grained sand beds; scattered glauconite grains; abundant Foraminifera and mollusk casts." "The pebble bed at the base of the Domengine is a remarkably consistent stratum. This bed represents the beginning of a transgression, as it overlaps the Yokut sandstone and Lodo Formation to the north and to the south of the Vallecitos structural basin."

"In places the Domengine sandstone appears to be a sandy facies at the base of the much thicker Kreyenhagen shale with a gradational contact between the two, and in other places one sees evidence that the contact is an erosional one."

"The Domengine sandstone varies in thickness. This variability probably is the result of local disconformities and of unequal rates of deposition. The thickness varies from a

GENERALIZED COLUMNAR SECTION OF EOCENE ROCKS

NORTH OF COALINGA [1]



1. Data from:
   a. White, Op.Cit., page 6
   b. Laiming, Boris, Foraminiferal correlations in Eocene of San Joaquin Valley, California, AAPG Bull, V24,#1

minimum of 5 feet, a short distance north of Arroyo Hondo, to a maximum of approximately 800 feet on San Carlos Creek."

Subsurface Stratigraphy of the Coalinga East Extension Field

The subsurface sections generally agree with the stratigraphy given above. In the subsurface sections, a few feet of highly glauconitic sand is encountered at the base of the Kreyenhagen shales, in most wells; this glauconitic sand is herein called the green sand. Below the green sand a variable thickness (10-40') of pebbly grit is found, which probably represents the Domengine Formation. Below the grit zone the upper shales of the Lodo Formation are found, and below them is the "Gatchell" sand. The interval between the grit and the "Gatchell" sand varies from 0-200'.

According to Laiming[2], the Yokut sand of the outcrop section is between the foram zones B-2 and B-3. The "Gatchell" sand is entirely B-3, and thus, there is a possibility that the Yokut and the "Gatchell" sands are in part contemporaneous.

Notes on the Structural History of the Area[3]

"The town of Coalinga lies in a sub-circular valley plain, Pleasant Valley, which is continued northwestward, greatly narrowed, in White Creek and Los Gatos Creek valleys. To the south and southeast it merges with the synclinal Kettleman

---

[2]Oral Communication

[3]Extracts from- Reed, R.D., and Hollister, J.S.- Structural Evolution of Southern Calif. A.A.P.G. 1936 Chapter III

Plain, which persists as far as the south border of the district. North of Pleasant Valley rises a 4,000 foot anticlinal mountain, Joaquin Ridge, which is continued to the southeast, by the much lower Anticline Ridge, the site of the Eastside oil field. The southward continuation of this ridge, and the east border of the Kettleman Plain, is formed by the Kettleman Hills. Three low passes connect the Pleasant Valley-Kettleman Plain lowland with the main San Joaquin Valley Plain. Two of these passes coincide with structural saddles, one of them lying between Anticline Ridge and the North Dome of Kettleman Hills, the other between the Middle and South domes."

"Stratigraphically, the Coalinga district is characterized by a nearly complete series of Mesozoic and Cenozoic formations, most of which are subject to much lateral variation. The most nearly continuous sections lie to the east and northeast; the most discontinuous to the west and southwest. The intermediate belt, corresponding to the foothills west of Pleasant Valley and Kettleman Plain, is characterized by numerous overlaps and unconformities."

"The structural evolution of the Coalinga district is related to that of the major province, the Northern basin, of which it forms a part. This province became differentiated about the end of the Cretaceous into a positive area lying toward the west, and a negative area lying between this positive area and the western edge of Mohavia. The positive area is the Diablo uplift; the negative area is the San Joaquin embayment."

"From the available data it seems safe to conclude that the most active areas of Cretaceous subsidence shifted from time to time and that the rate of subsidence, along with the rate of accumulation of sediments, differed much in different areas. Thus the lower Cretaceous underlies Priest Valley and Juniper Ridge, is absent from Joaquin Ridge, but has been recognized in the Panoche Hills father north. Similarly, the Upper Cretaceous beds are more than 20,000 feet thick west of Coalinga, thin to half of that amount or less on Joaquin Ridge, and thicken to 25,000 feet in Panoche Hills. These facts suggest strongly that Joaquin Ridge was represented during the Cretaceous by a belt of marked thinning transverse to the axis of the old Northern Geosyncline." "The absence of the Lower Cretaceous may mean either non-deposition, or removal by erosion during a (hypothetical) post-Knoxville erosion interval. In any event, Joaquin Ridge seems to have been represented to a Schwelle during the Upper Cretaceous. The positive character that it acquired not later than the end of the Lower Cretaceous seems to have persisted during the Cenozoic, and, as already indicated, to have been expecially pronounced at certain times, as during the middle of the Middle Miocene."

"In any case, there is strong evidence that the Coalinga district was folded very early along east-west lines, and that these early folds were later interrupted and cross-folded along lines more nearly parallel to the long axis of the old geosynclinal basin."

STRUCTURAL AND STRATIGRAPHIC RELATIONS OF THE "GATCHELL" SAND

In order to bring out the structural and stratigraphic relations of the "Gatchell" sand, four contour maps and two structure sections are presented. These are described below. All data has been secured from electrical logs.

Structure contour maps

1. Drawn on green sand at base of Kreyenhagen.
2. Drawn on top of "Gatchell".
3. Drawn on base of "Gatchell".

Conclusions from these maps

1. Of all these horizons, the base of the "Gatchell" is dipping the steepest. The green sand horizon, however, dips more steeply than the top of the "Gatchell."

2. The northern area represents a secondary axis of folding, or a crenulation on the main axis of the Coalinga "nose". The sand in the northern area is structurally considerably lower than that of the "nose" area.

3. The map on top of the "Gatchell" shows closure in the northern area. As will be shown later, this closure is due to stratigraphic relations rather than to folding.

Isopach Map of the "Gatchell" Sand

A glance at this map will show the remarkable thickening of the sand body to the east. Another striking thing is the apparent straightness of the line of pinchout on the west.

There is considerable contrast between the northern and southern areas. The sand is considerably thicker in the northern area than it is in the "nose" proper. The rate of thickening is also much more rapid in the area to the north. The lines of equal thickness are closely spaced on the north and have a similar relationship on the north side of the "nose". On the "nose" proper, however, the isopachs suddenly fan out, and the rate of thickening and total thickness diminish.

As has already been mentioned, there is evidence that the Coalinga Anticline has been a growing structure since Mesozoic time, for Cretaceous and later rocks thin across the anticline, and overlaps and unconformities are common there. Since the "Gatchell" shows a marked thinning on the "nose", it seems reasonable to infer that the structure was a growing one during the Eocene and that the deposition of the sand body was influenced by the presence of the anticline.

Structure Sections

There are several factors to be evaluated in understanding the structural relations of the "Gatchell" sand body. These are as follows:

1. There is an unconformity at the base of the Domengine grit zone.

2. The Hondo silts below this unconformity thicken westward.

3. The "Gatchell" sand body thickens eastward.

4. The "Gatchell" is not of precisely the same age in both areas.

The importance of the unconformity is difficult to ascertain. A study of sections drawn on the basis of electric logs indicates that the unconformity is somewhat angular. Beds in the shales above the"Gatchell" seem to dip less steeply than the grit, and they are truncated by the grit. The unconformity truncates the "Gatchell" on the eastern side of the field. Under the discussion of the composition of the "Gatchell" a highly koalinized sand is described which occurs in wells on the eastern side of the "nose area. This koalinization is believed to be due to weathering of sands under the unconformity.

The thickening of the Hondo silts to the west can be partly explained by the paragraph above. However, examination of sections (based on electrical logs) particularly in the northern area shows that along the upper contact there is interfingering of sands and shales. The upper contact is not a time line, because there is transgressive overlap from west to east of Hondo shales on "Gatchell" sands.

On the basis of Foraminifera, the sand in the northern area is older than that in the southern area. The "Gatchell" in the northern area is mostly in the zone B-4, but in the upper part may be B-3; in the southern area the "Gatchell" is all B-3.[4]

In order to bring out these relations, two structure

---

[4]Boris Laiming-Oral Communication

sections are presented. Section A-A' is in the southern area and B-B' is in the northern area. The two sections are rather different in several respects; (1) The westward thickening of the silts above the "Gatchell" is much greater on the north. (2) the rate of eastward thickening of the "Gatchell" is greater on the north and (3) There is definite evidence of inter-fingering of shales and sands along the upper contact on the north.

In wells 46-18 and 57-18 (northern area) a sand body lies between the Hondo silts and the Domengine grit. This sand thickens westward and northward, and is apparently truncated by the unconformity. The sand is locally known as the "Fleishacker" sand.

<u>Conclusions from the Structure Sections</u>

1. There was a pre-Domengine period of folding and erosion. The axis of this folding probably trends more or less N-S. This folding and truncation in part explains the thickening of the shales to the west.

2. Sands are changing to shales along the upper western contact of the sand body, particularly in the Amerada area. No evidence of similar relations for the lower contact is found in the sections. At any rate, the upper contact of the sand is not entirely a time line, though in the "nose" area it approaches a time line.

3. The northern sands are older. Provided the sand in the two areas is connected, as they seem to be, then the

picture seems to be one of growth of the sand body from north to south, transgressing over shales.

COMPOSITION OF THE "GATCHELL" SAND

The mineralogy of the sand has been investigated under the petrographic microscope in the following ways. The light minerals (S.G. less than 2.8) have been determined in thin section, and in slides of the mounted sand grains. In thin sections, relative percentages were obtained by the Rosiwal method, with the aid of the intergrating stage. In grain slides relative percentages were obtained by counting. The heavy minerals or accessory minerals of the sand have been obtained by bromoform separations. The species present were determined, and relative percentages obtained by counting. A more detailed description of the methods used together with the results of the determination is given below.

The Light Minerals

In thin section the various constituents of the sand are easily recognizable. Moreover, as long as the sections are not broken up, that is as long as the grains are prevented from spreading and separating, relative percentages of the constituents can easily be obtained by making traverses across the slides, measuring and integrating the length of all grains encountered. R. Von Huene, who made the sections, succeeded in making excellent slides by first impregnating the sand with resin.

In grain slides, however, the determination of the constituents is a slow process at best, and considerable time has been spent in trying to devise methods to speed up this phase of the work. The method described by Gabriel and Cox for the rapid determination of quartz, orthoclase, and plagioclase has proved to be useful.[5]

This method involves treating the sand grains with Hydrofluoric acid fumes. In this process, quartz is not affected but all feldspars are attacked. If the acid treatment is too long, all grains are attacked, and it has been found that the most critical step in the method is the length of time the acid treatment is applied. When orthoclase or a potash feldspar is attacked by HF, a certain amount of potash is set free. The next step in the method is to cover the grains with a solution of sodium cobaltinitrite. This reagent is used in simple chemical tests to discover the presence of potash, for when it is added to a solution containing potash, a yellow precipitate is formed. ($Na_3Co(NO_2)_6 + 3K^+ \rightarrow 3Na^+ + K_3Co(NO_2)_6$ (yellow)). When the acid-treated grains are covered with the solution, the reagent reacts with the potash set free in the silica gel formed around grains of K feldspar in the previous step. As a result, grains of potash feldspar become covered with a dense yellow coating. When the grains are then carefully washed and studied under the microscope, quartz is found to be quite clear, plagioclase dull and white, and orthoclase a brilliant yellow.

[5] Gabriel and Cox- A Staining Method for Quantitative Determination of Certain rock minerals, Am. Min., Vol. 14, pp 290-292, 1929.

In the actual process the following technique was used:

1. Sieved samples were used, so that the grains were all of about the same size.

2. The grains were mounted on a glass slide by means of a thin film of Canada Balsam. The balsam was then cooked until it was fairly hard, but not brittle. The film of balsam should be thick enough to hold the grains, but should not cover any of them.

3. For the acid treatment a small lead box was used. The acid was poured into the box until it covered the bottom. The slide to be treated was placed on a little shelf, so that only the fumes of the acid could reach it, and the box was covered.

4. Best results were obtained when the slide was treated with the acid fumes for about one minute at 50 degrees C.

5. After the acid treatment, the slide was covered with a drop of the reagent for 2 minutes. The slide was then washed, allowed to dry, and was ready for use.

When grains are dirty, as they often are in sediments, plagioclase is difficult to determine with certainty by this method, because dirty or highly altered grains greatly resemble the etched plagioclase grains. Values for orthoclase are thought to be very reliable, for the test is quite sensitive.

In the "Gatchell", very little plagioclase has been determined in thin section, and the percentage of plagioclase in the sand is so low as to be negligible.

The light minerals of the sand are as follows:

Quartz The majority shows strained extinction, but the grains are clear. Occasional grains show needle inclusions-rutile(?) Grains made up of a mosaic of intergrown quartz are not uncommon.
Chert grains are found in small amounts throughout the sand. These look black megascopically, but under the microscope are seen to be made up of very fine grained quartz, with a disseminated dark gray, opaque dust (magnetite?)

Feldspar Large fresh grains of feldspar are rather common. Most of the feldspars are only moderately koalinized and to a lesser degree sericitized.

Orthoclase and Microcline are very abundant, orthoclase being a little commoner than microcline.

Perthite orthoclase-albite perthites have been noted.

Albite-oligoclase Plagioclase has been determined but is very rare.

Biotite, chlorite, and glauconite are to be noted.

The cement is for the most part argillaceous, but in some places, particularily where the sand is extremely hard and tight it is calcareous.

Quantitative data on the quartz-feldspar ratios are given below. The data in table I indicates that the composition of the sand is very constant. It varies only from a little under 20% K feldspar to a little over 30% K feldspar. In table II, A, and B, an indication is given as to the grain size distribution of the feldspar. In the material between 1-½mm, there is

Table I. Data obtained from Thin Sections by the Rosiwal method.

Well	Sample Depth	Median Grain Size[6]	Total Distance Traversed	%Qtz	%Potash Feldspar	K Feldspar / Qtz
1-7F	6921'	.54mm	114mm	72%	28%	.38
1-7F	6980'	.56mm	129mm	77%	23%	.30
1-7F	7065'	.40mm	101mm	75%	25%	.33
1-7F	7138'	.54mm	96mm	79%	21%	.27
48-7F	7189'	.52mm	102mm	75%	25%	.33
48-7F	7341'	.34mm	128mm	71%	29%	.41
48-7F	7565'	.34mm	128mm	72%	28%	.39
88-12C	6800'	.46mm	140mm	70%	30%	.43
88-12C	6895'	.55mm	122mm	76%	24%	.32
88-12C	6950'	.43mm	130mm	72%	28%	.39
88-12C	6968'	.56mm	119mm	75%	25%	.33
1-19F	7530'	.54mm	180mm	78%	22%	.28
1-19F	7613'	.42mm	128mm	82%	18%	.22
1-19F	7658'	.42mm	133mm	80%	20%	.25
1-19F	7683'	.40mm	150mm	79%	21%	.28
1-19F	7742'	.58mm	190mm	75%	25%	.33
1-19F	7832'	.44mm	221mm	78%	22%	.28
1-19F	7927'	.41mm	122mm	75%	25%	.33
1-19F	8010'	.48mm	132mm	70%	30%	.43

1-20 7740' Megascopic-rather fine grained, tight, white sand. Similar to fine "Gatchell" but white.

Microscopic-Fresh feldspar is lacking. Sand is made up of quartz of a medium grain size, set in a very fine matrix. This matrix is made up of Kaolin and sericite. In a few cases the outline of feldspar grains can be made out.

1-20 7811' Megascopic-Similar to the sand above but coarser. Few grains of black chert.

[6] Median grain size is from sieve analysis, described under texture.

Table I- Continued.

1-20	7811	Microscopically-No fresh feldspar. Composed of quartz grains medium to coarse grained, set in fine matrix. Few very badly weathered grains of feldspar. It has a shattered and altered appearance. Fine matrix made up of kaolinand sericite.

Table II. Quantitative data from Grain Counts

A. Well #48-7F. Determinations made on material between $\frac{1}{2}$ and $\frac{1}{4}$ mm.

Depth of Sample	Total no. grains counted	%Quartz	%Feldspar(K)	K Feldspar / Quartz
7034'	258	57%	43%	.75
7074'	296	68%	32%	.47
7130'	323	68%	32%	.47
7162'	244	70%	30%	.43
7189'	284	70%	30%	.43
7280'	246	64%	36%	.56
7308'	163	66%	34%	.52
7341'	227	65%	35%	.54
7380'	252	67%	33%	.49
7461'	200	72%	28%	.39
7536'	180	70%	30%	.43
7565'	219	71%	29%	.41

B. Well #82-13C. Determinations made on material between 1mm and $\frac{1}{2}$mm.

Depth of Sample	Total no. grains counted	%Quartz	%Feldspar(K)	K Feldspar / Quartz
6773'	108	80%	20%	.25
6815'	205	78%	22%	.28
6840'	111	82%	18%	.22
6880'	145	85%	15%	.18
6890'	155	84%	16%	.19
6820'	105	82%	18%	.22
6945'	156	85%	15%	.18
6970'	153	84%	16%	.19
6976'	140	83%	17%	.20
7001'	168	83%	17%	.20
7040'	133	80%	20%	.25
7072'	146	86%	14%	.16
7086'	114	80%	20%	.25

consistently less feldspar than in the material between ½ and ¼ mm. It would seem that there is little chance of zoning the sand on the basis of the light mineral content, for the variations in composition are relatively slight. However, there is probably a correlation between the median grain size of samples, and the total percentage of feldspar. Fine grained samples should contain relatively higher percentages of feldspar than coarse grained samples. An examination of table I seems to bear this out.

<u>Heavy or Accessory Minerals of the "Gatchell"</u>

The procedure in the study of the heavy minerals has been as follows:

1. Seived material has been used, so that grains are all of about the same size.

2. The samples were washed with acetone to remove oil.

3. They were then treated with HNO_3 to remove pyrite.

4. Separations were made with bromoform in separating funnels.

5. Slides were made of each sample, the heavies being mounted in Canada Balsam.

6. Species were determined under the petrographic microscope. Relative percentages were determined by counting.

The accessory minerals were found to be concentrated in the fine grain sizes. Separations were made on all the various seive sizes used in the textural analyses, but useable amounts of material was recovered only in the sand between 1/8 and 1/16 mm. In the coarser grain sizes, a very small amount of zircon, garnet, and tourmaline occurs.

Even in the finer grain sizes the heavies are disappointingly scant, either from the point of view of the size of the crop, or variety of species. Pyrite is abundant throughout the sand, which necessitated the treatment with HNO_3. When a sample of the sand weighing about 100 gms is sieved, 3-6 gms of material between 1/8-1/16 mm is obtained. After separating with bromoform, only 50-150 clear, non-opaque grains can be counted.

Even after removal of pyrite, a large percentage, around 50%, of the crop of heavies is made up of opaque grains.

Accessory minerals of the "Gatchell" Sand include the following species:

1. Zircon. Zircons are universally abundant in the sand. Grains are usually small, well formed prismatic crystals, usually containing inclusions. Occassionally a well rounded grain is to be noted. Crystals grade from highly prismatic grains which are 10 times as long as wide, to nearly equidimensional grains.

2. Tourmaline is also abundant. The great variety of colors shown by this mineral is notable. Colored varieties include grains with the following types of pleochroism.

Black-Yellow brown
Blue-colorless
Green-colorless
yellow-colorless

Tourmaline occurs as angular fragments and as prismatic crystals.

3. Garnet is sporadically abundant. It occurs only as very angular non-polarizing grains, most of which are markedly reddish tinted.

4. Epidote is present in most samples and common in some. It occurs in more or less rounded, pleochroic grains.

5. Amphiboles

Glaucophane is not abundant in any sample, but its presence is notable in most. Occasionally fresh grains, beautifully pleochroic, are to be seen and these are easily identified. Other grains, more or less badly altered, are difficult to definitely identify.

Hornblende, both green and brown varieties, has been determined in several samples, but on the whole it is rather rare.

6. Pyroxenes

Augite has been recognized, but is very rare.

Other minerals which are present are Biotite, and Kyanite(?)

Relative percentages of these minerals are given below, in table III. These are thought to be representative, for about 40 separations have been examined, and the best ones counted.

Summary of Mineralogical composition of the Sand.

1. The sand is surprisingly arkosic. When viewed

Table III. Relative Frequencies of Heavy minerals in the "Gatchell" Sand.

FREQUENCIES

Well	Sample Depth	Zircon	Tour-maline	Garnet	Glauc.	Epidote	Biotite	Hnb.
88-12C	6800'	8	6	2	2	2	1	-
88-12C	6825'	7	7	4	3	-	1	2
88-12C	6878'	7	7	6	1	-	1	1
88-12C	6895'	7	7	5	2	1	3	-
88-12C	6968'	7	7	-	1?	2	1	1
48-7F	7130'	7	7	-	-	4	3	2
48-7F	7308'	8	6	-	3	4	2	2
48-7F	7461'	8	6	-	1	3	1	-
Exeter 2	7449'	8	6	3	-	1	1	1

Frequency	Percentage
1	present
2	½-1%
3	1-3%
4	4-6%
5	7-13%
6	14-27%
7	28-59%
8	60-100%

Frequencies are based on actual counts. They are used to facilitate graphical presentation and comparison, and to avoid attaching unjustified accuracy to the grain counts.

megascopically, much of the sand appears to be very quartzose.

2. The composition of the sand is very constant. Either from the point of view of the light minerals or of the heavy minerals, the composition of the "Gatchell" is rather monotonous. The possibilities of zoning the sand body on the basis of the mineralogy are now thought to be very slight. The accessory minerals are so few both in amount and variety, and differences in the assemblage so far noted are so insignificant, that mineral zones based on heavy minerals do not seem promising. When the light minerals in well 1-19F were first examined it appeared that there is somewhat more feldspar toward the base, and that perhaps the feldspar ratios would form a basis for zoning the sand. It seems, however, that this may only be a reflection of a finer grain size toward the base of the sand body.

3. The evidence of the light and heavy fractions, that is an arkosic sediment on the one hand and a scanty assemblage of heavies made up largely of stable minerals on the other, is somewhat contradictory.

4. The presence of glaucophane in even small amounts is a good indication that at least some of the material was derived directly from the Franciscan areas to the west, for glaucophane is an unstable mineral and would probably not last through more than one cycle.

Any attempt to interpret the mineralogical data so far obtained, and arrive at a conclusion regarding the source of the material is at the present time dangerous. The sediments studied to date are too local to permit a regional picture of the source to be drawn.

If similar data were available on other Eocene sands, the inferences to be drawn as to source or sources of the sand would be on much firmer ground. It is the plan of the author to continue the work along similar lines, studying the outcrop and other subsurface occurrences of Eocene sands. Final judgement must be reserved until as many available sources of data as possible have been examined. Nevertheless, it would be useful to examine the data available at this time, to see what hypotheses may be possible.

The stable assemblage of heavies is suggestive of a reworked sediment as origin of part of the sand. The glaucophane is fairly good evidence that at least some of the material was derived directly from Franciscan rocks to the west.

The relatively high percentage of feldspar indicates a granitic rock as origin for some of the sand (unless it can be shown that the pre-Eocene sediments are arkosic enough to have formed the "Gatchell"). If this supposition is correct, then a question which arises is, where are the accessory minerals which should also have been derived from such a granitic source? The absence of such material could be accounted for if the source of the material were rather distant. It is reasonable to infer that the light minerals would be carried furthest from the source, and the heavies would tend to lag behind by a natural sorting action.

Possible granitic sources for the arkose could be found both to the east and to the west. The largest available source is the Sierra Nevada batholith, but there are smaller bodies of igneous rocks closer at hand in the Coast Ranges.

The uniformity of composition of the sand may be explained in two ways. Either the source itself was very uniform, or the source (or sources) was distant enough to permit complete mixing of the constituents to take place.

The evidence of the mineralogy seems to point to a land mass on the west shedding sediments to the east into an Eocene San Joaquin embayment. Whether the bulk of the "Gatchell" came from this land mass or was brought in from the east cannot yet be demonstrated.

TEXTURE OF THE "GATCHELL"

Shape of the Grains

The sand grains of the "Gatchell" are quite angular, but attempts to obtain quantitative data on the degree of rounding have not proved very satisfactory.

An approximation of the sphericity (shape) was obtained for a number of samples, by diameter measurements. In this method, sphericity equals breadth/length of grain. This is not an accurate determination of shape, but is thought to be a fairly good approximation.

For determining the degree of rounding, the method of Wadell was used, in which the roundness of a grain equals the average radius of curvature of a corner/radius of maximum inscribed circle. Perfect rounding would yield a value of 1, regardless of shape, while well rounded grains would yield figures of from .60 to 1. The method is very slow, because of the large number of measurements, but in spite of this does not give very satisfactory results. Indeed, the results do not seem to be capable of repetition, and a somewhat different value is obtained by different observers. The difficulty lies in picking a corner, or in defining a corner and an edge. Where grains tend to be angular, there are many small projections and irregularities, and the difficulty is increased. Where grains are large, so that they need not be greatly magnified, and where they are at least fairly well rounded, the method should yield good results.

About 30 or more representative grains of quartz, in each sample studied, were drawn with the aid of the camera lucida, and the necessary measurements made on these grains. It was found that the last 10 grains changed the limits for roundness, and the average value for roundness, very little, so that the total number measurements was probably sufficient. Average values obtained, together with limits are tabulated below in table IV.

It is the author's opinion that sufficiently accurate values for rounding could be obtained much more quickly in the following manner. A set of standards could be drawn up, showing about 6 different grades of rounding for a number of possible shapes of grains. If a number of representative grains of a sample to be studied were then photographed, so that they were about the same size as the standards, then by comparison approximate figures for roundness could be obtained. In practice the standard grains could be drawn on tracing cloth and superimposed over the unknowns, to facilitate comparison. This method will be applied to future studies of the Eocene sands.

The shape and roundness of grains are definite physical properties of the sand. Such measurements could be used in two ways. They may prove to have stratigraphic significance when values for different Eocene sands are compared. That is, it may be that significant similarities or differences in grain-shapes of the various sands will show up from such a

Table IV. Data on the Shape and Roundness of the "Satchell"

Well	Sample Depth	Shape(av.)	Limits	Roundness	Limits
1-19F	7613'	.75	.60-1.0	.34	.21-.44
1-19F	7658'	.73	.40-1.0	.29	.19-.40
1-19F	7742'	.70	.40-1.0	.35	.18-.44
1-19F	7832'	.73	.45-1.0	.31	.19-.45
1-19F	7927'	.72	.45-1.0	.32	.18-.44

study. Moreover, values for roundness and shape give certain indications of mode of deposition, and of the past history of the sediment. Well rounded grains indicate either a former sediment as a source, or that the sand was subjected to long or violent transportation. Predominance of angular grains suggests that the sands were not much reworked.

There is doubtless a grain size diameter below which rounding by water transportation does not take place. What this lower limit is is not known, but it is thought that the grain size measured in the above determinations (1mm-2mm) is sufficiently large to undergo rounding.

The conclusion to be drawn from the shape of the sand grains is that the sediment has not been derived predominantly from a pre-existing sediment. Indeed, when the composition and shape of the grains are taken together, then the conclusion that the sand has been derived largely from a granitic source is further strengthened.

In the sand so far studied, there are no grains of quartz which are well rounded. The feldspars tend to be even more angular, due to cleavages. It is interesting to note that the only well rounded grains are the black chert grains and pebbles mentioned under the discussion of the composition of the sand. This probably indicates that these chert pebbles have undergone several cycles of sedimentation. Perhaps their ultimate source was the Franciscan cherts of the Coast Ranges.

Grain size distribution within the "Gatchell"

The method used for determining the size distribution of the sand was mechanical or sieve analysis. Samples were put through a series of sieves arranged according to the Wentworth Scale (2mm, 1mm, 1/2mm, 1/4mm, 1/8mm, 1/16mm, pan). In actual practice, the drilling mud was carefully cleaned from a length of core. Then a sample weighing about 90 grams was broken off perpendicular to the axis of the core, and disaggregated; in this process, sand grains, particularly grains of feldspar may be broken if too much violence is used. Usually the sand could be easily crumpled up by rubbing between one's fingers. In a few cases, acid treatment had to be resorted to, when, due to calcareous cement, a sample was very hard. The samples used were thus spot samples, in all cases.

The thoroughness of the disaggregation was in all cases checked by a search for aggregations of grains with a hand lens. The sand was next weighed and sieved with the shaking machine for a 10 minute period; then, the sand caught by each sieve was weighed, and percentages of the various sizes calculated. From the size distribution data, the median grain size, and the 1st and 3rd quartile grain sizes were calculated; the spread between the quartiles is a measure of the degree of sorting of the sand.

To determine the variation in size distribution, grain size, and sorting through the sand body, nearly 300 sieve analyses have been made. The data from these analyses is tabulated in the appendix. In practice, wells which cored the

"Gatchell" continuously have been used, and samples of the sand every 10-30 feet studied. The median grain size and sorting for all samples in each well have been calculated, and plotted against depth. These charts are also shown in the appendix.

The percentage of material less than 1/4mm in average diameter has proved to be rather constant, as an examination of the data in the appendix will show. The largest variation in the size distribution is in the two ranges 1mm to 1/2mm, and 1/2mm to 1/4mm. In some cases the first of these has far more material, and in others the 2nd is the largest. The median diameter varies from .70mm to .30mm, due to these variations.

When the median grain size is plotted against depth, a curve is obtained which shows the distribution of the coarse and fine sand within the sand body. An interesting correlation has appeared between this curve and the electrical log. In a general way, where the sand is coarsest the resistivity is highest. The permeability of the sand also shows a similar relation to the resistivity curve. This suggests that there is a relationship between the grain size distribution and permeability.

The sand of the "Gatchell" is well sorted. Trask indicates that a value for the coefficient of sorting of less than 2.5 indicates a well sorted sediment, a value of 3.0 a normally sorted sediment, and a value greater than 4.5 a poorly sorted sediment. (Coefficient of sorting equals square root of Q_1/Q_3, where Q_1 is the larger quartile and Q_3 the smaller). The coefficient of sorting of the "Gatchell" is always under 2, lying between 1.3 and 1.9. The sorting is generally best where median grain size is smallest.

The texture of the sand, like its composition, is rather strikingly constant; variations in absolute median grain size are not large, although relatively they are quite notable. Because the texture throughout the "Gatchell" sand body is quite similar, it might be concluded that the sand body represents a "unit of sedimentation".

From the uniformity of grain size certain conclusions may be drawn. The agent transporting and depositing the sand , must have been capable of exerting a high degree of selectivity over the grain size and size limits of sand brought into the area and deposited. One agent capable of producing such a degree of sorting is the wind. However, since the sand is highly angular, and lacks frosting, the possibility that the sand is in part of eolian origin can be discarded. Fluvial sands are not well sorted, and it is very doubtful that the "Gatchell" can represent a fluvial deposit. The most likely agent for the transportation and eventual deposition of the "Gatchell" would seem to be marine currents. Currents of this type are weak enough to eliminate the coarser sizes, strong enough to eliminate the finer sizes, and efficient enough to have brought in sufficient sand to form the sand body.

In wells that show an equal amount of sand, the curves showing the median grain size plotted against depth are quite similar. In other words, the coarse and fine zones extend horizontally for some distance. Moreover, the sand in the upper portion of the sand body is generally coarser than the sand lower in the body. Horizontally, no significant trends in the grain size have been noted. That is, it cannot be said with surety that the sand is coarser on the north, south, east, or west.

On the other hand, no fine sands comparable to the material found in thicker sections of the "Gatchell" have been found in wells near the line of pinch out. This is thought, however, to be due largely to the westward transgressing of higher coarser sand over the finer sands found in the thicker sections to the east. These relations will be clearer after the discussion of the internal structure of the sand body.

It is possible that the sand is becoming slightly coarser toward the west, or toward the line of pinchout, but the available data is very hard to evaluate.

The texture of the sand may be summarized in a sentence; it is a uniform, very angular, very well sorted, medium to coarse grained sand.

INTERNAL STRUCTURE OF THE "GATCHELL"

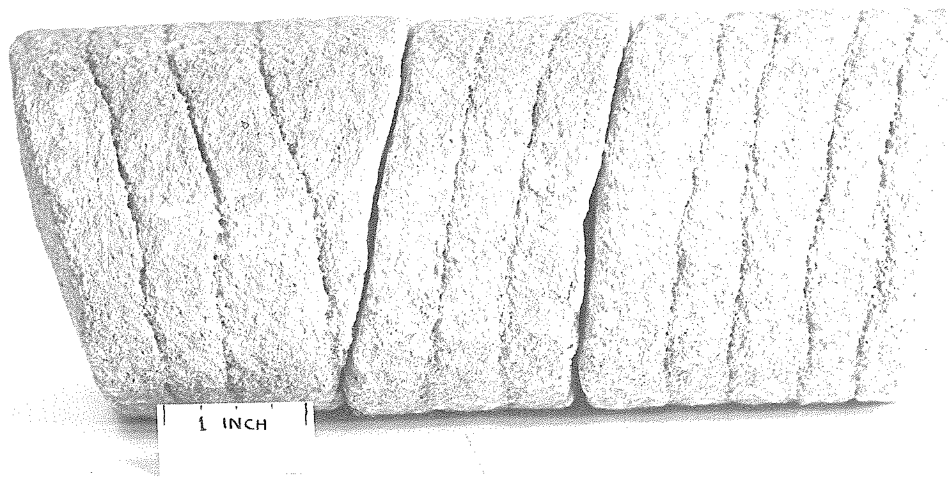
Theoretically, the internal structure of the sand body might be determined (1) from bedding within the sand body, (2) from mineral zones, or (3) from textural zones.

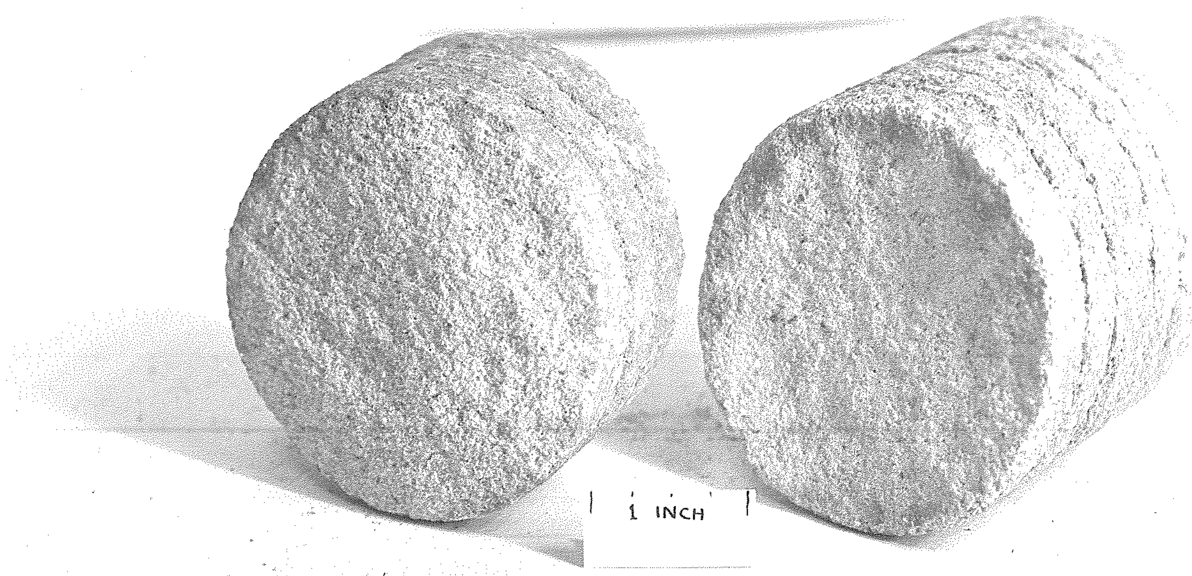
Original sedimentary structures seem to be lacking for the most part, within the "Gatchell". In all the cores examined, no well marked bedding has been noted. The only suggestion of bedding is a parting or tendency to break obliquely across the axis of the cores. In many places this parting is well developed, and several different types can be noted. In one type, the parting planes are nearly perpendicular to the axis of the core, and the planes are noticeably convex or concave upward. This type can be explained as being due to shearing or rotational forces set up by a tendency for the core to rotate in the core barrel. In a second type, the parting planes are distinctly oblique to the axis of the core, and all are oriented in the same manner. It is more difficult to explain this type as a secondarily induced structure, due to shearing, and indeed, partings of this sort may well be due to an original structure in the sand body. The third type is even more suggestive of an original structure, for not only are the parting planes oblique to the axis of the core, but also they present a pattern which is strikingly like cross bedding. Various types of parting are illustrated below.

The "Gatchell" sand shows, then, some slight suggestions of bedding, and in some places of incipient cross bedding, but

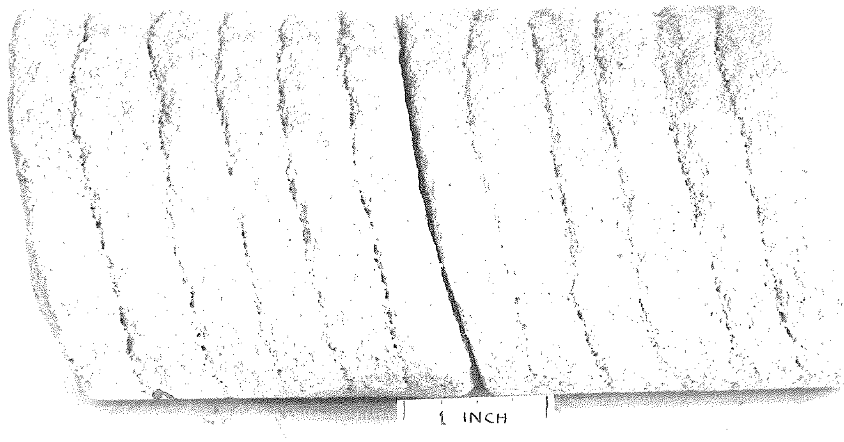
PARTING IN THE "GATCHELL" SAND: This type of parting is interpreted as due to "incipient" cross bedding.

PARTING IN THE "GATCHELL" SAND: Note curved parting planes.


1 INCH


1 INCH

PARTING IN THE "GATCHELL" SAND: This is the commonest type. Note great regularity of the parting.


1 INCH

on the whole structures which might throw some light on the internal structure and origin of the sand are lacking. This can be interpreted as due to continuous deposition of a single variety of sediment, coupled with uniform conditions of sedimentation.

As has been discussed above, the mineralogy of the sand is so uniform, and the heavy minerals so few, that prospects of zoning the sand on this basis are slight. It would seem then that the only possibility of showing the internal structure of the sand is by textural zones.

As has been noted above, the median grain size, and the size distribution of the sand have been plotted against depth for a number of key wells in the southern area. These curves are presented in the appendix. For each well studied, the electric log, a graph of the median grain size against depth, and of the sorting against depth are shown. The wells are arranged according to the amount of sand penetrated, beginning with the thinner sections and ending with the thicker sections. An index map is also presented, so that the wells can be quickly located.

Curves of the median grain size for wells which penetrated the same amount of sand are quite similar; the vertical distribution of the coarse and fine sand is nearly identical in such sections. In wells which penetrated less sand, that is in wells which are nearer to the line of pinchout, the curves obtained are similar to the upper part of curves for thicker portions of the sand body. In other words, the sand in wells near the line of pinchout is thought to be represented in wells to the east by the upper part of the sand body; the lower sands in wells on the east are not present in wells on the west. The upper part of the "Gatchell" is in general coarser grained than the lower.

The evidence for the above conclusion is not compelling when based on the median grain size curves alone, but when the electrical logs are also considered, the same picture is obtained.

The similarities of the curves and logs presented, suggest that were sufficient data available on more wells, fairly close correlations could be made on the basis of the two lines of evidence. With available data, no attempt will be made to draw more than the most general picture of the structure within the "Gatchell".

There is a strong suggestion that during the deposition of the "Gatchell" of the Coalinga "nose" area, sands were transgressing from east to west over silts. The coarser sands of the upper "Gatchell" tend to overlap the finer sands in the lower part, so that only the coarse sand is present on the west. The fact that the upper sands are coarser may be due (1) to a change in the source material, or (2) to an increased efficiency of the currents bringing the sands to their final resting place; such a change could have been brought about by a gradual shallowing of the water, or by a change in the configuration of the sea floor or coast line, or some other mechanism.

As has been discussed before, the upper contact of the "Gatchell is not a time line, for sand is grading into shale. The amount of this lateral gradation into shale along the upper contact is not thought to have much relation to the rate of thickening of the "Gatchell", at least in the southern area. On the other hand in the northern area, as an examination of the section B-B' will show, sands are grading rapidly into shale along the upper contact, particularily on the western end of the section; here the lateral gradation is a significant factor in the thickening of the sand body.

In a broad way, the sand body of the "nose" area may be regarded as slightly convex upward, while in the northern area it is rather strongly convex upward. Another point of contrast between the two areas is that in the southern area shale interbeds are extremely rare if not absent, while on the north several good shale interbeds have been noted.

INTERPRETATION OF DATA

Before a final conclusion may be reached regarding the origin of the "Gatchell" and other Eocene sands of the Coalinga area, considerably more work must be done. As has been mentioned above, the study so far has been on too local a scale to permit a more regional picture to be drawn. If detailed data were available on the mineralogy, texture, thickness, and age of the various Eocene sands (both subsurface and outcropping) it would be possible to draw paleogeographic maps for various stages in the Eocene, and perhaps to explain the distribution of sands and silts. The "Gatchell" although economically the most important of the sands, is nevertheless only one of several large sand lenses, and it is logical to expect that these various sand bodies are somehow related in mode of origin.

It is felt by the author that it would be useful at this stage in the research to attempt to set up possible hypotheses which fit most of the available data. Several such hypotheses can be formulated; whether one of these or a new one is finally established as being most likely must depend on acquiring more information in future studies. The tentative nature of the several hypotheses given below must be emphasized.

To aid in the consideration of such hypotheses, the conclusions and inferences of the research to date are listed below.

Summary of data and inferences to be drawn from data

1. The sand in the two areas is probably connected.

2. The sand is thicker in the northern area, and thins across the main axis of the "nose".

3. The sand in the northern area is older and transgresses southward over silts.

4. The presence of glaucophane in the sand indicates that at least some material was derived from the Franciscan rocks to the west.

5. The bulk of the sand was derived from a granitic source. Whether the ultimate source of the sand was the Sierra Nevada batholith or Coast Range granitic rocks cannot at present be determined.

6. The absence of accessory minerals in the sand must be explained; perhaps it is related to the distance from source, and a natural sorting action which would cause the heavy minerals to lag behind.

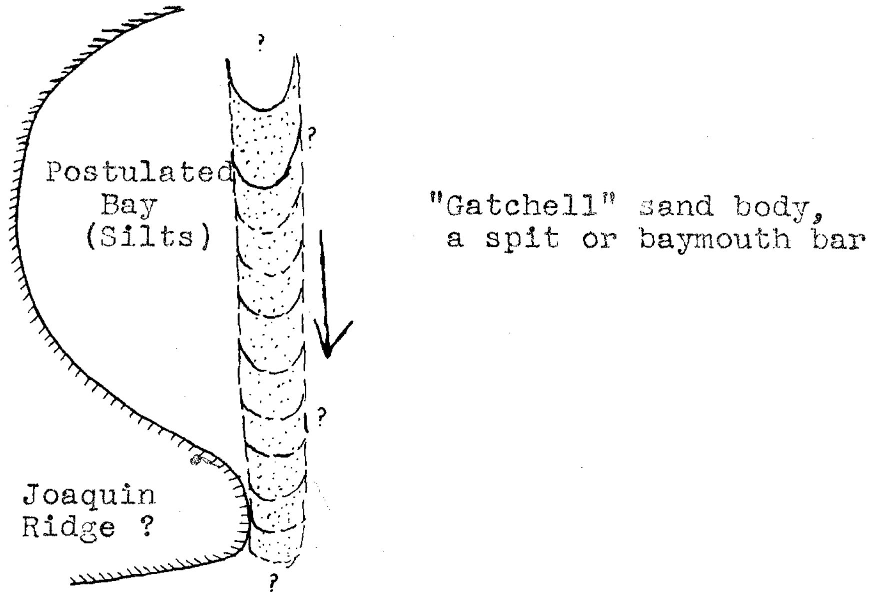
7. There was probably an Eocene San Joaquin embayment, with land masses both to the east and west shedding sediments into the basin.

8. The sand was most probably sorted and transported by the action of longshore currents, and deposited when these currents became weak.

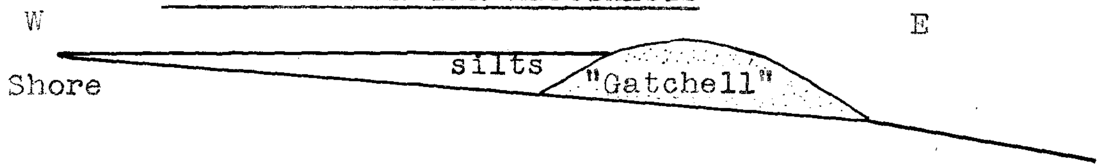
9. The sand body probably grew from north to south as is indicated by the foraminiferal data. The internal structure of the "Gatchell" of the southern area indicates that the sand body also transgressed from east to west.

DIAGRAMATIC SKETCHES ILLUSTRATING VARIOUS HYPOTHESES

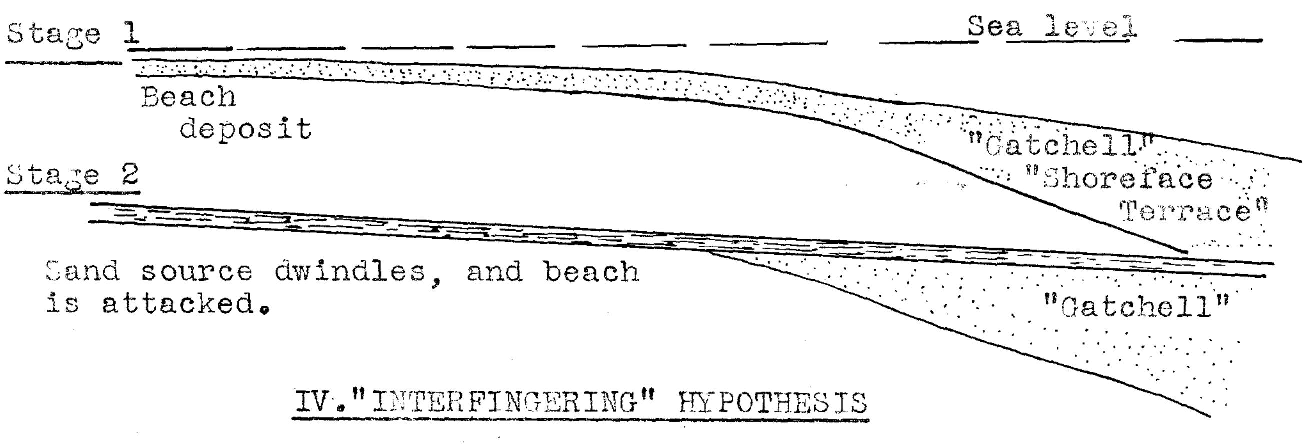
I. BAYMOUTH BAR-SPIT HYPOTHESIS



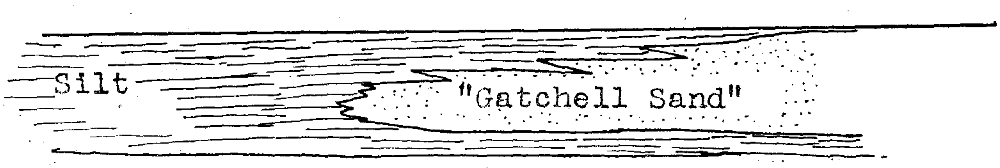
II. OFFSHORE BAR HYPOTHESIS



III. "SHOREFACE TERRACE" HYPOTHESIS



IV. "INTERFINGERING" HYPOTHESIS



10. Broadly, the sand body in the "nose" area is slightly convex upward, while in the northern area it is more strongly convex upward.

11. The Joaquin anticline is a very old structure, and was definitely present and growing during the Eocene. It seems to have effected the deposition of the "Gatchell". There were probably other structures trending more or less E-W, and striking out into the San Joaquin embayment.

12. Northwest of Joaquin Ridge, in the vicinity of Cantua Creek, there was a large embayment, which was probably on the west side of the San Joaquin embayment and was doubtless connected with it. This is the basin in which the Cantua was deposited. The foraminiferal evidence indicates that the youngest Cantua sands and the oldest "Gatchell" are about contemporaneous. It would seem therefore, that the Cantua embayment was present during the deposition of the "Gatchell". The Eocene shore line would then have had a large re-entrant or bay in that area, with the Coalinga anticline forming a point, jutting out into the sea.

Working Hypotheses

When the above data is taken in its entirety and assumed to be accurate, then of all possible environments of deposition the first one of the following hypotheses seems to be most likely.

1. The Spit or Baymouth Bar Hypothesis. (See Figure 1)

The possibility that the sand body represents a baymouth bar was first suggested to the author by Dr. John H. Maxson. The possibility arose in a discussion of various types of bars, when it became apparent that the great thickness and size of the sand body tended to eliminate some such deposits as possibilities. The only limit on the thickness and size of a spit or baymouth bar is the total amount of relief and submergence at the time of deposition. Existing bars of this type have a cross profile convex upward and behind them muds and silts accumulate.

If the San Joaquin anticline existed in "Gatchell" time as a ridge, and north of the ridge there was a large bay as is suggested by the Cantua section, then it seems quite likely that the "Gatchell" body represents a spit or baymouth bar which grew southward across the bay. In connection with this hypothesis there seem to be two possibilities. The sands in the "Gatchell" may have been derived from a Coast Range stream farther north and deposited across the bay by longshore drift. In this case, it would appear that there is another old ridge like the Joaquin ridge on the north side of the bay, and that the sand body is a true baymouth bar. On the other hand the sand may have been derived from the delta of a Coast Range stream only a little to the north. In this case the sand was carried southward in the course of time by longshore drift, and gradually there was built a spit like body which transgressed upward in the section to the south.

If the above hypothesis is true, then there must have been relief of at least 600 feet during the deposition of the "Gatchell". This figure is for submarine relief only, and since in the case of present day baymouth bars there is usually a comparable subaerial relief, the total relief at the time of deposition would have approached 1000-1200 feet. Such relief should be indicated by an unconformity adjacent to the "Gatchell". Since no such unconformity has yet been recognized, there is a strong argument against the hypothesis.

2. Offshore Bar Hypothesis. (Figure 2)

The "Gatchell" sand body has been regarded by some geologists as an offshore bar. Existing sand bars of this type are linear features, convex upwards, and are transgressive, often, over muddy marsh deposits. Their seaward sides tend to be very straight, and the shoreward side more crenulate. Offshore bars are usually considered as features of emergence as described in the typical shoreline cycle. As features of emergence, it is difficult to see how they could ever attain a very great thickness. Although the author has not found figures on the thickness of existing offshore bars, the 600-800 feet thickness of the sand in the easternmost wells of the field would appear too thick for a typical offshore bar. The "Shoestring Sands" of Kansas have been described as offshore bars, but the thickness of these sand bodies is not over 0-100 feet.

The controlling factor in the formation of an offshore bar is probably the profile, and if a very gentle offshore profile is maintained, a bar could probably form under conditions of submergence. A low slope leads to waves breaking far from shore, and the piling up of sand to form a bar. A picture of the very gentle profile necessary for the formation of an off-shore bar is indicated by the fact that waves break when the depth of water is approximately equal to the height of the wave.[7] If continued downwarping or subsidence during the deposition of the bar is postulated, perhaps a greater thickness could be attained. Such a view is full of difficulties. The principal difficulty is that as the bar increased in size, the depth of water in front of the bar would also increase. This would have two effects on the growth of the bar. In the first place, as the depth of water increased, the supply of material for building the bar would tend to decrease, due to the weakening of the ability of longshore currents to bring in new sands. Secondly, and most important, the deepening water in front of the bar would expose the bar itself to direct wave action. The bar would be driven landward, and gradually destroyed. If the amount of material available were large, the result would be a very broad bar, but not one with a great thickness.

3. <u>"Shoreface Terrace" Hypothesis. (Figure 3)</u>

An environment of deposition similar to D. Johnsons shoreface terrace can be imagined for the "Gatchell". Again the formation of such a deposit is probably controlled by the

[7] Johnson, D., Shore Processes and Shoreline Development, 1938

offshore profile. If the offshore profile is gentle and uniform from the shore outward for some distance, and then steepens abruptly, as at the edge of the continental shelf, a terrace is built outward from the break in slope. The material for the terrace is derived from the beach, and is transported outward largely by the action of gravity in conjunction with weak wave agitation.

If in "Gatchell" time, there was such a profile, namely a gentle slope from the shore out to a point, then a rapid steepening of the slope, the "Gatchell" sand body may be a modified shoreface terrace. The sand in this event would have been derived from a beach deposit to the west. This beach deposit in turn was built of material brought in by longshore currents, since the sand is underlain by silts. In this hypothesis, after the "Gatchell" sand was deposited, the sandy beach itself must have been destroyed. If the source of sand dwindled, then the sandy beach would have been rapidly carried away, and finer sediments could then have buried the "Gatchell".

4. The Interfingering Hypothesis. (Figure 4)

From a consideration of somewhat sketchy data on the distribution of the Eocene sands and silts, still another hypothesis can be set up. The Eocene section at the northern end of Kettleman Hills is largely sandy, as it is also in a few wells which have penetrated the Eocene, near Fresno.[8] The outcrop section on the Coalinga anticline is predominately

[8] Barbat, Oral Communication

shaley. Farther north, of course, the Eocene rocks are again sandy. On the basis of these generalizations, it might be argued that the "Gatchell" is only a large finger of sand from a predominantly sandy section on the east, fingering into a predominantly shaley section on the west.

APPENDIX

In the following Section, charts showing the electric log, median grain size against depth, and sorting against depth for eleven wells in the southern area are presented. These charts are arranged according to the thickness of the sand in each well, beginning with the thinnest sections and ending with the thickest.

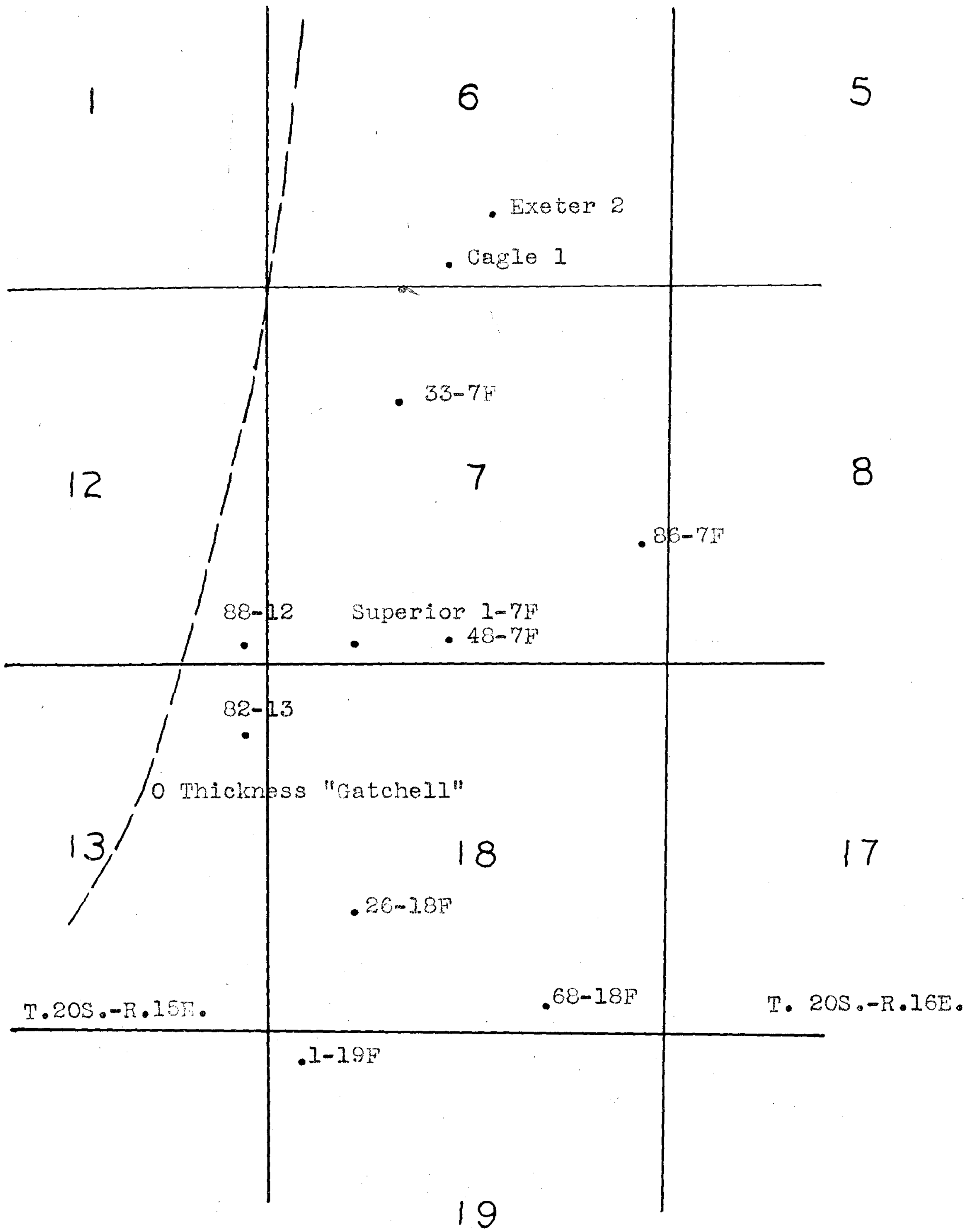
The order of the charts is as follows:

88-12C
82-13C
Superior 1-7F
1-19F
26-18F
53-7F
48-7F
68-18F
Cagle #1
86-7F
Exeter #2

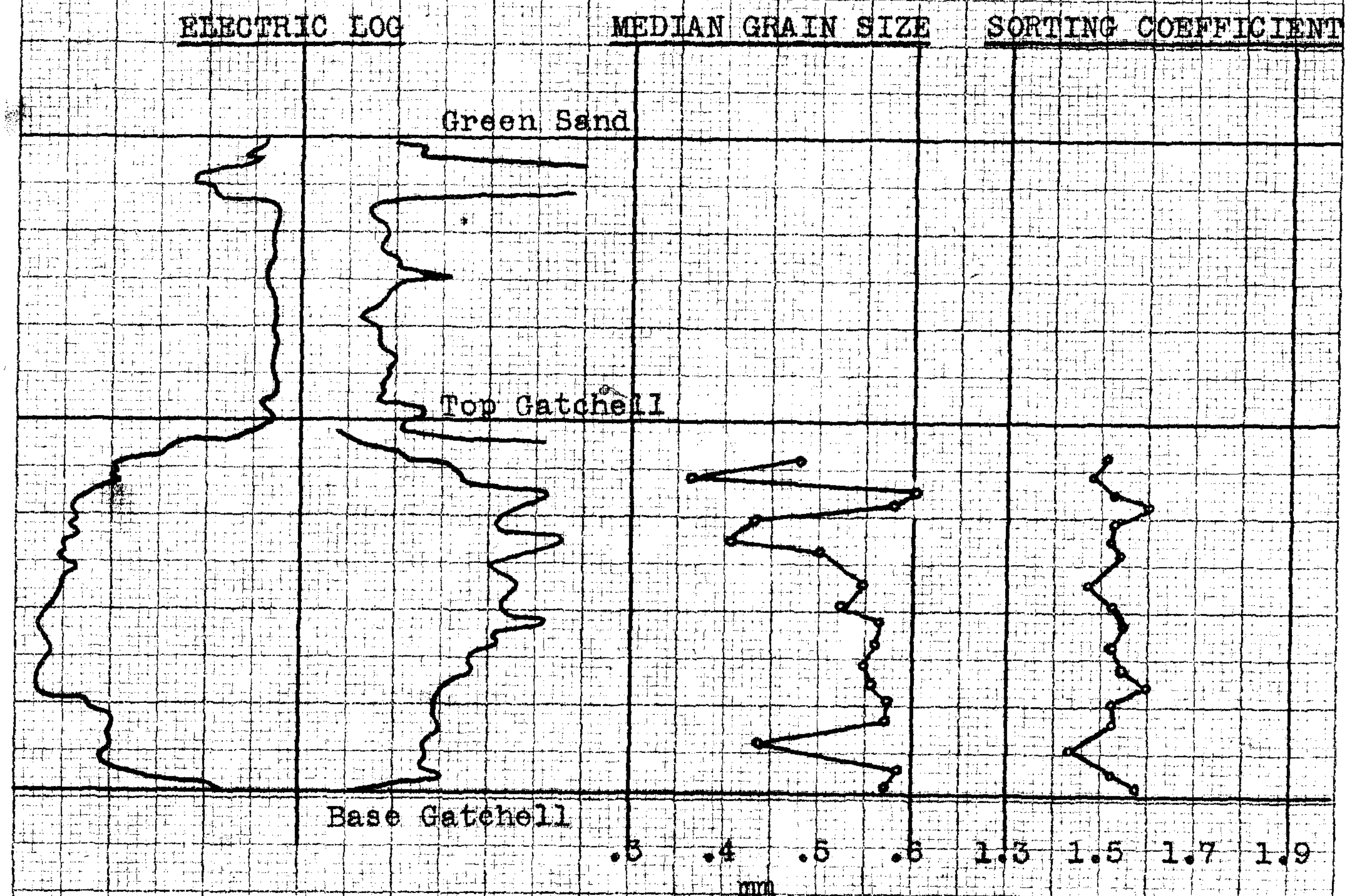
An Index Map showing the location of these wells is presented below. The actual data from sieve analyses is tabulated at the end of the Appendix.

INDEX MAP SHOWING LOCATION OF WELLS

Scale 1" = 2000'



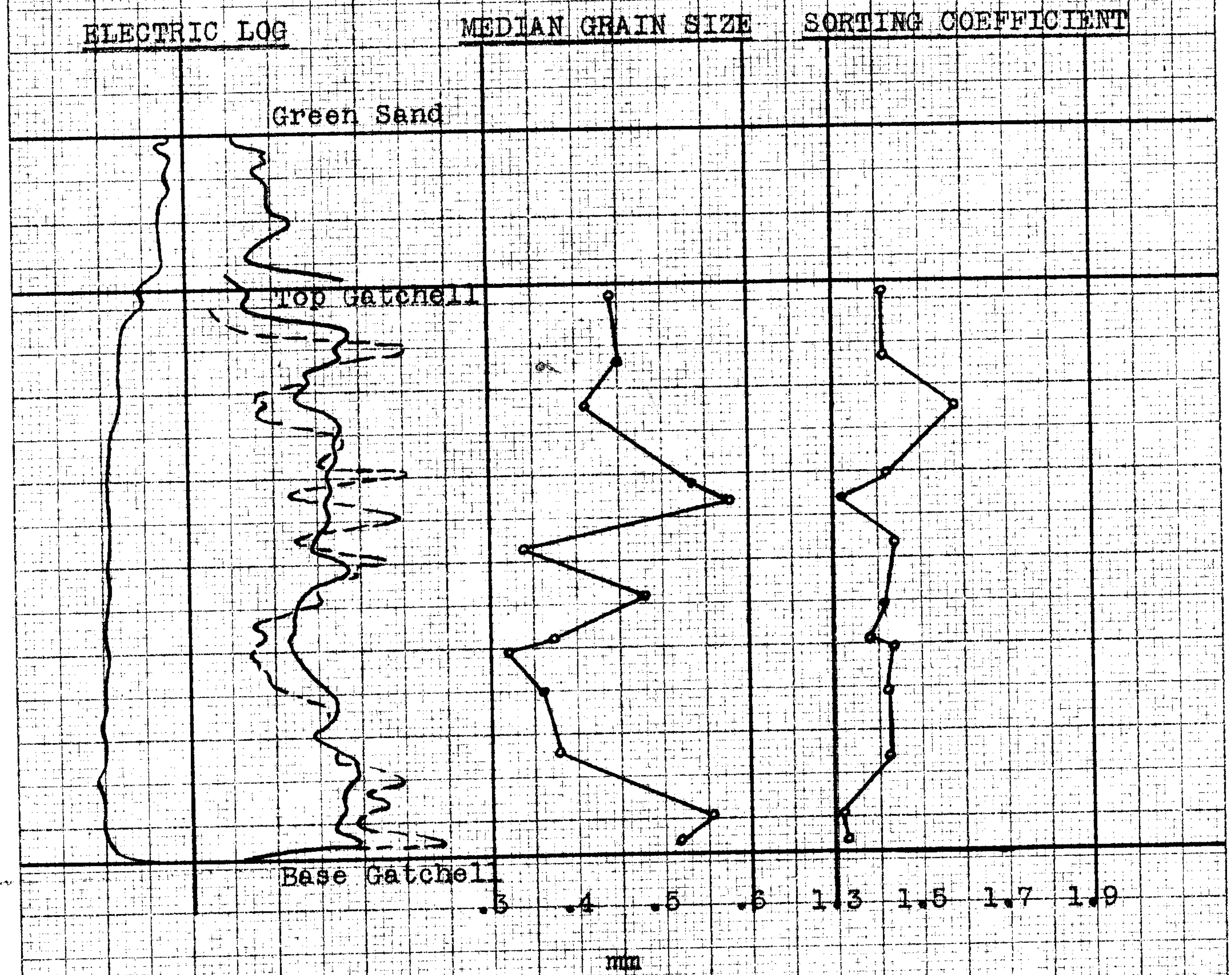
WELL 88-12C 20/15



Vertical Scale 1"=100'

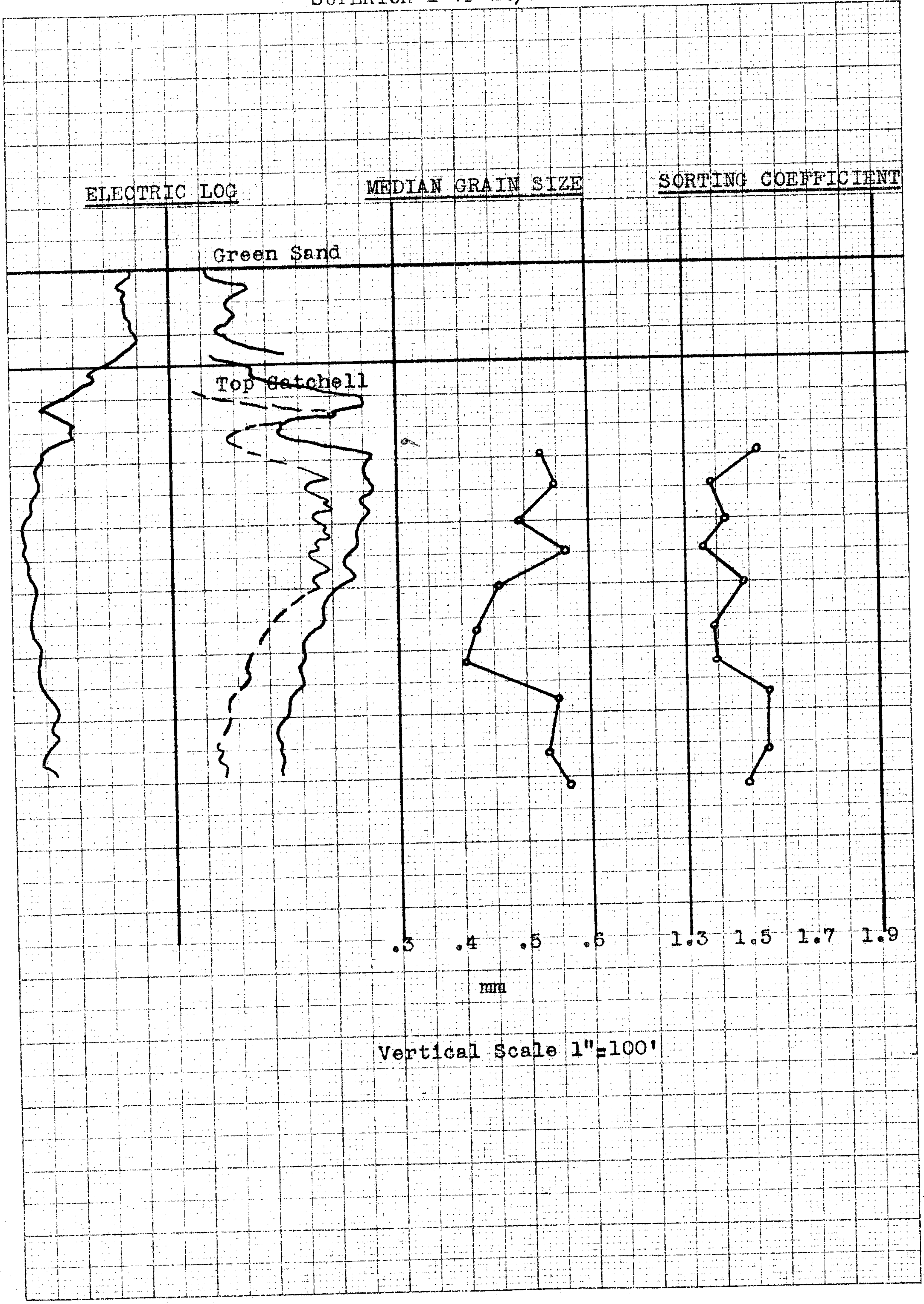
Note- The electric log shown above is from 71-13C. This well is near 88-12C and penetrated the same amount of sand

WELL 82-13C 20/15

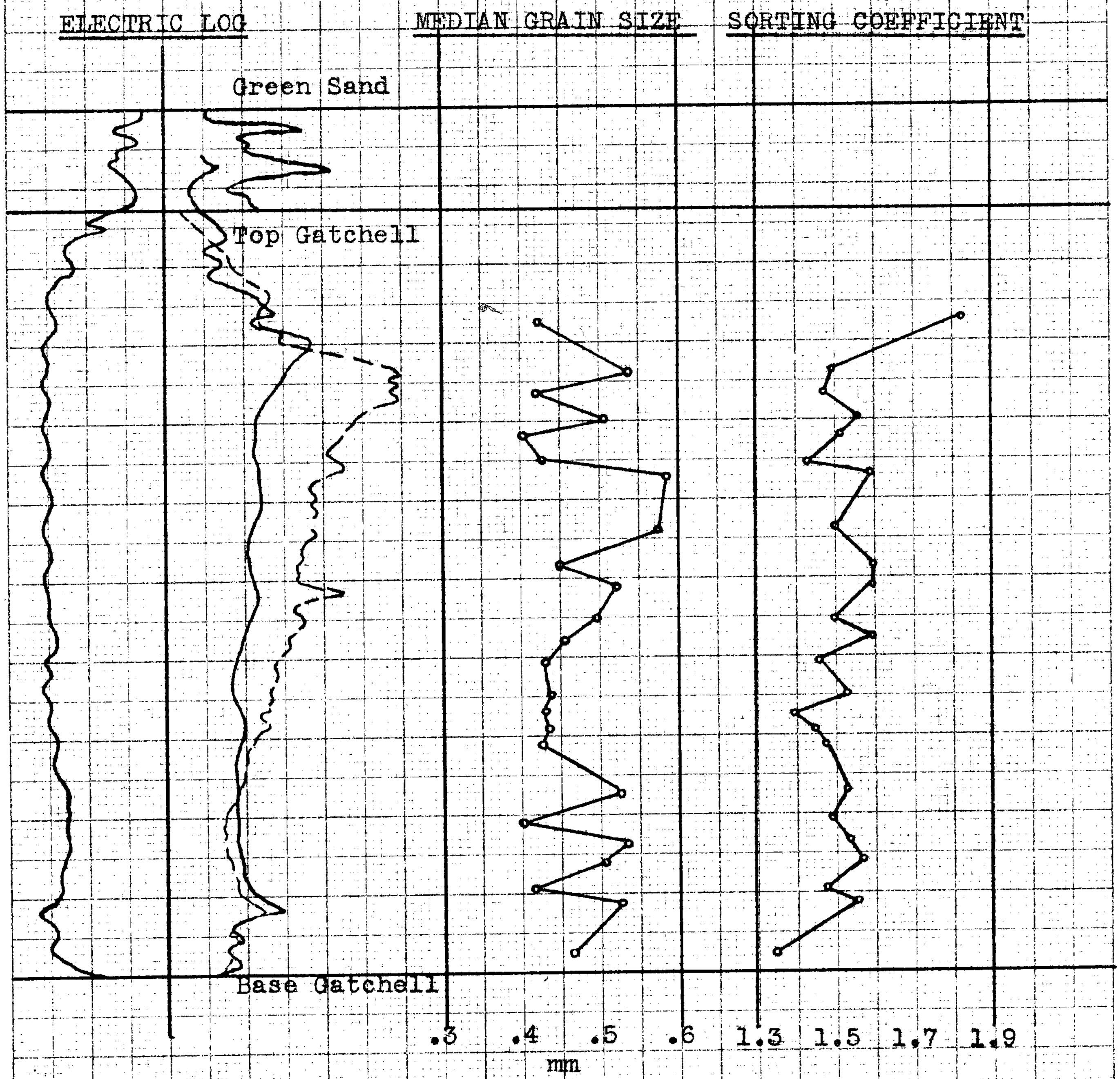


Vertical Scale 1"=100'

SUPERIOR 1-7F 20/16

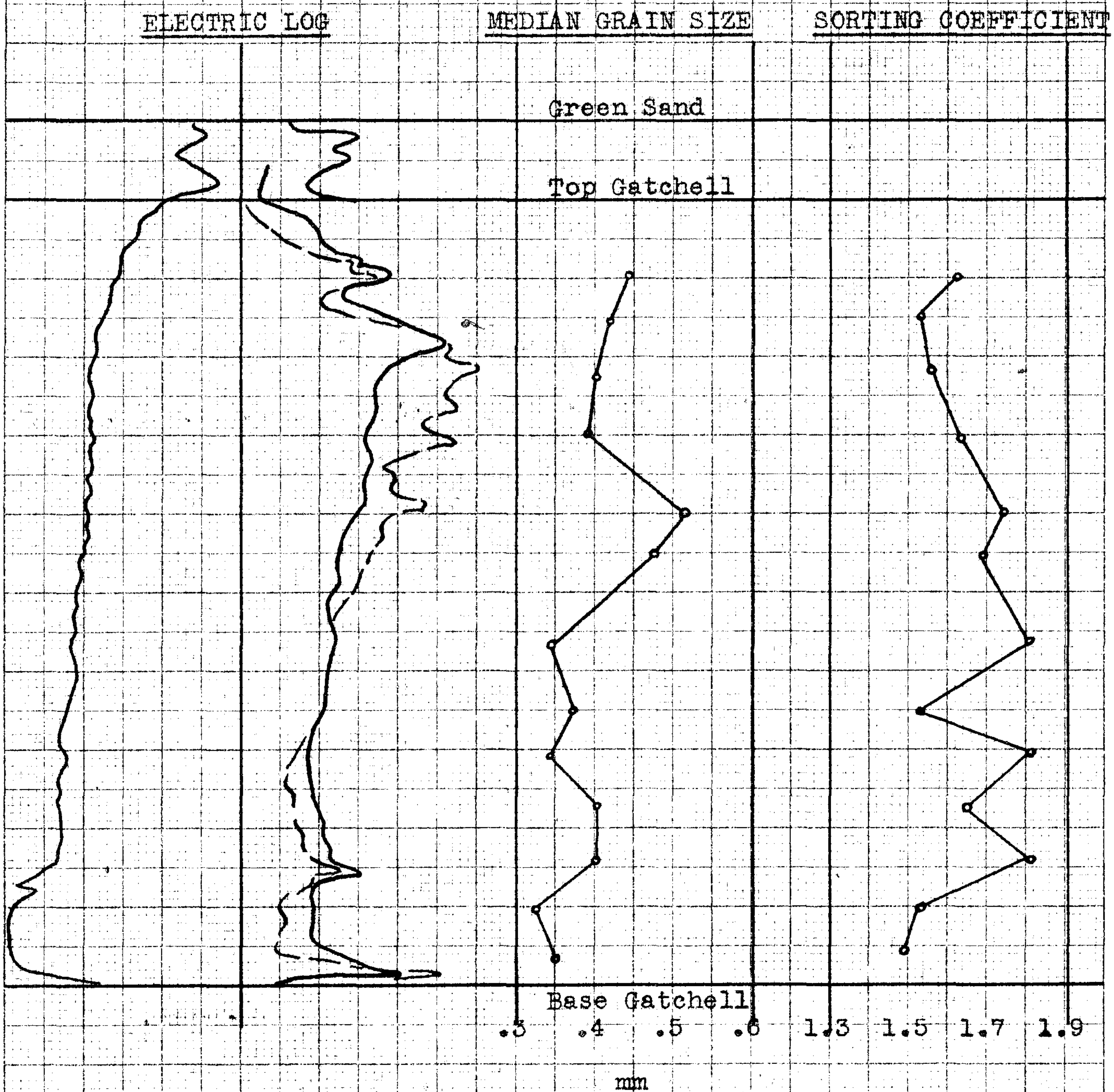


WELL 1-19F 20/16



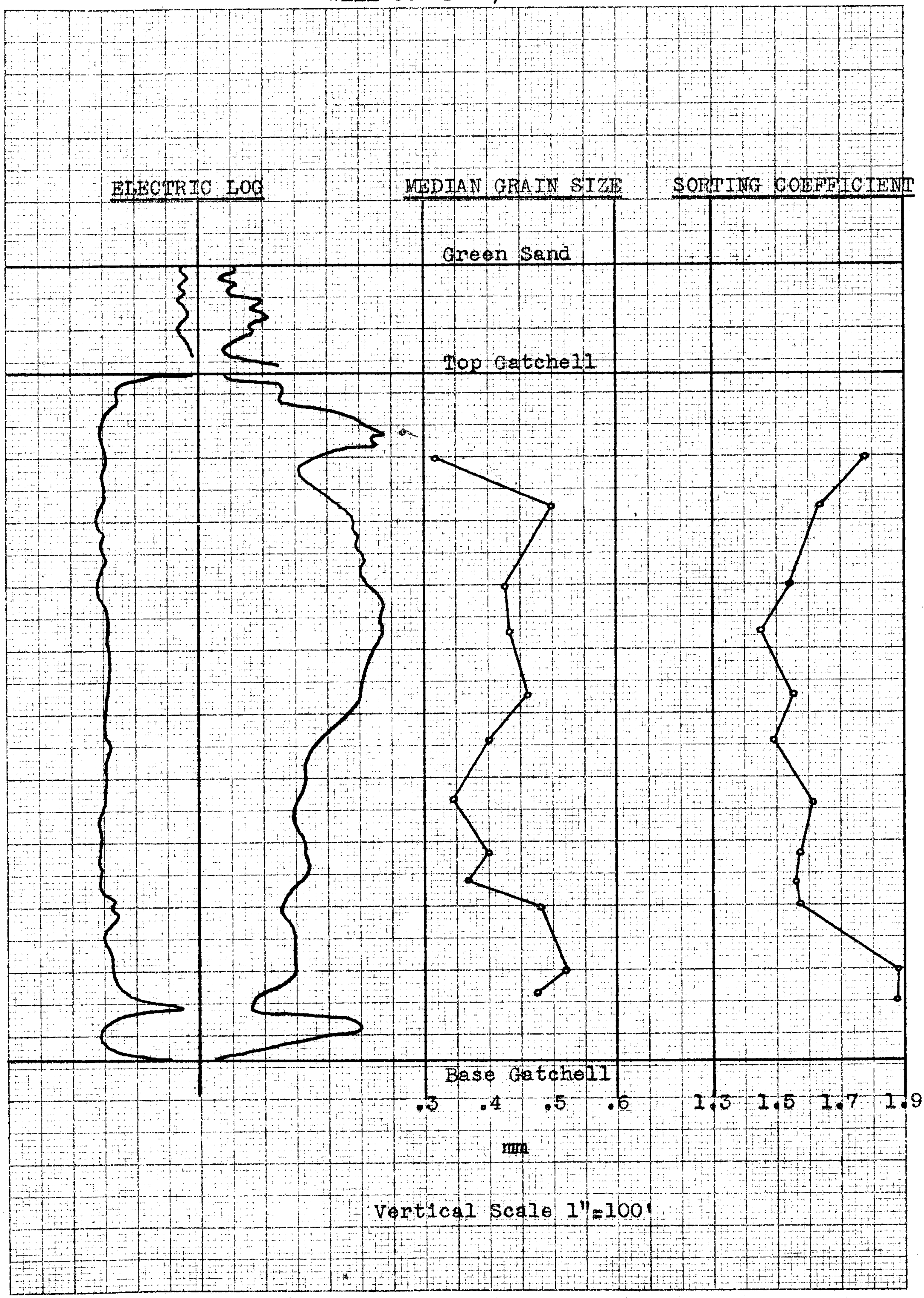
Vertical Scale 1"= 100'

WELL 26-18F 20/16

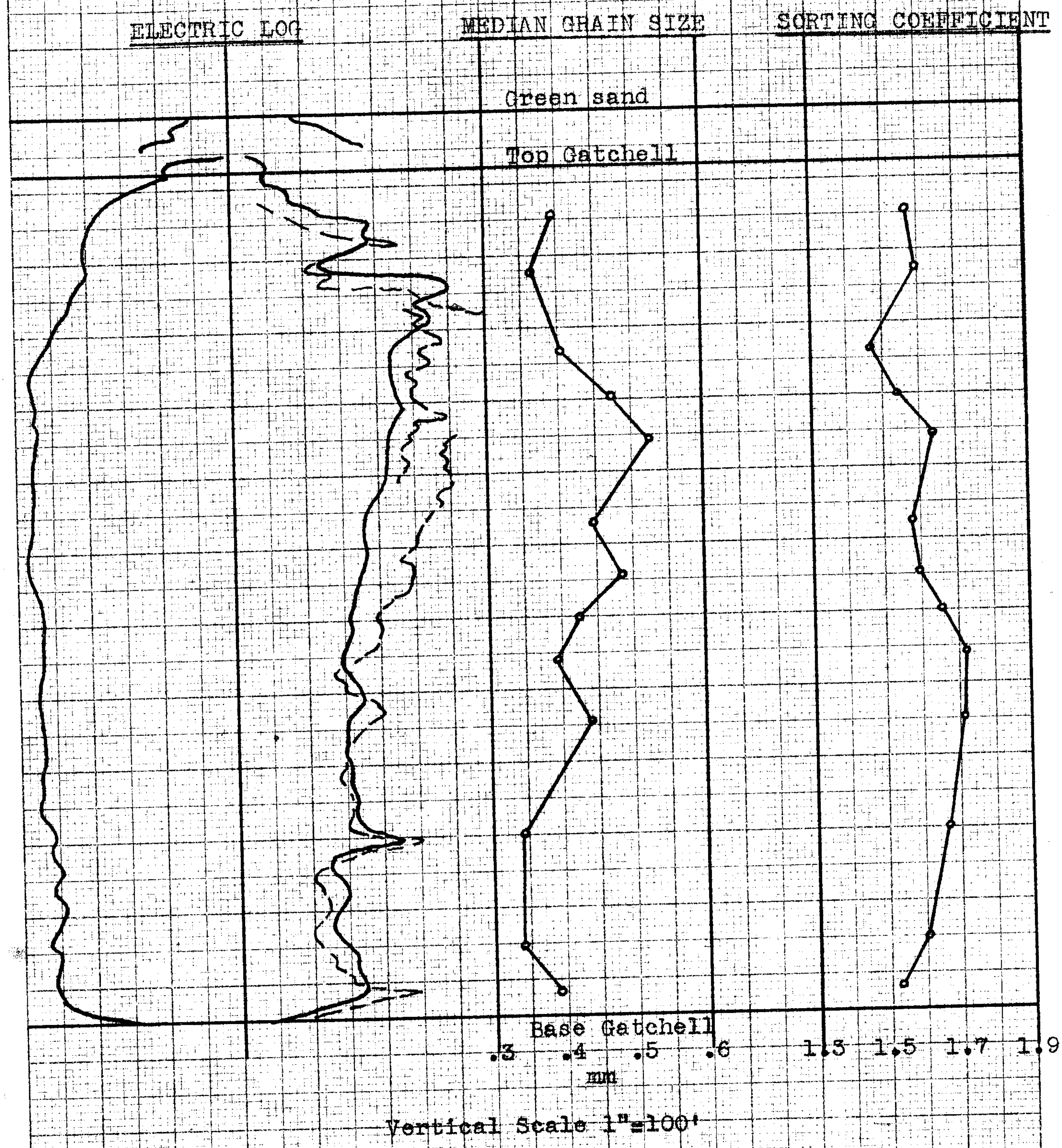


Vertical Scale 1"=100'

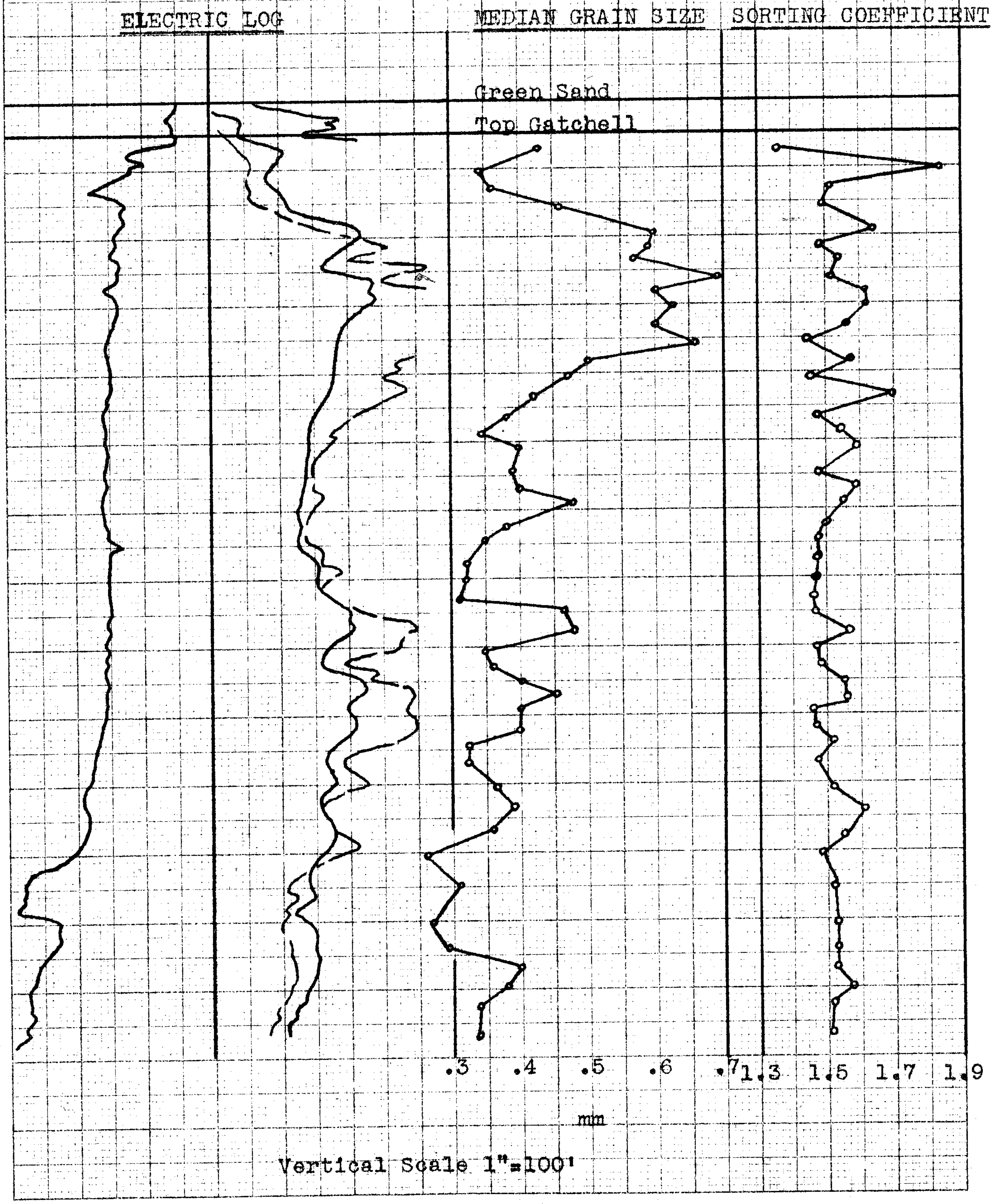
WELL 33-7F 20/16



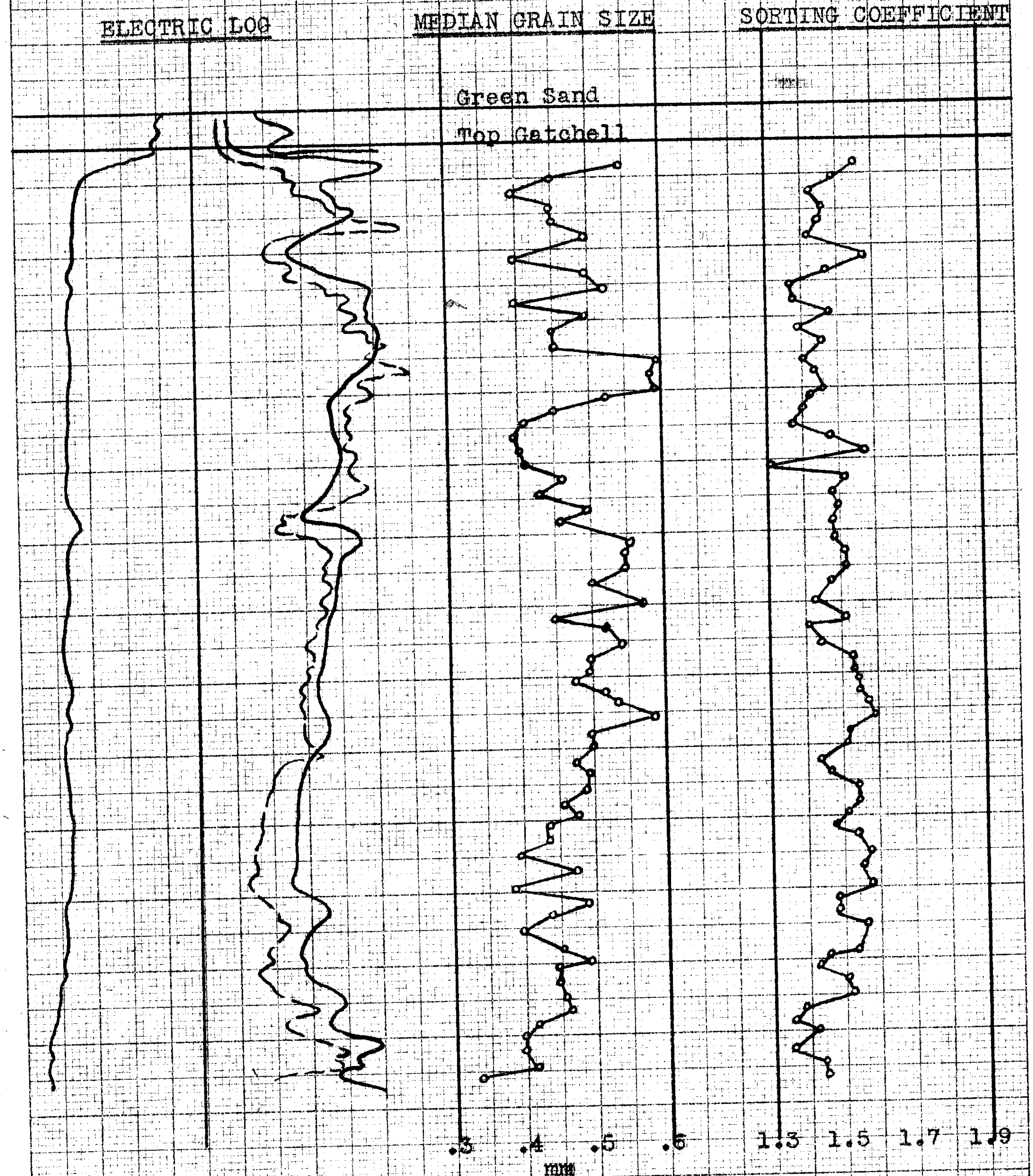
WELL 48-7F 20/16



WELL 86-7F 20/16

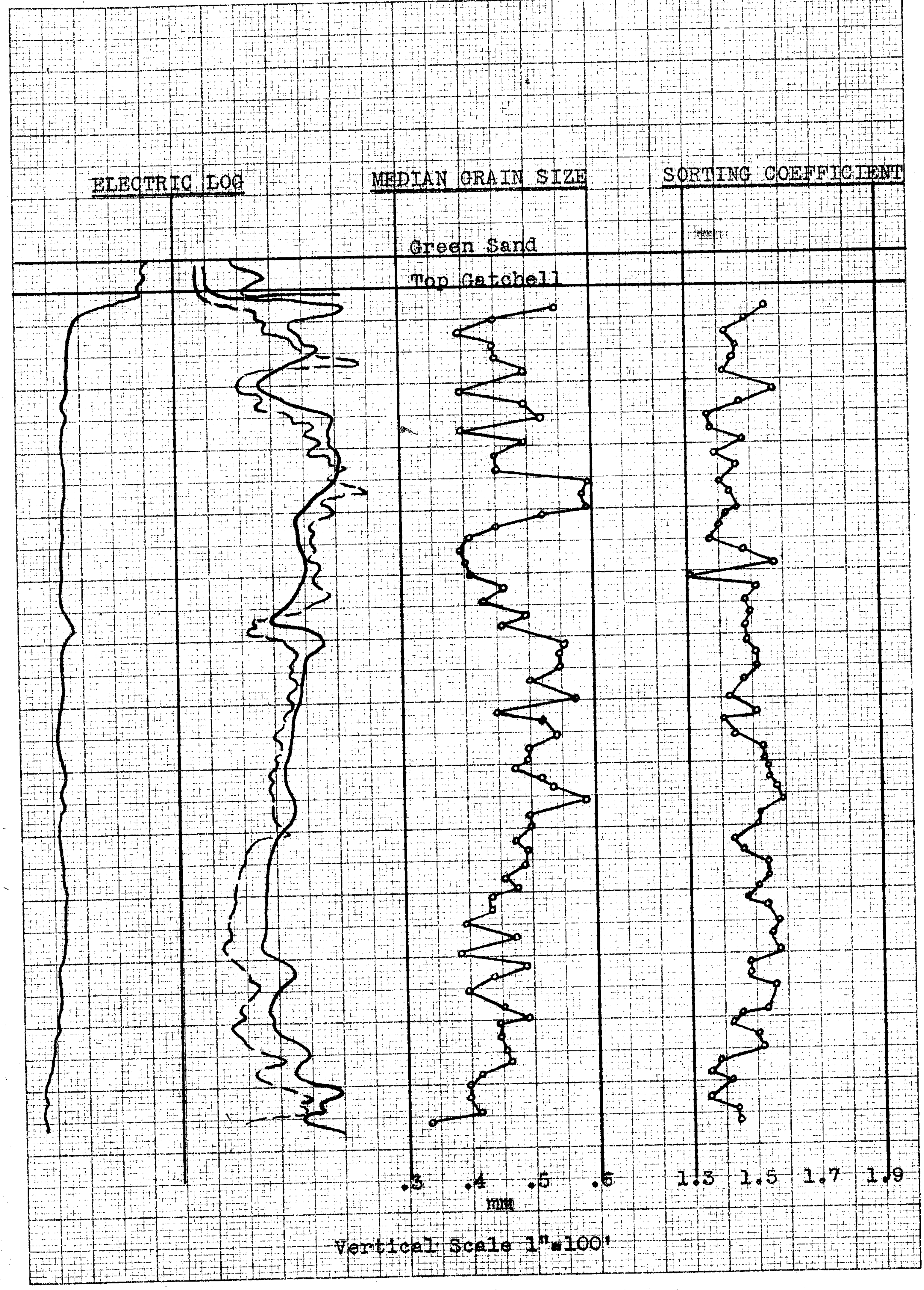


EXETER #2

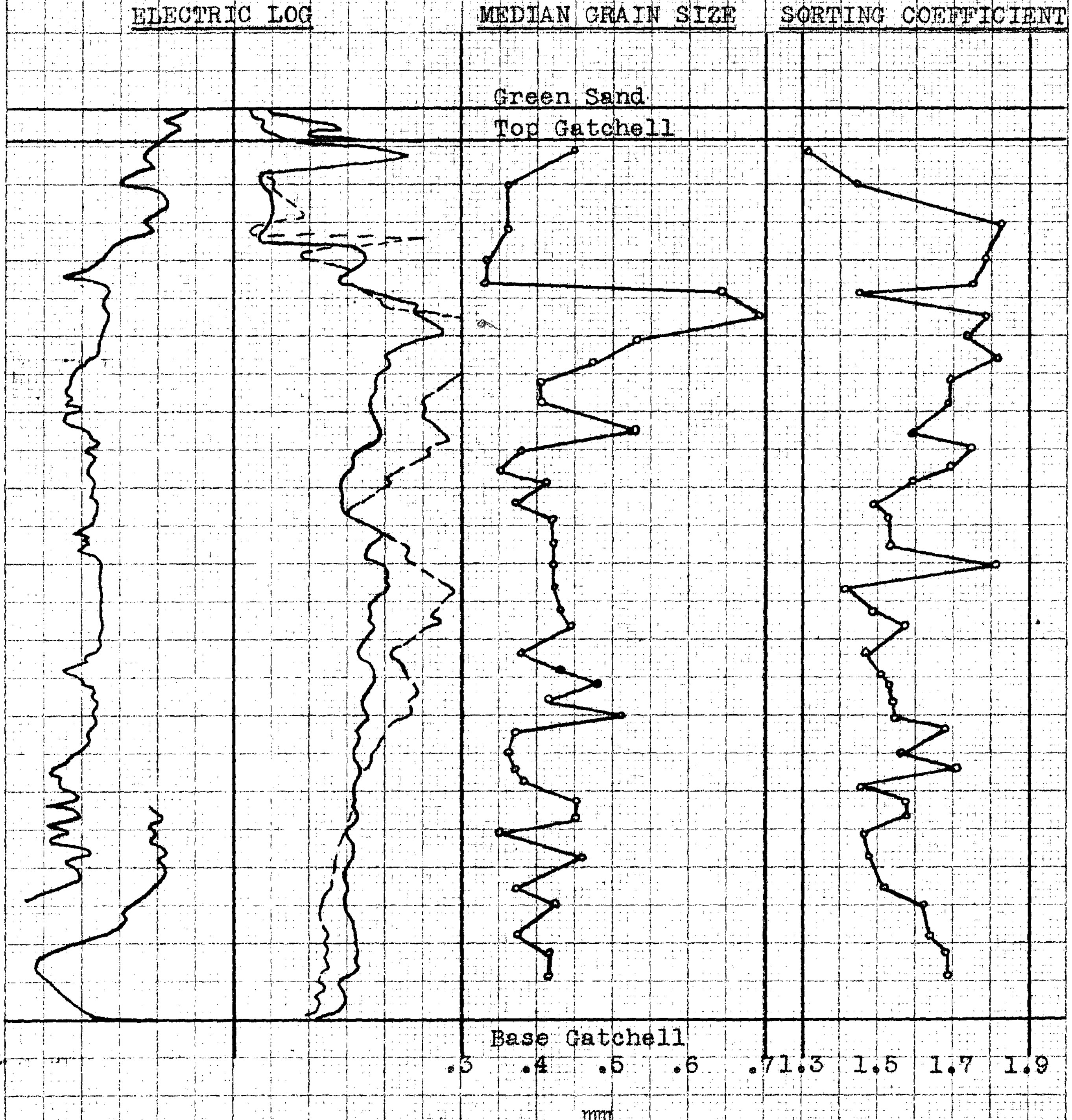


Vertical Scale 1"=100'

EXETER #2

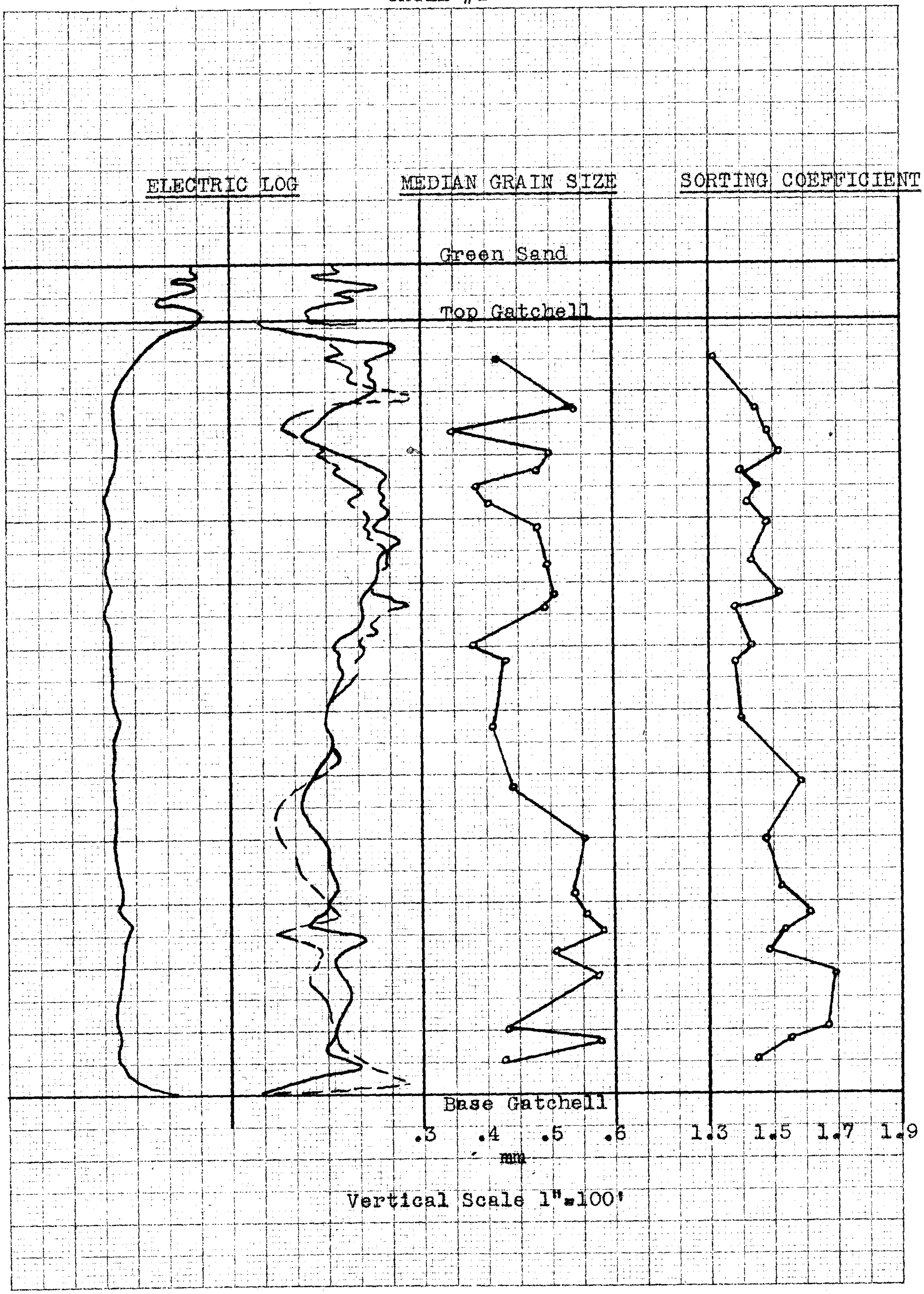

ELECTRIC LOG
MEDIAN GRAIN SIZE
SORTING COEFFICIENT
Green Sand
Top Gatchell
.3
.4
.5
.6
mm
1.3
1.5
1.7
1.9
Vertical Scale 1"=100'

WELL 68-18 20/16



Vertical Scale 1"=100'

CAGLE #1


ELECTRIC LOG
MEDIAN GRAIN SIZE
SORTING COEFFICIENT
Green Sand
Top Gatchell
Base Gatchell
.3 .4 .5 .6
mm
1.3 1.5 1.7 1.9
Vertical Scale 1"=100'

SIEVE ANALYSES OF WELL #88-12C
(Cumulative %)

SIEVE SIZE

Depth	2mm	1mm	½mm	¼mm	1/8mm	1/16mm	Pan
6800	0.0	0.2	44.5	79.3	91.2	96.3	99.3
6809	0.1	0.6	25.5	73.6	88.4	96.3	100.1
6820	0.2	9.3	57.4	82.4	91.8	97.0	100.2
6825	0.4	9.2	56.1	79.0	89.7	95.3	99.3
6832	T	1.4	38.9	73.9	88.4	95.3	99.4
6844	T	1.4	33.3	70.7	86.7	94.4	99.0
6850	0.0	0.2	48.5	78.6	90.5	95.9	99.5
6867	T	2.1	55.4	83.5	93.6	97.4	99.7
6879	0.4	3.6	50.5	80.6	92.5	97.2	100.5
6886	0.0	2.7	58.2	82.1	93.0	97.6	99.6
6895	T	2.1	56.5	80.9	92.5	96.5	99.5
6908	0.0	2.6	56.5	81.7	82.2	97.0	100.1
6818	0.0	0.6	54.3	75.5	91.1	96.2	99.7
6925	0.0	1.2	56.8	77.4	90.0	95.3	98.8
6938	0.0	0.4	58.4	78.7	91.0	96.5	100.5
6950	0.0	T	37.5	77.3	90.3	95.7	99.6
6960	0.0	0.8	61.1	82.5	92.5	98.0	100.9
6968	0.0	0.8	58.3	78.5	89.4	95.1	98.7

WELL #82-13C

Depth	2mm	1mm	½mm	¼mm	1/8mm	1/16mm	Pan
6773	0.4	6.0	56.0	86.1	94.0	97.8	99.2
6815	0.0	1.7	58.2	84.2	93.8	98.1	100.7
6840	0.2	5.0	51.9	77.2	89.9	96.0	100.0
6880	0.2	5.0	66.3	84.8	93.0	97.0	99.2
6890	0.3	10.7	74.8	87.2	93.7	97.6	99.7
6920	0.0	1.0	39.4	78.2	90.5	97.5	100.6
6945	0.1	8.2	65.4	81.9	91.0	96.3	99.4
6970	0.0	0.9	43.3	80.5	91.4	97.2	100.7
6976	0.0	0.6	30.5	75.8	89.0	95.7	99.9
7001	0.0	0.5	42.8	79.6	90.4	96.3	100.3
7040	0.0	0.4	45.1	79.3	90.3	96.0	99.3
7072	0.0	2.8	73.6	90.2	96.3	98.9	100.4
7086	0.0	3.7	68.3	85.7	93.1	96.8	99.0

SUPERIOR #1-7F

Depth	2mm	1mm	½mm	¼mm	1/8mm	1/16mm	Pan
6900	0.2	2.5	53.2	78.8	91.5	96.2	98.5
6921	0.1	1.8	55.1	84.0	95.5	98.7-	100.6
6954	T	1.2	46.0	80.3	89.3	93.9	96.4
6980	0.3	3.3	59.0	82.7	91.6	97.6	99.6
7005	0.3	1.2	42.3	78.5	90.0	95.8	99.1
7040	0.0	0.3	32.5	79.4	90.1	95.8	99.1
7065	0.0	0.4	30.6	76.3	88.7	95.3	98.1
7095	0.7	8.1	56.1	80.4	90.7	96.1	100.0
7138	T	2.4	54.0	78.0	88.9	95.4	100.0
7158	T	3.7	60.4	80.1	89.4	94.9	99.3

SIEVE ANALYSES OF WELL #1-19F
(Cumulative %)

SIEVE SIZE

Depth	2mm	1mm	½mm	¼mm	1/8mm	1/16mm	Pan
7530	0.0	7.0	62.8	80.3	88.6	95.8	98.2
7618	0.5	4.6	42.0	68.3	82.3	91.9	98.0
7638	0.3	3.4	60.1	81.6	91.5	97.5	99.5
7658	0.0	1.5	35.5	75.5	88.4	97.9	100.3
7670	0.2	2.7	51.2	76.7	87.6	97.8	98.8
7693	0.1	1.9	32.0	73.6	85.9	94.5	97.7
7701	0.6	1.5	37.6	72.2	88.5	97.9	99.7
7705	0.2	5.0	52.2	77.9	88.7	96.2	99.7
7742	0.0	1.8	57.5	79.7	88.6	96.2	98.9
7762	0.1	1.7	43.0	72.0	84.0	92.0	98.3
7775	0.1	2.3	54.0	77.9	88.3	94.9	99.9
7797	0.0	1.4	50.9	78.6	88.4	96.7	98.9
7812	0.0	0.9	45.1	73.4	88.0	93.8	99.1
7832	0.0	0.6	39.0	77.5	88.1	95.6	99.2
7846	0.0	0.9	42.3	75.6	87.8	94.5	99.9
7858	0.0	0.7	36.8	79.3	90.1	95.0	99.0
7864	0.0	0.3	42.6	78.1	89.9	96.0	100.5
7876	0.0	0.4	39.4	77.3	87.8	95.4	99.9
7907	0.0	0.9	56.6	78.9	89.0	94.9	99.5
7927	0.0	0.3	56.1	75.0	87.0	95.5	99.0
7935	0.0	0.8	58.2	79.9	88.5	95.0	99.2
7950	0.6	7.7	53.7	77.6	88.5	94.8	98.5
7970	0.0	0.3	38.3	77.1	87.9	95.7	98.9
7978	0.3	8.9	55.8	78.1	88.9	95.2	99.4
8010	0.0	0.1	21.3	77.1	87.4	94.8	100.1

WELL #26-18F

Depth	2mm	1mm	½mm	¼mm	1/8mm	1/16mm	Pan
7213	0.0	0.8	43.5	74.1	88.5	94.9	99.2
7247	0.0	0.5	39.9	76.3	87.9	95.0	98.9
7282	0.0	0.9	33.9	73.1	86.1	97.9	99.2
7318	0.0	0.8	33.4	71.9	85.2	96.1	99.1
7364	0.2	3.8	54.9	76.2	86.2	95.3	97.8
7394	T	2.7	45.2	77.5	87.5	94.2	98.7
7449	T	0.9	26.5	63.6	79.6	90.3	97.6
7490	0.0	1.2	27.7	68.8	83.7	95.5	99.1
7521	0.0	0.9	26.3	65.3	81.4	96.5	100.9
7552	0.0	0.8	34.4	71.9	84.9	94.0	98.5
7586	0.0	0.9	36.3	68.7	82.7	92.7	97.7
7613	0.0	0.2	17.2	68.8	84.1	95.8	99.6
7649	0.0	0.4	21.8	71.6	85.1	94.7	99.9

SIEVE ANALYSES OF WELL #33-7F
(Cumulative %)

SIEVE SIZE

Depth	2mm	1mm	½mm	¼mm	1/8mm	1/16mm	Pan
6866	0.0	0.6	25.2	57.4	81.9	92.9	98.9
6900	0.1	2.5	49.5	76.2	88.3	97.7	100.0
6960	0.0	0.4	35.2	75.5	86.7	97.2	99.5
6994	0.0	0.5	32.5	76.1	88.6	97.2	99.5
7046	T	1.0	44.1	75.3	87.6	95.0	99.1
7083	0.0	0.1	24.7	72.5	85.9	94.5	99.1
7126	0.0	0.9	16.9	64.8	82.1	94.9	99.8
7165	T	1.3	31.0	70.7	85.8	96.3	99.3
7188	0.0	T	22.8	60.0	86.0	96.0	99.2
7223	T	3.2	48.2	73.7	86.0	95.6	100.0
7260	0.2	3.2	53.0	70.9	79.9	89.3	97.1
7276	0.0	0.1	44.5	63.2	77.8	90.9	99.0

WELL #48-7F

Depth	2mm	1mm	½mm	¼mm	1/8mm	1/16mm	Pan
7034	0.0	1.5	26.8	70.6	86.1	95.5	99.1
7074	0.0	0.9	22.7	68.3	83.7	96.4	99.2
7130	0.0	0.7	26.3	74.3	87.8	98.6	99.1
7162	0.1	1.2	45.1	76.2	88.0	99.0	99.3
7189	0.2	4.0	52.9	74.1	86.1	98.7	99.0
7249	0.0	0.8	53.8	71.7	85.3	97.7	99.1
7290	T	2.6	44.2	75.1	85.2	98.3	99.9
7306	0.0	1.0	38.9	70.4	84.2	93.1	99.7
7341	0.0	0.2	28.5	67.6	82.3	94.1	98.9
7380	0.0	0.2	40.5	70.1	83.8	94.4	98.9
7461	0.0	0.4	25.4	66.0	81.8	91.6	99.0
7536	0.0	0.5	16.8	67.3	83.2	94.4	98.8
7565	0.0	0.3	21.0	70.8	84.1	97.1	99.1

SIEVE ANALYSES OF WELL #68-18
(Cumulative %)

SIEVE SIZE

Depth	2mm	1mm	½mm	¼mm	1/8mm	1/16mm	Pan
7468	0.0	1.0	37.6	81.5	90.8	95.5	98.2
7487	0.0	0.1	19.6	71.8	88.7	96.0	100.4
7517	0.0	0.7	32.5	64.8	82.4	91.4	97.1
7539	T	0.6	14.9	61.2	77.1	86.9	99.9
7551	0.0	0.1	11.7	59.4	77.4	87.9	99.4
7560	0.6	14.7	68.6	81.9	88.8	95.7	99.5
7572	5.1	28.2	66.0	80.8	89.3	99.0	99.9
7590	0.3	3.5	49.9	75.9	85.7	95.4	98.7
7607	0.1	3.3	41.0	71.6	82.7	90.4	98.9
7619	0.1	3.0	31.7	70.4	82.2	90.3	99.0
7634	0.3	4.7	34.3	69.4	81.8	89.4	98.3
7652	0.0	3.8	53.8	77.1	86.9	95.7	99.7
7664	0.0	0.4	24.4	71.3	83.7	91.7	99.5
7676	0.0	0.5	21.2	69.0	82.6	91.3	99.6
7686	0.0	1.0	33.5	71.9	84.3	92.5	99.6
7697	0.0	0.2	18.3	70.0	84.1	92.6	100.3
7710	0.0	0.2	28.6	73.0	85.0	92.7	97.5
7725	0.0	0.9	28.3	70.0	82.9	91.3	98.5
7740	0.2	4.6	53.9	77.4	87.6	94.4	100.3
7755	0.0	0.7	28.6	73.5	86.2	94.7	99.2
7770	0.0	1.5	33.8	74.4	86.6	93.4	98.9
7782	0.0	1.3	40.6	73.9	85.8	93.2	99.1
7797	0.0	0.2	21.4	71.2	85.4	94.1	99.8
7808	T	1.5	35.4	73.1	85.1	92.9	97.8
7818	0.1	2.7	44.2	78.8	89.5	97.3	100.1
7828	0.0	0.8	25.5	71.2	85.1	92.8	98.6
7839	0.0	3.9	51.4	77.4	88.0	94.2	99.3
7850	T	1.0	31.7	68.1	82.5	91.8	97.8
7862	0.0	0.9	23.0	69.2	84.3	92.9	100.1
7875	0.0	0.3	30.5	68.0	82.5	91.4	98.8
7883	0.0	0.1	22.8	71.8	85.7	93.7	100.0
7895	0.0	1.5	38.9	74.2	86.2	93.5	99.3
7907	0.1	1.9	39.4	75.2	87.1	93.9	99.5
7919	0.0	0.1	17.7	70.9	86.0	93.9	99.2
7934	0.0	0.4	42.2	74.4	86.6	93.2	98.6
7953	0.0	0.1	25.7	69.3	84.4	92.8	99.6
7963	0.0	0.2	38.6	73.3	86.3	93.5	99.2
7986	0.0	0.2	29.8	68.8	83.8	92.2	99.1
7997	0.0	0.3	38.7	68.8	83.3	91.6	99.2
8012	0.0	1.0	38.9	68.7	84.0	92.2	98.6

SIEVE ANALYSES FOR CAGLE #1
(Cummulative %)

SIEVE SIZE

Depth	2mm	1mm	½mm	¼mm	1/8mm	1/16mm	Pan
7129	0.1	0.8	28.1	81.0	93.1	97.5	100.1
7162	1.6	13.2	54.6	85.8	93.7	98.0	98.9
7179	0.0	0.4	27.5	66.4	89.0	97.5	99.4
7196	0.1	1.2	49.9	77.2	90.2	95.5	98.8
7213	0.0	1.2	43.6	80.2	91.0	96.3	99.3
7226	0.0	0.2	25.0	76.9	89.9	96.1	99.6
7235	0.0	0.4	29.9	76.6	89.5	96.7	99.9
7255	T	0.7	46.1	79.9	90.5	97.8	98.8
7287	0.0	0.9	47.7	81.4	91.5	98.2	98.7
7308	0.0	1.1	51.8	79.4	90.5	98.0	98.9
7317	0.0	0.6	47.3	83.2	92.8	99.2	99.3
7354	0.0	0.2	22.6	73.6	89.3	98.5	99.1
7362	0.0	0.5	36.9	80.1	91.2	97.2	98.6
7414	0.0	0.4	31.7	77.9	90.1	98.1	99.5
7458	0.0	1.6	41.9	72.5	89.0	96.5	99.4
7495	0.2	4.1	59.6	80.3	90.4	95.5	97.9
7540	0.2	4.2	53.6	79.4	90.0	96.0	99.2
7556	0.1	4.3	57.1	78.6	89.5	97.1	99.0
7568	0.0	4.4	60.3	81.3	90.8	97.0	98.7
7598	0.0	1.0	52.1	77.0	89.1	97.4	100.2
7605	1.4	15.7	58.5	78.2	89.9	96.4	99.2
7640	0.0	1.2	41.6	73.4	87.7	96.1	99.0
7655	0.3	6.6	65.2	84.8	93.4	95.6	99.5
7669	0.0	0.1	42.9	79.6	91.5	98.1	100.4

SIEVE ANALYSES OF WELL #86-7F
(Cumulative %)

SIEVE SIZE

Depth	2mm	1mm	½mm	¼mm	1/8mm	1/16mm	Pan
7770	0.0	0.7	33.0	79.3	90.4	96.2	99.8
7786	0.0	0.3	26.1	60.4	81.3	93.9	98.4
7797	0.1	1.2	21.5	69.3	87.8	95.6	100.4
7812	0.0	1.5	46.7	78.0	90.9	96.4	99.7
7830	2.0	15.8	60.7	80.4	90.1	96.0	100.4
7840	0.3	6.5	63.7	83.4	91.5	97.5	99.0
7850	2.2	9.5	60.3	83.7	92.0	98.3	99.6
7864	0.4	17.1	69.1	84.9	93.1	99.5	99.8
7873	0.5	13.3	60.0	77.9	89.0	96.9	99.4
7885	0.4	16.3	63.0	82.0	91.9	100.0	100.5
7897	0.3	7.7	61.9	81.9	91.6	99.0	99.8
7909	0.6	9.8	68.8	86.1	93.4	98.9	99.4
7920	0.1	4.4	49.1	78.1	89.1	98.5	98.7
7932	0.0	2.8	45.8	79.6	90.3	98.0	98.6
7950	0.4	3.4	37.6	69.9	84.2	94.6	97.9
7962	0.0	0.8	26.0	71.2	86.2	95.4	99.4
7973	0.0	0.5	14.3	66.1	85.5	94.9	100.0
7985	0.3	3.0	29.3	71.7	86.2	94.2	99.5
8004	0.0	1.5	34.3	76.0	88.2	94.8	99.5
8013	0.0	0.8	29.0	74.6	87.9	94.2	98.0
8025	0.1	1.3	47.1	77.7	89.0	95.9	99.2
8043	0.0	0.4	25.6	72.7	86.6	94.0	98.5
8052	0.0	0.3	17.1	70.6	87.0	96.2	100.7
8067	0.0	0.1	14.2	68.7	86.0	94.6	99.8
8079	0.0	0.1	14.4	71.9	87.4	95.6	100.2
8094	0.0	0.1	13.4	67.2	86.1	94.6	100.5
8106	0.0	2.2	44.0	79.4	90.5	96.6	100.7
8118	0.1	3.2	47.2	76.9	88.2	96.0	99.3
8130	0.0	0.3	20.7	70.1	86.5	95.1	100.3
8142	0.0	0.3	21.4	71.2	86.0	94.2	99.8
8154	0.0	1.2	36.6	74.0	87.0	94.8	99.8
8166	0.0	1.4	42.5	78.4	89.6	97.1	99.4
8175	0.0	1.0	27.5	75.8	88.3	95.0	99.4
8187	0.0	1.0	31.4	76.4	89.2	96.0	100.2
8200	0.0	0.2	16.0	65.7	84.3	93.5	100.0
8211	0.0	0.2	11.4	64.0	84.2	93.7	100.1
8232	0.0	0.1	22.5	71.6	86.4	94.0	99.4
8250	0.0	0.1	31.1	69.7	84.6	93.2	98.9
8268	0.0	0.4	22.4	69.6	85.1	93.2	99.4
8282	0.0	T	11.0	66.0	85.1	94.3	99.3
8303	0.0	0.6	23.5	69.0	84.8	93.0	99.8
8332	0.0	0.1	15.4	65.9	84.2	93.3	100.4
8349	0.0	0.2	20.0	68.4	84.5	92.7	99.3
8363	0.1	1.4	33.5	73.5	87.2	93.8	99.5
8377	T	0.9	30.8	71.5	86.3	93.5	97.9
8393	0.0	0.3	19.1	67.8	84.0	92.2	99.5
8413	0.0	0.1	18.6	65.9	82.9	91.4	98.6

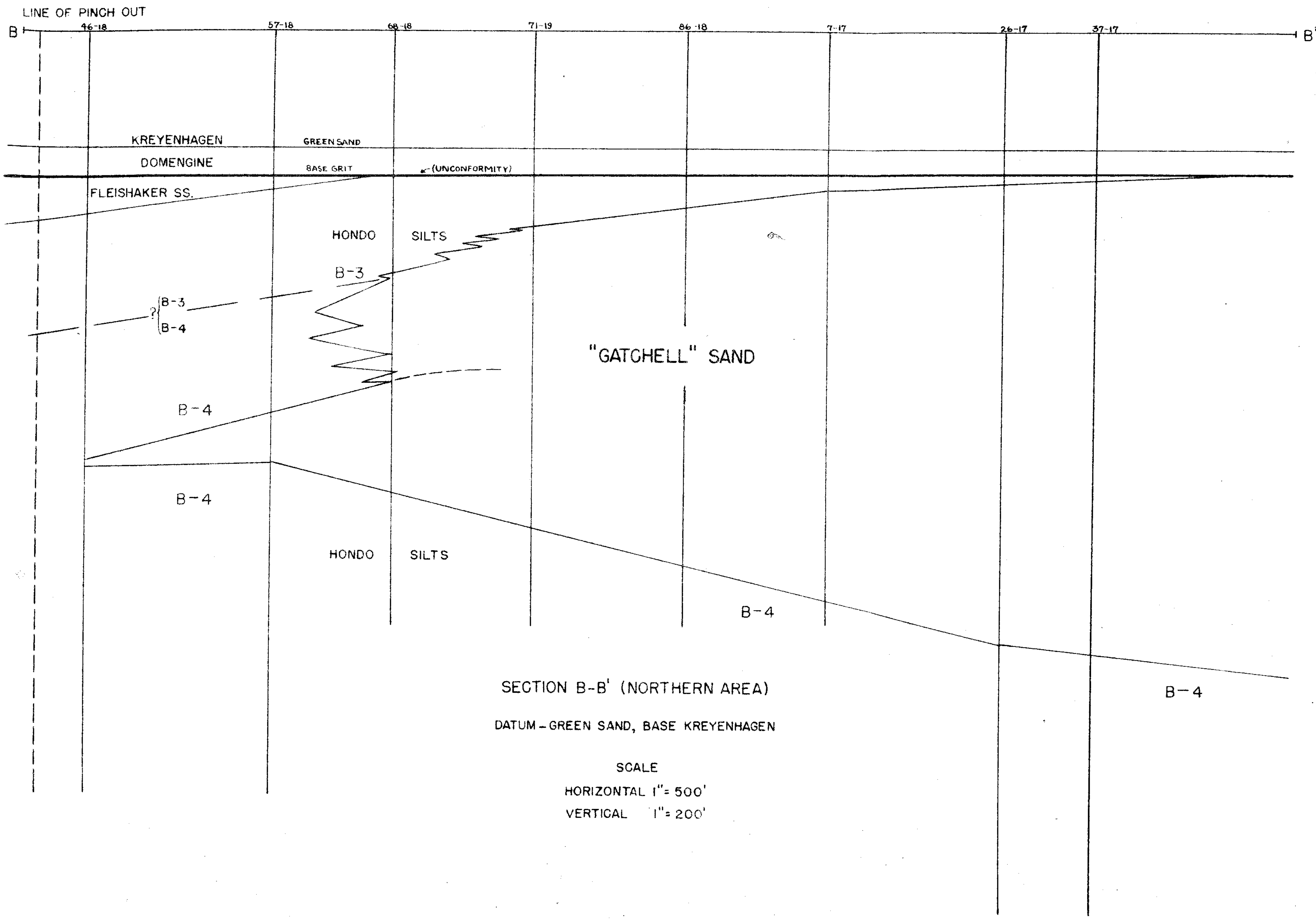
SIEVE ANALYSES FOR EXETER #2
(Cumulative %)

SIEVE SIZE

Depth	2mm	1mm	½mm	¼mm	1/8mm	1/16mm	Pan
7449	0.8	17.7	59.1	85.5	94.1	98.4	100.8
7459	0.3	1.7	36.5	78.0	91.3	97.6	101.5
7468	0.3	1.4	27.3	75.3	89.9	97.6	101.6
7478	0.0	1.1	43.1	80.3	91.9	97.2	99.6
7488	0.0	0.9	44.6	80.7	91.2	97.4	98.8
7498	1.1	8.0	50.5	85.6	92.8	99.5	99.8
7508	0.0	0.8	29.2	69.2	87.7	94.8	99.0
7518	0.3	2.9	48.9	76.4	89.8	96.4	99.7
7528	0.4	4.7	64.2	82.9	90.6	97.0	98.3
7538	0.0	0.1	21.0	75.5	89.1	95.3	99.2
7548	0.0	1.7	51.7	79.1	90.1	97.2	99.7
7558	0.2	1.3	32.9	77.8	90.3	98.1	98.9
7568	0.9	3.4	42.6	77.2	89.5	98.5	100.4
7578	0.4	7.9	66.9	84.8	93.1	98.2	99.5
7589	0.2	3.2	58.7	83.3	93.1	96.9	99.5
7599	0.2	8.1	59.6	81.8	92.2	100.5	101.0
7604	0.0	0.9	45.5	81.0	92.1	99.4	99.8
7615	0.3	1.0	34.1	79.1	90.9	99.1	100.2
7626	0.0	0.8	30.8	79.7	91.4	99.9	100.3
7636	0.0	0.3	27.1	73.8	88.3	97.5	99.1
7646	0.0	0.5	33.5	71.3	86.0	86.4	98.8
7656	0.0	0.5	36.7	76.7	89.8	98.6	100.4
7665	0.0	0.9	45.9	79.7	91.4	100.1	100.9
7674	0.0	0.5	39.8	77.3	89.5	97.8	99.2
7685	0.0	1.0	50.3	80.2	91.8	99.9	100.8
7696	0.0	0.6	44.7	79.7	90.9	99.6	100.0
7707	0.2	4.2	59.1	81.4	92.1	100.1	100.4
7717	0.0	2.9	57.2	80.1	90.9	98.6	99.5
7728	0.0	2.7	56.8	80.6	90.5	96.8	98.3
7738	0.0	1.6	49.1	78.7	90.2	98.4	99.4
7749	0.2	8.9	62.8	81.6	91.2	98.9	99.8
7759	0.0	2.1	43.8	76.9	89.0	96.1	99.3
7769	0.0	2.4	52.9	78.0	88.9	96.9	99.4
7781	0.0	2.6	55.3	78.7	89.4	97.9	98.8
7791	0.0	0.8	47.8	77.9	89.4	97.1	99.0
7801	0.0	0.3	49.7	80.2	90.8	98.4	100.3
7808	0.0	0.4	45.8	75.9	88.4	98.0	100.1
7814	0.0	0.4	53.7	79.1	90.0	97.7	100.0
7825	0.0	1.0	56.3	78.9	89.6	99.2	100.1
7837	0.1	11.6	65.4	82.6	91.5	97.8	99.2
7846	0.0	1.3	49.6	78.9	89.9	99.1	100.2
7856	0.3	3.5	52.0	80.1	90.5	98.6	99.9
7867	0.0	0.4	46.4	80.2	90.5	96.4	99.9

EXETER #2 (Cont'd)

Depth	2mm	1mm	½mm	¼mm	1/8mm	1/16mm	Pan
7877	0.0	0.3	49.0	78.7	89.2	96.6	99.3
7887	0.0	0.2	47.7	77.2	88.5	96.1	99.6
7899	0.0	0.1	42.5	75.5	87.0	94.7	99.0
7905	0.0	0.5	45.9	77.7	88.3	95.1	99.0
7912	0.0	0.7	41.9	77.5	88.9	96.9	100.6
7922	0.0	0.4	41.3	75.2	87.5	94.9	100.3
7933	0.0	0.3	35.8	73.1	86.2	94.4	99.5
7943	0.1	2.9	46.0	75.7	87.6	95.2	100.3
7956	0.0	0.1	25.6	73.1	86.2	93.6	98.9
7966	0.0	1.0	47.1	78.6	88.9	95.7	99.0
7978	0.0	0.7	40.6	75.6	87.2	95.2	99.0
7989	0.0	0.1	33.3	72.4	85.2	93.4	98.8
7999	0.0	2.3	45.5	78.0	89.5	96.0	100.4
8009	0.0	0.7	48.7	82.4	91.6	97.6	100.1
8015	0.0	0.5	35.5	76.0	88.7	95.2	99.6
8024	0.0	0.3	35.3	78.2	89.8	95.8	100.0
8036	0.0	0.4	36.3	79.4	90.0	97.5	99.6
8046	0.0	1.2	44.2	81.5	91.4	97.4	100.3
8055	0.0	0.3	31.7	80.2	90.7	98.3	100.0
8065	0.0	0.2	29.5	74.7	87.6	95.2	99.3
8077	0.0	0.3	28.6	79.0	89.8	96.3	99.3
8088	0.0	0.6	36.5	78.8	89.9	98.4	99.8
8097	0.0	0.1	17.9	74.1	87.3	98.4	99.3



SECTION B-B' (NORTHERN AREA)

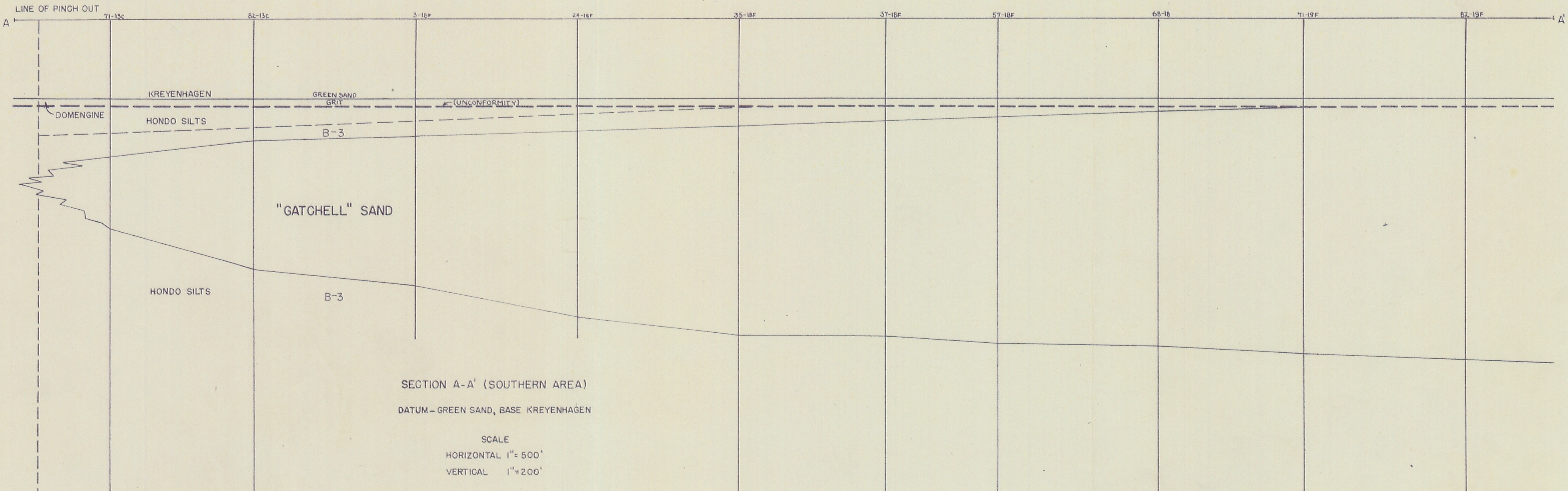
DATUM - GREEN SAND, BASE KREYENHAGEN

SCALE

HORIZONTAL 1" = 500'

VERTICAL 1" = 200'

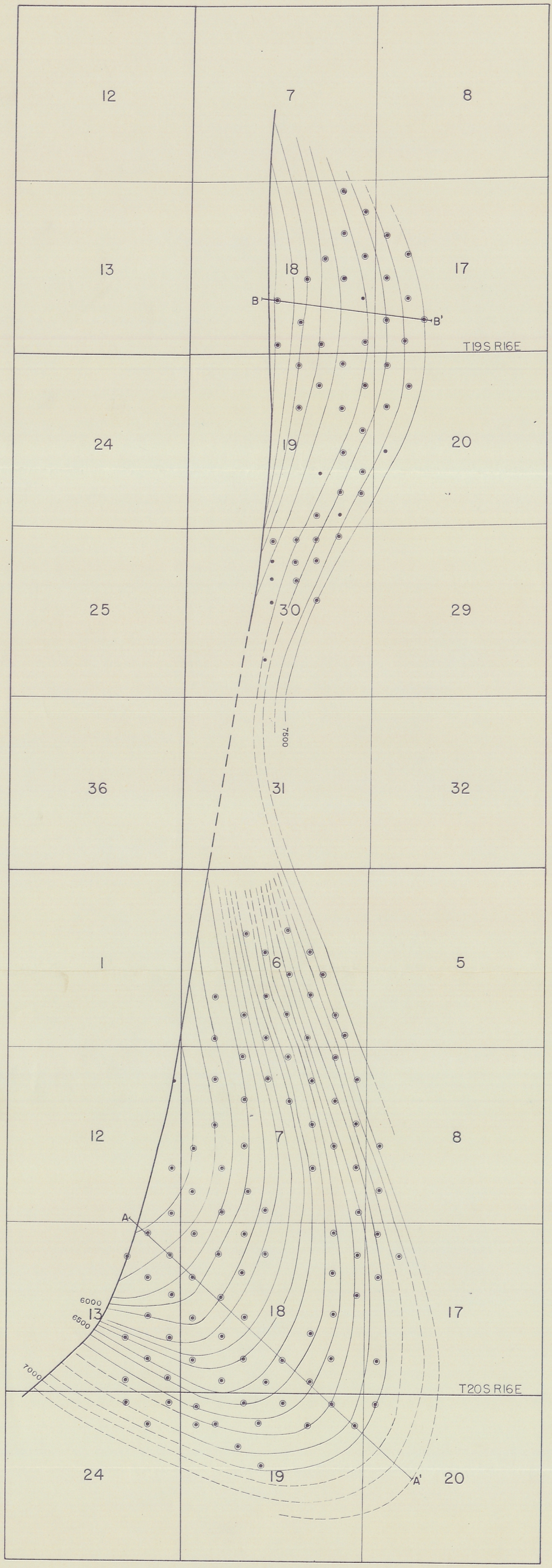
Regan - Ij - 1941 p. 61
MS



SECTION A-A' (SOUTHERN AREA)

DATUM – GREEN SAND, BASE KREYENHAGEN

SCALE
HORIZONTAL 1" = 500'
VERTICAL 1" = 200'



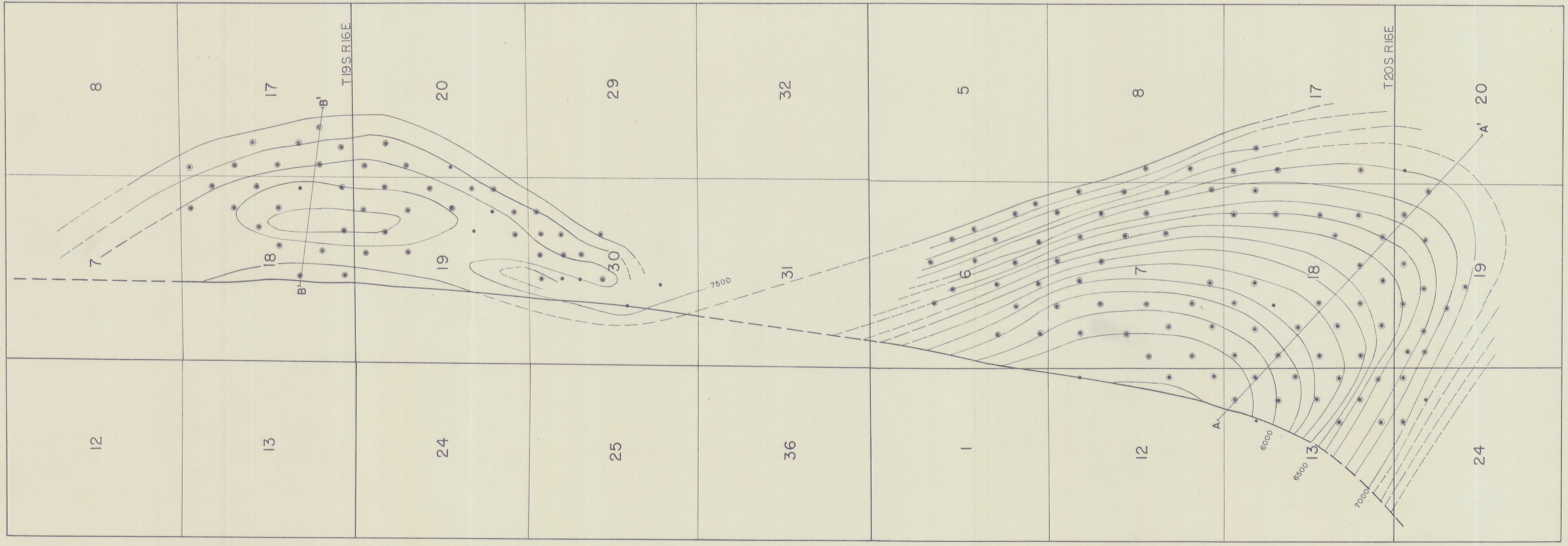
STRUCTURE CONTOUR MAP-
CONTOURS ON GREEN SAND

SCALE 1" = 2000'
CONTOUR INTERVAL 100'

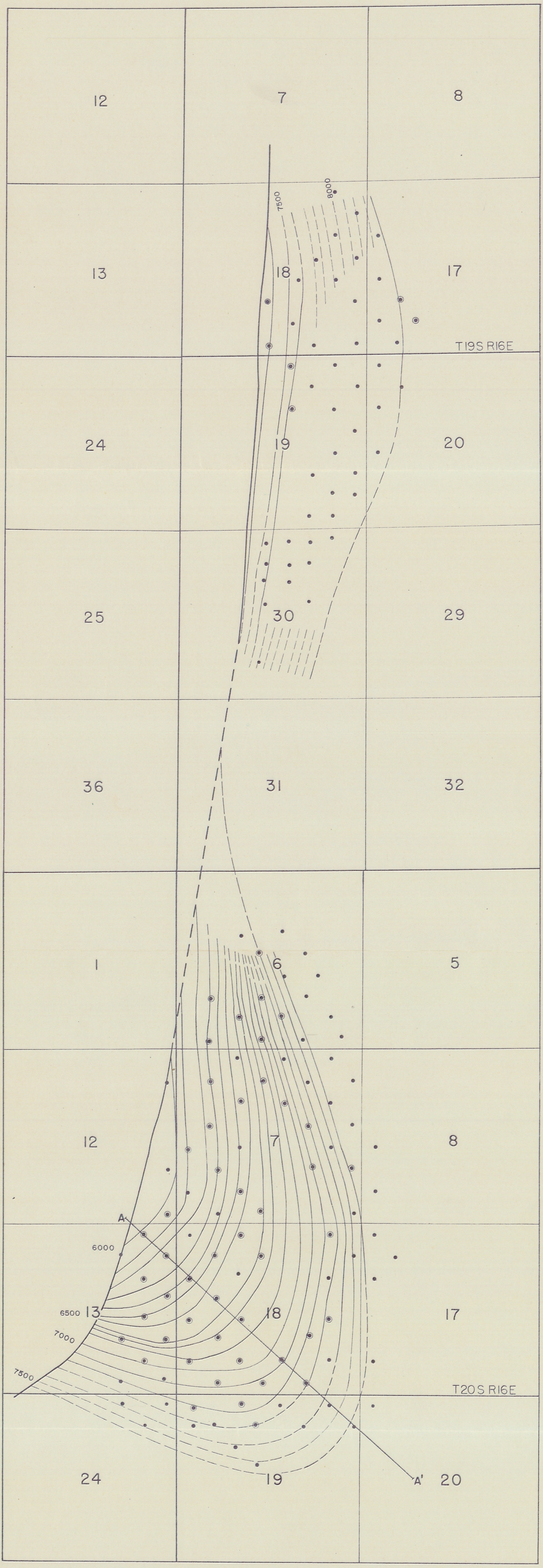
◉ WELL FROM WHICH DATA WAS USED
• NO DATA WELL

Regan-lj-1941 p. 62
MS

Regan 1j-1941 p.63
MS



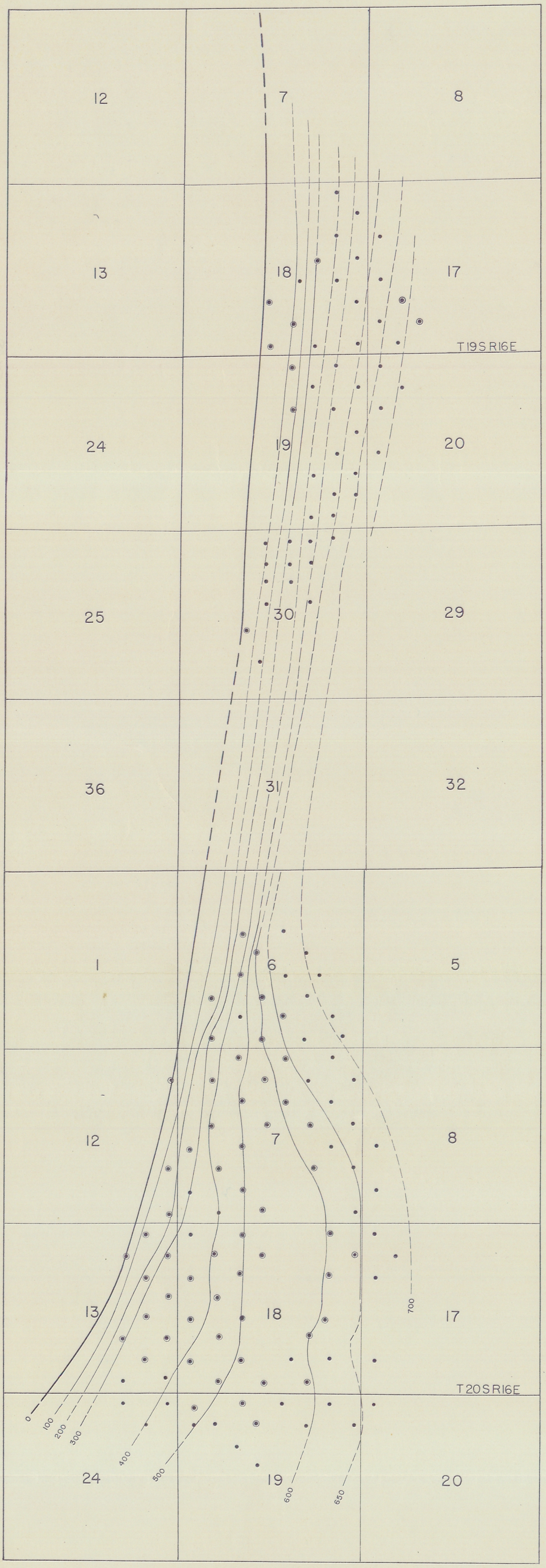
STRUCTURE CONTOUR MAP
CONTOURS ON TOP OF "GATCHELL"
SCALE 1"= 2000'
CONTOUR INTERVAL 100'
⊙ WELL FROM WHICH DATA WAS USED
• NO DATA WELL



STRUCTURE CONTOUR MAP
CONTOURS ON BASE OF "GATCHELL"

SCALE 1"=2000'
CONTOUR INTERVAL 100'

Regan-1j- 1941
MS p.64



ISOPACH MAP
THICKNESS OF "GATCHELL"
SCALE 1" = 2000'
CONTOUR INTERVAL 100'

◉ WELL FROM WHICH DATA WAS USED
• NO DATA WELL

Regan-ij-1941 ms
p-65