DEPOSITIONAL ENVIRONMENTS AND DIAGENESIS OF UPPER PENNSYLVANIAN MARCHAND SANDSTONES ON SOUTH, EAST, AND NORTHEAST FLANKS OF THE ANADARKO BASIN

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PREFACE

This thesis concerns the depositional environment and diagenesis of the Upper Pennsylvanian Marchand sandstones. Electric logs, gamma-ray logs, and compensated formation density logs were used to prepare isopach maps and cross sections. Analyses of cores and cross sections and isopach maps were used to interpret depositional environment. Thin section studies and scanning electron microscopy of selected samples permitted interpretation of diagenetic history.

The writer wishes to thank Dr. John W. Shelton, thesis adviser, for his guidance and assistance during this study. Suggestions concerning diagenesis were made by Dr. Zuhair Al-Shaieb and are gratefully acknowledged. Dr. John Naff assisted in the paleontology of the Marchand. Thanks for critical review of the manuscript go to Dr. R. Nowell Donovan and Dr. Gary F. Stewart. Gratitude is also extended to my fellow graduate students, especially Bryan Lee and Kent Bowker, for their comments and suggestions.

Information and material came from several sources: the Oklahoma Geological Survey provided cores, Cities Service Company and the Oklahoma Well Log Library provided access to well logs.

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CHAPTER I

ABSTRACT

The Marchand sandstones are thought to be marine sands deposited on the slope or ramp of the Anadarko basin. Evidence for this interpretation is the somewhat unique characteristics of the Marchand sandstones as seen in core study, apparent depositional topography related to the sandstones, and the relationship of the Marchand with its lateral equivalents (Layton Sandstone and Coffeyville Formation).

During Marchand deposition, the Anadarko basin is thought to have consisted of a broad shallow shelf, which was a carbonate platform to the north and a deltaic platform to the east, together with a less well defined slope-basinal area. The depositional slope on the shelf-slope transition was 0.5 to 1^{o}. Maximum water depths for the central part of the basin were approximately 400 to 500 feet. Water depths in that area of Marchand deposition was probably 200 to 300 feet.

Based on composition, the major source area for the Marchand sandstones was probably the Ouachita uplift. However, distribution and composition of the Marchand in the Cement field area suggests the Wichita uplift was, locally, an important source area for the extreme southern part of the study region. Contributions from the distant craton or Appalachian region cannot be disproved.

Diagenesis of the Marchand sandstones is thought to have occurred in four main stages. Development of secondary porosity is, from an economic standpoint, the most important of these phases.

CHAPTER II

INTRODUCTION

The area for investigating the Upper Pennsylvanian Missourian strata consists of 57 townships along the south, east, and northeast flanks of the Anadarko basin (in T5-7N, R4-10W and T8-11N, R4-12W, including parts of Caddo, Canadian, Grady, McClain and Oklahoma Counties, Oklahoma) (Fig. 1). The interval studied is from the top of the Tonkawa Limestone to the base of the "Lower Checkerboard" Limestone (Fig. 2). The section is highly productive of oil and gas. The major producing horizons are the Medrano Sandstone of the Cement field and Marchand sandstones of the Cement, Northwest Norge, Northwest Chickasha, Verden, Dutton, Binger, East Binger, and South Hydro fields.

Objectives and Methods

The principal objectives of this investigation are: (1) to determine, on a regional scale, the depositional environment(s) of the Upper Pennsylvanian Missourian Marchand sandstones, (2) to ascertain the nature and sequence of diagenetic changes which have affected Marchand sandstones, and (3) to compare the Marchand to similar Missourian sand bodies and to determine some aspects of sand deposition with respect to basinal configurations and characteristics.

The geometric features, trend, width, thickness, and boundaries of the Marchand sandstones were determined through examination of gamma-ray

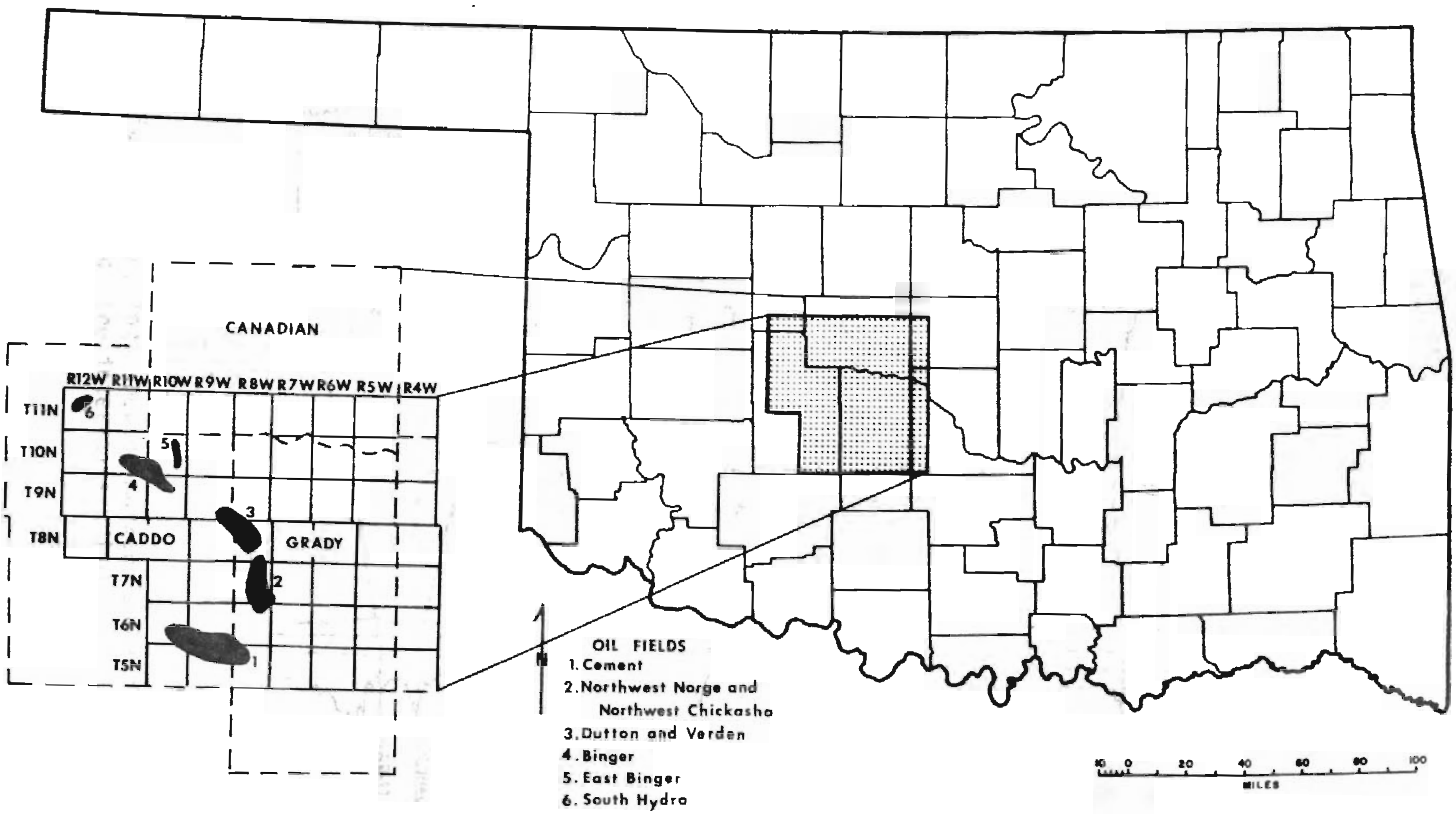


Fig. 1.--Location map of area and of oil and gas fields producing from Marchand sandstones.

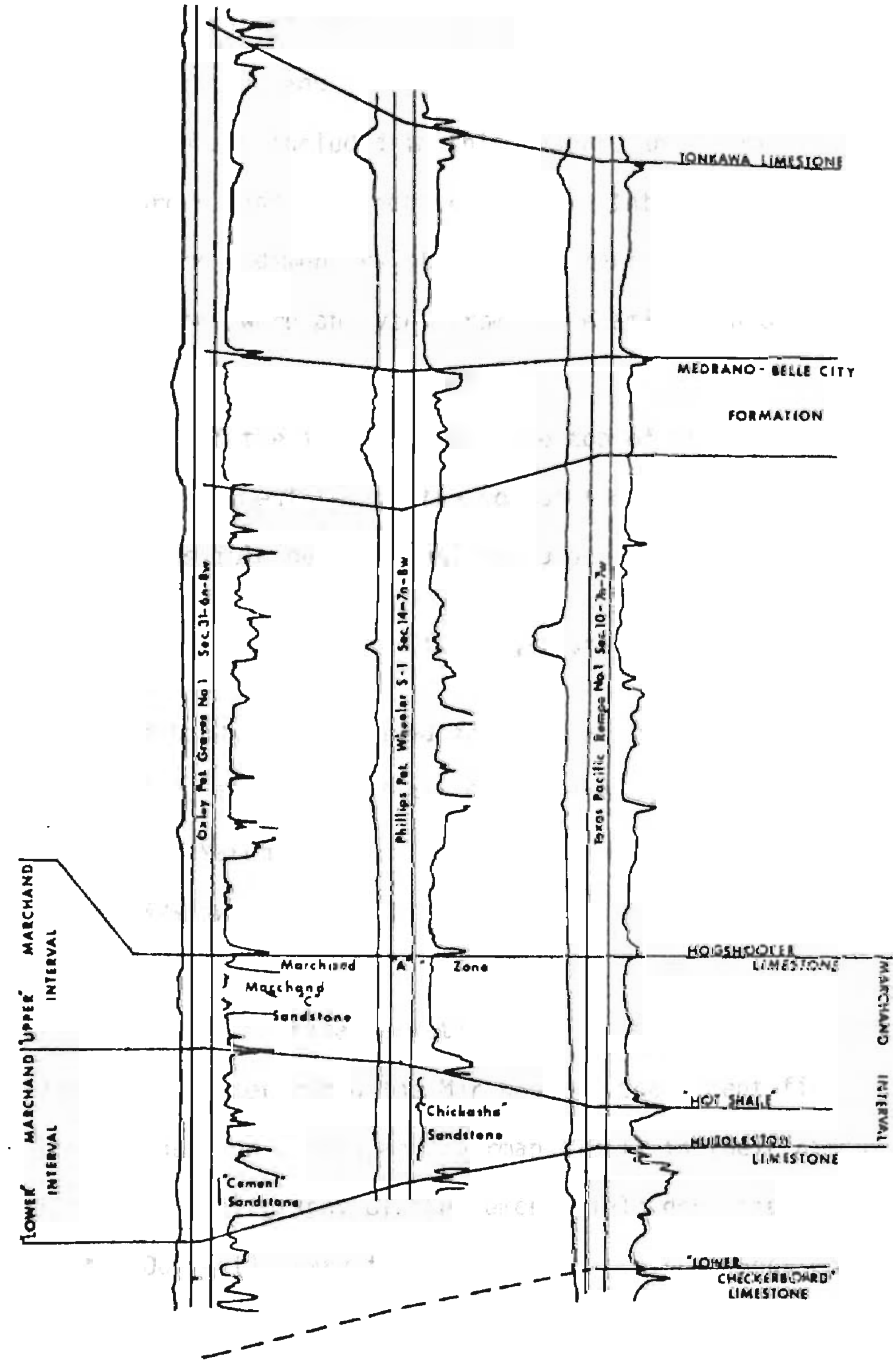


Fig. 2.--Type logs showing markers and principal subdivisions of the interval studied.

logs, compensated formation density logs and induction electric logs from 576 wells, by preparation and interpretation of 16 stratigraphic cross-sections, 9 of which are included in this report, and isopach maps of net and gross sand (gross sand maps not included). Internal features of the sandstones, including sedimentary structures, textures, constituents and diagenetic alterations were analyzed from the examination of 7 cores and 21 thin sections.

An isopach map of the interval from the top of the "Hot Shale" marker, below the Hogshooter Limestone, to the top of the Huddleston Limestone was prepared to show possible depositional topography.

Previous Investigations

The Marchand Sandstone is named for the Marchand lease of Gordon Trust in NW¼ Sec. 2, T5N, R9W, of the Cement field, Caddo County, Oklahoma. Production from the Marchand was first discovered in the Ohio No. 3 Marchand in SE¼ SW¼ NW¼ Sec. 2, T5N, R9W, Caddo County, Oklahoma (Jordan, 1957).

Based on lithologic characteristics and abundant conglomeratic facies, Eisner (1949, 1955) interpreted the Marchand of the Cement field as a stream deposit. Harlton (1960) and Herrman (1961) in their discussions of the structure and stratigraphy of the Cement field described the Marchand as thick (0 to 200 feet), very fine- to medium-grained sandstones with occasional oolitic limestone beds and thick (0 to 500 feet) conglomerates composed of chert and limestone fragments. Harlton (1960) correlated the Marchand interval to the Crinerville Formation of the Ardmore basin. Cox (1963) described the Marchand sandstones of the Binger field as lenticular sand bodies correlative to the "Layton-Cottage Grove" sandstones to the northeast. Ash (1971) in his study of the Northwest Chickasha, Verden, and Dutton fields interpreted the depositional environment of the Marchand as an offshore barrier bar complex with intersecting channels. He thought the "Hot Shale" represented a minor transgression. Graff (1971) considered the Marchand Sandstone of the Northwest Chickasha field to be of deltaic origin, with a drainage system to the northeast. Sawyer (1972) interpreted the Marchand in much the same way as did Ash (1971). The more recent investigations of the Marchand sandstones include those of Curlee (1974), Kessler (1976), Wilson (1976) and Baker (1980). Curlee (1974) in a study of the Northwest Norge and Verden fields concluded the depositional environment of the Marchand was tidal channel infill with later barrier bar development. Kessler (1976) and Wilson (1976) ascribed the Marchand to more basinal facies. Kessler (1976) suggested that the Marchand was deposited by low-velocity currents that traveled down low-gradient submarine canyons fed by westward accreting delta distributaries. Wilson (1976) in his study of the Northwest Chickasha and Northwest Norge fields concluded that the Marchand was deposited on a submarine slope in approximately 300 feet of water. The presence of glauconite, absence of carbonaceous material, and the gamma-ray log pattern led Baker (1980) to interpret the depositional environment of the Marchand Sandstone of the Binger field as a "tidal sand ridge."

CHAPTER III

STRUCTURAL FRAMEWORK

Regionally, Marchand sandstones are located on the south, east, and northeast flanks of the Anadarko basin. In southern Oklahoma and adjoining parts of Texas, structural evolution which eventually led to the development of the Anadarko basin (among other provinces), is thought to have begun during the Cambrian and to have been related to continental rifting and spreading (Hoffman, 1974; Friedman and Sanders, 1978). Late Paleozoic orogenic pulses beginning during Late Morrowan and continuing intermittently to Early Virgilian are responsible for the present configuration of the basin as a west-northwest-trending, asymmetric structural and depositional basin (Friedman and Sanders, 1978). The Anadarko basin is characterized by a broad, gently dipping cratonal shelf area to the north and a narrow, steeply dipping southern flank bounded by the Amarillo-Wichita frontal fault system. This frontal fault system is composed of west-northest-trending faults and north-trending offset faults. Together the two trends form a complex of horsts and grabens (Halrton, 1972). The patterns are thought to reflect a strong, if not dominant, role of strike-slip faulting.

Several previous investigators have produced excellent structural contour maps on various horizons throughout the area. The best of these are Herrman (1955), Harlton (1960), Ash (1971), Wilson (1976), and Fritz (1978). The southwestern one-third of the area is involved in faulting along the Amarillo-Wichita mountain front and is characterized by the faulted structures of the Cement, Chitwood, Laverty, and Ft. Cobb-Eakley anticlines (Fig. 3). The remaining part of the area is structurally simple, being dominated by a southwesterly to south-southwesterly homoclinal dip which ranges from 100 to 300 feet per mile (Fritz, 1978). General discussions of the structural development of all or parts of this area are included in the following references: Herrman (1955), McDaniel (1955), Tomlinson and McBee (1959), Harlton (1961, 1972), and Fritz (1978). The detailed structural features and history of this area, which are rather well documented, are beyond the scope of this study.

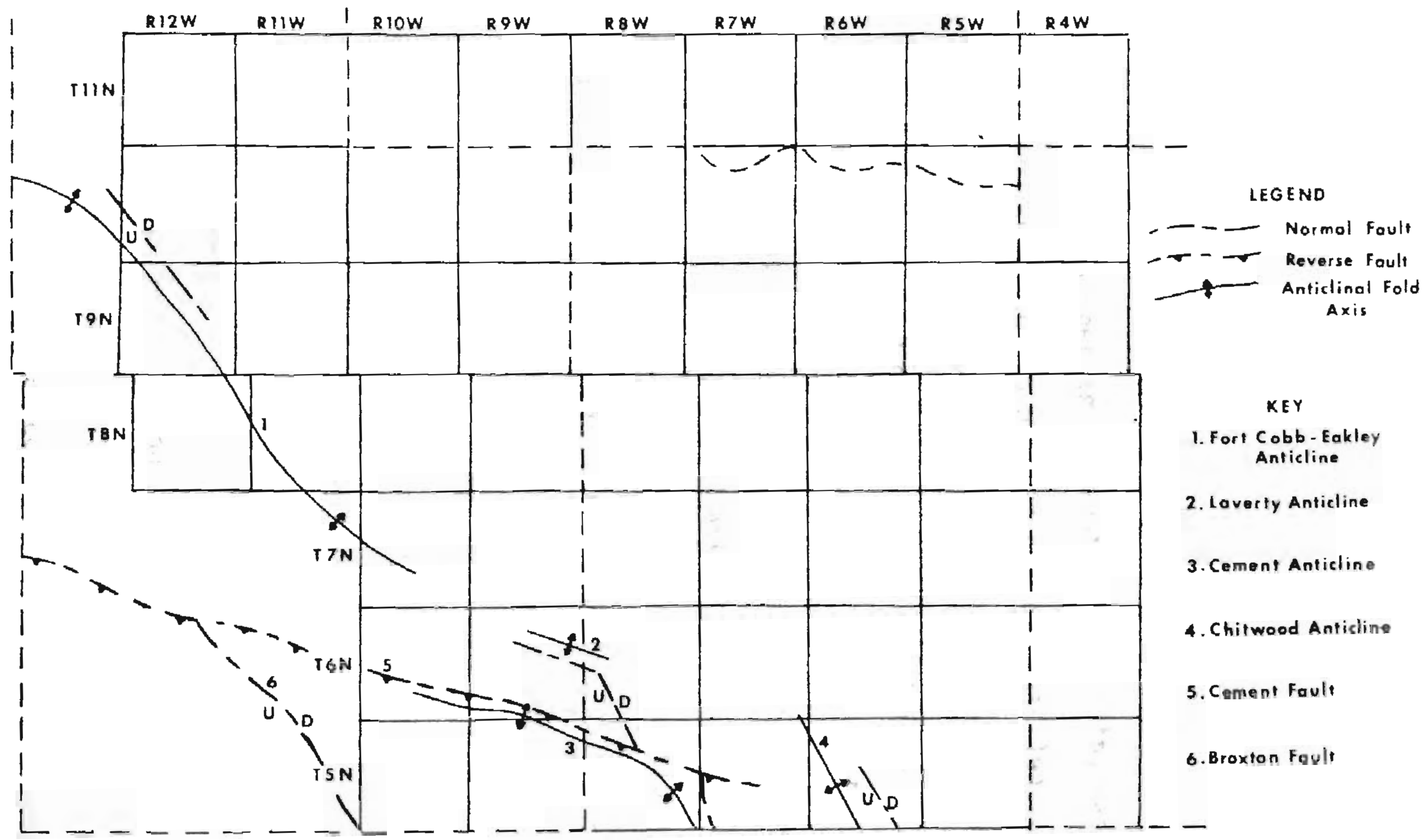


Fig. 3.--Major structural features of the study area.

CHAPTER IV

STRATIGRAPHIC FRAMEWORK

Marchand sandstones are present on the south, east, and northeast flanks of the Anadarko basin as thick, elongate lenticular bodies. Stratigraphically, they are in the basal part of the Hoxbar Group of the Missourian Series. The Hoxbar Group is defined as the interval from the top of the Upper Oolitic Limestone to the base of the Culp-Melton Limestone; it ranges from 2300 to 4000 feet in thickness (Jordan, 1957; Herrman, 1961). The Hoxbar is composed of marine carbonates, sandstones, and shales exhibiting complex intertonguing relationships (Jordan, 1957).

That part of the Hoxbar Group examined in this study is the section from the top of the Tonkawa Limestone to the top of the "Lower Checkerboard" marker (Fig. 2). The main emphasis of this investigation is on the Marchand interval, herein defined for purposes of this study as the section from the base of the Hogshooter Limestone to the top of the Huddleston Limestone (Fig. 2). This includes the previously mentioned "Hot Shale" marker.

Regionally, the Marchand sandstones are thought to be stratigraphically equivalent to the Crinerville Formation of the Ardmore basin. The Crinerville has been divided into three parts: an upper limestone, a middle sandstone and conglomerate, and a lower oolitic limestone (Tomlinson and McBee, 1959). To the northeast and east of the study area Marchand sandstones are the approximate equivalents of the deltaic and shallow marine deposits of the subsurface Layton Sandstone and the Coffeyville Formation on outcrop (Wilson, 1976). On the north the Marchand is equivalent to the carbonates of the lower part of the Kansas City Group.

Correlation

Sixteen stratigraphic cross sections, nine of which are included here, were prepared using the Hogshooter Limestone as a datum (Fig. 4, Plates 1 to 9). Information from these sections was then used to construct a Paleotopographic cross section. The Tonkawa Limestone and the "Hot Shale" marker were used as datums (Plate 10). This Paleotopographic section along with the nine principal sections was used to interpret the stratigraphic relationships within the section. Various local markers were utilized to determine in detail the boundaries of the Marchand sandstones (Figs. 5 to 9).

The interval from the base of the Hogshooter Limestone to the top of the Huddleston Limestone ranges from 290 to 500 feet in thickness (Plates 1 to 4). Increase in thickness is to the west and southwest at approximately 10 feet per mile. North-south variations are minimal, except for the area adjacent to Cement. Thinning of this and other intervals is thought to reflect a positive feature on the sea floor. Thus, the two limestones which delineate this interval exhibit near-parallelism over the entire study area (Plates 1 to 10).

An apparent facies change has been noted in the Hogshooter Limestone. In the eastern half of the area the Hogshooter was described by Wallace (1953), Boeckman (1956), and Markas (1966) as a light gray to tan, finely crystalline, oolitic, fossiliferous and occasionally sandy limestone. In the western half of the area the Hogshooter is a black, radioactive shale.

The Marchand interval is readily divisible into two subintervals using the "Hot Shale" marker (Fig. 2). The first subinterval is the section from the base of the Hogshooter Limestone to the top of the "Hot Shale" marker. This interval contains what will be referred to in this report as the "Upper" Marchand sandstones. The second subinterval is the section from the top of the "Hot Shale" marker to the top of the Huddleston Limestone. This second subinterval contains what will be referred to in this report as the "Lower" Marchand sandstones (Fig. 2). Although the Marchand interval as a whole shows only a gradual basinward thickening, the two subintervals show a marked reciprocal relationship (Plates 1 to 10).

In the eastern half of the study area, the interval from the top of the "Hot Shale" marker to the top of the Huddleston Limestone, the "Lower" Marchand sandstone interval, is remarkably uniform in thickness, averaging between 40 and 50 feet. In the western half of the area along a north-south line near the boundary between R7 and 8W, the section expands rapidly to over 500 feet in thickness (Plates 1 to 4 and 11). Increase in thickness is approximately 50 feet per mile to the west-southwest with some areas thickening by as much as 100 feet per mile (Plate 11). North-south variations are minimal with the exception of the area around Cement. The map (Plate 11) is thought to portray the depositional topography on which "Lower" Marchand sandstones were deposited.

The "Hot Shale" marker is considered to be equivalent to the Checkerboard Limestone of Wallace (1953), Boeckman (1956), and Markas (1966), and it shows a facies change similar to that described for the Hogshooter Limestone. Deposition of the "Hot Shale" may represent a transgression and corresponding shift in sand deposition within the area.

The interval from the base of the Hogshooter Limestone to the top of the "Hot Shale" marker, the "Upper" Marchand sandstone interval, displays a westward thinning wedge from 190 to 300 feet within the area and thus exhibits a reciprocal relationship to the underlying "Hot Shale" to Huddleston interval (Plates 1 to 4). Where the interval from the base of the Hogshooter Limestone to the top of the "Hot Shale" is less than 200 feet thick, it shows an eastward thickening of approximately 50 feet per mile. Where the interval is 200 feet or more in thickness, it shows an eastward thickening of 10 to 20 feet per mile. North-south variations are minimal (Plates 5 to 9). In this eastern part of the area the interval displays a relatively uniform thickness which may correspond to the shelf.

The section from the top of the Tonkawa Limestone to the base of the Medrano-Belle City formation is the other interval which was studied in some detail (Fig. 2). The interval from the Tonkawa to the Medrano-Belle City ranges in thickness from 150 to 600 feet. In the eastern part of the area the interval averages approximately 150 to 200 feet in thickness and shows little variation in both north-south and east-west directions (Plates 1 to 10). In the western half of the area along a north-south line near the boundary between R6 and 7W, the interval thickens markedly. Increase in thickness is to the west at approximately 50 to 60 feet per mile. North-south variations are minimal with the exception of the Cement area (Plates 1 to 10).

From the description above, a marked similarity exists between the Tonkawa Limestone to Medrano-Belle City interval and the "Lower" Marchand sandstone interval. Plate 11 shows the juxtaposition of the "hinge lines" along which the two sections thicken.

CHAPTER V

GEOMETRY OF MARCHAND SANDSTONES

"Upper" Marchand Sandstones

The "Upper" Marchand sandstones are those sands below the base of the Hogshooter Limestone and above the "Hot Shale" marker (Fig. 2). This interval usually contains two sandstones: (1) immediately below the Hogshooter Limestone, known as the Marchand "A" sandstone, and (2) a lower unit immediately above the "Hot Shale" marker, known as the Marchand "C" sandstone (Fig. 2). The names are those used by workers in the Binger area and they are used in this report. The Marchand "C" sandstone in the Binger and South Hydro fields and the Marchand "A" sandstone in the East Binger field are productive of hydrocarbons.

On the Marchand "A" and "C" net sandstone maps (Plates 12 and 13), special notice should be taken of the areas marked "Undivided Upper Marchand Sandstone". These are areas where the sandstone present in this upper section cannot be subdivided and designated, with any reasonable degree of certainty, into the "A" and "C" sandstone. The undivided sandstone is mapped and shown on both "A" and "C" sandstone maps to acknowledge that it may be equivalent to either one of the sandstone bodies. Problems of correlation in this area are due to sparse well control, relatively large distances between wells with undivided sandstone and known Marchand "A" and "C" sandstones, and structural complexity.

Trends and Widths

Both the Marchand "A" and "C" sandstones display dominant northeast-southwest trends with well developed east-west secondary trends (Plates 12 and 13). The dominant trends, which are approximately 16 to 20 miles in length, may be longer as it is acknowledged that the sandstones probably extend beyond the study area. The width of the sandstone bodies range from less than one mile to a maximum of approximately four miles.

Thickness

The Marchand "A" and "C" sandstones are best developed in the area just north of Cement field (Plates 12 and 13). Net thickness of Marchand "A" sandstone ranges from 0 to 90 feet; net thickness of Marchand "C" sandstone ranges from 0 to 65 feet (Plates 12 and 13). Gross sandstone attained thickness of more than 100 feet and 80 feet, respectively, and the patterns were similar to those shown by net sandstone.

Net sandstone is herein defined as units with deflections greater than 20 millivolts on the self-potential curve or greater than 20 A.P.I. units on the gamma-ray curve. Gross sandstone is defined as the interval from the base of the sandstone, based on the criteria listed above, to the top of the sandstone.

Boundaries

Both the Marchand "A" and "C" sandstones are elongate, lenticular sandstone bodies exhibiting sharp lateral and basal contacts (Figs. 5 and 6). Within this "Upper" Marchand sandstone interval, several locally correlatable markers are absent in some wells apparently due to erosion during deposition of the two sandstone bodies (Figs. 5 and 6).

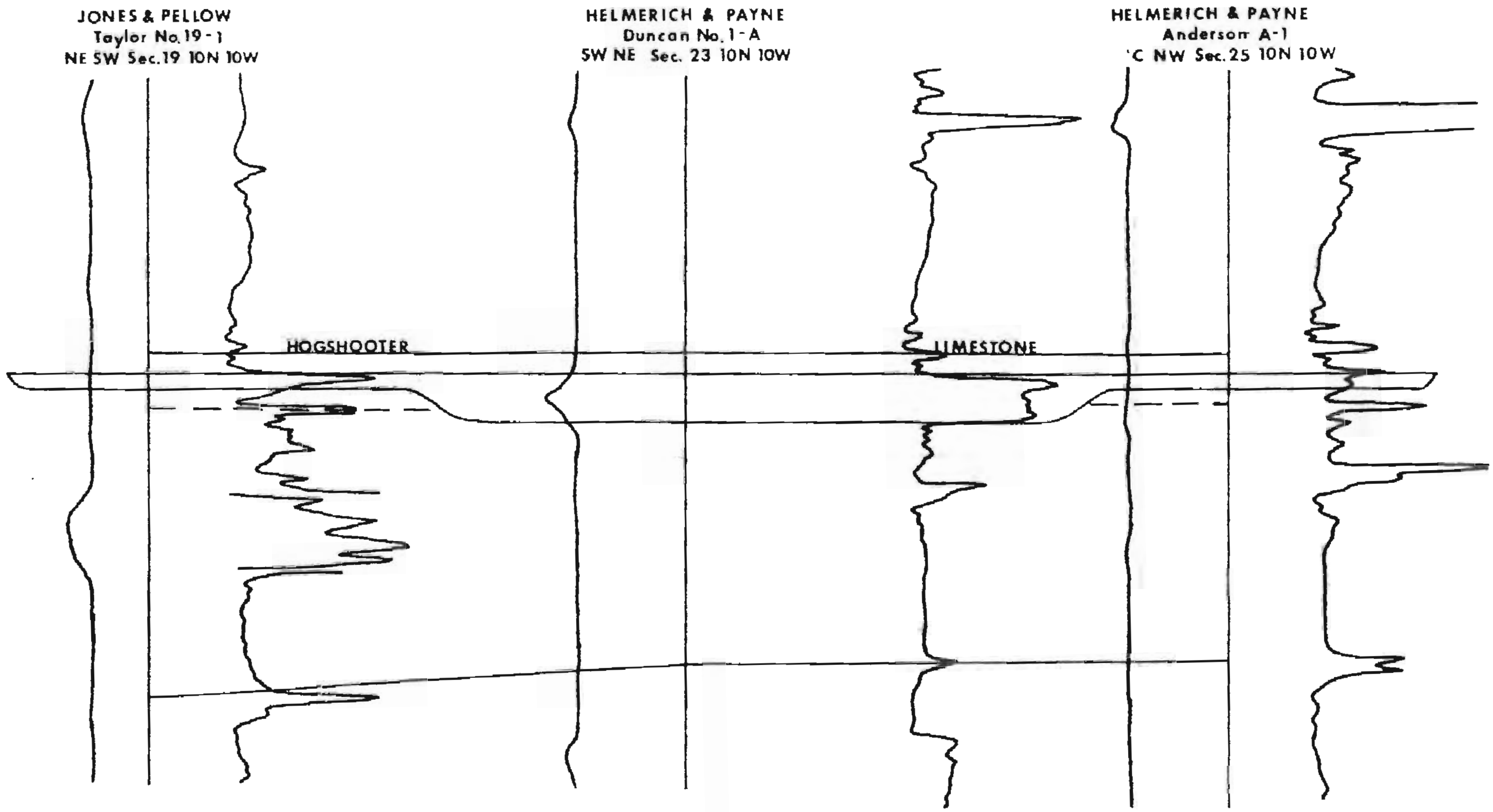


Fig. 5.--Correlation section showing sharp lower and lateral contacts of Marchand "A" sandstone. Note absence of local marker (dashed line) suggestive of erosion.

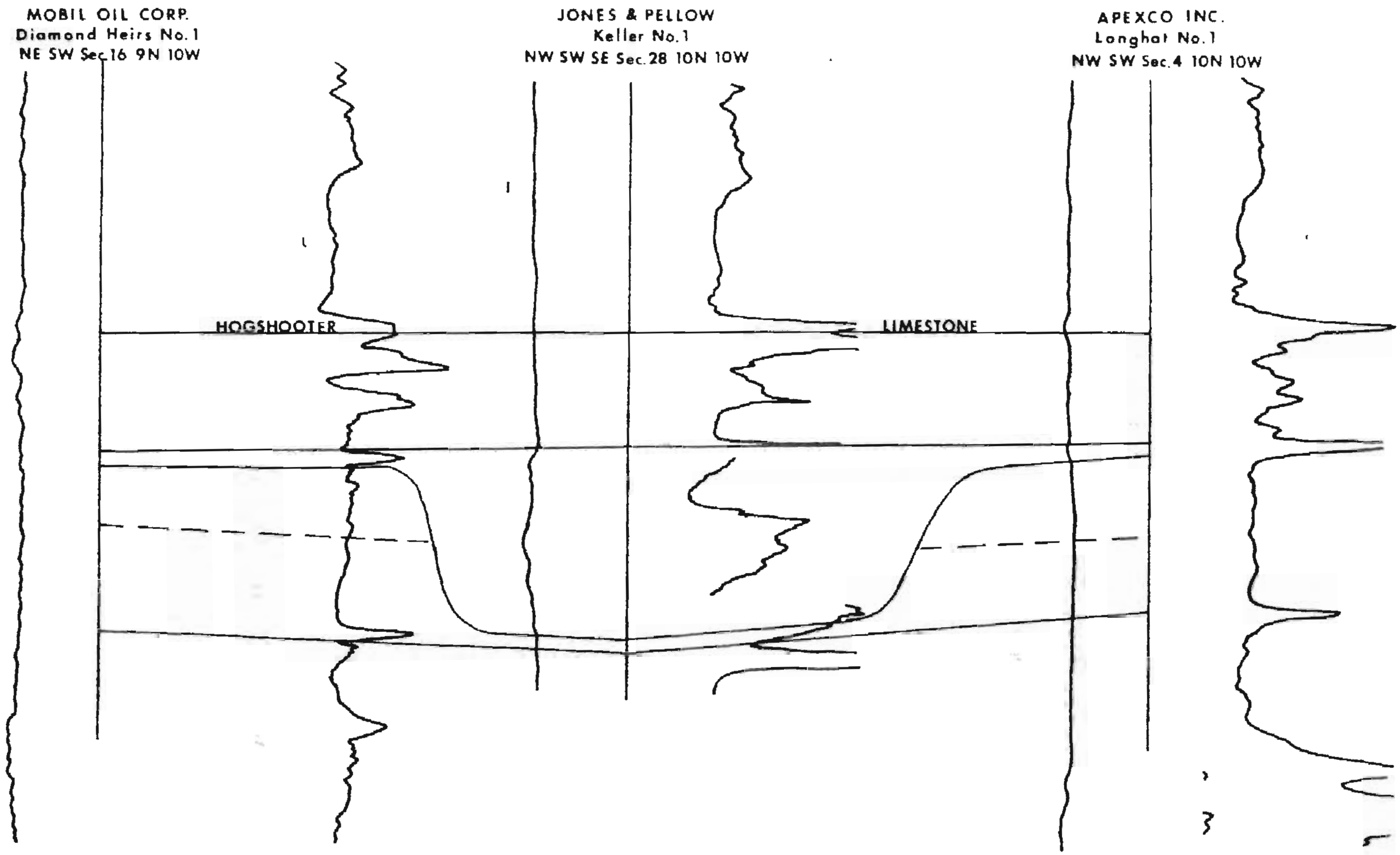


Fig. 6.--Correlation section showing sharp lower and lateral contacts of Marchand "C" sandstone. Note absence of local marker (dashed line) and thickening at expense of adjacent shale suggestive of channeling.

"Lower" Marchand Sandstones

The "Lower" Marchand sandstones are those sandstones within the interval from the top of the "Hot Shale" marker to the top of the Huddleston Limestone (Fig. 2). The interval contains two sandstones: (1) a lower sandstone which is confined to the southern one-third of the study area adjacent to Cement field and referred to as the "Cement" sandstone and (2) an upper sandstone in the Cement, Northwest Norge, Northwest Chickasha, Verden, Dutton, and East Binger fields referred to as the "Chickasha" sandstone. Both sandstones appear to be multistoried and multilateral.

Trends and Width

The "Cement" sandstone is present as a discrete acruate belt of sandstone in the southern one-third of the area (Plate 14). It ranges from 3 to 6 miles in width. Due to its arcuate pattern and the fact that it extends beyond the study area, estimation of trend is difficult. From the limited amount of sandstone present, the trend appears to be nearly east-west and 15 or more miles long.

The "Chickasha" sandstone is well developed within the study area and is the main producing member of the Marchand sandstones. The "Chickasha" sandstone ranges in width from less than 1 mile to approximately 6 miles (Plate 15). Trend is dominantly north-south in the southern part of the area and changes to northwest-southeast in the northern part of the study area (Plate 15). The trend is subparallel to the hinge line along which the interval from the top of the "Hot Shale" to the top of the Huddleston Limestone thickens (Plate 11). The trend extends through the study area for a distance of approximately 50 miles and probably continues beyond. Several secondary northeast-southwest trends are present and may "feed into" the main trend. These secondary trends are up to 24 miles in length (Plate 15).

Thickness

Net thickness of the "Cement" sandstone varies from 0 to approximately 80 feet (Plate 14). Gross sandstone pattern was similar to that shown by net sandstone and was as much as 120 feet or more in thickness.

Net thickness of the "Chickasha" sandstone ranges from 0 to more than 170 feet (Plate 15). Gross sandstone thickness locally exceeded 200 feet and displayed a pattern and trend similar to that of net sandstone.

Boundaries

The "Lower" Marchand sandstones appear to be elongate lenticular, multistoried and multilateral complexes exhibiting sharp lateral and basal contacts (Plates 14 and 15; Figs. 7 to 9). Upper contacts generally are sharp with the overlying "Hot Shale" marker and are gradational only locally (Figs. 7 to 9).

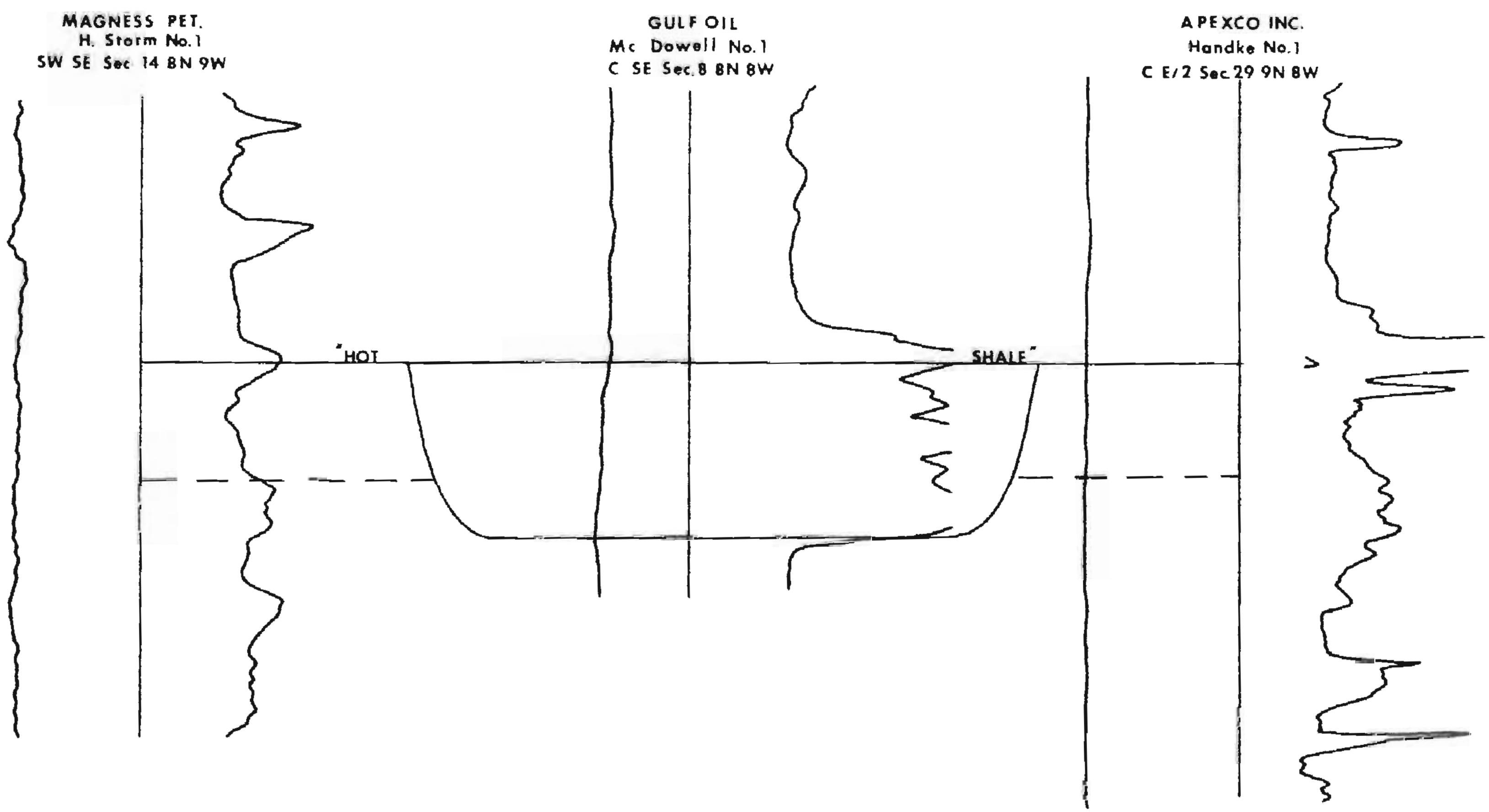


Fig. 7.--Correlation section showing sharp lower and lateral contacts of Marchand "Chickasha" sandstone, Verden field. Note absence of local marker (dashed line) and thickening at expense of adjacent shale suggestive of channeling.

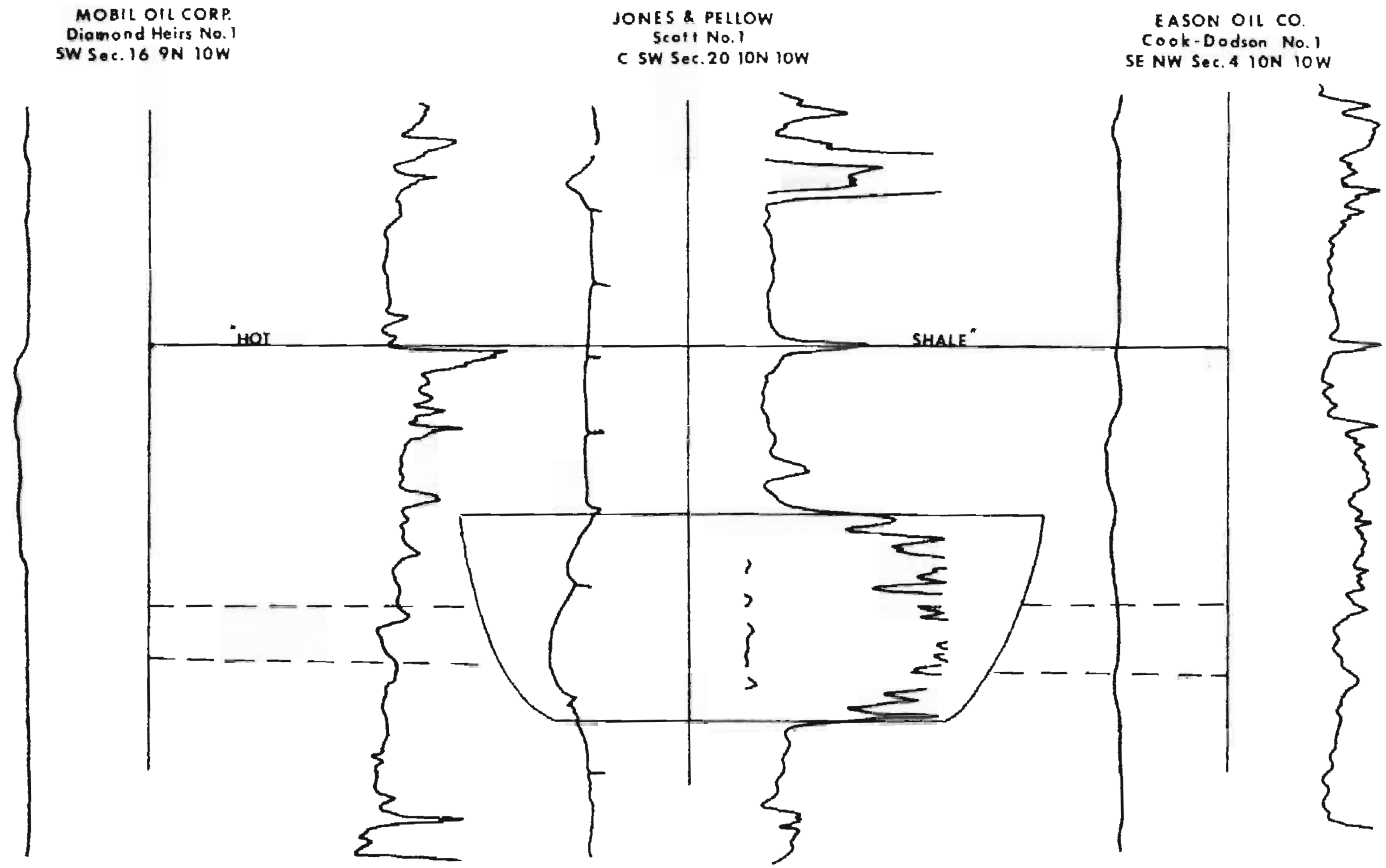


Fig. 8.--Correlation section showing sharp lower and lateral contacts of Marchand "Chickasha" sandstone, Binger field. Note absence of local markers (dashed lines) and thickening at expense of adjacent shale suggestive of channeling.

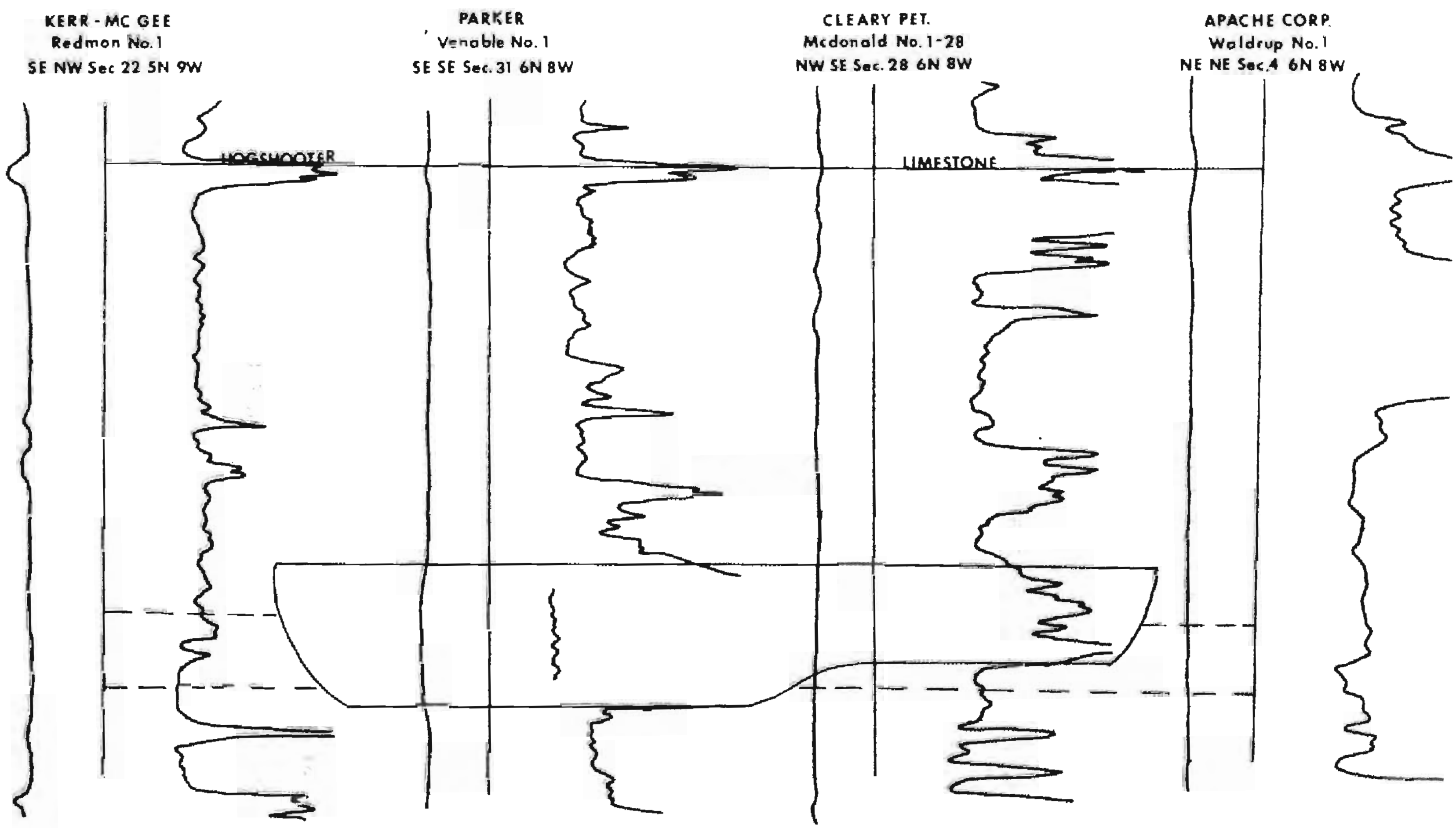


Fig. 9.--Correlation section showing sharp lower and lateral contacts of Marchand "Cement" sandstone, Cement field. Note absence of local markers (dashed lines) and thickening at expense of adjacent shale suggestive of channeling.

CHAPTER VI

INTERNAL FEATURES

Sedimentary Structures

The sedimentary structures in the seven cores studied during this investigation do not display recognizable vertical sequences described from such well-documented depositional environments as alluvial braided and point bars, deltaic distributary and front, tidal-ridge bars, barrier bars, and deep marine fans.

The common sedimentary structures observed in the cores, in approximate order of overall abundance, are interstratification of sandstone and shale, horizontal lamination, flowage, small-scale crossbedding, medium-scale crossbedding, massive bedding, bioturbation and burrows, and low-angle initial dip (Figs. 10 to 16). Although a detailed vertical sequence of sedimentary structures does not characterize Marchand sandstones, an overall vertical sequence is as follows: (1) a lower zone of interstratified sandstone and shale, (2) a middle zone consisting of laminated and crossbedded or massive sandstone with minor interstratified shale, and (3) an upper zone of interstratified sandstone and shale. The interstratified zones commonly possess a moderate angle of dip (1^{o} to 10^{o}). Interstratified sandstones show horizontal lamination and small-scale crossbedding. Bioturbation is rare. Flowage features are abundant in all three zones.

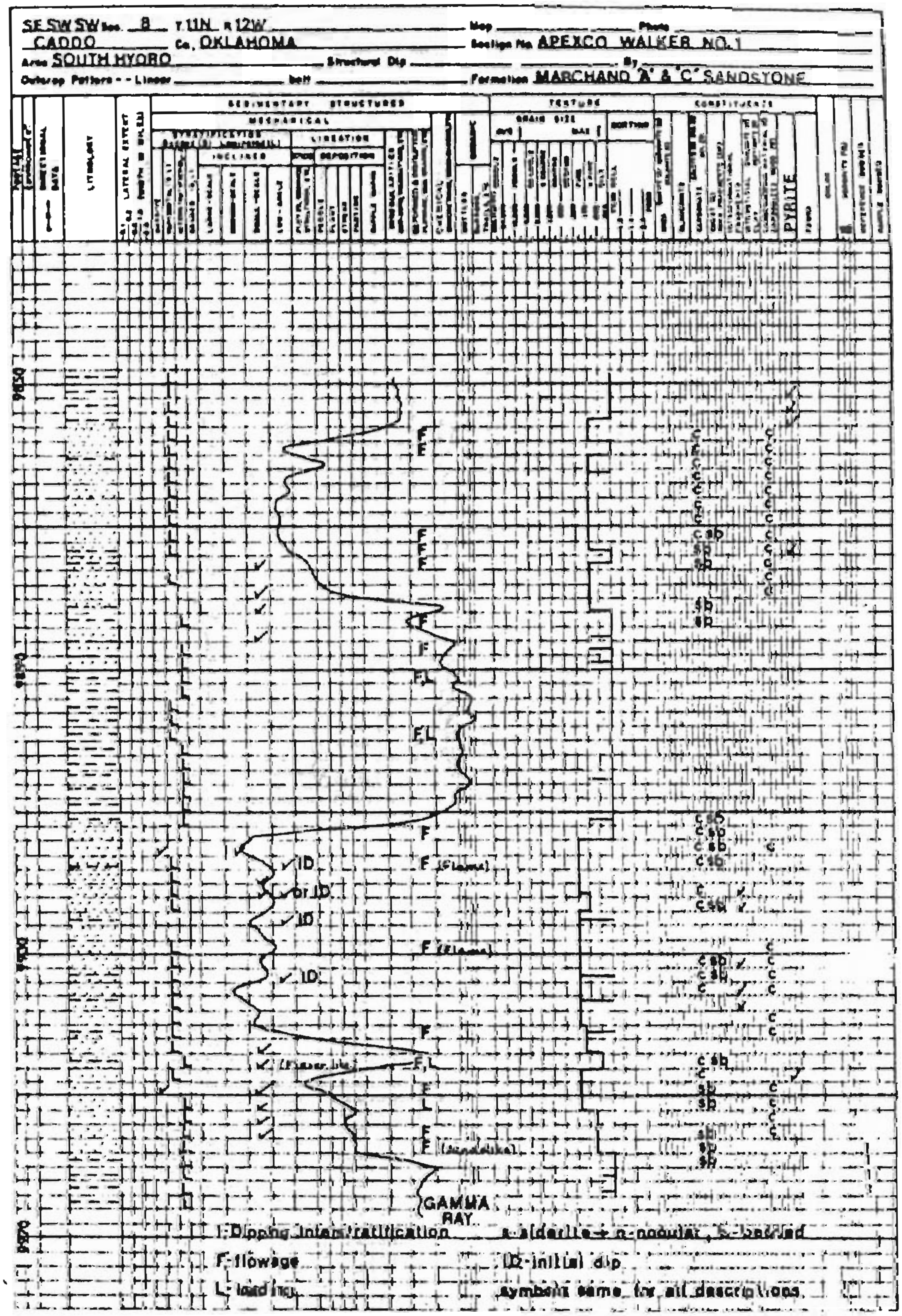


Fig. 10.--Core description of Marchand "A" and "C" sandstones, Apexco Inc., Walker No. 1.

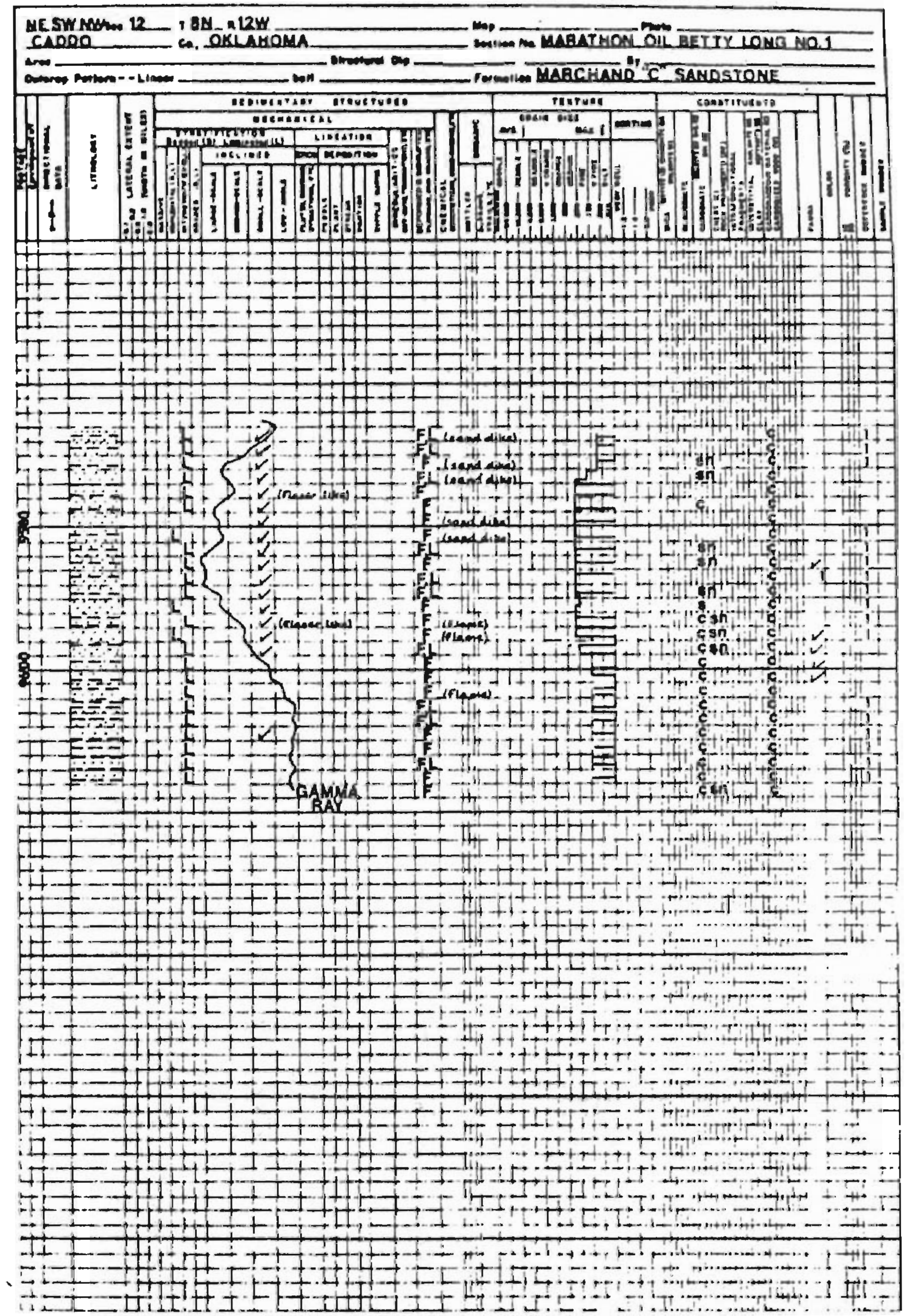


Fig. 11.--Core description of Marchand "C" sandstone, Marathon Oil, Betty Long. No. 1.

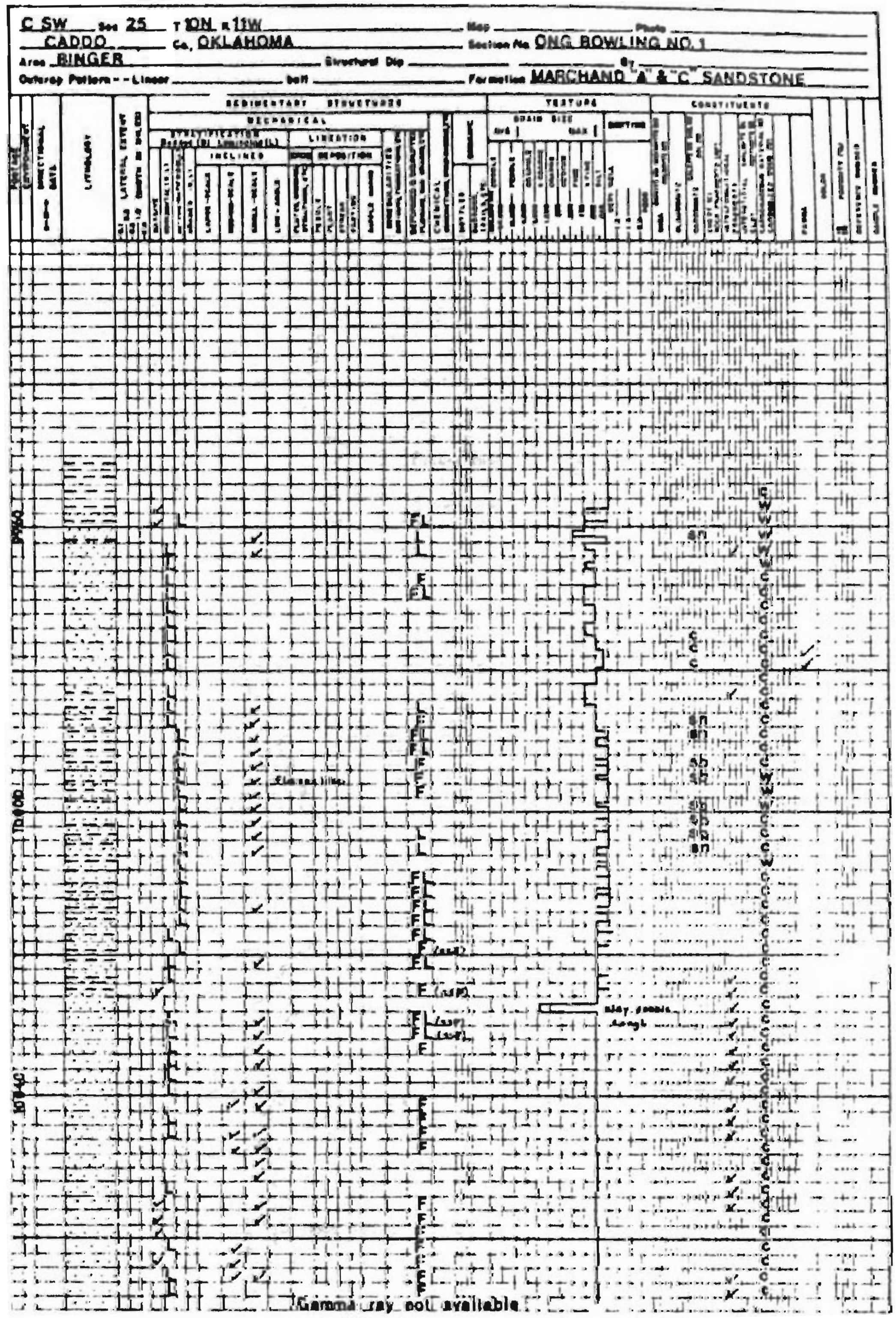


Fig. 12.--Core description of Marchand "A" and "C" sandstones, ONG, Bowling No. 1.

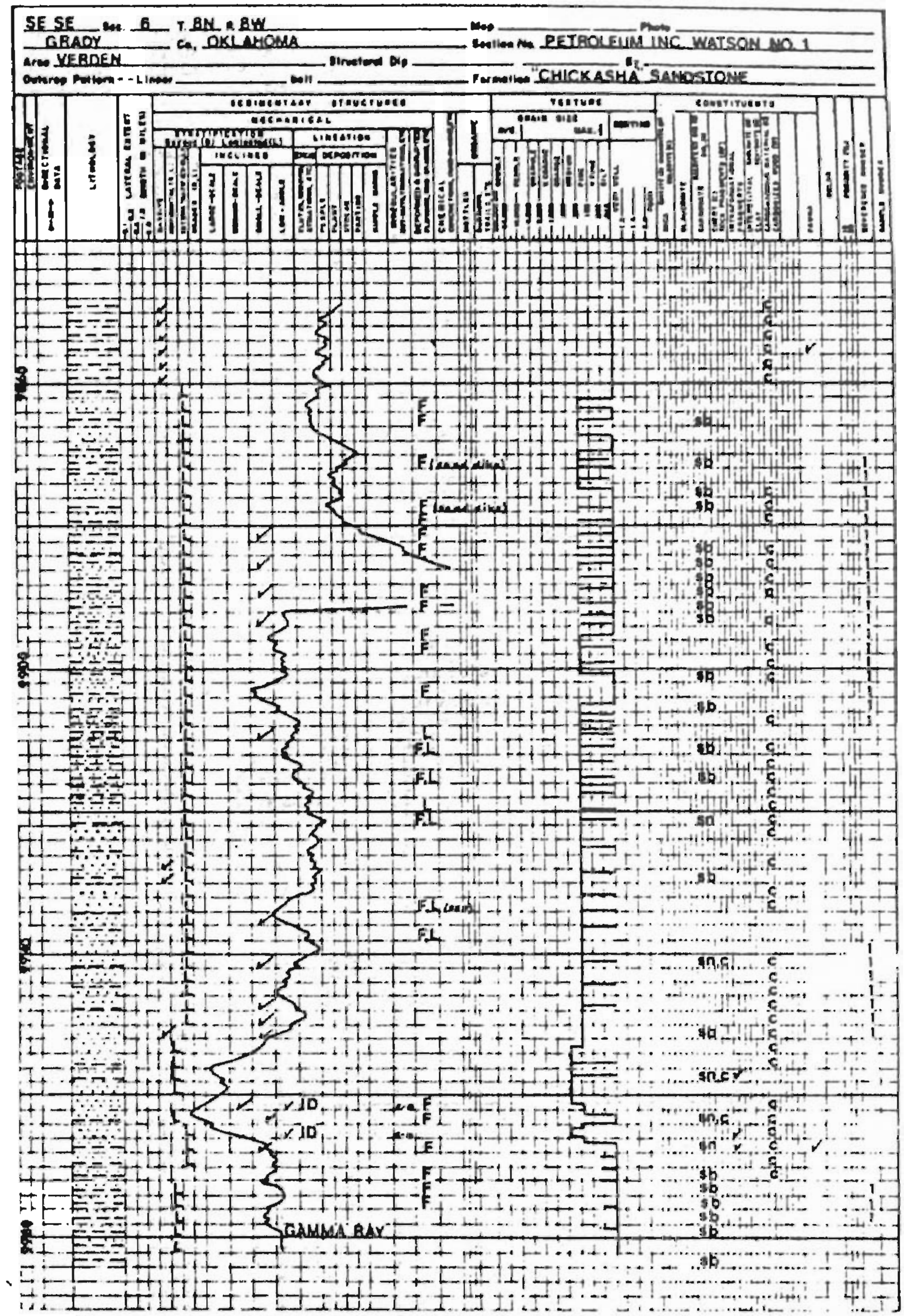


Fig. 13.--Core description of Marchand "Chickasha" sandstone, Petroleum Inc., Watson No. 1.

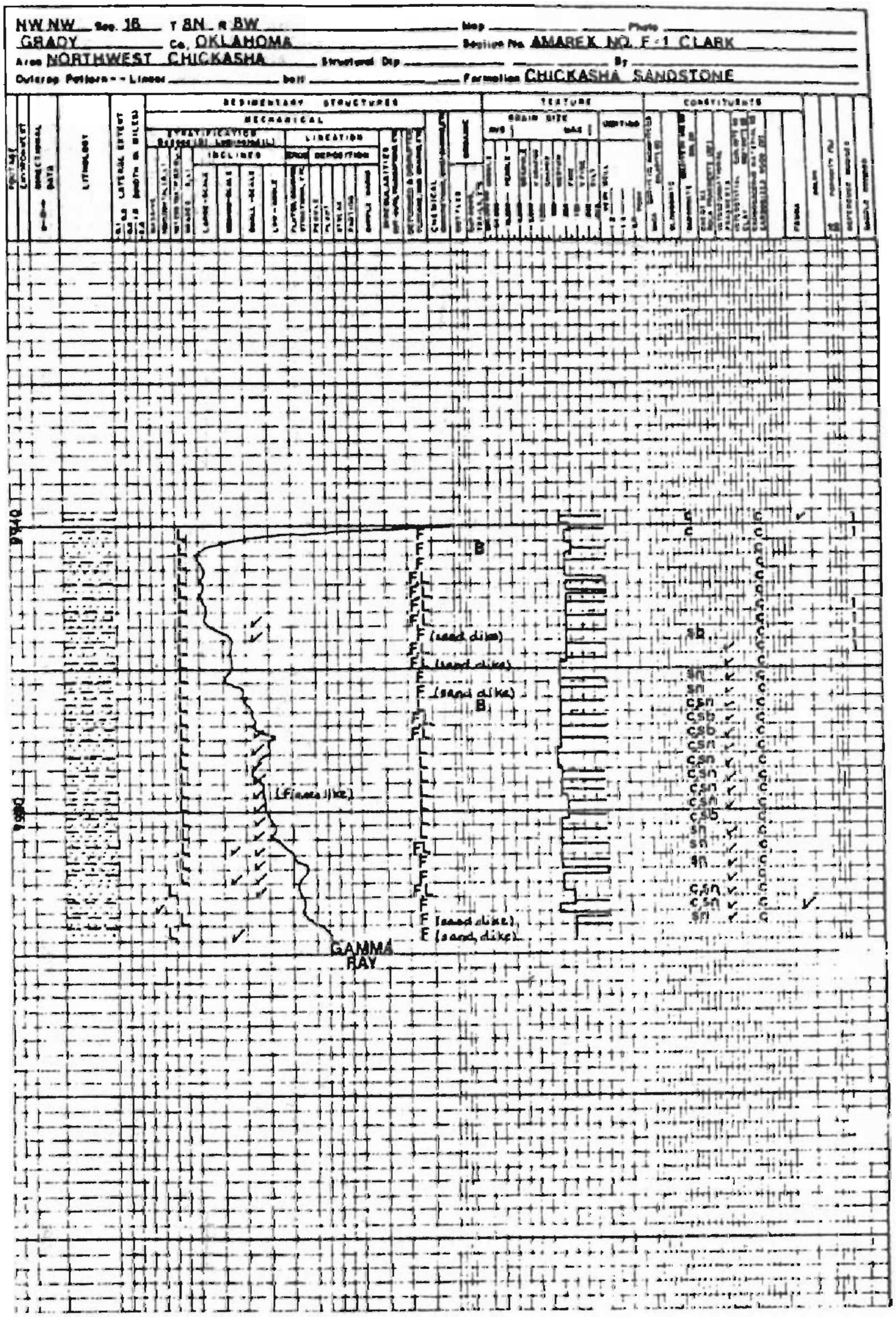


Fig. 14.--Core description of Marchand "Chickasha" sandstone, Amarex Inc., No. F-1 Clark.

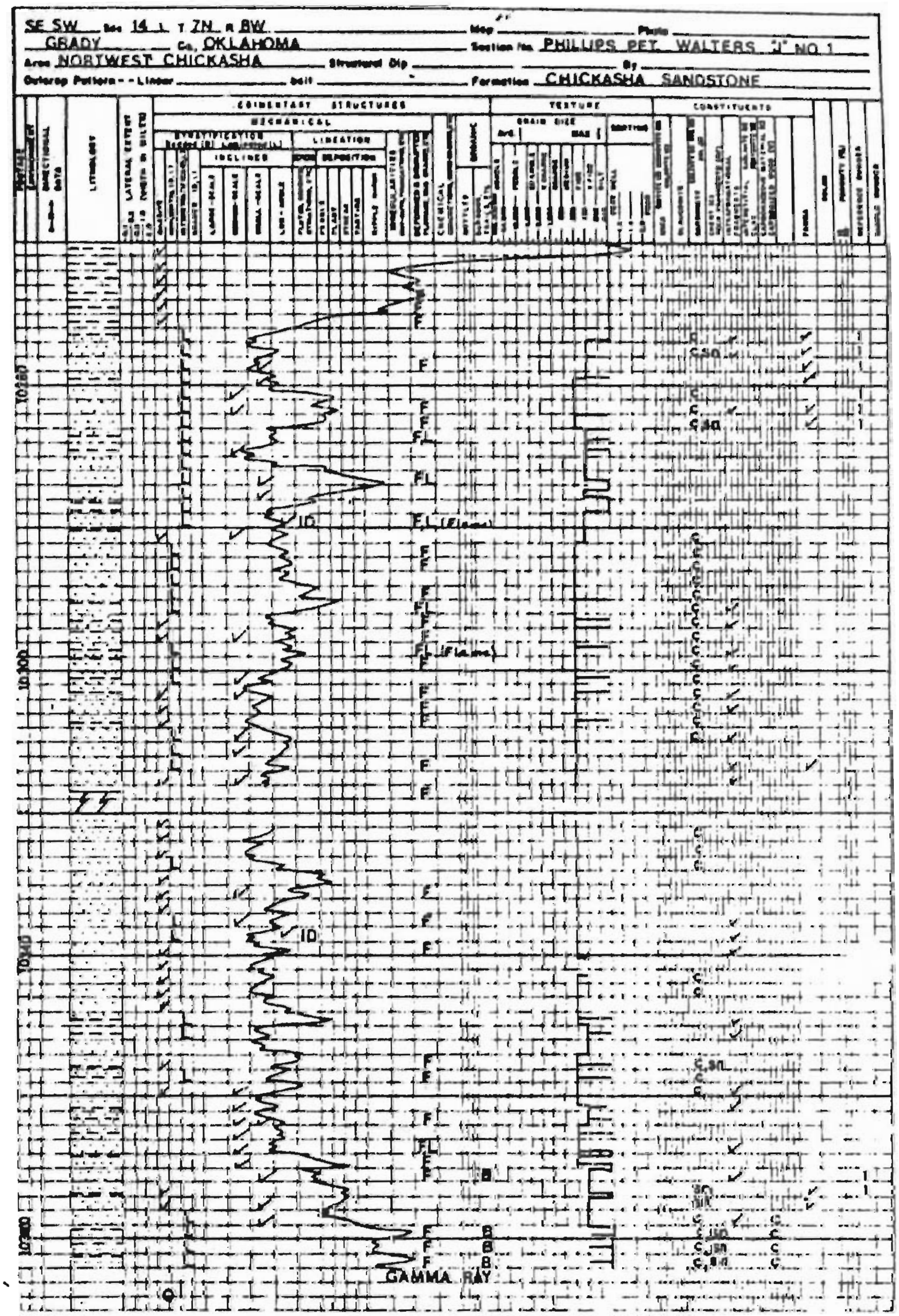


Fig. 15.--Core description of Marchand "Chickasha" sandstone, Phillips Petroleum Co., Walters "J" No. 1.

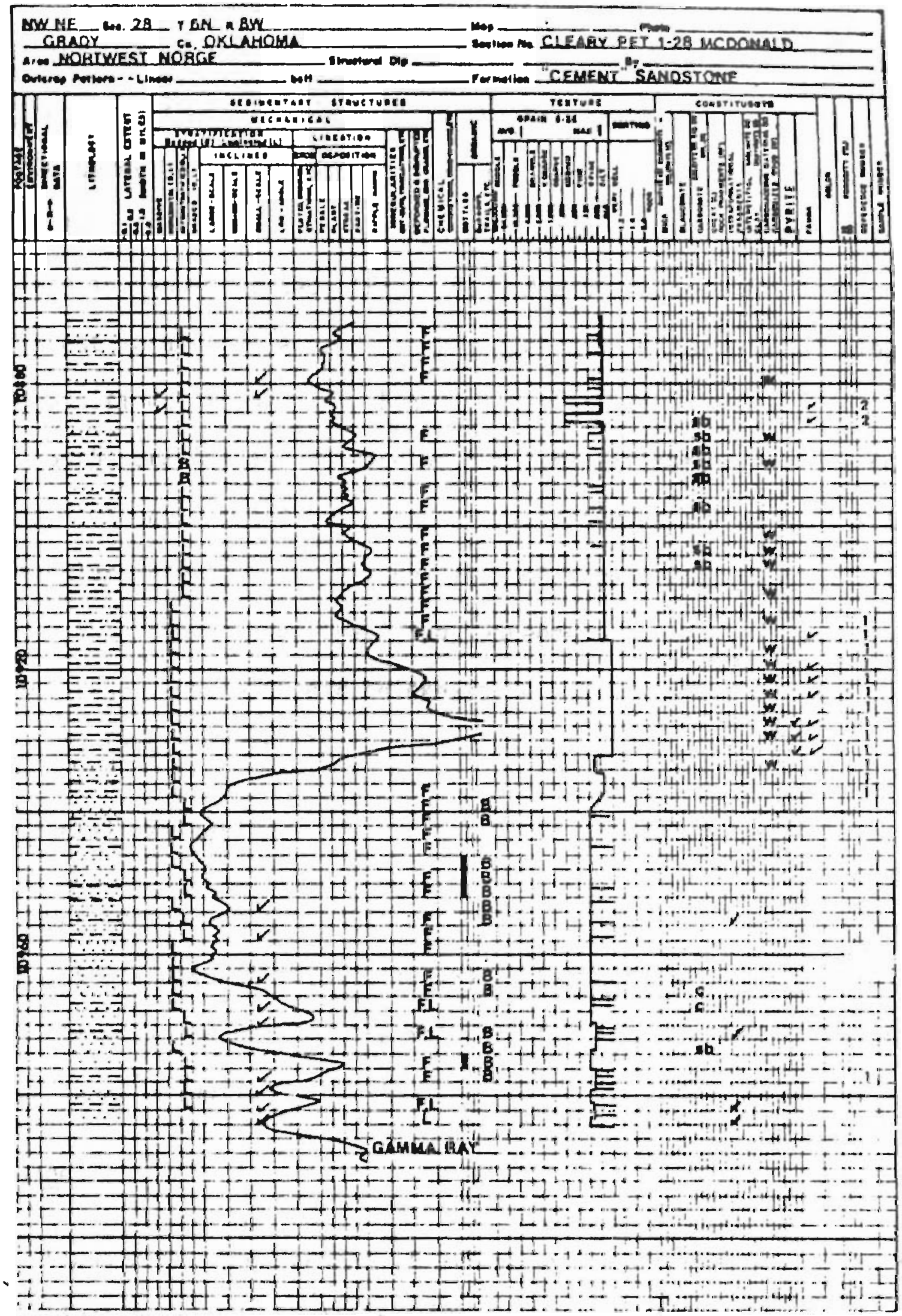


Fig. 16.--Core description of Marchand "Chickasha" sandstone, Cleary Petroleum, McDonald No. 1-28.

Interstratification

Interstratification of sandstone and shale is the most common sedimentary structure observed in the Marchand sandstones, especially in the upper and lower portions of any Marchand sandstone section (Figs. 10 to 16). Sandstone laminae in shale beds are more common than shale laminae in sandstone beds (Fig. 17). Dip of interstratification may represent locally developed "bank-slope" or a more regional slope related to depositional topography (Fig. 18).

Both parallel and lenticular interstratification are present, parallel being dominant. Occasional flaser-like features are present within the lenticular interstratified zones in some cores (Figs. 10, 11, 14).

Within these interstratified sequences, the beds of sandstone and shale, regardless of their thickness, exhibit sharp upper and lower contacts (Figs. 17 and 18).

Horizontal Lamination

Horizontal lamination is present in all seven cores examined during this investigation (Figs. 10 to 16). This sedimentary structure characterizes the bulk of the interstratified zones and is common in the other zones as well.

Flowage

Flowage is also present in all seven cores examined during this investigation (Figs. 10 to 16). Flowage is a characteristic feature of all sections of the Marchand. In the interstratified zones it is present as contorted and irregular laminae, sand dikes, and flame structures (Fig. 19). In the other zones it is represented by irregularly shaped

Fig. 17.--Interstratified sandstone and shale from Petroleum Inc. Watson No. 1, depth 9909 feet. Note sharp contacts on all beds.

Fig. 18.--Interstratification with dip from Petroleum Inc. Watson No. 1, depth 9896 feet. Note sharp contacts on all beds.

Fig. 19.--Flowage in interstratified sand-
stone and shale from Amarex
No. F-1 Clark, depth 9943 feet.

clasts, outlining small folds and by folded and contorted lamination (Fig. 20). Other deformational structures present are load features and soft-sediment faulting.

Medium- and Small-Scale Crossbedding

Small-scale crossbedding is abundant and more common than medium-scale crossbedding in all the Marchand cores except the Phillips Petroleum Walters J. No. 1 (Figs. 10 to 16). Small-scale crossbedding is common in both types of sequences, whereas medium-scale crossbedding generally is confined to the thicker sandstone intervals. Medium-scale crossbedding is absent in the Cleary Petroleum No. 1-28 McDonald and Marathon Oil Company Betty Long No. 1, both of which exhibit dominantly interstratified sequences (Figs. 11 and 16).

Massive Bedding

Massively bedded sandstone is present in all the cores studied except those from the Marathon and the Cleary Petroleum wells (Figs. 10 to 16). It is most common in the Phillips Petroleum Walters J. No. 1 (Fig. 15). Massive sandstone occurs only as isolated zones in the other four cores.

Claystones overlying the Marchand sandstones exhibit massive character in the Cleary Petroleum, Petroleum Inc., Phillips Petroleum and Oklahoma Natural Gas Co. cores. Elsewhere mudrock units are laminated (shales).

Bioturbation and Burrows

Bioturbation and burrows are not common in the Marchand sandstones and were observed only in the ONG, Phillips Petroleum and Cleary Petroleum cores (Figs. 12, 15, 16). Bioturbation is most common in the last well

Fig. 20.--Flowage in sandstone, Oklahoma Natural Gas Company Bowling No. 1, depth 10,055 feet.

in which the sandstone section is burrowed throughout (Fig. 16). Bioturbated and burrowed zones are locally developed in cores from the other two wells (Figs. 12 and 15). Bioturbation appears to be most common in the interstratified sections.

Burrows present in the cores are a very general type, which defy specific classification. Therefore, they cannot be used to aid environmental interpretation.

Initial Dip

Low-angle dip was observed in the Petroleum Inc., Apexco Inc., and Phillips Petroleum cores (Figs. 10, 13, 15); it is most common in the last two. It is present in only two 2-foot sections in the Petroleum Inc. core.

Texture

The units and sandstone bodies do not show significant vertical changes in grain size. Excluding clay-sized material, the range of grain size of the Marchand sandstones is from silt to medium sand. Wilson (1976), in his study of the Northwest Norge and Chickasha fields, reported a grain size range from 0.16 mm to 0.375 mm for "Lower" Marchand sandstones. The only significant variations in grain size are from interstratified lithologies and intraformational clasts (clay).

For the most part, the Marchand sandstones are well sorted.

Constituents

Based on the examination of 21 thin sections taken from the seven cores (Figs. 10 to 16), major framework grains in the Marchand sandstones include quartz, potassium feldspar, plagioclase, chert, and fossil fragments. Other framework grains are intraformational clasts of clay and siderite.

Quartz is the dominant framework mineral with amounts ranging from 89 to 97 percent. Chert grains are also present with amounts varying from 5 to 10 percent of the framework.

Feldspar is the second most abundant framework mineral in Marchand sandstones. Plagioclase composes 1 to 3 percent of the grains. Potsssium feldspar is slightly more abundant with percentages ranging from 1 percent to as much as 5 percent.

Fossil remains, as a major grain in the sandstone, compose from 1 to 5 percent of the framework. The fossils are predominantly calcite in composition.

Accessory minerals include zircon, tourmaline, sphene, muscovite, biotite, glauconite, and pyrite.

Cement of the Marchand sandstones is composed dominantly of ferroan calcite and some ferroan dolomite. Locally, quartz overgrowth and clay compose significant portions of the cement. Clay, as sericite, is recognizable in one thin section; elsewhere it is largely unidentifiable. Cement composes 11 to 34 percent of the sandstones.

According to the classification proposed by Pettijohn (1963), the sandstones of the Marchand interval are quartzarenites in composition.

Fossils

Fossils visible in thin sections include the following: pelecypod shells, brachiopod shells, echinoid spines and plates, crinoid fragments, and foraminifera. The only fossils identifiable in hand specimen are

Paracunularia crustula (Annelid) and Pseudorthoceras (Cephalopod). Most of the fossils present were probably transported into the depositional site; others had such broad environmental affinities as to be poor environmental indicators.

CHAPTER VII

DEPOSITIONAL ENVIRONMENT

Marchand Sandstones

Within the study area the Marchand sandstones are present as distinct to coalescing lobes. These lobes are elongate and lenticular and may consist of genetic units formed in the same environment. Their configuration is somewhat similar to delta-front sands of the more elongate deltas and to the configuration of some submarine fan deposits. Sharp lower and lateral boundaries and absence of local markers are evidence of channeling.

The wedges of strata formed by the "Hot Shale" and the Hogshooter and Huddleston Limestone are suggestive of significant even though depositional slope within the study area. The marked thickening of the interval from the top of the "Hot Shale" marker to the top of the Huddleston Limestone is thought to define the more uniform shelf deposits on the east and the more variable basinal fill on the west. Plate 10 (Part A) and Plate 14 are thought to portray the topography on which "Lower" Marchand sandstones were deposited. A westward slope from the shelf into the basin is suggested by the attitude of the Huddleston Limestone and also the Hogshooter Limestone when the "Hot Shale" is used as a datum (Plate 10, Part A).

The interval from the base of the Hogshooter Limestone to the top of the "Hot Shale" marker displays a relatively uniform thickness on the east and a marked thinning to the west. This eastward thickening of the interval toward the shelf may reflect a westward increase in the water depth during deposition of the limestone. The topography on which "Upper" Marchand sandstones was deposited may be portrayed approximately by the Hogshooter Limestone (Plate 10, Part A).

The uniform fine to very fine grain size of the Marchand sandstones is not particularly definitive in estimating depositional environment. It is suggestive of deposition a significant distance from an elevated source, or a source of remarkably uniform textural characteristics.

The well sorted nature of the Marchand sandstones is comparable to deposits of the delta front, barrier bar, and certain deep marine deposits described by Harms (1974), Seimers (1978), and Gunn (1979). Sorting is unlike that of deposits affected by turbidity currents.

Detrital constituents generally provide more information concerning provenance than environment of deposition. The amount of feldspar in the Marchand sandstones suggest that the igneous core of the Wichita uplift was not a major source area for these sediments. The presence in the Cement field of conglomerates composed of chert and limestone fragments suggests that older Paleozoic sedimentary rocks were a significant source of sediment for the Marchand in the extreme southern portion of the area (Eisner, 1949, 1955). The trend and distribution of the Marchand sandstones is also suggestive of this southern source. Extensive shelf carbonates in Kansas suggest that the craton was supplying only minor amounts of clastic material. Thus, as evidenced by composition and sandstone trends, major source areas for the Marchand sandstones probably lay to the east and southeast in the area of the Ouachita uplift.

Faunal content, presence of siderite, and very minor amounts of glauconite in the Marchand sandstones are evidence of either coastal-transitional or marine conditions.

Uniform grain size in the Marchand sandstones may differentiate them from deposits of several environments. The fining-upward sequences of delta distributaries and tidal channels, the coarsening-upward sequences of delta-front and regressive barrier and marine bar complexes are dissimilar to the Marchand. Graded bedding of environments for turbidity currents is also markedly different from features of the Marchand.

The lack of a diagnostic vertical sequence of sedimentary structures in the Marchand sandstones also may make them somewhat unique in representing an environment or environments different from distributaries, barrier and marine bars, tidal sand bodies, tidal flats, and deep marine environments affected by turbidity currents.

The configuration of the sandstone deposits and the associated lithologies observed in the Marchand interval also aid in environmental interpretation. As previously mentioned, the Marchand sandstones bear some resemblance to the delta-front and distributary-mouth bar deposits of some elongate deltas. However, the lack of any well-defined distributary system and its associated interdistributary bay, marsh, and overbank deposits within the area of study as well as differences in texture and sedimentary structures mitigate this interpretation. In fact, the area to the east of the Marchand sandstones is a rather broad uniform shelf markedly devoid of much coarse (sand) clastic material.

The configuration of the Marchand sandstones has been interpreted by some investigators as barrier-bar and tidal-channel infill. However, as previously mentioned, the sandstones lack the clastic internal features associated with these environments, such as coarsening and fining-upward sequences, abundant medium-scale and accretionary crossbedding, flaser bedding, bioturbation, and shell debris.

Shallow marine sands present a wide variety of forms from blanket-like deposits to isolated or groups of bars. The Marchand sandstones are not blanket-like in their distribution. Shallow-marine bar deposits are generally dissimilar to the Marchand sandstones. Diverse fauna, abundant bioturbation, and authigenic minerals such as chamosite and glauconite generally are associated with shallow marine deposition and are not characteristic of the Marchand sandstones.

The fossiliferous, oolitic limestone facies of the Hogshooter Limestone and "Hot Shale" marker are evidence of shallow marine conditions in the eastern part of the study area. However, the black, radioactive shale facies of the western part of the study area, where Marchand sandstones were deposited, are suggestive of deeper basinal settings.

The sharp upper and lower contacts and uniform grain size in Marchand sandstones are evidence of rather rapid deposition, probably as discrete pulses. The abundance of laminated clay interstratified with, and generally enclosing, the sandstones suggest that introduction of sand of the Marchand interval interrupted deposition of clay.

The abundant flowage features within the Marchand sandstones are suggestive of an unstable slope during deposition, or possibly loading by the rapid introduction of material at the depositional site. The ubiquitous dip of the interstratification and clay laminae may be another indication of significant slope on the surface of deposition.

The parallel interstratification present may be environmentally significant. Although it resembles flaser bedding, poor development of cross lamination and the marked continuity of the beds, regardless of their thickness, is a sharp contrast to the delicately cross laminated wavy to lenticular characteristics of flaser bedding.

As previously mentioned, wedges of strata, which vary independent of subsidence, containing the Marchand sandstones contrast sharply to the more uniform eastern equivalents (Layton Sandstone and Coffeyville Formation) and suggest deeper-marine-slope to basinal conditions. The interpretation of these eastern equivalents as deltaic and shallow-marine deposits by Visher et al. (1975) is somewhat supportive, in a regional context, of this slope to basinal interpretation as the basinward equivalents of the Layton and Coffeyville might be expected to be of a deeper marine origin.

Wilson (1976) estimated the water depths in the area of Marchand deposition to be approximately 300 feet. This writer agrees with Wilson. Water depths in the central and western part of this study area, based on the variations in thickness of the intervals studied and assuming that the Huddleston and Hogshooter Limestone formed at or near sea level, were approximately 400 to 500 feet for the "Lower" Marchand sandstones and 150 to 200 feet for "Upper" Marchand sandstones (Plate 10, Part A). The topography was of a broad shallow shelf with a vey low-angle shelf-slope break of approximately 0.5^{o} to 1^{o} inclination. A conceptual model for deposition of the Marchand sandstone is shown in Figure 21.

Although the mechanism(s) by which Marchand sandstones were deposited is not clearly known, it is thought deposition was accomplished by low-density, non-turbid currents flowing down the slope of the basin (Harms, 1974). These currents initially flowed westward into the basin and then northward and/or southward parallel to the slope. Possible modification by geostrophic currents within the basin is not ruled out.

Deposits of the type described above have been reported by Bouma (1972) and Bouma and Hollister (1972) from modern continental rises and

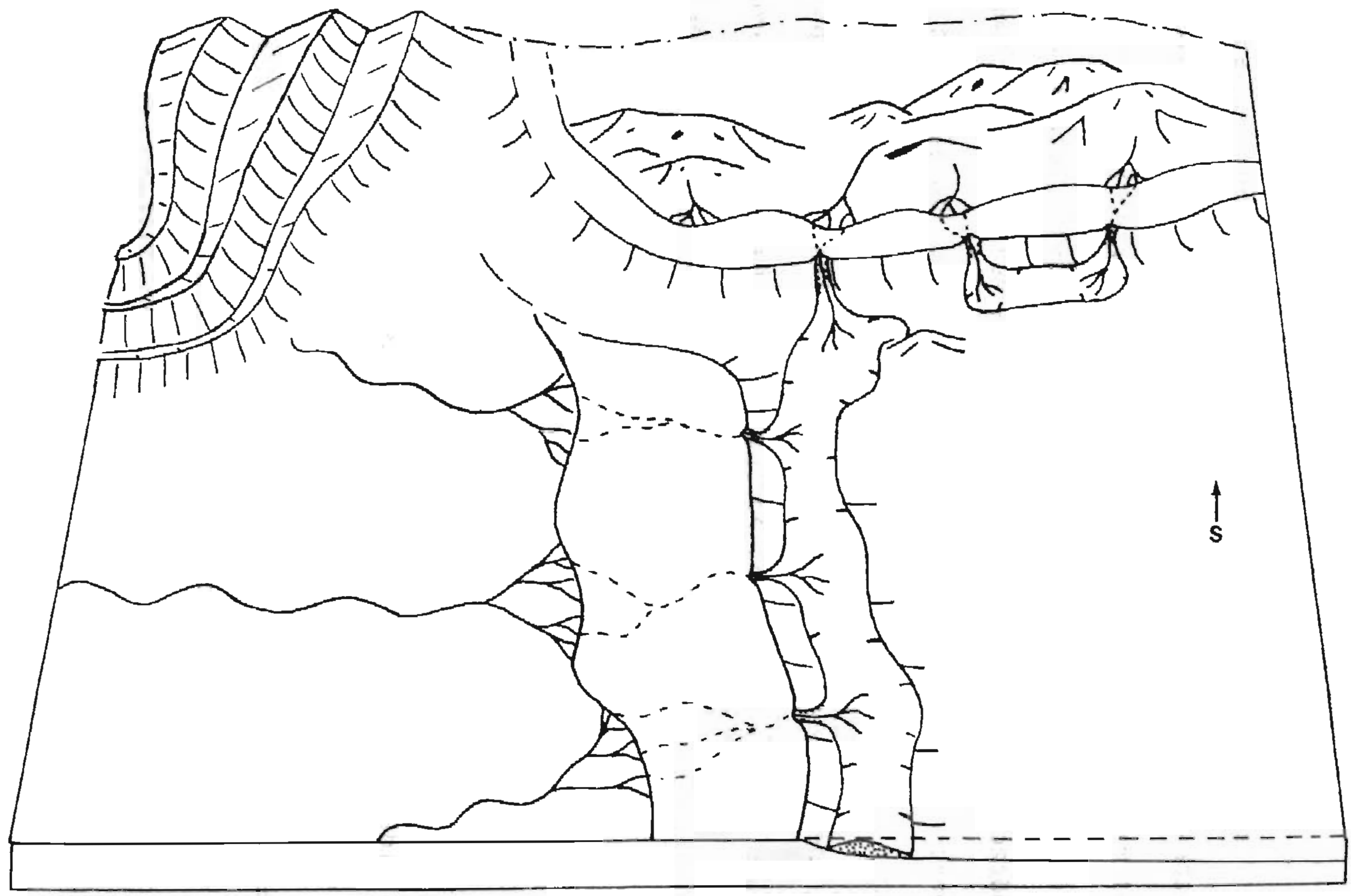


Fig. 21.--Conceptual model for deposition of Marchand sandstones. Sediments from deltaic systems to the east and southeast were transported across a broad shelf and deposited on the slope of the Anadarko basin. The major source area for these sediments is thought to have been the Ouachita Uplift. The Wichita uplift was an important source for the southern part of the study area.

the Paleozoic rocks of Switzerland; by Harms (1974) in the Brushy Canyon Formation of the Permian basin, Texas; by Seimers (1978) in the subsurface Woodbine-Eagle Ford strata of central Texas; and Gunn (1979) in the Desmoinesian rocks of the Knox-Baylor Trough, Texas.

The proposed facies model for Marchand sandstones is interstratified complexes of sand, silt and shale, and locally massive sandstone. Bed thickness are generally small, ranging from less than 5 cm to 1 or 2 feet and exhibit sharp upper and lower contacts. The dominant sedimentary structures are lamination and small-scale crossbedding with or without flowage. Bioturbation and fossil remains are generally rare. No ordered sequence of sedimentary structures is present. Grain size is markedly uniform ranging from fine to very fine sand. Deposits are generally well sorted. Marked facies changes are absent even over large distance.

Medrano-Belle City Formation

The Tonkawa Limestone to Medrano-Belle City interval bears a marked similarity to "Lower" Marchand Sandstone interval. The thinner, more uniform deposits on the east and the thicker, more variable deposits on the west are also thought to represent transition from shelf to basin. The facies change of the thick Belle City Limestone on the east into the Medrano sandstone on the west is evidence that clastic material was being transported across the shallow marine shelf,on most of which carbonate deposition was occurring, and deposited in the deeper basinal areas. Galloway (1977) illustrated this facies change as a seismically mappable feature and inferred a corresponding depositional topography. The nine principal cross sections and the paleotopographic cross-section are thought to demonstrate this type of topography in the study region (Plates 1 to 10).

Plate 11 shows the juxtaposition of the hinge lines along which the Tonkawa to Belle City-Medrano and "Lower" Marchand sandstone intervals thicken. For the most part, the Tonkawa to Belle City-Medrano line is east or shelfward of the "Lower" Marchand hinge lines. This suggests that progradation into and filling of the basin may have been interrupted by transgressive phases, reflecting gross changes in the rate of sedimentation or basinal subsidence.

Within the study area during that time, the Anadarko basin appears to have been relatively shallow. Calculations of water depth for the Tonkawa to Medrano-Belle City interval in the central part of the study area are approximately 500 to 600 feet. Water depths in the adjacent shelf areas was probably between 50 to 100 feet.

CHAPTER VIII

DIAGENESIS

Thin Section Analysis

From thin section analysis, diagenesis of the Marchand sandstones is thought to have progressed through four principal stages, as follows:

Stage 1: Cementation by syntaxial overgrowths of quartz and feldspar (Fig. 22). Locally these overgrowths form interlocking texture and show only minor development of later diagenetic stages. Overgrowths may have completely destroyed the original primary porosity of the sandstones.

Stage 2: Extensive replacement and corrosion of Stage 1 overgrowths and detrital grains by carbonate cement (Fig. 23). The carbonate mineral present in thin section is dominantly ferroan-calcite with some ferroan dolomite. Calcite is present locally.

Stage 3: Economically this is the most important stage. Stage 3 involves the formation of secondary porosity by dissolution of Stage 2 carbonate cement. Secondary porosity is recognized by oversized and elongate pores, floating grains, and partial dissolution of carbonate cement (Fig. 24). As much as 18 percent porosity has been developed in this manner.

Stage 4: This stage concerns the development of authigenic clay minerals which are difficult to identify in thin section. Therefore, scanning electron microscope examination was performed on selected samples.

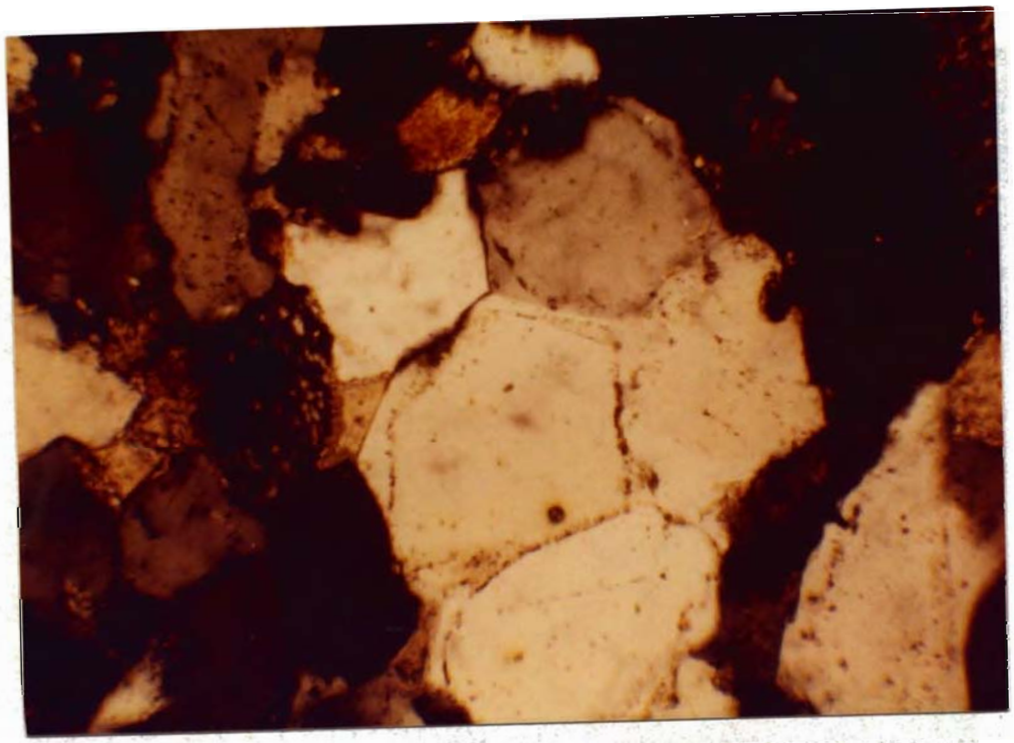


Fig. 22.--Overgrowths of quartz and feldspar representing Stage 1 diagenesis.

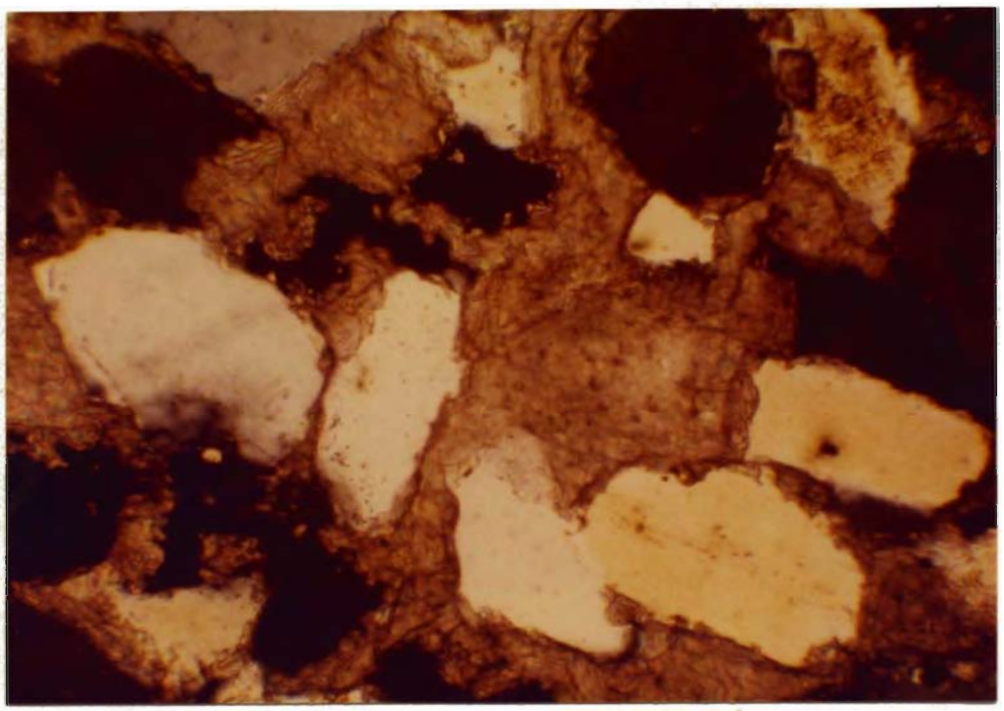
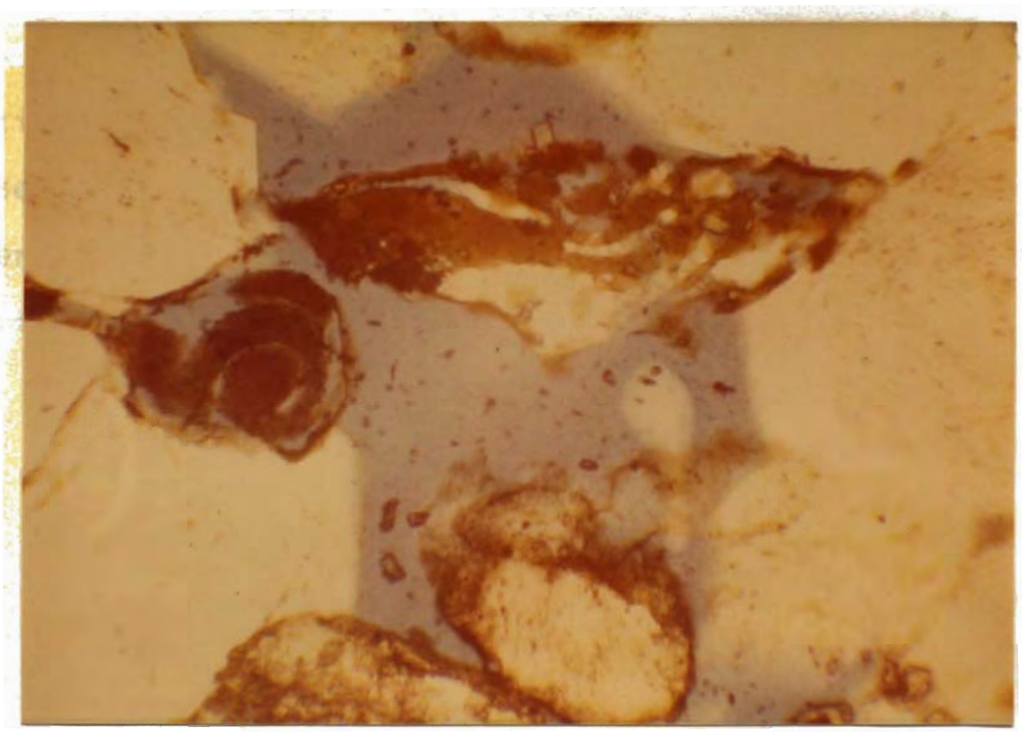


Fig. 23.--Extensive replacement and corrosion of Stage 1 overgrowths and original grains by carbonate cement, representing Stage 2 diagenesis. Carbonate is dominently ferroan-calcite.



g. 24.--Dissolution of Stage 2 carbonate cement forming secondary porosity, representing Stage 3 diagenesis. Note large pore and dissolution of fossil fragments.

Scanning Electron Microscopy

Scanning electron microscopy revealed that chlorite and mixed-layer clay (probably a mixed-layer illite) form the major authigenic clay mineral cements in the Marchand sandstones (Figs. 25 and 26). Chert and well ordered illite are present as minor authigenic constituents.

Clay cements are locally well developed and significantly reduce porosity and permeability in some samples. However, for the most part, they are present as only partial coatings on detrital grains and as coatings or replacements of residual carbonate cements (Figs. 27, 28, 29). These coatings and replacements suggest that these clays formed sometime after the development of secondary porosity; they therefore represent the fourth stage of diagenetic alteration.

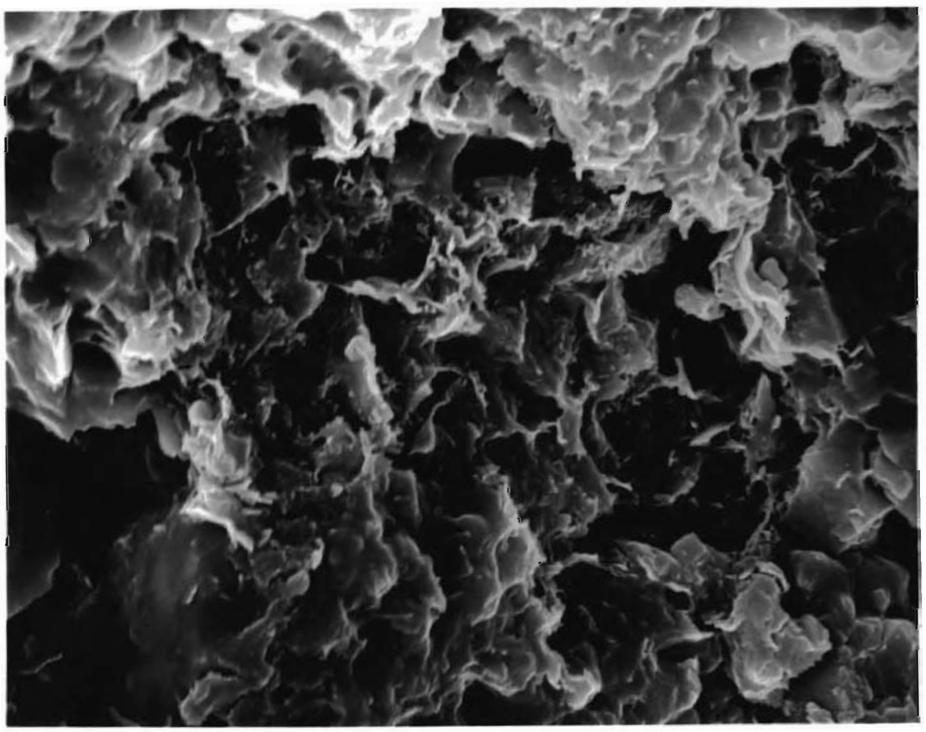


Fig. 25.--Mixed-layer clay coating grains and filling pores. Magnification 2400X. Sample from Phillips Petroleum Company Walters "J" No. 1, depth 10,365 feet.

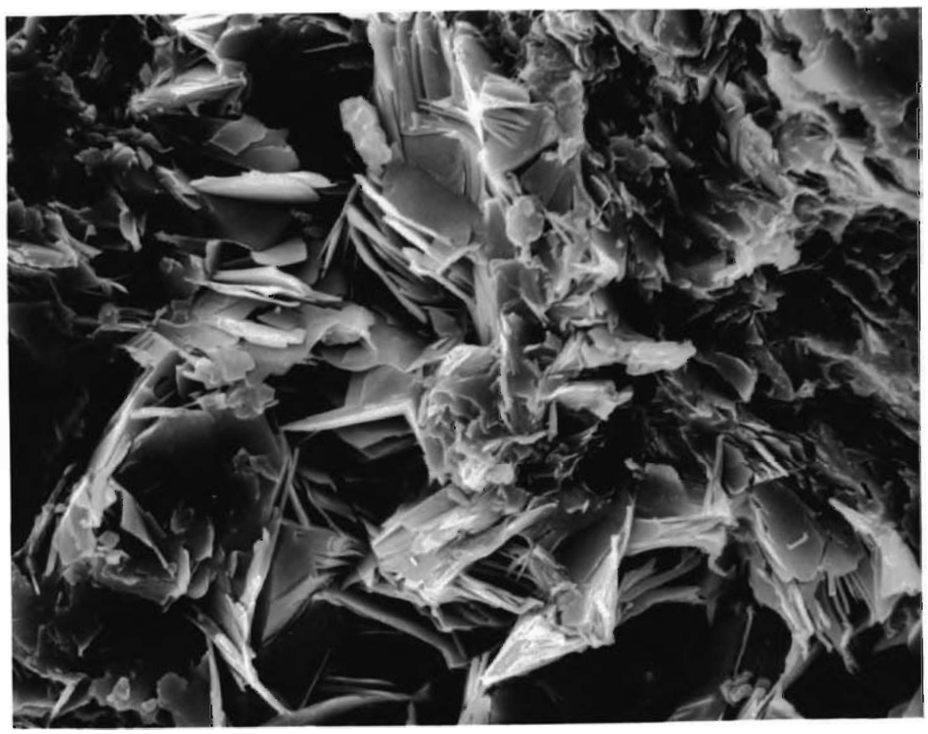


Fig. 26.--Chlorite filling in pore space. Magnification 2000X. Sample from Apexco Inc. Walker No. 1, depth 9912 feet.

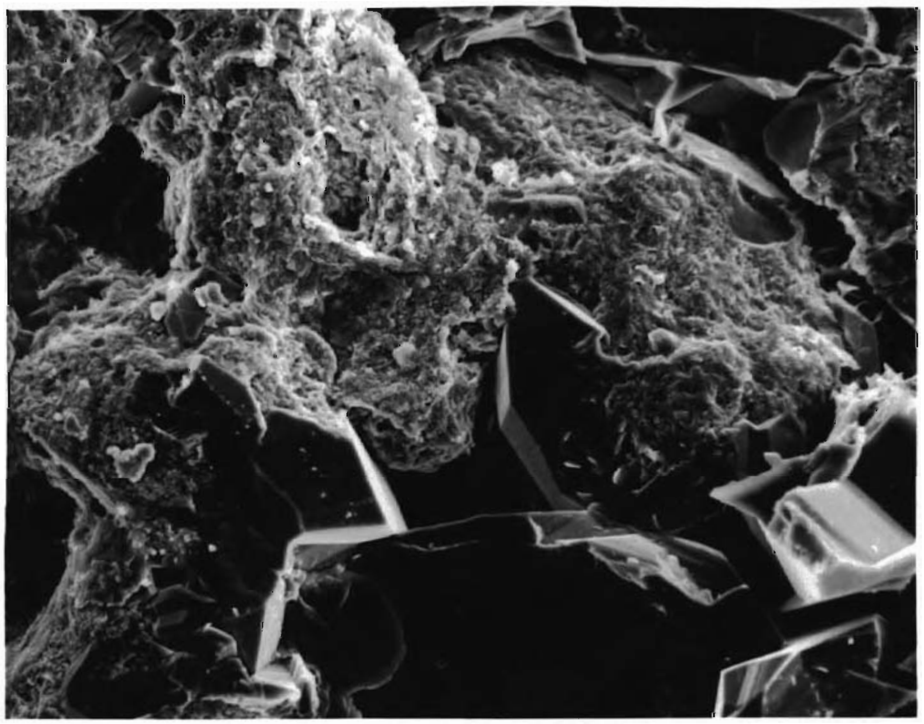


Fig. 27.--Clays as partial coatings on grains. Note presence of corroded surfaces on quartz and presence of euhedral overgrowths. Magnification 200X. Sample from Phillips Petroleum Company Walters "J" No. 1, depth 10,388 feet.

Fig. 28.--Chlorite partially coating corroded quartz grain. Corrosion probably was by earlier-phase carbonate cements (Stage 2 diagenesis) which were subsequently removed by dissolution (Stage 3 diagenesis). Magnification 2000X. Sample from Apexco Inc. Walker No. 1, depth 9912 feet.

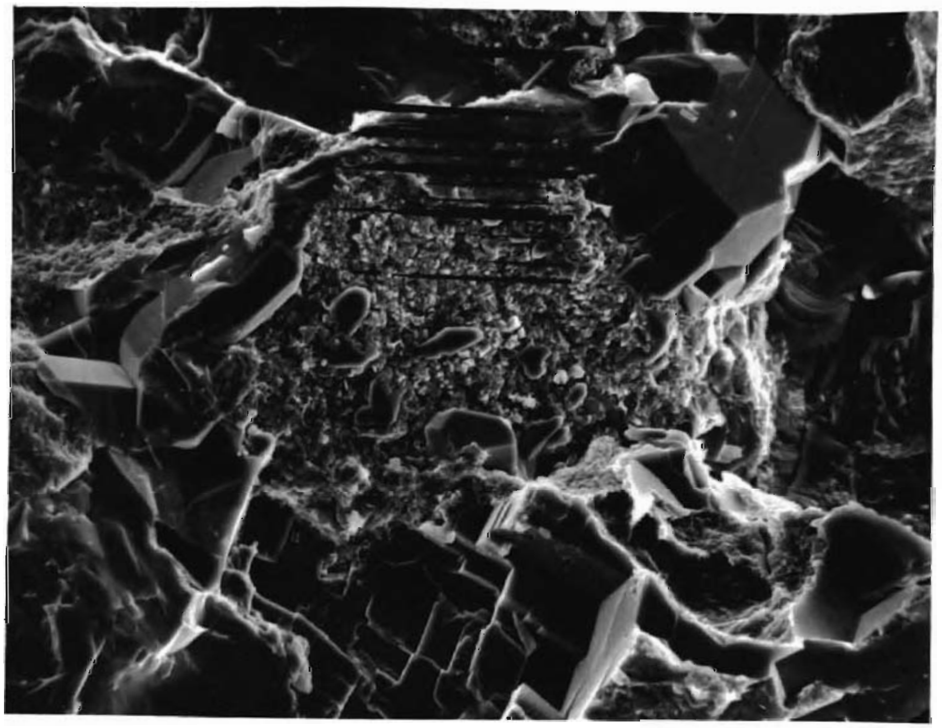


Fig. 29.--Clay coating and partially replacing residual carbonate cement (ferroan-dolomite), suggesting clays formed after Stage 3 dissolution. Magnification 240X. Sample from Phillips Petroleum Walters "J" No. 1, depth 10,388 feet.

CHAPTER IX

POSSIBLE EXPLORATION METHODS

It is thought the most profitable methods of exploration for sandstones similar to the Marchand lie in the use of seismic stratigraphy (with a reasonable amount of local control) and regional stratigraphic analysis. The use of seismic stratigraphy was demonstrated, in part, by Galloway (1977) who presented the facies change in the Medrano-Belle City Formation and the depositional topography related to it.

Mitchum et al. (1977) described the process of seismic stratigraphic analysis whereby a seismic section is subdivided into packages interpreted as depositional sequences. The seismic reflections within each sequence are then analyzed as to their configuration, continuity, lateral extent, amplitude, frequence, and internal velocity. These parameters are thought to be influenced by the processes which deposit sediment and can be used to interpret lithology, lateral extent, environment (to a certain extent), and in some cases the fluid properties of the rocks. Use of this form of exploration is related to the quality and amount of data available.

Regional stratigraphic analysis is the method of exploration in areas lacking in seismic data. Analysis of this type usually is in the form of isopach mapping of defined intervals and/or individual sand bodies. These methods will generally outline those areas where signific depositional topography existed as well as giving trend of sand bodies.

Interval isopach maps, together with individual sand maps, regional facies maps, and cross sections may outline those areas favorable for sand deposition. Emphasis here must be placed on "regional" studies, as local field studies generally do not include sufficient area to delineate such features as depositional topography.

Sedimentologic aspects of a given sandstone should be studied whereever possible. Although core study of the Marchand was not itself definitive in estimating depositional environment, it did eliminate some environments from further consideration. Analysis of the internal features of sandstones, such as grain and crossbed orientation from oriented cores, can be related to trend. The use of this observed sedimentologic data also presents the only information from which to calibrate stratigraphic and seismic data.

CHAPTER X

SUMMARY

The principal conclusions of this study are as follows:

1. The Marchand sandstones are present as thick wedges of coarse clastic material on the south, east, and northeast flanks of the Anadarko basin.

2. A reciprocal relationship exists between the thickness of the Hogshooter Limestone to "Hot Shale" interval and the "Hot Shale" to Huddleston Limestone interval.

3. Both the Hogshooter Limestone and the "Hot Shale" marker exhibit facies changes from finely crystalline oolitic and fossiliferous limestones in the eastern part of the area to black radioactive shales in the western part of the area.

4. The Lower Missourian shelf edges, defined by rather abrupt changes in thickness, separate the more uniform shelf deposits from the more variable sediments of the slope and basin areas where Marchand and Medrano sandstones were deposited.

5. The Marchand shelf edge is, for the most part, 4 to 5 miles west of the Tonkawa to Medrano-Belle City shelf edge suggesting limited transgressive phases interrupted by overall regressive conditions.

6. Trends of net and gross thicknesses of sandstone are dominantly parallel to the shelf edge of the Anadarko basin for Lower Missourian strata; minor trends which are perpendicular to the shelf edge may

represent channels which were the means of sediment (sand) supply for the slope-basinal sand bodies.

7. Distribution patterns of the Marchand sandstones indicate deposition as distinct to coalescing lobes.

8. The Marchand sandstones are composed of multistoried and multilateral channel deposits commonly exhibiting sharp upper, lateral, and basal contacts.

9. Channel forming processes eroded local lithologic markers.

10. Dominant sedimentary structures are: interstratification of sand and shale, horizontal lamination, flowage, and small-scale crossbedding. Deposits generally lack a diagnostic sequence of sedimentary structures comparable to those of known depositional environments.

11. Composition and trend of Marchand sandstones suggest the Ouachita uplift was a major source area for Marchand sediments. The Wichita uplift was probably a minor source area.

12. Low density, non-turbid currents, possibly related to temperature or salinity differences, are thought to have been the primary depositional mechanism for formation of the Marchand sandstones.

13. Water depths where Marchand sandstones were deposited were probably 200 to 300 feet.

14. Maximum water depths for the basin during that time were probably 400 to 500 feet.

15. The Marchand sandstones are thought to have been deposited in the marine-slope or ramp environment of the Anadarko basin.

16. The Marchand sandstones possess geometric and internal characteristics similar to marine-slope sandstones of the Cretaceous Woodbine-Eagle Ford rocks of Tyler County, Texas, and the Pennsylvanian

sediments of the Permian basin and Knox-Baylor trough, Texas. They also resemble in some aspects certain sediments of the modern continental rises.

17. Most profitable methods of exploration for sandstones similar to the Marchand are thought to lie in the use of seismic stratigraphy and regional stratigraphic analysis.

18. Diagenesis of the Marchand sandstones occurred in four principal stages which entail the complete cementation of the sandstone and destruction of primary porosity to dissolution of cement and formation of secondary porosity.

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APPENDIX

LOCATION OF ELECTRIC LOGS USED IN

PREPARATION OF STRATIGRAPHIC CROSS SECTIONS

East-West Stratigraphic Cross Section A-A'

No.	Operator and Well Number	Location
1.	Frankfort Oil Co., Black Bear #1-A	SE NE NE Sec. 9-5N-10W
2.	Kerr-McGee Corp., Redman #1	NE NW SE NW Sec. 22-5N-9W
3.	Mobil Oil Corp., Ella Elliot #1	CNW SE Sec. 19-5N-9W
4.	BTA Oil Products, Rady Ford #1	CNE SW Sec. 22-5N-8W
5.	Phillips Pet. Co., Dahl #2	CNE SW Sec. 22-5N-8W
6.	J. Walker Duncan, Jr., Fairwell Unit #1	SW SW Sec. 21-5N-7W
7.	Harper Oil Co., Hiller-Ritter #1	NE NE Sec. 25-5N-7W
8.	Dupont and McCurdy, Waters Johnson #1	NE NE Sec. 25-5N-7W
9.	Hanover Management Co., Lents #1	SW NW NE Sec. 2-5N-6W
10.	J. D. Wrather, Jr., Lance #1	SW NW NE Sec. 2-5N-6W

East-West Stratigraphic Cross Section B-B'

1.	Davis Oil Co., Moore #1	CNE Sec. 12-7N-10W
2.	Gulf Oil Corp., Lawrence #1	C SW SE Sec. 21-7N-9W
3.	Phillips Pet. Co., Kochn "A" #1	SW NE SW Sec. 21-7N-8W
4.	Phillips Pet. Co., Wheeler "S" #1	CN WSE Sec. 14-7N-8W
5.	Resource Exp. Inc., Dietrich #1	N/2 SE NW SW Sec. 12-7N-8W

No.	Operator and Well Number	Location
6.	Helmricht Payne, Inc. McCarty #1	C S/2 N/2 SW Sec. 18-7N-7W
7.	Amoco Prod. Co., Milton Hatcher Unit #1	CNE Sec. 22-7N-7W
8.	Cotton Pet. Co., Bush #1	Sec. 13-7N-7W
9.	Phillips Pet. Co., Boyd "B" #1	SE NW SE Sec. 29-7N-5W
10.	Phillips Pet. Co., Boyd "B" #1	SE NW NE Sec. 29-7N-5W

East-West Stratigraphic Cross Section C-C'

1.	Hassie Hunt Trust, W.F. McAnally #1-A	CNW Sec. 9-9N-12W
2.	Midstates Oil Corp., Hennessey #1	CSE SE Sec. 19-9N-11W
3.	Mobil Oil Corp., Polly Diamond Heirs #1	NE SW Sec. 16-9N-10W
4.	C. W. Culpper, M. McMurray #1	C SW Sec. 10-9N-9W
5.	Edwin L. Cox, Pullin #1	NE Sec. 17-9N-8W
6.	Woods Pet. Co., Pullin #1	NE Sec. 17-9N-8W
7.	Apexco Inc., Williams Unit #1	C SW Sec. 23-9N-8W
8.	Gulf Energy and Minerals Co. U.S., Jacobs 1-30	C SW Sec. 20-9N-7W
9.	Shenandoah Oil Corp., Verle Barnes #1	NE NE SW Sec. 25-9N-7W
10.	Tidewater Oil Co., Schonwald #1	SW NE SW Sec. 18-9N-6W
11.	Pan American Pet. Corp., H. B. Hambleton #1	NE SW Sec. 26-9N-6W
12.	N.C.R.A., Skaggs Ranch #1	C NW Sec. 16-9N-5W
13..	C. R. Walbert, Surbeck #1	NW NW SE Sec. 13-9N-5W
14.	Suaray Mid-Continental Oil Co., Bond Estate #1	SE SE NE Sec. 11-9N-4W

East-West Stratigraphic Cross Section D-D'

No.	Operator and Well Number	Location
1.	Apexco Inc., Walker #1	SE SW SW Sec. 8-11N-12W
2.	Woods Pet., Carl Unit #1	C W/2 Sec. 7-11N-11W
3.	Monsanto Co., Arnold #1	C SE Sec. 23-11N-11W
4.	Samedan Oil Co., Fedderson #1	SE SW NE Sec. 22-11N-10W
5.	Woods Pet. Co., Willard Unit #1	NE Sec. 21-11N-9W
6.	Cities Service Co., Petree Ranch #1	SE SE Sec. 18-11N-8W
7.	Pasotex Pet. Co., Fedderson Et Al. Unit #1	SW NE Sec. 14-11N-8W
8.	Pan American Pet. Corp., Catz Unit #1	NE Sec. 30-11N-7W
9.	McKellan Inc., Hill #1	SE NW Sec. 27-11N-7W
10.	Pan American Pet. Corp., Nettie Patcock #1	SE NE Sec. 28-11N-6W
11.	Union Oil Co. of Calif., Purdin 1-21	SW NE Sec. 21-11N-5W
12.	Ashland Oil and Ref. Co., Zurline #1	SE NW Sec. 16-11N-4W

North-South Stratigraphic Cross Section E-E'

1.	Republic Natural Gas Co., Harris #1	C SE NW Sec. 34-5N-4W
2.	Anderson Prichard Oil Corp., Franklin Unit #1	NE SE Sec. 22-5N-4W
3.	Creslenn Oil Co., Willis #1	NW SW Sec. 22-6N-4W
4.	Universal Oil Co., Ada Moore #1	NE NE Sec. 20-7N-4W
5.	An-Son Corp., Hester #1	NW SW Sec. 15-8N-4W
6.	Sunray Mid-Continental Oil Co., Bond Estate #1	SE NE Sec. 11-9N-4W
7.	Stanolind Oil Co., Eula Kelly #1	SE SE Sec. 10-10N-4W
8.	Ashland Oil and Refining Co., Zurline #1	CSE NW Sec. 16-11N-4W

North-South Stratigraphic Cross Section F-F'

No.	Operator and Well Number	Location
1.	Hanover Management Co., Lents #1	C W/2 Sec. 9-5N-6W
2.	Hanover Management Co., Young #1	C W/2 Sec. 22-6N-6W
3.	Phillips Pet. Co., Bailey Unit #1	SE NW SE Sec. 20-7N-6W
4.	Hiawatha Oil Co., SE Aba #1	SW Sec. 14-8N-6W
5.	Pan American Pet. Corp., H. B. Hambleton	NE SW Sec. 26-9N-6W
6.	H. L. Brown, Jr., Turne Unit #1	C SW Sec. 20-10N-6W
7.	Cleary Pet. Co., Hunt No. 1-11	E/2 E/2 W/2 NE Sec. 11-10N-6W
8.	Pan American Pet. Corp., Nettie Patzuck #1	SE NE Sec. 28-11N-6W

North-South Stratigraphic Cross Section G-G'

1.	Phillips Pet. Co., Duke #1	SW SW SE Sec. 28-5N-8W
2.	Phillips Pet. Co., Dahl #2	
3.	Cleary Pet. Corp., McDonald #1-28	NW NE Sec. 28-6W-8W
4.	Apache Corp., Waldrup #1	NE NE Sec. 4-6W-8W
5.	Phillips Pet. Co., Wheeler's #1	NW SE Sec. 14-7N-8W
6.	Apache Corp., Nightingale #4	C SE NW Sec. 11-7N-8W
7.	Parker Drlg. Co., Ast-Verden #1	S W NW SE Sec. 27-8N-8W
8.	Petroleum Inc., Dahal #1	S/2 SE Sec. 16-8N-8W
9.	Amarex, Inc., Richardson #1	C SW SW Sec. 4-8N-8W
10.	Apexco Inc., Bradford #1	SE Sec. 28-9N-8W
11.	Woods Pet., Pullin #1	SW Sec. 4-9N-8W
12.	Apexco Inc., Chester #1	SW Sec. 4-9N-8W
13.	Natomas N.A., M.C., Comas #1-25	SW NE SE NW Sec. 25-10N-8W
14.	Ladd Petr. Corp., McCaughey #1	NE Sec. 19-10N-8W

No.	Operator and Well Number	Location
15.	Pasotex Petr. Co., Fedderson Et Al. Unit #1	SW NE Sec. 14-11N-8W

North-South Stratigraphic Cross Section H-H'

1.	Frankfort Oil Co., Black Bear #1	SE NE NE Sec. 9-5N-10W
2.	Amerada Pet. Corp., Little Chief #2	NE NE NE Sec. 3-5N-10W
3.	Cleary Pet. Co., E.F. Freie #1-21	NW NE Sec. 21-6N-10W
4.	Tidewater Oil Co., Minnie Fross #1	NE NE Sec. 11-6N-10W
5.	Davis Oil Co., John Moon #1	NE Sec. 13-7N-10W
6.	Bonray Oil Co., Foster Stephens #1	SW NE SW Sec. 15-8N-10W
7.	Mobil Oil Corp., Polly Diamond, Heirs #1	NE SW Sec. 16-9N-10W
8.	Apexco Inc., Longhat #1	NW SW Sec. 4-9N-10W
9.	Champlin Pet. Co., #1 B.J. Croy	NW Sec. 22-10W-10W
10.	Sanedon Oil Co., Seiglet #1	NW Sec. 9-11N-10W

North-South Stratigraphic Cross Section I-I'

1.	W. E. Snee Et Al., Roddy #1	SW NE Sec. 26-8N-12W
2.	Marathon Oil, Betty Long #1	NE SW NW Sec. 12-8N-12W
3.	Phillips Pet. Co., Eagle "A" #1	SE NW Sec. 35-9N-12W
4.	Hassie Hunt Trust, McAnally #1-A	E/2 NW Sec. 9-9N-12W
5.	Conoco Smith #1	CSE NW Sec. 32-10N-12W
6.	Davis Oil Co., Clay #1-A	SE NW Sec. 21-10N-12W
7.	Apexco Inc., Walker #1	SE SW SW Sec. 8-11N-12W

Plates 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, and 15.

PLATE 1

EAST-WEST STRATAGRAPHIC CROSS-SECTION
A-A'
Marchand Study Area

PLATE 2

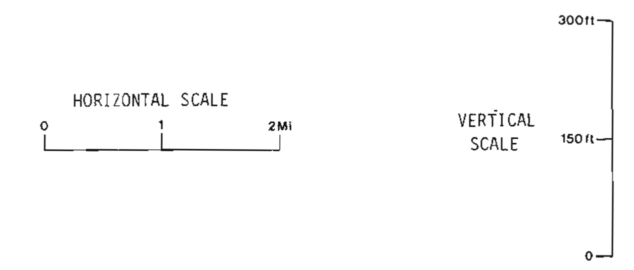

WEST
EAST
B'
B
NOT TO SCALE ACTUAL DISTANCE .5 MILES
1
2
3
4
5
6
7
8
9
10
11
12
13
TOP
MEDRANO
LIMESTONE
LIMESTONE
DATUM
BASE
HOGSHOO
LIMESTONE
TOP
SHALE
MARKER
LIMESTON
TOP
"LOWER
MARKER
TOP
EAST-WEST STRATAGRAPHIC CROSS-SECTION
B-B'
Marchand Study Area
HORIZONTAL SCALE
VERTICAL SCALE
T11N
T10N
T9N
T8N
T7N
T6N
T5N
CADDO
GRADY
R6W

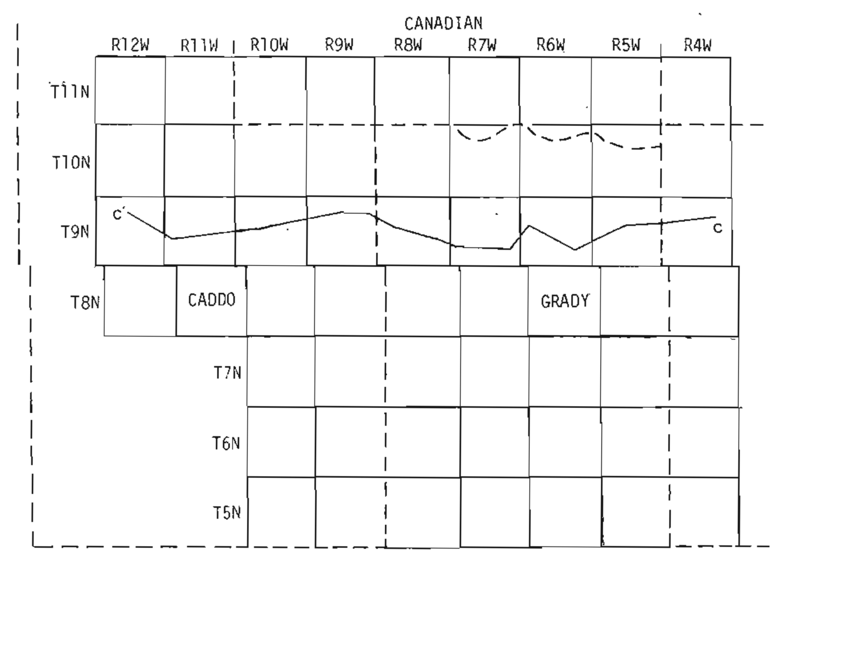
PLATE 3

EAST-WEST STRATAGRAPHIC CROSS-SECTION

C-C'

Marchand Study Area





WEST

D'

EAST

D

EAST-WEST STRATAGRAPHIC CROSS-SECTION

D-D'

Marchand Study Area

HORIZONTAL SCALE

VERTICAL SCALE

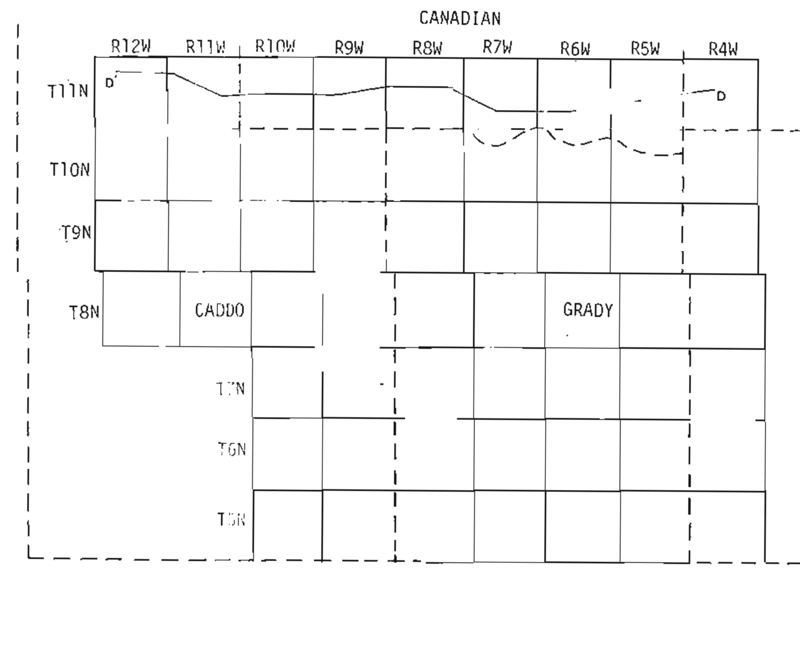
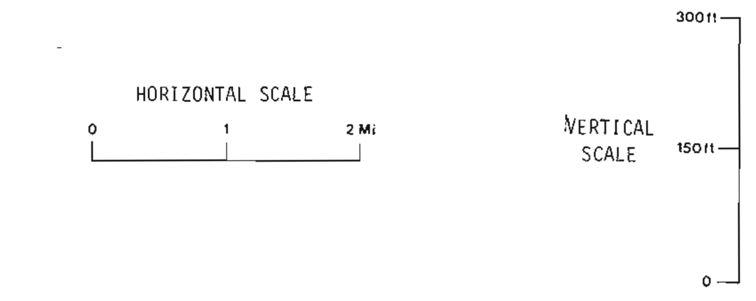


PLATE 5

NORTH-SOUTH STRATAGRAPHIC CROSS SECTION

F-E'

Marchand Study Area



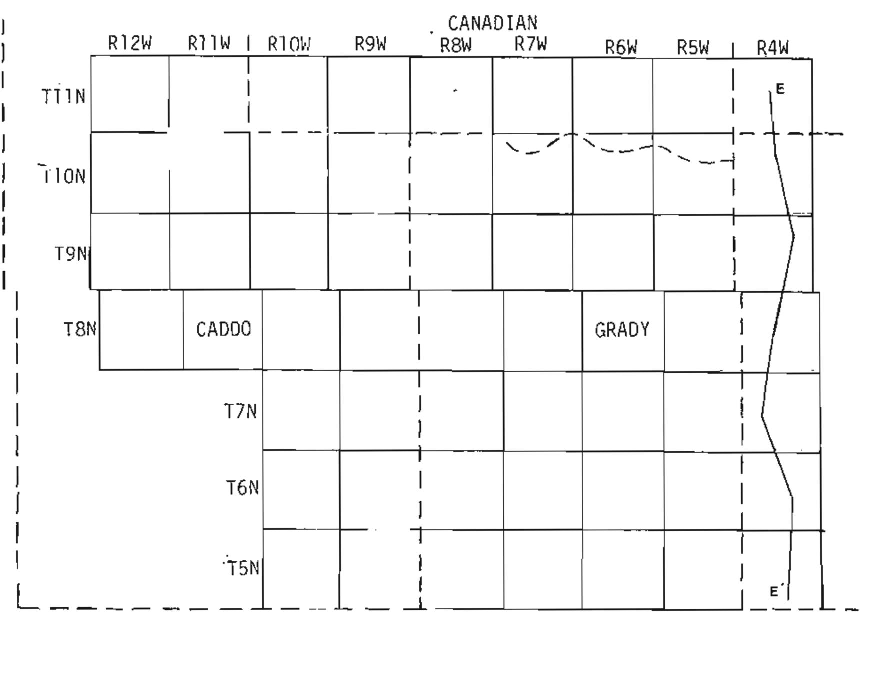
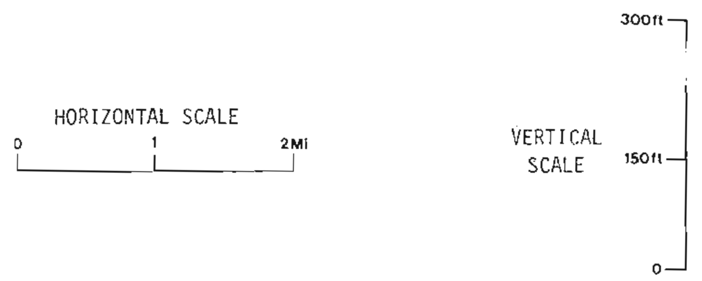


PLATE 6

NORTH-SOUTH STRATAGRAPHIC-CROSS SECTION
F-F'
Marchand Study Area



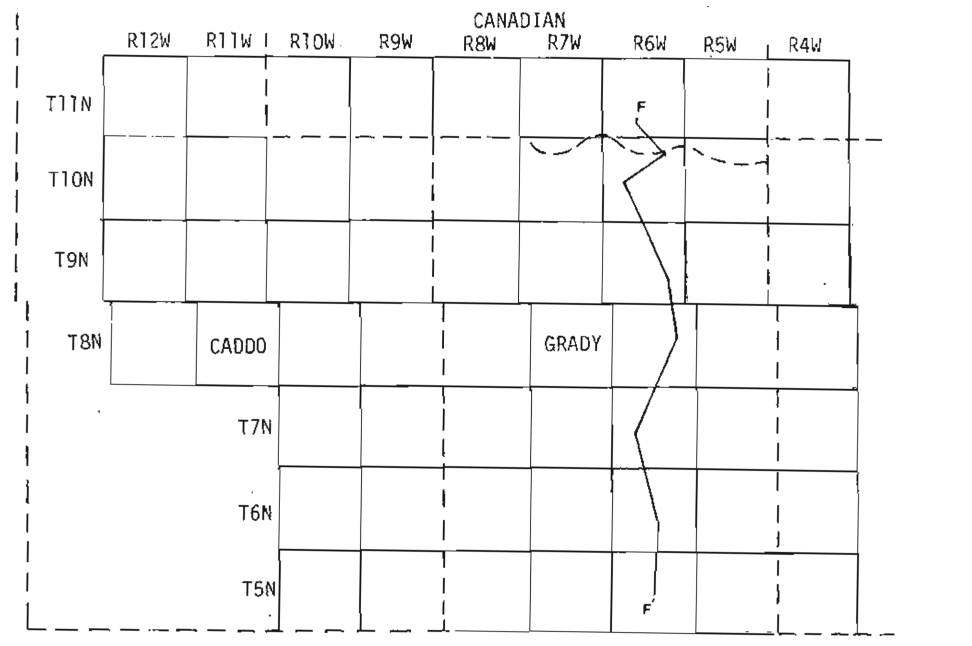


PLATE 7

NORTH-SOUTH STRATAGRAPHIC CROSS-SECTION
G-G'
Marchand Study Area

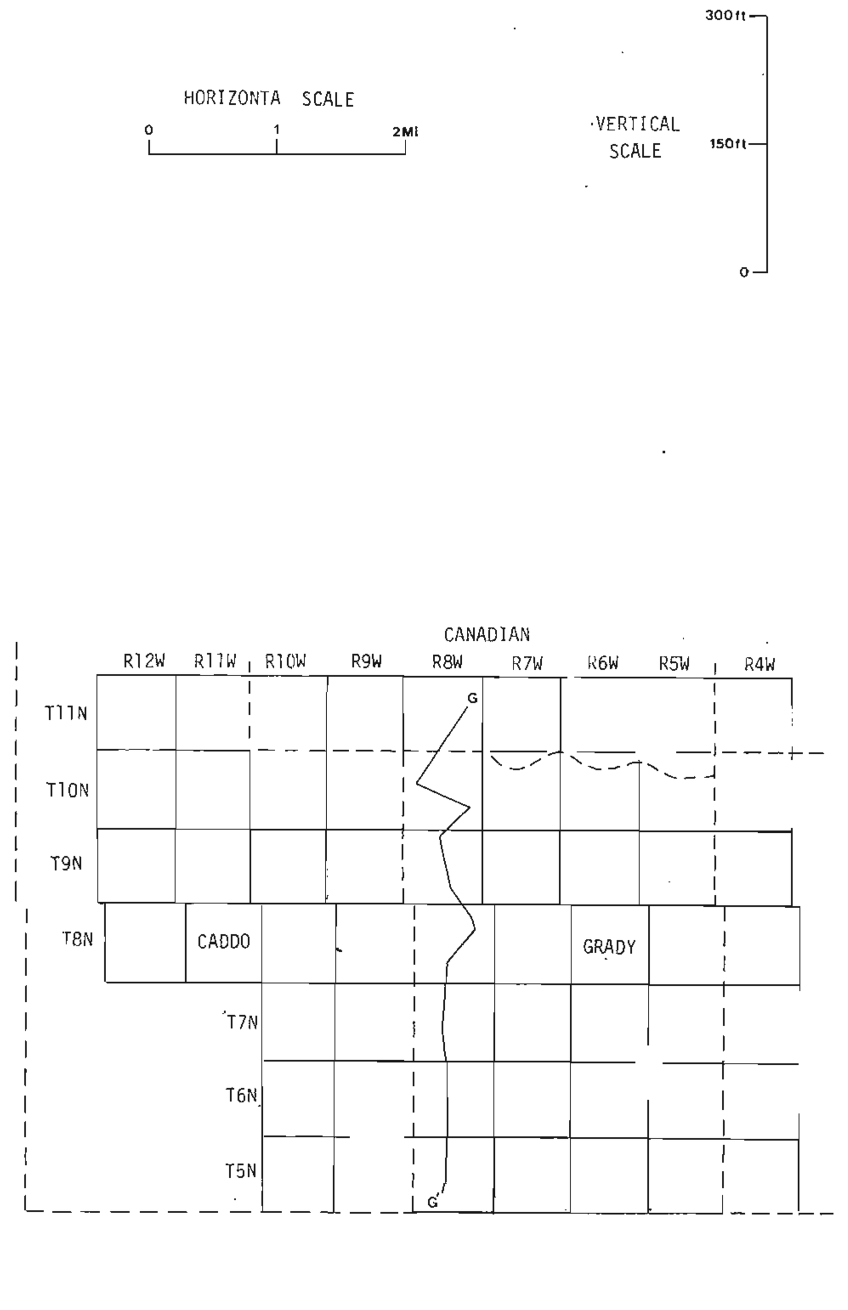


PLATE 8

NORTH-SOUTH STRATAGRAPHIC CROSS-SECTION
H-H′
Marchand Study Area

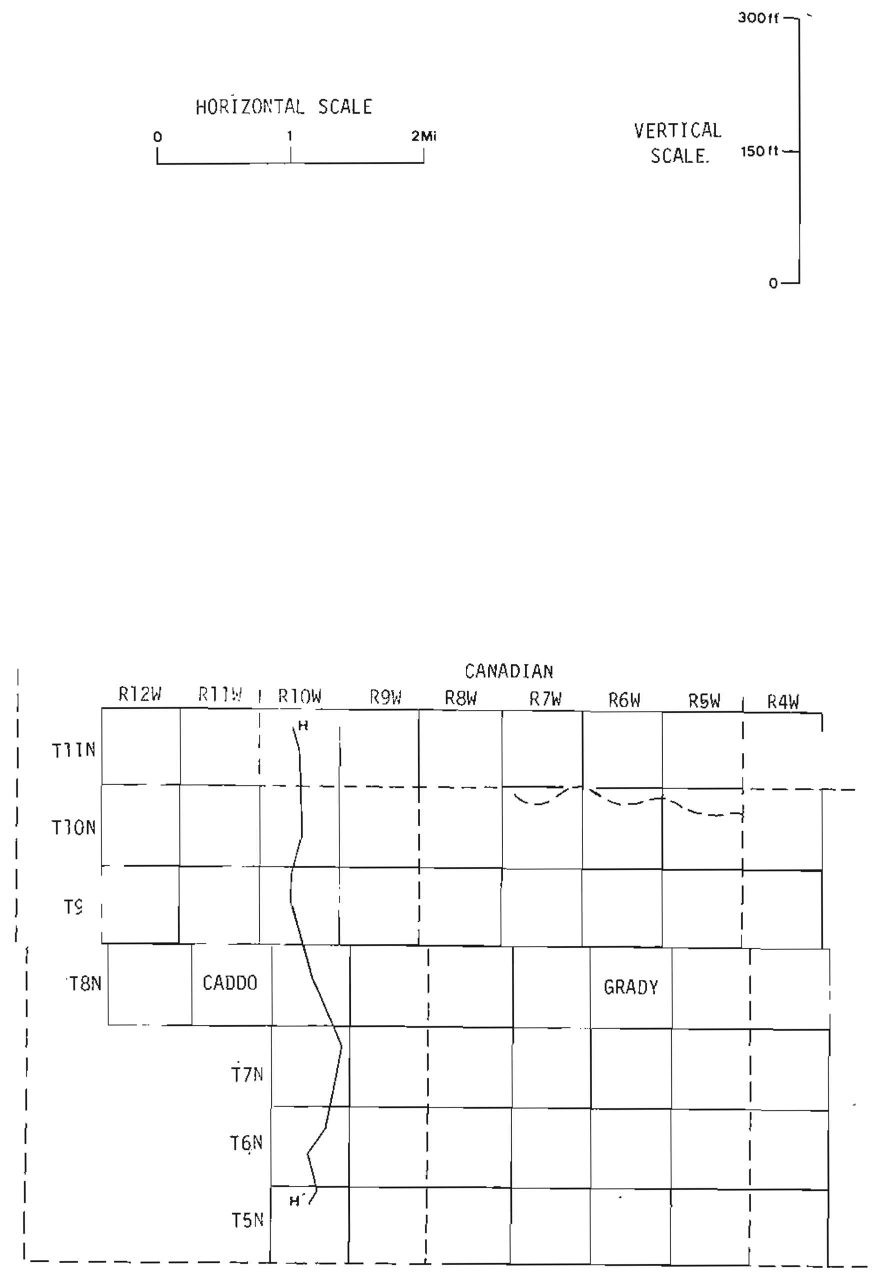
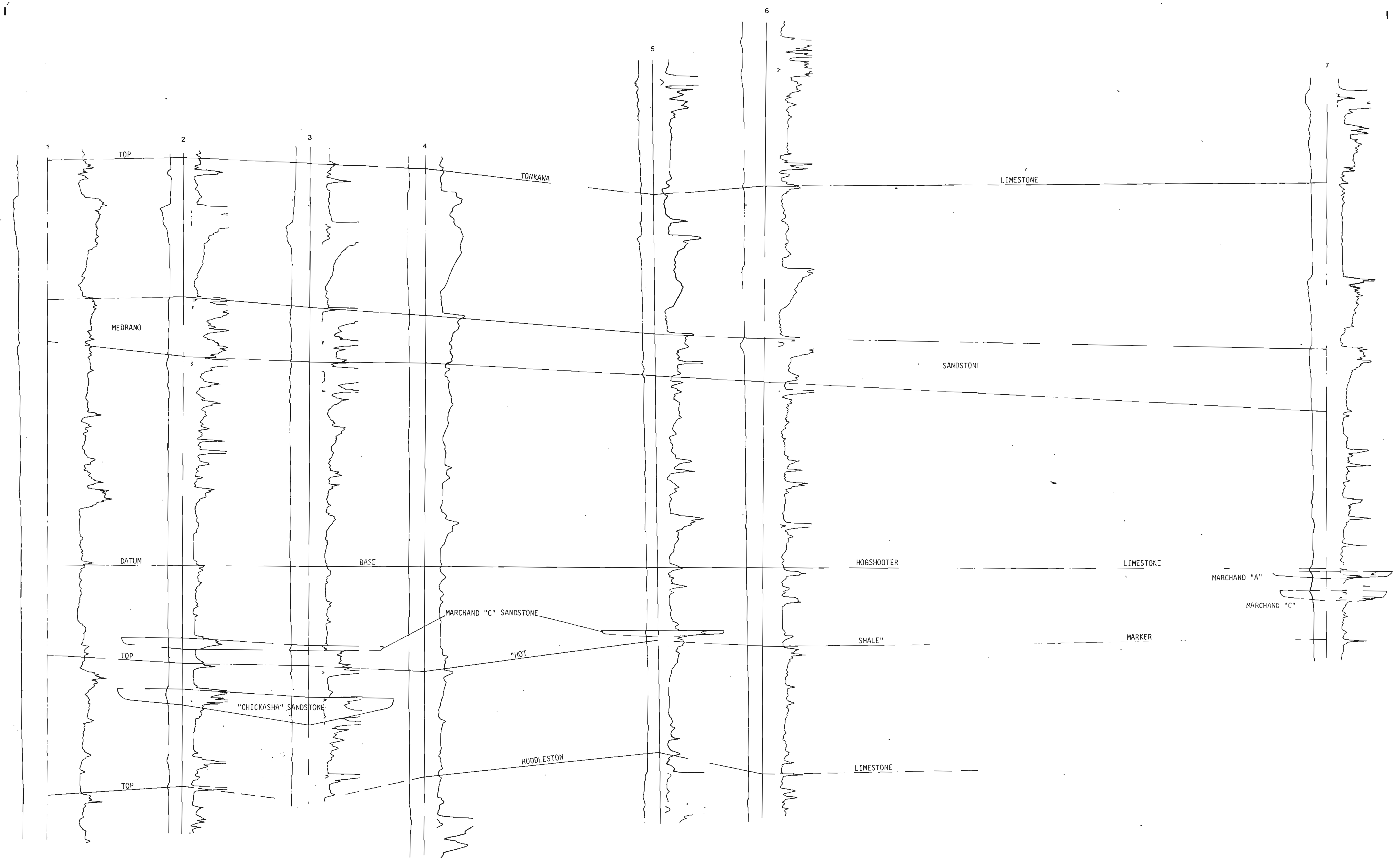


PLATE 9

SOUTH

NORTH



NORTH-SOUTH STRATAGRAPHIC CROSS-SECTION

I - I′

Marchand Study Area

HORIZONTAL SCALE

0 1 2Mi

VERTICAL SCALE

300ft 150ft 0

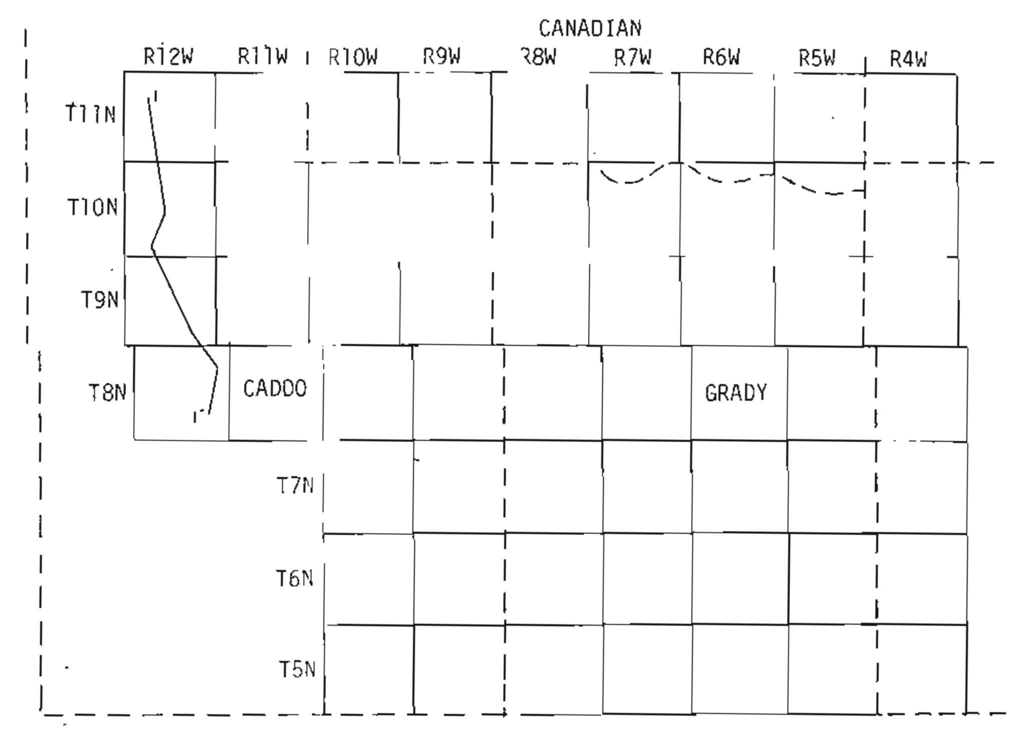


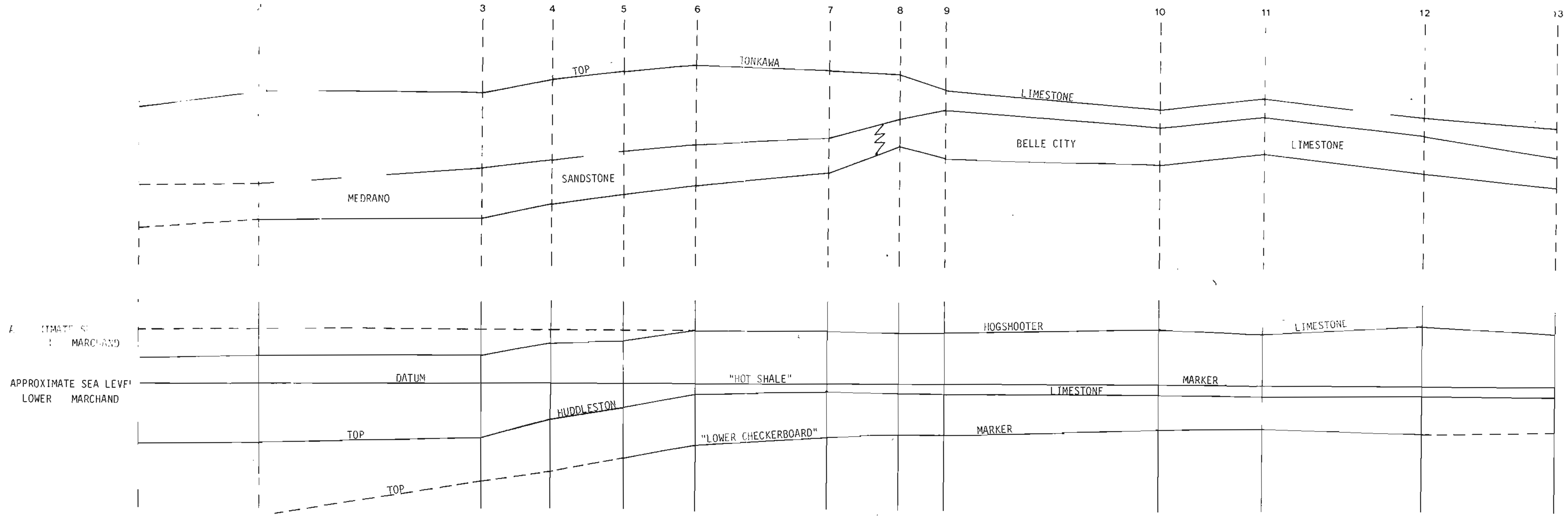
PLATE 10

PALEOTOPOGRAPHIC CROSS SECTIONS
Along B-B′

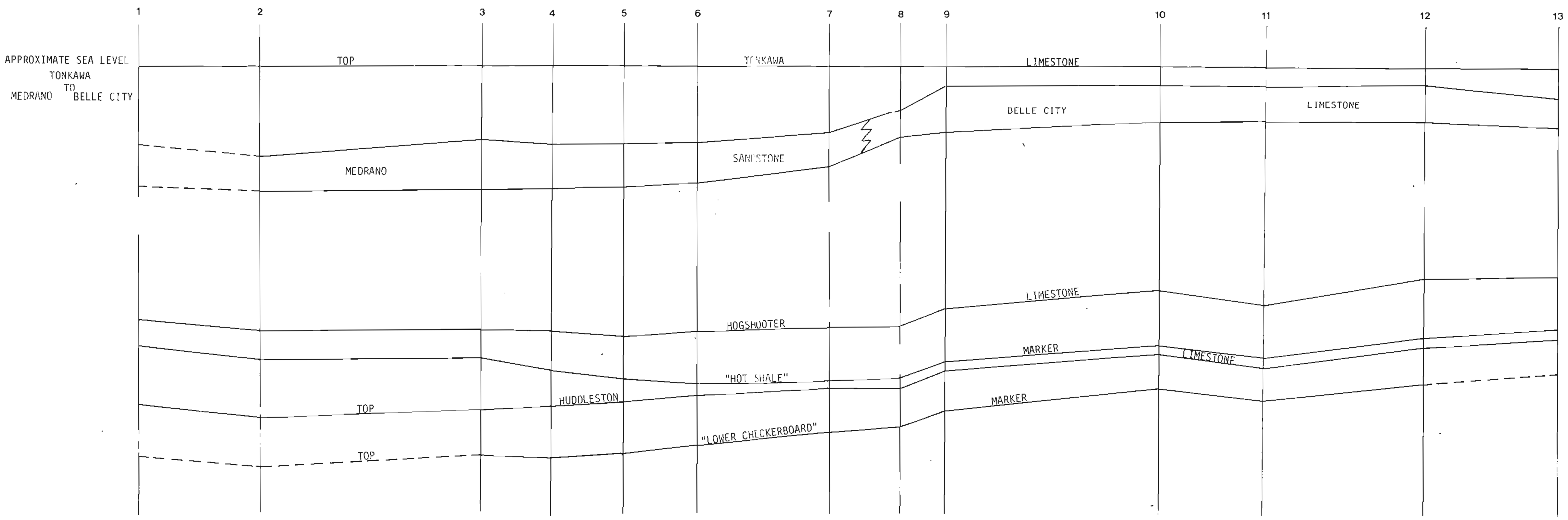
Part A: Hot Shale as Datum

Part B: Tonkawa Limestone as Datum

WEST B′ — Part: A — EAST B

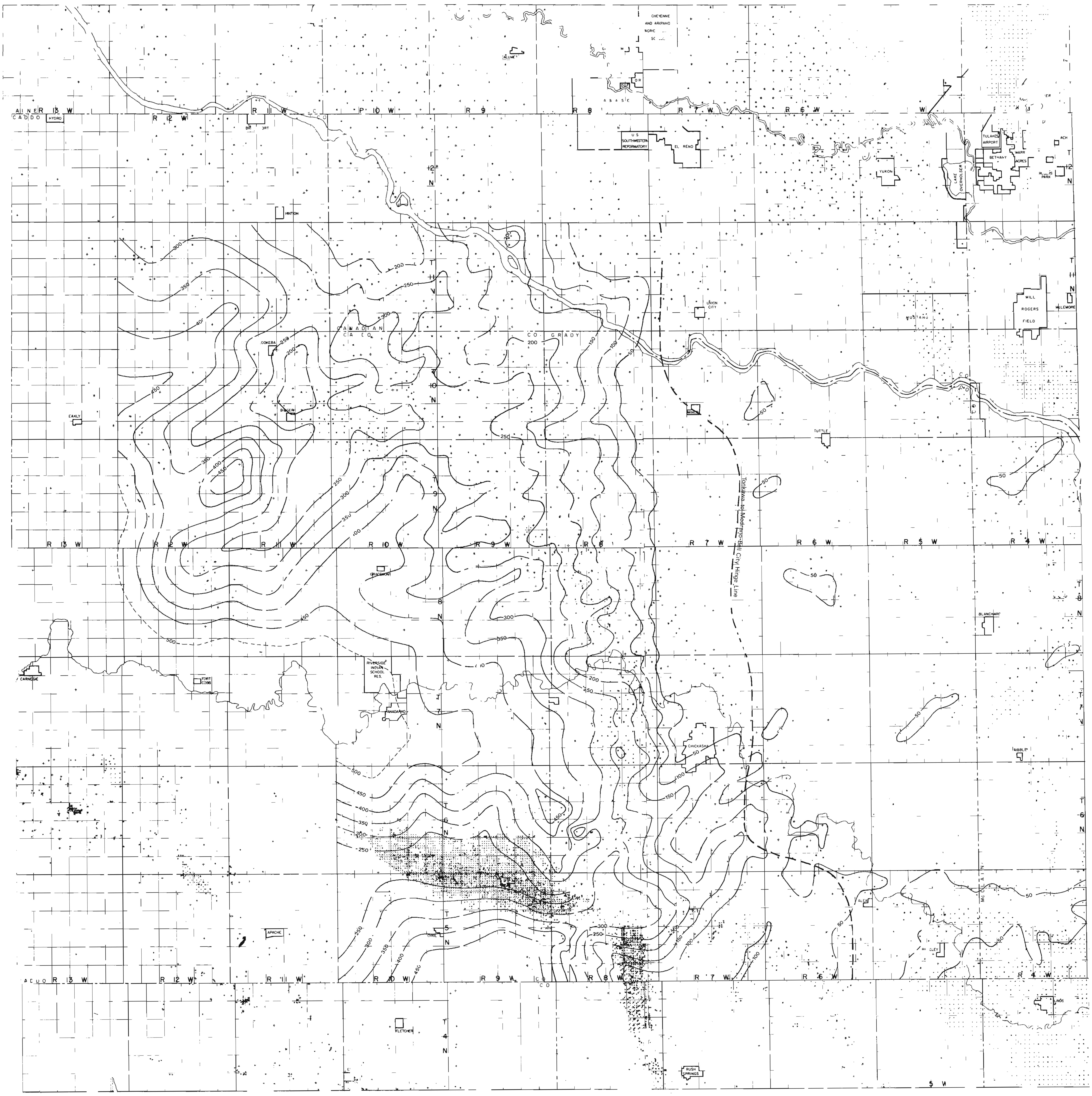


WEST B′ — Part: B — EAST B



HORIZONTAL SCALE 0 — 2MI

VERTICAL SCALE 0 — 400ft



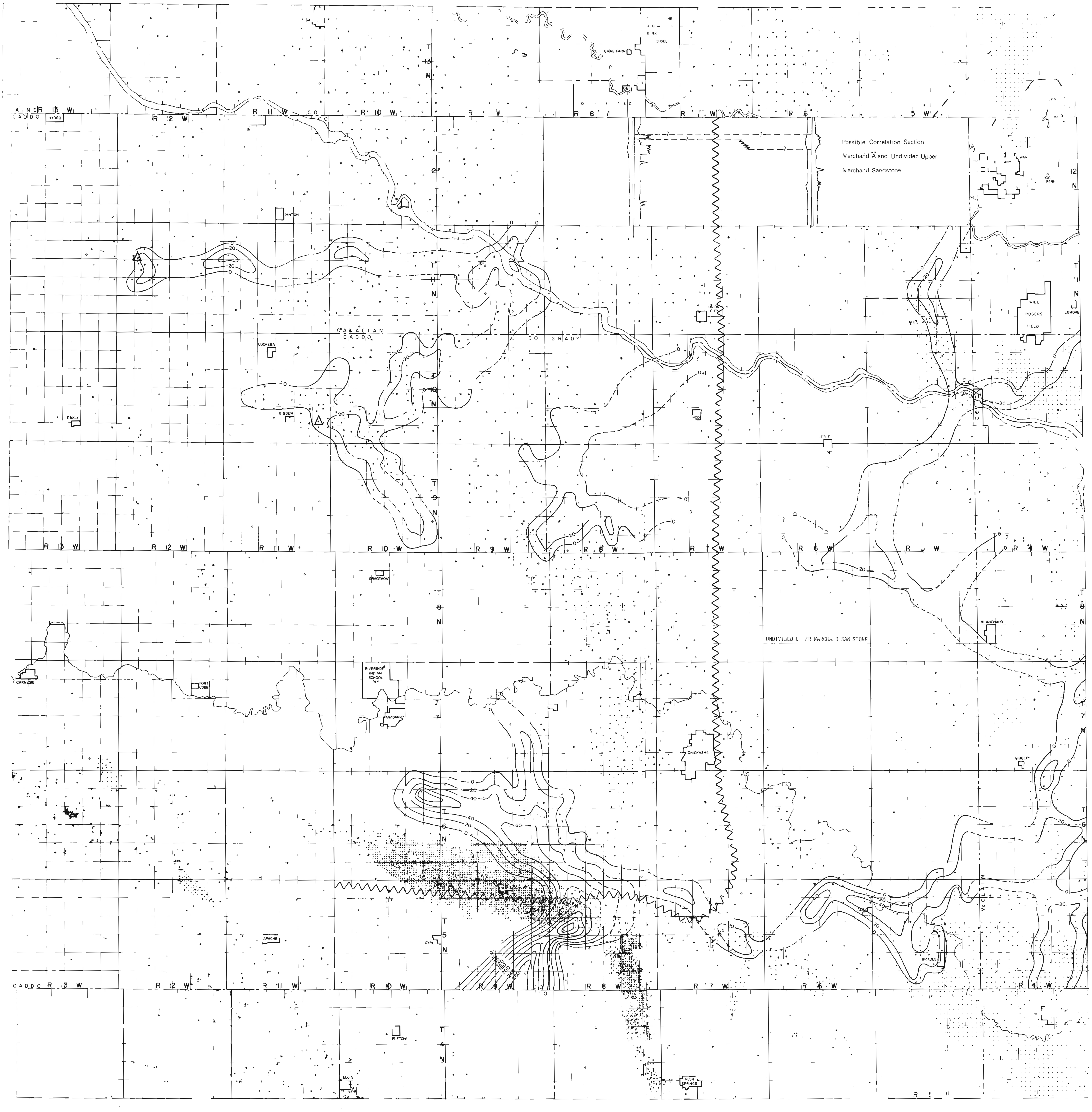
INTERVAL ISOPACH MAP

"HOT SHALE" Marker to Huddleston Limestone

CONTOUR INTERVAL 50'
CONTOUR LINE —

SCALE
5 0 5Mi

PLATE 11



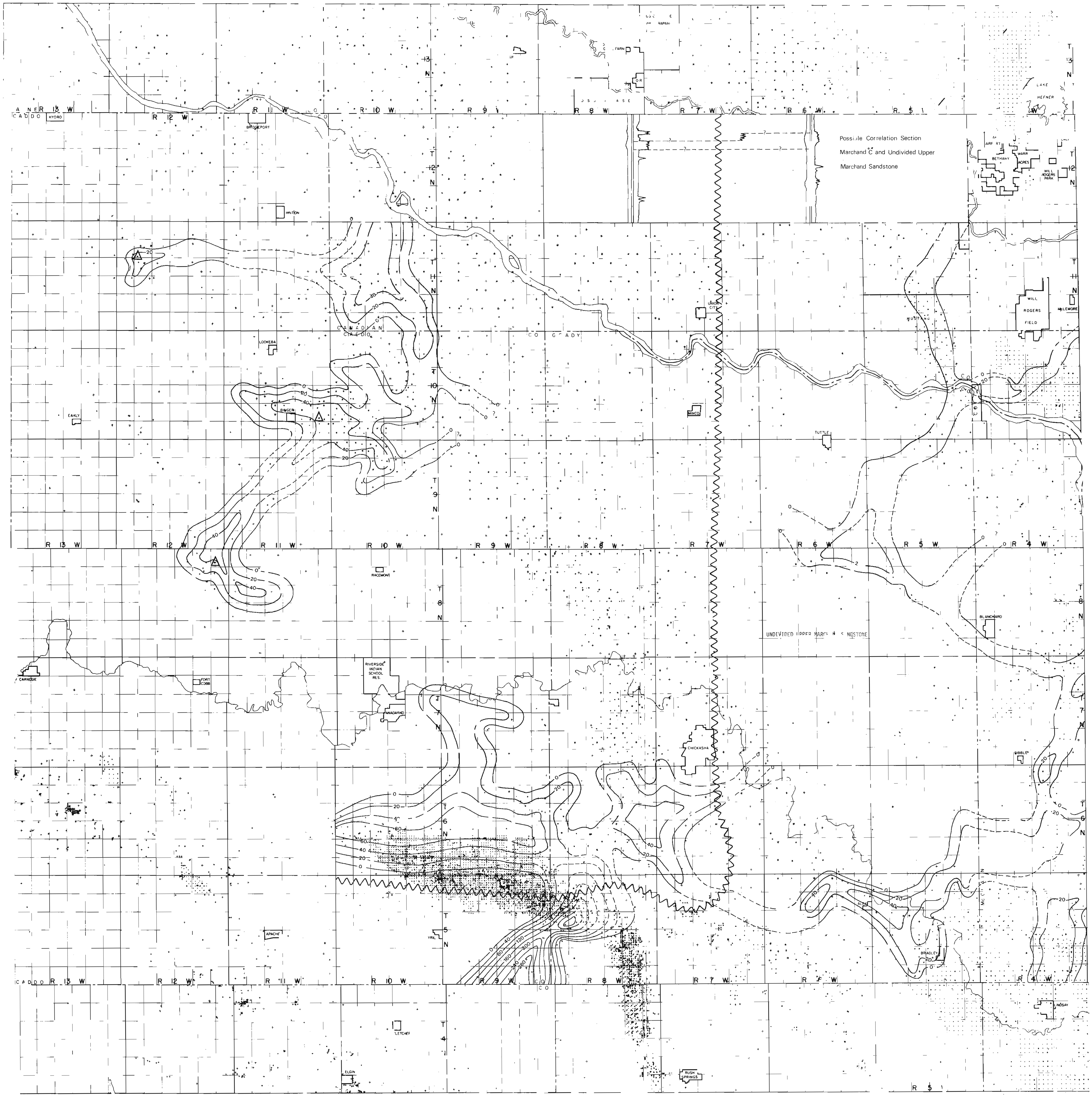
ISOPACH MAP NET THICKNESS

Marchand "A" Sandstone

SCALE
5 0 5Mi

CONTOUR INTERVAL 20' and 40'
CONTOUR LINE ——
CORE LOCATIONS △

PLATE 12



ISOPACH MAP NET THICKNESS

Marchand "C" Sandstone

SCALE

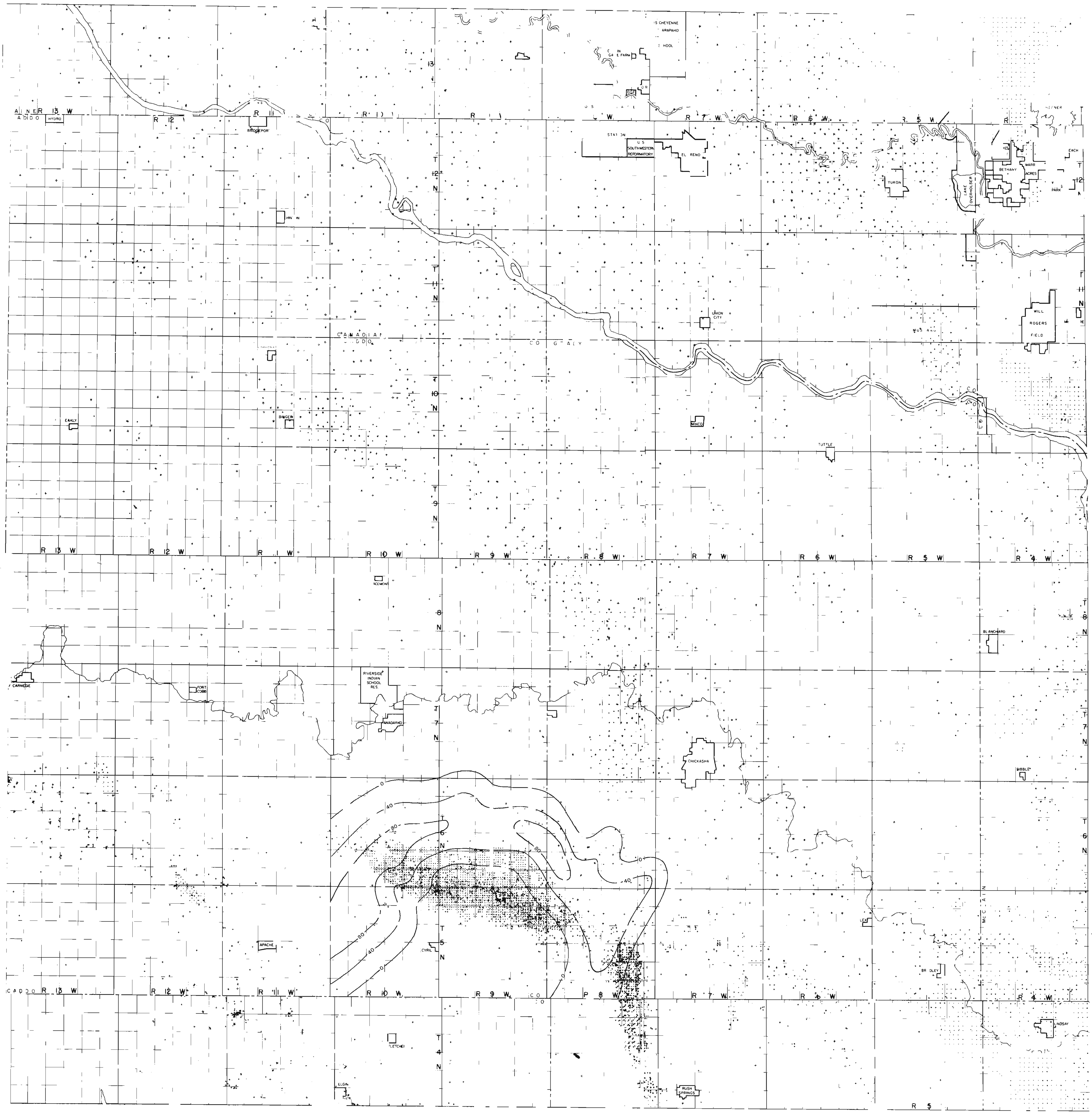
5 0 5 Mi

CONTOUR INTERVAL 20' and 40'

CONTOUR LINE —

CORE LOCATIONS △

PLATE 13



ISOPACH MAP NET THICKNESS

Marchand "CEMENT" Sandstone

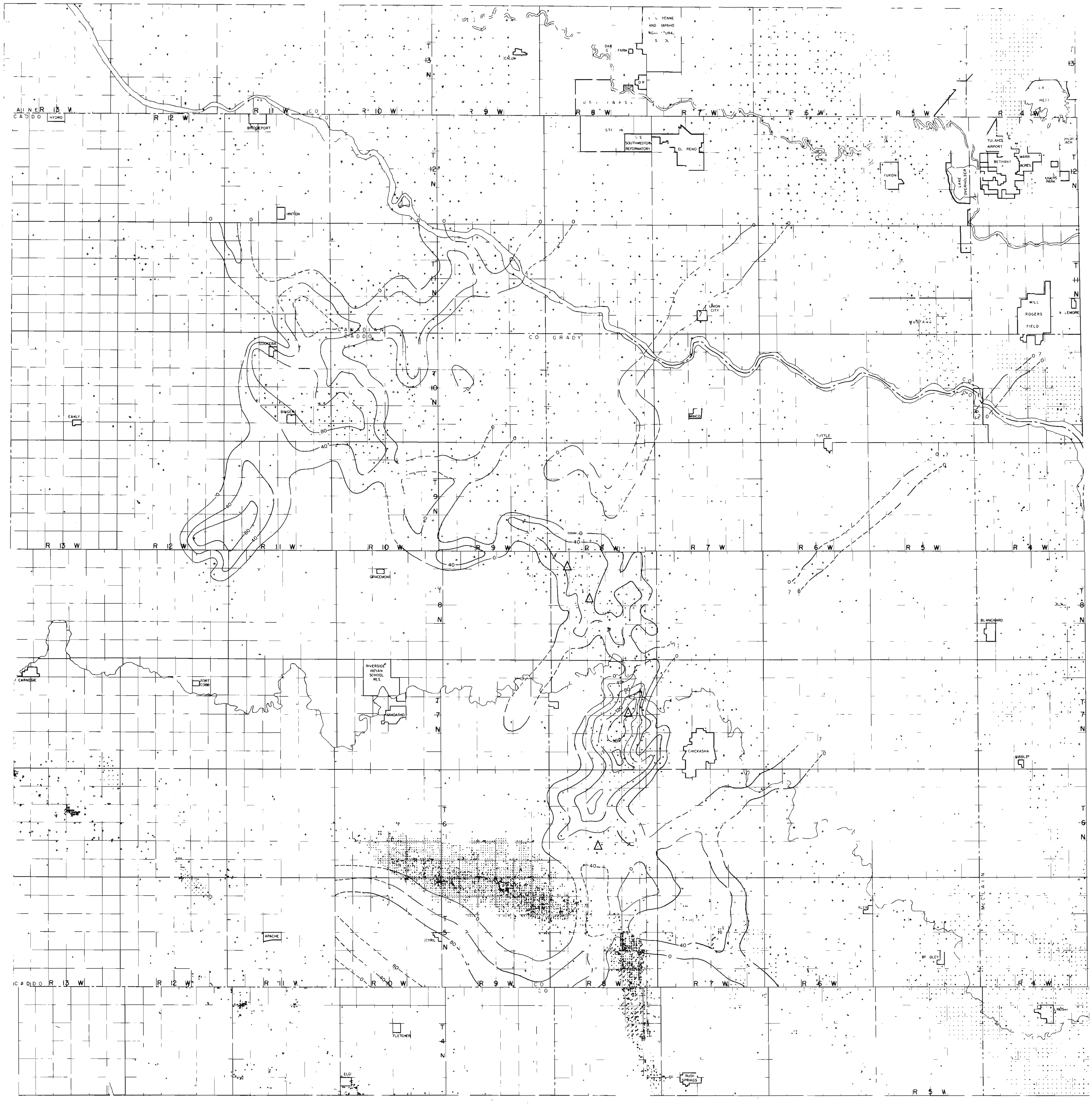
SCALE

5 0 5 Mi

CONTOUR INTERVAL 40'

CONTOUR LINE ——

PLATE 14



ISOPACH MAP NET THICKNESS

Marchand "CHICKASHA" Sandstone

SCALE

5 0 5M

CONTOUR INTERVAL 40'
CONTOUR LINE
CORE LOCATIONS △

PLATE 15

VITA

John David Seale

Candidate for the Degree of

Master of Science

Thesis: DEPOSITIONAL ENVIRONMENTS AND DIAGENESIS OF UPPER PENNSYLVANIAN MARCHAND SANDSTONES ON SOUTH, EAST, AND NORTHEAST FLANKS OF THE ANADARKO BASIN

Major Field: Geology

Biographical:

Personal Data: Born in Shawnee, Oklahoma, September 1, 1956, the third son of Mr. and Mrs. Richard C. Seale.

Education: Graduated from Shawnee High School, Shawnee, Oklahoma, in May, 1974; received Bachelor of Science degree in Geology from Oklahoma State University in May 1978; completed requirements for Master of Science degree at Oklahoma State University in July, 1980, with a major in Geology.

Professional Experience: Junior Member of American Association of Petroleum Geologists; Geological Assistant, Ketal Oil Producing Company, 1976-77; Geologist, Energy Resources Group, Cities Service Oil Company, Summer, 1978; Teaching Assistant, Oklahoma State University, 1978-79; Geologist, Production Department, Cities Service Oil Company, Summer 1979; Teaching Assistant, Oklahoma State University, 1979-80.