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EVALUATION OF HEAVY OIL AND TAR SANDS IN BOURBON, CRAWFORD, AND CHEROKEE COUNTIES, KANSAS—FINAL REPORT

By

W. J. Ebanks, Jr., G. W. James, and N. D. Livingston
Kansas Geological Survey

Prepared for DOE Under Contract No. E-76-S-02-2997

Date Published—December 1977

Bartlesville Energy Research Center
U.S. Department of Energy
Bartlesville, Oklahoma

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Larman J. Heath
Technical Project Officer
Bartlesville Energy Research Center

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FOREWORD

The DOE (formerly ERDA) management plan for enhanced recovery of oil and gas is aimed at demonstrating new recovery technology and transferring it to the private sector. The program is hampered by little or no field testing of the economic and technical feasibility of new techniques. A federal research, development and demonstration (RD & D) program has been initiated which is targeted at mitigating these economic and technical uncertainties. In some areas or components of the program, there is a great need for a verification of the resource base and an improvement in reservoir data.

The DOE Management Plan, through its RD & D program, stresses the need, as an essential prerequisite, for government and industry to confirm the magnitude, location, and condition of the resource in the target reservoirs.

The resource evaluation portion of the program includes surface and subsurface mapping, structural studies, geochemical studies, and data acquisition and processing for an appraisal of potential heavy oil reservoirs.

This project is one of three being conducted by geological or mineral resource organizations within the states of Kansas, Missouri, and Oklahoma. Its purpose is for better defining the heavy oil deposits in the area contiguous to these three states.

The information in this report is timely and, although not as encouraging as had been anticipated, will be of immense value to the industry.

Larman J. Heath
DOE Technical Project Officer

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SUMMARY

The current national energy-resource situation has provided the incentive to investigate more fully deposits of heavy-oil bearing sandstone in southeastern Kansas, as part of a larger, three-state study. The results of this study indicate that the size of the heavy-oil resource in the three Kansas counties studied is smaller than earlier estimates suggested.

A resource of 200-225 million barrels of oil in-place is estimated to be present in areas of "known oil occurrence," as established by this study. The amount of this in-place resource which may be considered to be reserves, that is, recoverable under existing technology and economics, is zero. The estimates of resource-size are severely downgraded from earlier estimates mainly because of the discontinuous nature of the potential reservoir sandstone bodies and because of the thinness and shaliness of some of these sandstones. The earlier impression of these heavy-oil reservoirs, at least in Kansas, as being widespread, heavily oil saturated, "blanket" sandstones unfortunately is not correct. There are areas, shown on maps here, which may warrant further investigation because of locally good oil-saturation, i.e., more than 400 barrels per acre foot, in trends of sandstone thicker than 20 feet.

The Cherokee Group includes five separate stratigraphic intervals in which oil-bearing sandstones are present. The concept of the origin of these sands which is suggested by mapping trends of sandstone thickness and by study of their composition, texture, and internal structure is one of fluvial-deltaic systems extending periodically into the area of southeastern Kansas from the east. The highly variable paleogeography which resulted from this history accounts for the nature of the

sandstones. Errors in correlation of some of these sandstones which have been discovered in the course of this study do not affect estimates of the amount of oil they contain.

The geochemistry of the heavy-oils recovered from cores is best explained as a result of contact and washing of these sandstones by natural fresh waters, with accompanying alteration by bacteria. These heavy-oils contain little or no gasolene-range hydrocarbons, have only small amounts of C_{15+} normal paraffins, and have slightly higher sulfur and non-hydrocarbon contents than lighter Cherokee crude oils. The overall average bitumen content of these sandstones is quite low, 1.6%, compared with deeper oil sands, some Missouri surface samples, and with other heavy-oil or tar sand deposits of the world. The average hydrocarbon content of this bitumen, 70%, is, however, moderately high.

The conclusion of this study is that there will be no widespread exploitation of subsurface heavy-oil sandstones within the areas of Bourbon, Crawford, and Cherokee Counties, Kansas. Smaller areas indicated here may warrant further drilling and investigation, but the potential size of the heavy-oil resource is severely downgraded from earlier estimates.

INTRODUCTION

Purpose of Study

In the present atmosphere of uncertainty concerning the future availability of economically producible, conventional, domestic, petroleum resources, research has begun into the feasibility of using alternate sources of crude oil as an element of the nation's energy budget. The present study, funded in part by the U.S. Energy Research and Development Administration (ERDA), now Department of Energy (DOE), and in part by the University of Kansas, is a better documentation than has been available in the past of the extent and nature of the heavy-oil bearing sandstones in the shallow subsurface area of three counties in southeastern Kansas. Complementary studies of similar deposits in contiguous areas of Missouri and Oklahoma are being completed by organizations in those states. Support of these studies by ERDA is a result of that agency's interest in better definition of the nation's energy resources or, more specifically, in the extent of deposits of oil which may be recoverable in the future by methods which are the subject of other research sponsored by ERDA.

Estimates of Heavy-Oil Resources

Earlier studies by the U.S. Bureau of Mines (Ball, 1965; Petroleum Staff, 1967) indicated that there were approximately 350 million barrels of crude oil in the form of heavy-oil, that is, oil whose gravity is lower than 25° A.P.I., in several counties of southeastern Kansas in fields from which lighter oil is produced. Furthermore, attention was called to the area east of these producing fields in which there were known to be occurrences of heavy-oil, but for which no reliable estimate of resource-size could be cited.

A report by the Kansas Geological Survey (Ebanks and James, 1974) suggested that there may be as much as 400 million barrels of oil in heavy-oil deposits of Bourbon, Crawford, and Cherokee Counties, Kansas; but others have estimated the resource size to be as great as 1.6 billion barrels of oil in only parts of two counties in this area and several more billion barrels of heavy-oil in the three-state heavy-oil province (Enright, 1964). This disparity in estimates of resource size probably has contributed to uncertainty which may have slowed development of the resource. Other factors which have discouraged development have been a lack of success in tests of various enhanced recovery methods, mainly thermal stimulation techniques, for producing the highly viscous oils and the generally unfavorable economic climate for high-cost, high-risk efforts as would be required to produce these "problem oils." Recent improvements in the well-head price of crude oil and renewed activity in methods of producing heavy-oils (for example, Sperry, 1977), provide encouragement for studies such as the present one. Reference to earlier pilot projects conducted in the Missouri-Kansas area are given below in the section on "reserves."

Area of Study

The principal area of interest in the present study is the area of Bourbon, Crawford, and Cherokee Counties, Kansas (Fig. 1). An effort has been made throughout the study to coordinate results of field and laboratory work with that being done in adjacent states, so that the final compilation of results will reflect the truly regional aspect of the heavy-oil resource.

Compilation of existing data in these three counties preceded the drilling of thirty-three test holes (Fig. 1). The geologic interpreta-

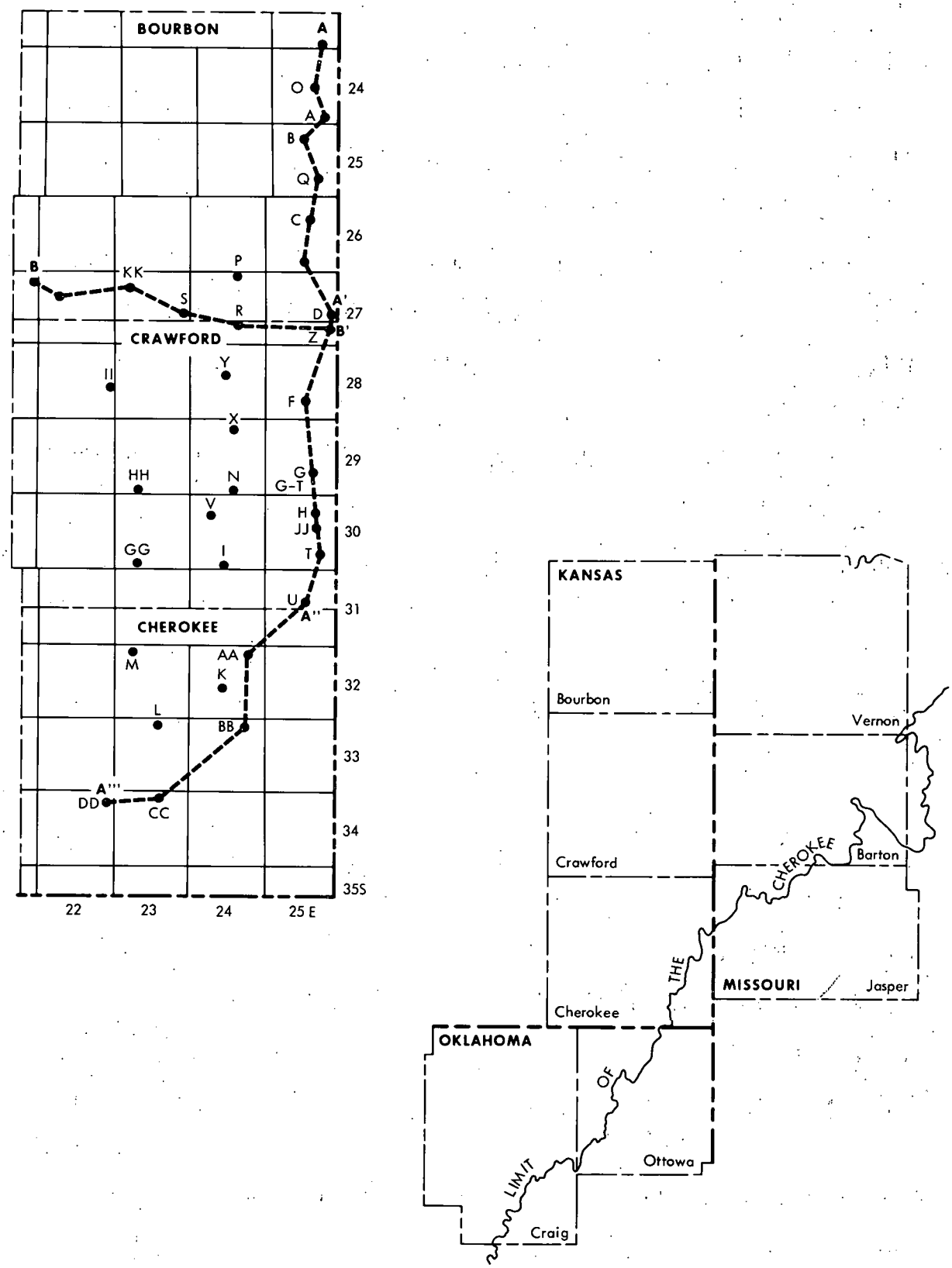


Figure 1.--Location Map of study area and of KGS-ERDA testholes; locations of cross sections in Figures 9 and 10.

tion offered here is based on all available data, whereas, the interpretation of reservoir rock quality and oil content of the sandstones is based almost wholly on data acquired during this research program. Further information on methods of operation and analysis are described in Appendix A.

In Kansas, the area of study comprises approximately one million acres. The locations of the thirty-three test holes drilled during this investigation were based in part on the need to evaluate oil shows in pre-existing points of control and in part on the absence of control in parts of the area. Although providing a fairly loose network of control, this drilling program succeeded in recovering materials which are probably representative of the subsurface section throughout the area, judging from the range of results achieved. Together with pre-existing data, these test holes should form an adequate basis for estimating the resource of heavy-oil in the area of study.

GEOLOGY

Regional Geology

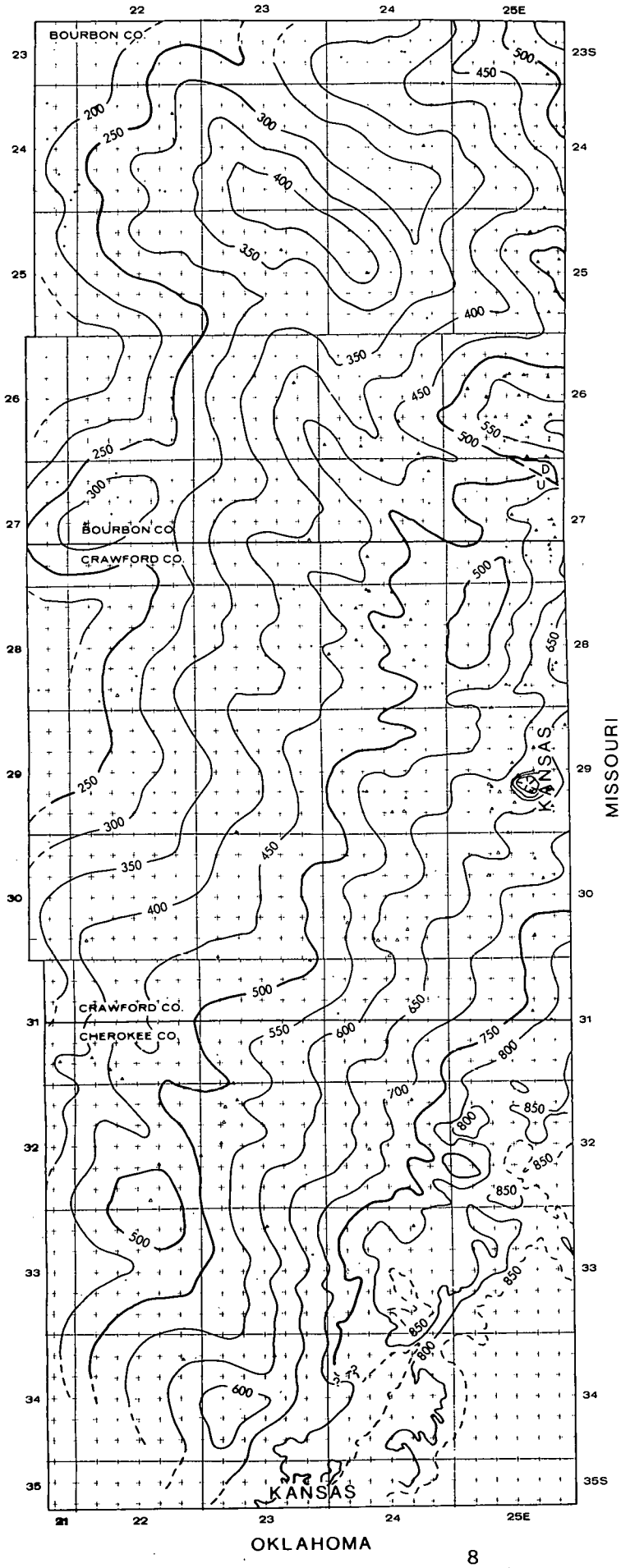
While there are numerous geologic formations which contains surface-indications of heavy, viscous oil or near-solid tar in southeastern Kansas and adjoining Missouri and Oklahoma (Jewett, 1940; Searight, 1957; Jordan, 1964), none is as important as are the formations of the Cherokee Group of Middle Pennsylvanian age (Wells and Anderson, 1968; Ebanks and James, 1974). These rocks, which occur at the surface within part of the area of study, are continuous downdip to the west with subsurface rocks from which more than a half-billion barrels of oil have been produced (Goebel, 1966). In southeastern Kansas, these

Cherokee Group rocks lie above an ancient erosional surface on the top of the Mississippian Limestone which dips northwestward at a rate of 40 to 50 feet per mile (Fig. 2). A mapping datum in the middle of the Cherokee and the top of the Cherokee dip in the same direction at a lesser rate, the latter at a rate of 20 to 30 feet per mile (Figs. 3-4), indicating a westward and southward thickening of the Cherokee section from 350 feet in eastern Bourbon County to 475 feet in western Crawford County. The Cherokee sediments tended to fill-in irregularities in the Mississippian surface, and, as will be discussed below, patterns of sandstone deposition were affected by some of these irregularities.

There are few examples of local structures which have influenced trapping of oil in Cherokee rocks. More often, structural attitude serves only to localize oil or gas in updip portions of discontinuous sandstones. Far more important in trapping oil is the actual extent of porous, permeable sandstone.

One local structure of note here is a small fault in the Mississippian limestone in T27S, R25E, Bourbon County. This northwest-southeast trending fault is probably an extension of the well known Chesapeake Fault of eastern Barton County, Missouri (Wells, 1977). It is noteworthy here because it obviously affected the thickness of lower Cherokee sandstone deposited along its trace. Movement on this fault apparently did not reoccur after the Mississippian.

The Cherokee sediments in southeastern Kansas probably have never been buried by more than 3500 feet of younger sediment (Ebanks and James, 1974), most of the previous cover in the area of interest here, of course, having since been eroded during the time following withdrawal of Cretaceous seas. Hydrocarbons accumulating in these rocks probably



KEY TO CONTROL

- Geophysical log
- Continuous core
- Well-sample log
- Driller log only
- Geophysical and Well-sample logs

SCALE

MILES

0 1 2 3 4 5

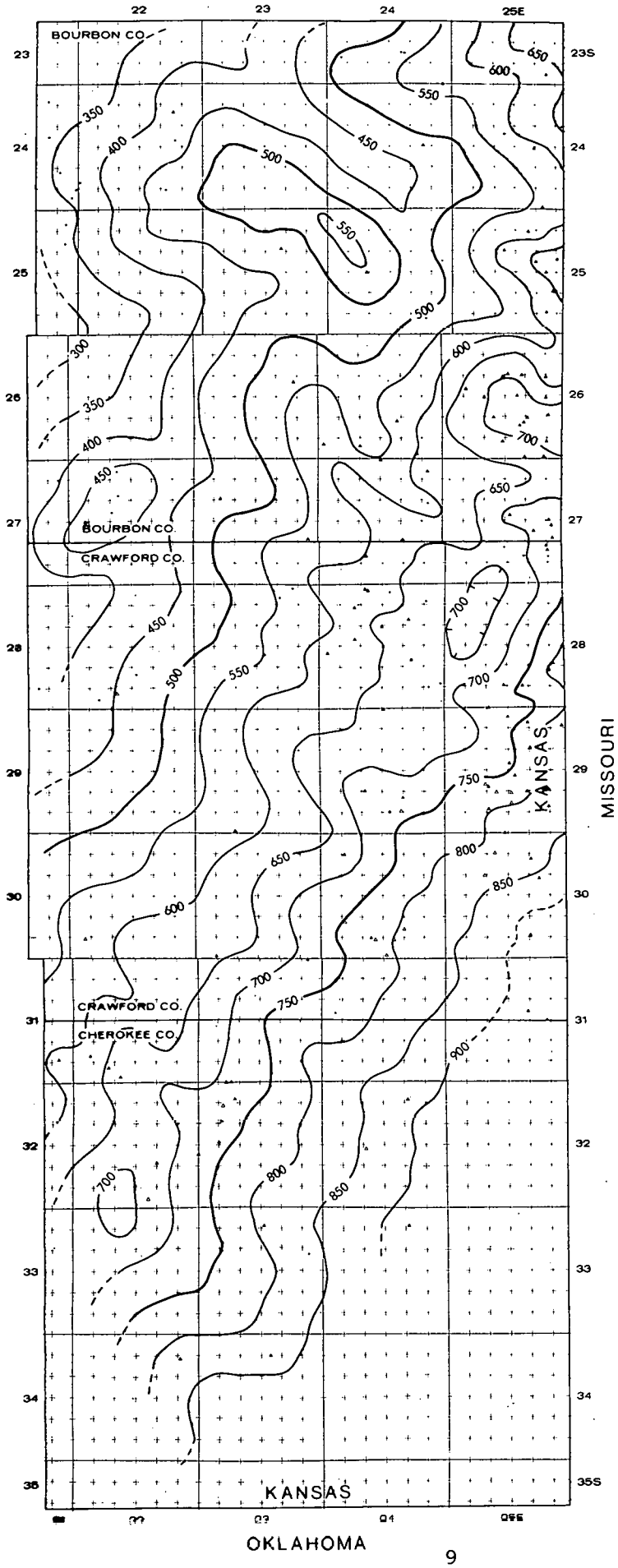
0 1 2 3 4 5 6 7 8

KILOMETERS

Datum: Sea level

Kansas Geological Survey	
S.E. KANSAS HEAVY OILS PROJECT	
STRUCTURE TOP OF MISSISSIPPIAN	
C.I.=50 FEET	FIGURE: 2
W.J. EBANKS, JR.	JUNE 1977

(Base from the State Highway Commission of Kansas, 1969)



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SCALE

MILES

0 1 2 3 4 5

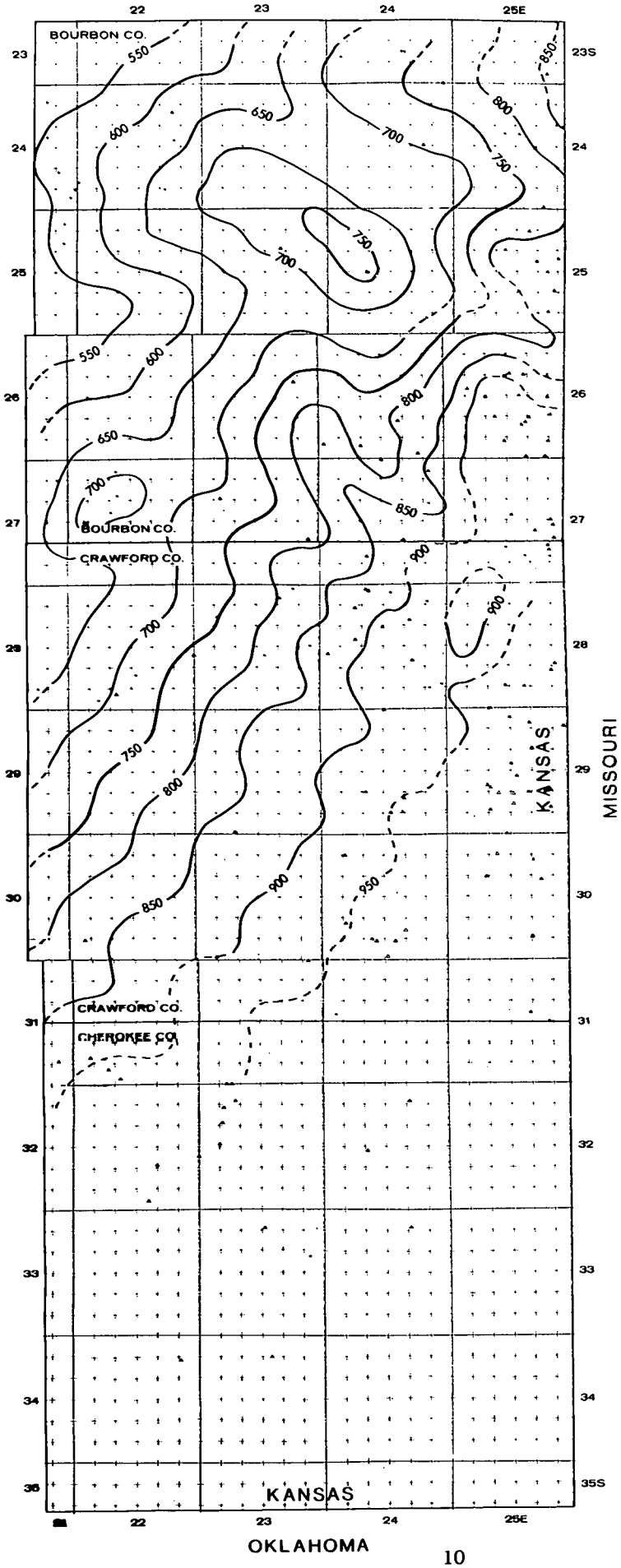
0 1 2 3 4 5 6 7 8

KILOMETERS

Datum: Sea level

Kansas Geological Survey	
S.E. KANSAS HEAVY OILS PROJECT	
STRUCTURE TOP OF BLUEJACKET MARKER	
C.I.= 50 FEET W.J. EBANKS, JR.	FIGURE: 3 JUNE 1977

(Base from the State Highway Commission of Kansas, 1960)



KEY TO CONTROL

- Geophysical log
- Continuous core
- Well-sample log
- Driller log only
- Geophysical and Well-sample logs

SCALE

MILES

0 1 2 3 4 5

0 1 2 3 4 5 6 7 8

KILOMETERS

Datum: Sea level

Kansas Geological Survey

S.E. KANSAS HEAVY OILS PROJECT

STRUCTURE TOP OF CHEROKEE GROUP

C.I.= 50 FEET | FIGURE: 4

W.J. EBANKS, JR. | JUNE 1977

(Base from the State Highway Commission of Kansas, 1966)

were generated in the enclosing shales. Evidence for this is found in the high organic-matter content of some of these shales and in the discontinuity of the sandstone reservoir rocks, which precludes migration from some more distant source (Weirich, 1953).

Thus, whatever chemical changes have been effected in these crudes, such as the alteration to heavy-oil, have occurred in a structural setting which was only slightly different from that in which they occur today, that is, shallow burial with only weak deformation. The small amount of change in the chemistry of the crude oil probably attributable to this simple structural history in the shallow tri-state province contrasts with the much greater effects probably caused by their exposure to fresh water. The causes and the variability of alteration of original oils to heavy-oils will be discussed below.

Stratigraphy

The Cherokee Group was the earliest of the Pennsylvanian "cyclic" sequences of sediments to be deposited in the Midcontinent area (Howe, 1956). Cherokee sediments are mainly terrigenous clastic sandstones and shales interbedded with thin coal deposits and underclays and a few thin limestone beds. Later cyclic sequences, such as the Marmaton Group, which overlies the Cherokee, include much more limestone and almost no coal, supporting the concept of increasingly widespread marine invasion of this area throughout middle and later Pennsylvanian time. Environmental conditions varied with the interplay of changing sediment supply and rates of basin subsidence. In this setting, the Cherokee Basin has been depicted as the site of shifting and prograding alluvial and deltaic systems, estuaries, tidal delta complexes, beaches, and shallow marine shelf environments (Bass, 1936); Baker, 1962; Hayes, 1963; Visher,

et al, 1971). Individual sand bodies in the Cherokee section have been described variously as ancient nearshore bars (Dillard, et al, 1941), barrier islands (Bass, 1936), tidal flat-tidal channel deposits (Hayes, 1963), and alluvial valley-fill sediments (Rich, 1923; Charles, 1941; McQuillan, 1968).

While each of these interpretations is probably correct in some area, the predominant mode of deposition of the heavy-oil bearing sediments in the present study area is interpreted here to have been repeated prograding of fluvial-deltaic systems from the east, westward into Kansas and ultimately southward into Oklahoma. Each progradation consisted of the extension of sand-rich depositional "lobes" and of "belts" of sandy deposits into or over environments in which mostly muddy or silty sediment existed or where peat swamps had formed. The sands deposited in this manner are, quite naturally, highly lenticular, curvilinear, and discontinuous. In the subsurface, they can be mapped only as areas in which certain amounts of sand probably will occur. These sandstones most certainly do not occur as continuous, evenly bedded, "blanket" sandstones of uniform thickness. This fact is important in formulating estimates of the volume of oil-reservoir rock in the area.

Oil Bearing Sandstones

Within the three-county area of this study there are five stratigraphic intervals of the Cherokee Group in which some heavy-oil bearing sandstone occurs. These sandstones are identified by surface geologic names in this report, and they are defined as occurring between certain correlation markers, as described in Appendix B. The names applied here, although they are names of actual sandstones which have been defined at surface locations in northeastern Oklahoma, are used inform-

ally. The reason for this practice is, in part, the discontinuity of these sandstones and, in part, mis-correlations among the three states which have been discovered as a result of the present study. Further work has been begun to resolve these differences, but they do not affect the assessment of heavy-oil resources presented here or in subsequent reports on Missouri and Oklahoma. The results of this additional study will be published by appropriate State Geological Surveys in the future.

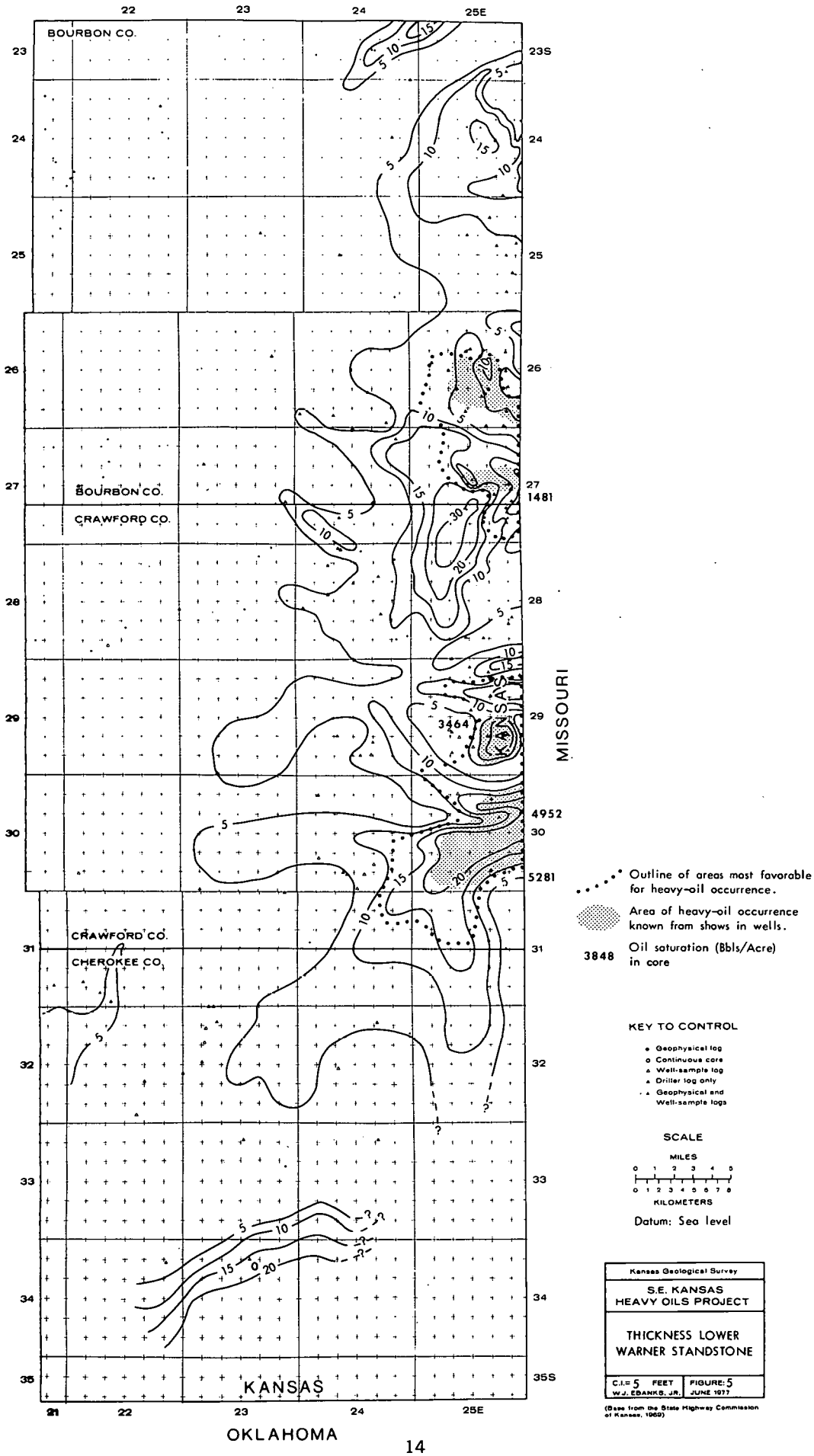
The oil-bearing sandstones of importance here are, from the lowest upward, the Lower Warner, Upper Warner, Lower Bluejacket, Upper Bluejacket, and Lower Cabaniss Sandstones. Only traces of oil were found to occur in any of the sandstones higher in the section than these.

The maps of sandstone distribution presented here (Figs. 5-8) are interpretive, relying on the concept that these Cherokee sandstones are parts of a larger system of fluvial, deltaic, and coastal sand deposits to guide extrapolation of data from penetrations of the sands in wells. Because of the scarcity of data in the western one-half of the study area, the result is a set of maps which may be optimistic in their portrayal of extent of the sandstones.

RESOURCE OF HEAVY-OIL

General

Factors to be considered in estimating the size of the resource of heavy-oil in southeastern Kansas subsurface Cherokee sandstones are: areal extent and thickness of potential reservoir rock; location and quality of oil shows in the reservoirs; and quality of the reservoir rock in terms of its porosity and permeability. Geochemistry of the oils, which is important to their refinability, will be discussed in a later section.


BOURBON CO.
BOURBON CO.
CRAWFORD CO.
CRAWFORD CO.
CHEROKEE CO.
KANSAS
OKLAHOMA
MISSOURI
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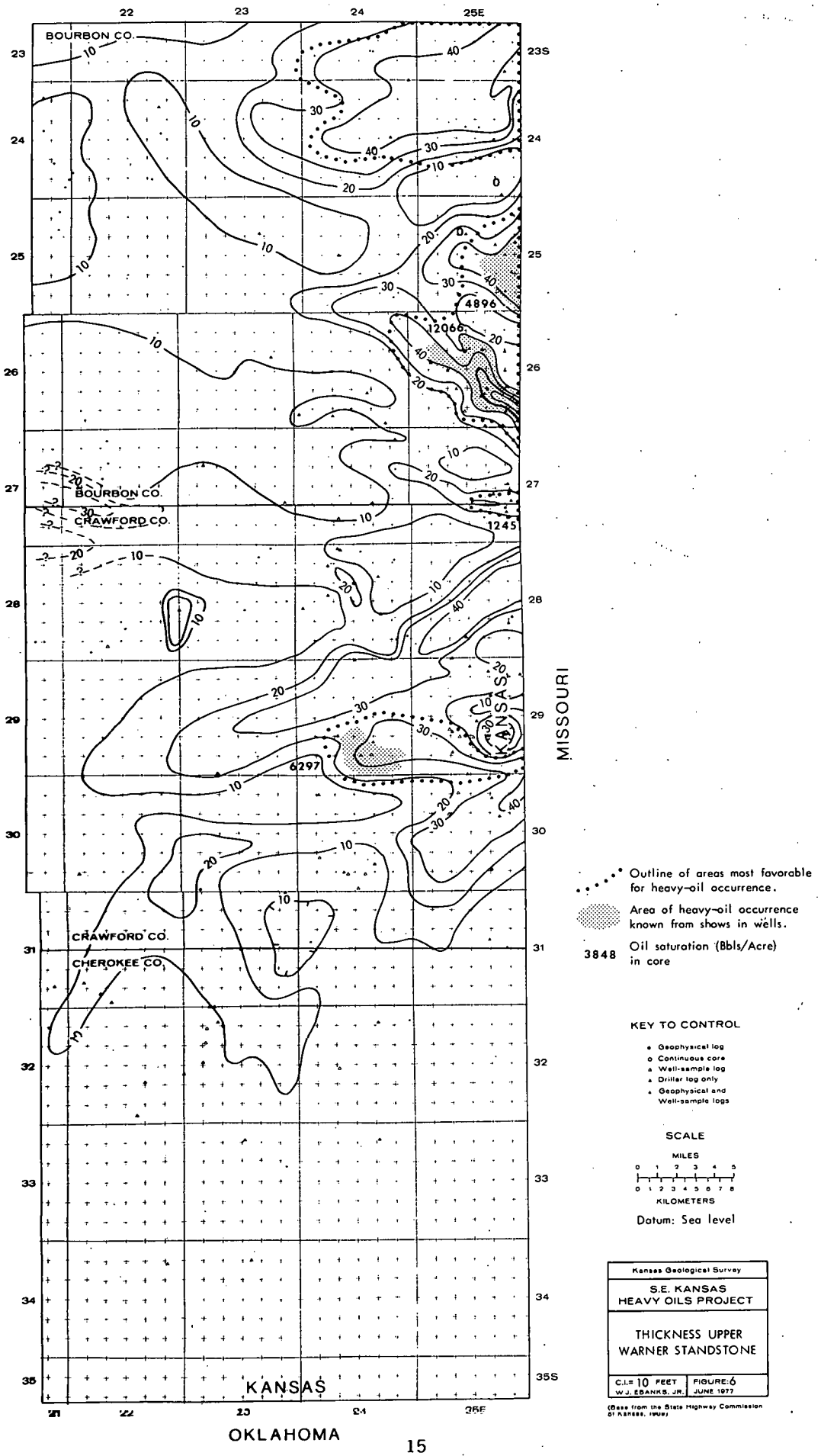
3464
4952
5281
Outline of areas most favorable for heavy-oil occurrence.
Area of heavy-oil occurrence known from shows in wells.
3848 Oil saturation (Bbls/Acre) in core
KEY TO CONTROL
Geophysical log
Continuous core
Well-sample log
Driller log only
Geophysical and Well-sample logs
SCALE
MILES
KILOMETERS
Datum: Sea level
Kansas Geological Survey
S.E. KANSAS HEAVY OILS PROJECT
THICKNESS LOWER WARNER SANDSTONE
C.I.= 5 FEET
FIGURE: 5
W.J. EBANKS, JR.
JUNE 1977
(Base from the State Highway Commission of Kansas, 1969)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BOURBON CO.
CRAWFORD CO.
CRAWFORD CO.
CHEROKEE CO.
KANSAS
MISSOURI
OKLAHOMA
4896
12066
1245
6297
10
20
30
40
Outline of areas most favorable for heavy-oil occurrence.
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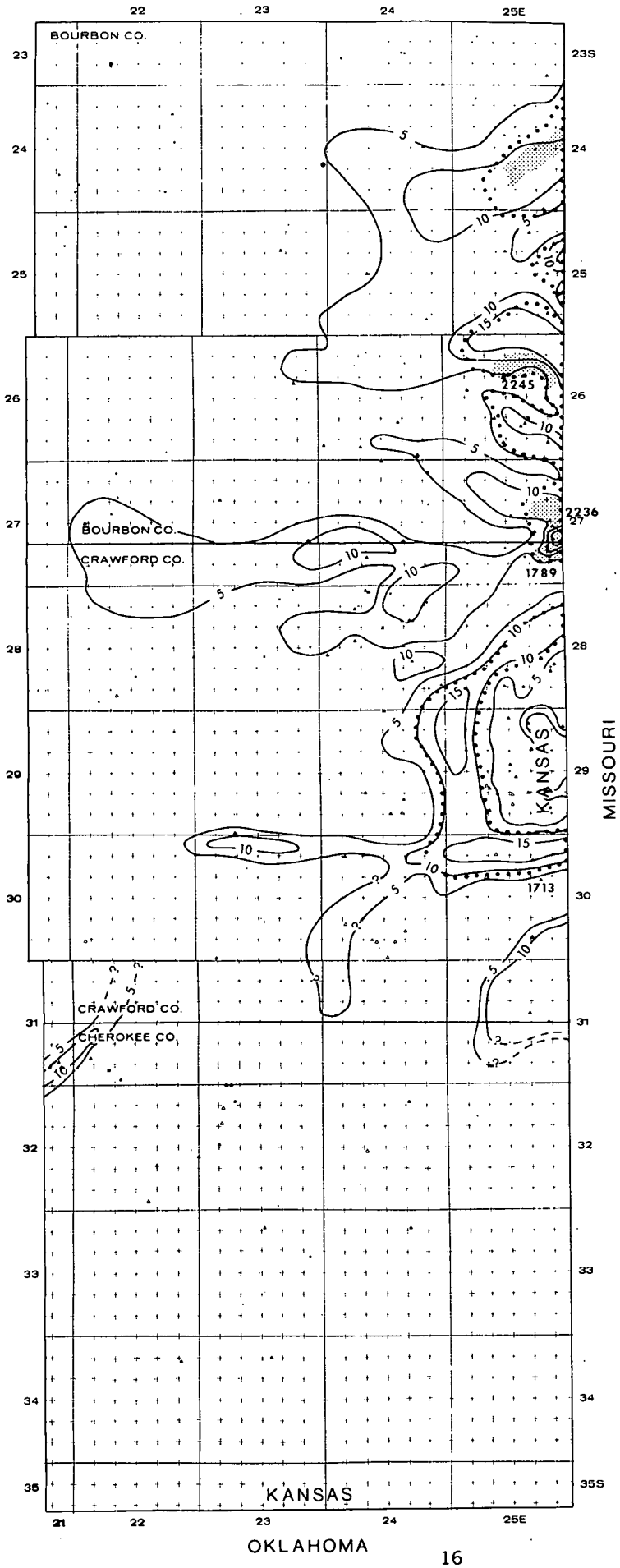
MILES
0 1 2 3 4 5
0 1 2 3 4 5 6 7 8
KILOMETERS
Datum: Sea level
Kansas Geological Survey
S.E. KANSAS HEAVY OILS PROJECT
THICKNESS UPPER WARNER STANDSTONE
C.I.= 10 FEET
FIGURE: 6
W.J. EBANKS, JR.
JUNE 1977
(Base from the State Highway Commission of Kansas, 1966)



Outline of areas most favorable for heavy-oil occurrence.

Area of heavy-oil occurrence known from shows in wells.

3848 Oil saturation (Bbls/Acre) in core

KEY TO CONTROL

- Geophysical log
- Continuous core
- Well-sample log
- Driller log only
- Geophysical and Well-sample logs

SCALE

MILES 0 1 2 3 4 5

0 1 2 3 4 5 6 7 8 KILOMETERS

Datum: Sea level

Kansas Geological Survey

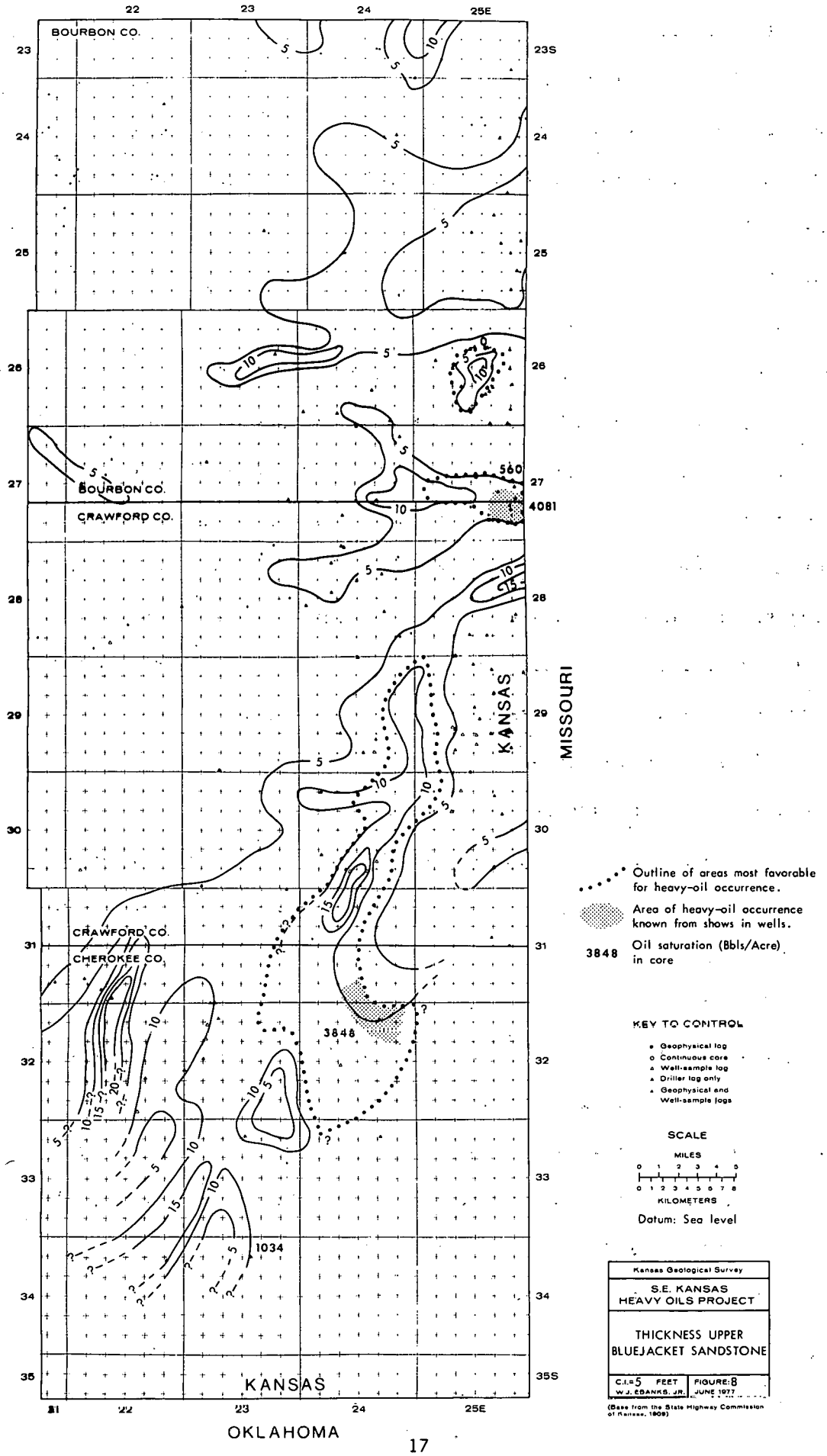
S.E. KANSAS HEAVY OILS PROJECT

THICKNESS LOWER BLUEJACKET SANDSTONE

C.I.= 5 FEET | FIGURE: 7

W.J. EBANKS, JR. | JUNE 1977

(Base from the State Highway Commission of Kansas, 1969)


BOURBON CO.
CRAWFORD CO.
CHEROKEE CO.
KANSAS
MISSOURI
OKLAHOMA
560
4081
3848
1034
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Geophysical and Well-sample logs
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MILES
KILOMETERS
Datum: Sea level
Kansas Geological Survey
S.E. KANSAS HEAVY OILS PROJECT
THICKNESS UPPER BLUEJACKET SANDSTONE
C.I.=5 FEET
FIGURE: 8
W.J. EBANKS, JR.
JUNE 1977
(Base from the State Highway Commission of Kansas, 1968)

Earlier estimates of resource-size in this area (Ebanks and James, 1974) were based on projections of at least 50,000 acres of this area being underlain by sandstones which have an average thickness of 20 feet and which contain approximately 400 barrels of oil-per-acre-foot of porous rock.

Oil Shows

Shows of oil were encountered in cuttings of one or more sandstones in 29 of the 33 test holes drilled during this project (see logs in Appendix C). Approximately 1,100 feet of sandstone were penetrated by drilling or coring. Of this total amount of sandstone penetrated, 354 feet were cored because of oil shows in the drilling samples from the top of the sandstone. Of the 354 feet cored, only 219 feet of oil-bearing sandstone were recovered which warranted analysis for the contents of the cores. Only 130 feet of the core analyzed contained oil-saturation greater than 15 percent of the pore volume; further, only 9 feet of oil sand contained an oil-saturation greater than 50 percent. Of the 219 feet of sandstone cores analyzed, only about one-fourth, or 56 feet, contained oil in amounts greater than 400 barrels of oil-per-acre-foot. The thickest individual sandstone with oil-saturation of this amount was only 12 feet thick (Hole C, Upper Warner Sandstone).

No free oil, that is, oil which would flow into an open hole, was encountered during this drilling. Most of the shows of oil in cuttings samples or in the drilling fluids were easily detected by the well-site geologist during drilling, because all of the drilling was performed during daylight hours. These shows ranged in quality from shiny flecks of brittle, dead oil (Gilsonite?), to smears or impregnation of the samples with tar-like heavy-oil, to tiny droplets of dark, live oil

"bleeding" from sample chips or cores. Shows of oil which are noted on logs of other wells drilled in the study area were evaluated through some of the drilling done here, and these greatly enlarged the base of data for recognition of areas which are favorable for further development. All such data which were available were considered in this study. There are obvious deficiencies, however, in the inability to incorporate information from many of the drillers' logs representing early drilling in the area.

Core Analyses

Results of the analysis of cores taken during this project are presented graphically in Appendix D and on maps of sandstone distribution (Figs. 5-8). Methods of handling of cores are described in Appendix A.

Results of the core analyses are important here for two reasons: they are the best sources of data available on actual amounts of oil-in-place in the various sandstones; they provide valuable information on the ranges of properties of these reservoir rocks. Twenty-five cores were taken from sixteen different test holes.

Amounts of extractable hydrocarbons in the cores (oil saturation) range from zero to 955 Barrels per Acre-foot. Commonly, the highest degree of oil saturation occurs in intervals of the rock which have the lowest porosity and are the least permeable, although this is not true in all cases. This characteristic has been noted by others (French, 1977) and interpreted to be an indication of natural flushing of the oil sands by groundwater at some earlier time. Geochemistry of the oils is compatible with this suggestion, as will be discussed below.

In Table 1 are listed average characteristics of the oil-bearing sandstones, as determined from core analyses. Appendix D contains the data from which these average values were computed. The rather large values of standard deviation for some of these sets of data indicate their variability. Further, the standard deviations of permeability values shown on the core graphs are apparently not valid, indicating that these values are not normally distributed. For these reasons, a single arithmetic "average" value of porosity or permeability of a sandstone does not adequately describe its nature as a reservoir rock. Reference to the core-graphs of Appendix D confirms this observation.

SANDSTONE	POROSITY (%)		PERMEABILITY (md.)
	Mean	Std. Dev.	
Lower Cabaniss	18.7	3.4	93.7
Upper Bluejacket	18.2	4.9	2.4
Lower Bluejacket	18.8	2.9	25.4
Upper Warner	20.8	3.0	94.1
Lower Warner	20.8	2.5	67.9

Table 1. Petrophysical properties of Cherokee sandstones in subsurface area of study. Numbers listed are arithmetic averages of values derived from cores taken in this study (Appendix D). Standard deviation is not given for permeability because values of this parameter are not normally distributed.

Some intervals of sandstone are heavily saturated with oil and include no significant discontinuities to fluid flow, such as shale partings, or layers which are tightly cemented. Other intervals are composed of thin, wavy interbeds of sand and shale, or are poorly

sorted, well cemented, conglomeratic sandstone which, although containing oil, are impermeable to air in core analysis.

The large amount of clay matrix in these sandstones, which is often accompanied by mica and finely divided, fibrous, carbonaceous material, is also detrimental to porosity and permeability. These constituents of the rock are most common in the upper parts of most of the sandstones, although they occur lower in some sands which are in gradational contact with fine sediments below. The most favorable petrophysical properties occur in the middle and lower parts of most of the sandstones encountered in this study. The fact that not all of the thickness of a sandstone will be effective as a reservoir rock and respond favorably to attempts to produce the oil it contains is, of course, important in the estimation of reserves of recoverable oil in a producing area. This factor is not considered in the approximate estimation of resources of heavy-oil given here.

Sandstone Distribution

Maps of sandstone distribution for each of the correlation intervals described above, except for the Lower Cabaniss Sandstone interval, are given in Figures 5-8. No map could be drawn for the latter because of the few points of control available. It is apparent from these maps that the discontinuity and changeable thickness of the sandstones strongly affects estimates of oil-resource size. For instance, sandstone thicker than 2 to 5 feet is not present in much of the western one-half of the study area.

The Lower Warner Sandstone is concentrated in lobate bodies near the Missouri-Kansas border (Fig. 5), with the exception of a poorly defined trend which probably extends, partly in outcrop, from Missouri,

across southeastern Cherokee County, to Oklahoma. The Upper Warner Sandstone is volumetrically the most important of the potential reservoir rocks. It may be as thick as 60 to 80 feet in limited areas, and it commonly is 30 to 40 feet thick (Fig. 6). This sandstone also occurs in lobate or digitate patterns which are mapped more or less accurately, depending on the density of control available.

The Lower and Upper Bluejacket Sandstones are thinner than the Warner sandstones. The Upper Bluejacket tends to occur more commonly along the Missouri-Kansas border, whereas the Lower Bluejacket is more common in occurrence in western Cherokee County (Figs. 7 and 8). Again, the thinness and discontinuity of these sandstones implies that oil deposits occurring in these sands will be rather small individually.

The Lower Cabaniss Sandstones are present in only a few wells in the study area, all in the western half. These sandstones probably occur as long, narrow, fairly thick sand bodies. Wells in which fairly thick sands are present are offset by wells within a mile or two in which no sand is present. The trend of elongation of these sands may be nearly north-south through the area of study. Oil is produced from sandstones which are equivalent to these in a complex of small fields on the border of northwestern Bourbon County and the next county west.

Estimation of Heavy-Oil Resource

Oil shows in wells and the results of core analyses of each sandstone were used to delineate areas which seem most favorable for the occurrence of heavy-oil deposits (Figs. 5-8). In addition, smaller areas, in which core analyses indicate that a significant amount of oil is present, are indicated. The extent of these areas is based on knowledge of the type and amount of sandstone, the structural attitude of

the beds, oil-content of key wells as derived from core analyses, and the presence of shows of oil in wells which are near those cored. The sizes of these "areas of known oil occurrence" are, nevertheless, a matter of judgment.

A total of 200 to 225 million barrels of oil are estimated to be in-place in only the areas of "known oil occurrence" described above and shown on maps in Figures 5-8. This amount is significantly lower than the amount of heavy-oil conjectured to be present by Ebanks and James (1974) and very much lower than other estimates, which have been as high as several billion barrels of oil (Enright, 1964). Even if estimates derived here are in error by as much as 100% due to lack of adequate control, the total resource would not be anywhere near the billion-barrel figure. If an arbitrary estimate of 100 million barrels of heavy-oil were to be assigned to the Lower Cabaniss Sandstones, which were not adequately defined by this study, the estimates of resource-size remain quite a bit lower than anticipated by earlier work. The principal reason for this lower-than-expected amount of heavy-oil resource is the discontinuity of potentially favorable reservoir rock.

Reserves of Recoverable Oil

The amounts of oil in the heavy-oil bearing sandstones of southeastern Kansas which can be considered in the category of "reserves," that is, oil which could be produced under currently available technology and economics, must be considered as zero. Previous attempts to recover oil from these types of deposits have met with only limited success and have never proven to be economically attractive. Presently, the outlook for the economic aspects of such projects, even if they

qualify for upper-tier price for the oil produced, are questionable because of uncertain government policy toward taxation of these very risky and expensive operations.

Past reviews of field experiments in recovering heavy-oil from Missouri-Kansas Cherokee sandstones (Emery, 1962; Trantham and Marx, 1966; Smith, 1966; Valleroy, et al, 1967; Heath, et al, 1972; Elkins, et al, 1974; Harvey and Arnold, 1974) indicate several characteristics of the deposits which have defeated successful application of various techniques of oil recovery. Among these are thinness and shaliness of many of the sandstones, shallow depth of burial, low oil-saturation, high viscosity of the oil, partial flushing by groundwater, and uneven permeability distribution which leads to poor sweep-efficiency in oil-displacement processes.

Unfortunately, most of these characteristics are common to the sandstones studied here. It may be possible, however, to locate, within the "areas most favorable for heavy-oil occurrence" shown on Figures 5 to 8, deposits whose quality and extent would encourage attempts at development. This possibility would be maximized by further drilling in areas in which prospects for encountering oil in more than one sandstone interval are good, such as in southeastern Bourbon and northeastern Crawford Counties.

GEOCHEMISTRY

Introduction

Regional variations of the chemical characteristics of Cherokee crude oils and oil sands in southeastern Kansas have been previously described and interpreted by Ebanks and James (1974) and Gould (1975). These studies concluded that the heavy crude oils (less than 25° API gravity) contain little or no gasolene-range hydrocarbons (C_4-C_7), and that they have only small amounts of C_{15}+ normal paraffins, higher sulfur contents, and higher non-hydrocarbon contents, compared with lighter oils (25° to 42° API gravity) present in other parts of the Cherokee basin. These characteristics were interpreted as resulting from a combination of fresh-water washing and bacterial alteration which took place when surface waters entered a reservoir rock, dissolving some of the lighter hydrocarbons and introducing bacteria which destroyed some of the lighter paraffins as well as the heavier normal paraffins (Williams and Winters, 1969). Further study of oils extracted from cores obtained in the course of the present study are discussed here (see Appendix E for locations of samples).

Results

The mean value of bitumen saturation of Cherokee oil sands for Bourbon, Cherokee, and Crawford counties are presented in Table 2. The standard deviations for the set of samples from each county are also presented to give an idea of the variation encountered. Mean values and standard deviations for the amount of hydrocarbons (saturated hydrocarbons and aromatic hydrocarbons) present in the bitumen, and the saturate to aromatic hydrocarbon ratios are also presented in this table. Results of individual analyses are tabulated in Appendix F.

Table 2 Average bitumen saturations of Cherokee oil sands in southeastern Kansas.

	% Bitumen	% Hydrocarbons	Saturates/Aromatics
Bourbon Co. (6 samples)	1.6 ± 1.2	67 ± 9	1.33 ± 0.16
Cherokee Co. (5 samples)	2.4 ± 0.6	71 ± 6	1.36 ± 0.35
Crawford Co. (20 samples)	1.4 ± 0.8	70 ± 8	1.41 ± 0.17

Table 3 Average values of hydrocarbon group analyses of Cherokee oil sands.

	Saturated H.C.	Aromatic H.C.	NSO's	Asphaltenes
Bourbon Co. (6 samples)	38 ± 6	29 ± 4	15 ± 5	18 ± 5
Cherokee Co. (5 samples)	41 ± 8	30 ± 4	15 ± 3	14 ± 7
Crawford Co. (20 samples)	40 ± 5	29 ± 4	15 ± 4	16 ± 9

Table 4 Hydrocarbon Analyses of Cherokee Oil Samples. For locations, see Appendix E.

	H.M.C.-J3-1-2	MO.D.N.R.-20-C	ERDA Bartlett
API Gravity	24°	21°	15°
% Light HC's	21	15	10
% C 15+	79	85	90
% Sat. HC	45	42	42
% Aro. HC	33	35	33
% NSO's	11	12	10
% Asphaltenes	11	11	15
Sat/Aro	1.36	1.20	1.27
% HC	83	80	78
% Non-HC	17	20	22

Methods of geochemical analysis and definitions of terms used here are given in Appendix G.

Table 3 contains the mean values and standard deviations for the results of the C_{15}+ hydrocarbon group analyses of the Cherokee oil sands. Group hydrocarbon analyses of three Cherokee oils from the area of study and adjacent areas are presented in Table 4.

Discussion

Although the bitumen saturations and hydrocarbon contents found in these samples are variable, the ranges of these characteristics are fairly consistent in all three counties. The overall average bitumen saturation of 1.6% is quite low when compared with deeper oil sands in Kansas and outcrops in western Missouri, as well as from the world's major oil sand deposits. Gould (1975) examined three samples of cores from Woodson, Allen, and Bourbon counties and found bitumen saturations of 5 to 6% in these Cherokee sands. James (unpublished data) examined samples from previously worked surface quarries (Iantha and Bellamy) in western Missouri and found saturations of 8 and 11%. Walters (1974) observed that the major oil sand deposits of the world commonly average 6 to 12% bitumen, and Allen and Sanford (1973) reported the bitumen content of the economical oil sand of the Athabasca Great Canadian Oil Sands operation as averaging 12%, and varying from 8 to 18%.

The hydrocarbon content of the bitumen present in the shallow Cherokee oil sands of southeastern Kansas is moderately high, averaging about 70%, although it is fairly variable (ranging from 50 to 82%). By way of comparison, the Athabasca oil sands average about 50% hydrocarbons. The wide range of saturate to aromatic hydrocarbon ratios (0.8 to 1.8) is interpreted as indicating a wide range in the amounts of

normal paraffins present in these samples. The hydrocarbon group analyses indicated that the bulk of these bitumens should be considered naphthenic in character as opposed to asphaltic. The compositions of the oil samples examined in this study are typical of the heavier oils frequently encountered in the Cherokee petroleum province, some of which are presently being produced by waterflood operations.

CONCLUSION

Results of this re-evaluation of the extent of heavy-oil deposits in southeastern Kansas are discouraging to the hope that this largely untapped resource might have become an important addition to the state's and to the nation's energy resource budgets. Even the most conservative earlier estimates of the volume of this resource seem now to have been optimistic.

While there is room for further drilling and definition of locally rich deposits in the shallow subsurface of the study area, and possibly in some adjoining areas, it is clear that the heavy-oils do not occur in widespread, "blanket-like" sandstones. Rather, they occur as smaller concentrations in irregularly distributed, discontinuous sandstone bodies which vary greatly in thickness in short distances. This characteristic will determine the size and scale of any operation designed to recover the oils.

These heavy-oils in Kansas occur mostly at depths which are too great to facilitate strip mining. Most of them are too shallow, however, to be amenable to high-pressure thermal recovery methods. Thinness and shaliness of some of the sands are other features which discourage development. There remains a possibility of application of some

techniques of enhanced recovery, probably involving thermal stimulation or some type of solvent flooding, if these methods can be shown to be applicable here, for recovery of heavy-oil in certain limited areas. Care should be taken, however, before initiating any such project, to establish the extent and continuity of a prospective sandstone reservoir and the amount of oil it contains. Further, the quality, that is the degree of alteration, of the crude oil should also be established. Each local deposit may vary considerably in these characteristics within a small area.

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APPENDIX A

FIELD AND LABORATORY METHODS

Data for the evaluations offered in this study were obtained through combined drilling and surface geologic field work. The three states which are involved in the project, Missouri, Kansas, and Oklahoma, coordinated field and laboratory findings through frequent conferences and exchanges of data during the project.

Thirty-three test holes were drilled, of an original thirty-nine locations staked based on priorities established early in the project, before budget constraints prevented further drilling. Permitting, drilling, casing, plugging, and reporting of the test holes were done in accordance with regulations of the Kansas Corporation Commission. Drill sites were restored to the satisfaction of county officials. An air-rotary drilling technique was employed which assured almost no sample mixing, good sensitivity to shows of oil and gas, and good definition of coal and limestone beds. Most locations were in a shallow ditch or wide shoulder along a county road, as approved by county officials and utilities representatives. Elevations of drill sites were surveyed in from the nearest section corner, or bench mark if possible, and are reported to an accuracy of the nearest even one-foot.

Geologists observed the drilling constantly and collected cuttings samples for preservation at intervals of five feet during drilling. Cuttings were examined at intervals as small as one foot in some cases to obtain desired definition of thin beds. Coring points were chosen usually on the basis of shows in the cuttings, but a few cores were taken in anticipation of oil-bearing sandstone which occurs in a nearby

well. All holes were drilled to the first sign in cuttings of chert or limestone at the anticipated depth of the Mississippian Limestone. This procedure, while minimizing the chance of encountering gas or loss of circulation at total depth, did make possible the confusion of the top of a residual-chert and shale formation for the "true" top of Mississippian in a few cases.

Cores were examined and described in the field. Oil-stained sections of most cores were placed in air-tight plastic bags for transport to the core analysis laboratory. Most or all of the fluid loss observed before analysis is considered to be due to evaporation of water or to the presence of air in these cores. Very little fluid loss is thought to be due to the bleeding or flushing of oil from the cores, because of the highly viscous nature of the oils. Live-oil bleeding from cores was noted only in the less permeable sections, and, here, the fluid loss is probably negligible.

Following rig removal from a well-site, a geophysical logging unit occupied the location. A suite of logs, including natural gamma ray, induced neutron, gamma-gamma density, caliper, and long- and short-normal resistivity logs were run. No reliable self-potential logs could be obtained. The logs obtained were not recorded in an A.P.I.-approved format or with sufficient standardization to permit ordinary log analysis. No reliable sample of water from a Cherokee sandstone could be obtained for measurement of formation water resistivity. This further reduced the value of the logs for quantitative analysis, but the logs were extremely useful in complementing sample descriptions and facilitating detailed well-to-well correlations.

Cores were analyzed by a commercial laboratory, using a fluid extraction, difference-of-fluids technique to measure porosity and fluid saturations and to derive oil-content on a foot-by-foot basis. Permeability to air was also measured and used to calculate permeability-capacity of the cores.

Well samples and cores were returned to the laboratory for further analysis. Cores were cut longitudinally with a rock-saw and were examined in detail for sedimentary structures, composition, and texture. Selected samples were thin-sectioned. The thin-sections were examined with a petrographic microscope and estimates of modal composition were made. Selected samples of matrix and cementing minerals were analyzed by X-Ray Diffraction technniques.

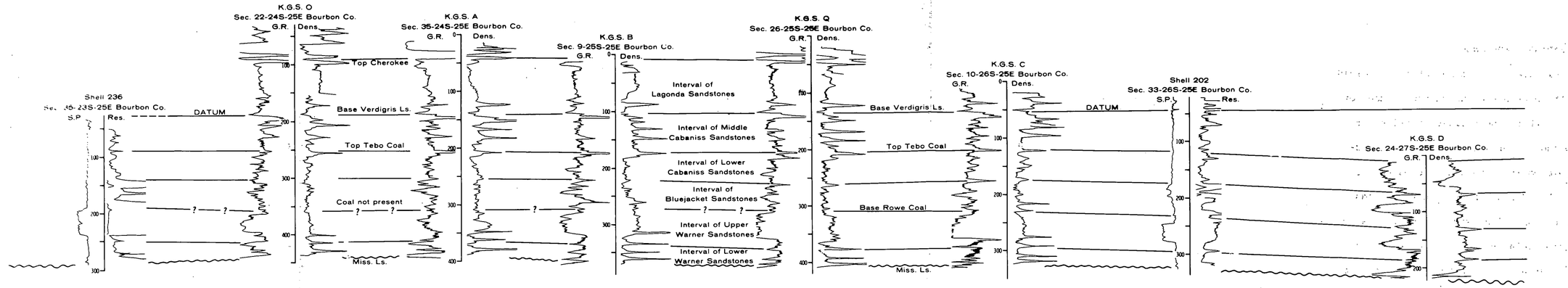
Results of the compositional analyses were combined with physical descriptions and log examination to map and interpret the origin of the sandstones of most interest here. Methods of organic-geochemical analysis of the oils extracted from these sandstones are described in Appendix G.

APPENDIX B

CORRELATION OF OIL-BEARING SANDSTONES

Traditional stratigraphic nomenclature of the three states involved in this project does not recognize the non-continuous nature of many of the sandstones in the area of study; rather, these classifications of formations have fostered the widespread use of the same name for sandstones in about the same stratigraphic position in widely separated areas. While it is clear that some thin "marker beds," that is, beds which are recognizable on combination geophysical-sample logs because of some distinctive character and position relative to other markers, do provide a basis for relatively long-distance correlation, the sandstone beds between these markers do not correlate widely.

The stratigraphic cross-sections accompanying this report (Figs. 9 and 10) demonstrate the system of correlations used to subdivide the Cherokee in the area of study and provide a basis for comparing these correlations with those in Missouri and Oklahoma. The correlations are based on recognition of several important markers: 1)Top of Cherokee Group, or base of Fort Scott Limestone ("Oswego Lime" of drillers); 2)Base of the Verdigris Limestone ("Ardmore Lime" of drillers), actually marked on Gamma Ray logs at the top of a highly radioactive black shale which occurs consistently at the base of this limestone (there is some inconsistency among local geologists as to proper choice of beds to be called "Ardmore" - hence the choice here of the unequivocal radioactive shale); 3)Top of the Tebo Coal, actually marked at the top of the radioactive black shale between the Tebo below and the Tiawah Limestone above (both the coal and limestone are more inconsistent in occurrence than is the shale marker between them); 4)Approximately the dividing point

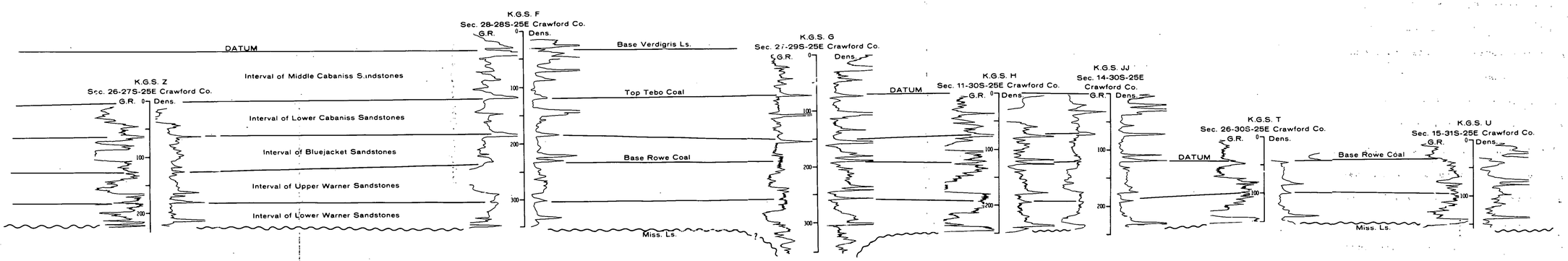


Kansas Geological Survey

S.E. KANSAS
HEAVY OILS PROJECT
Stratigraphic Cross-Section A-A'

½ mile
0.8 km.
HORIZ. SCALE

W.J. Ebanks, Jr. June 1977



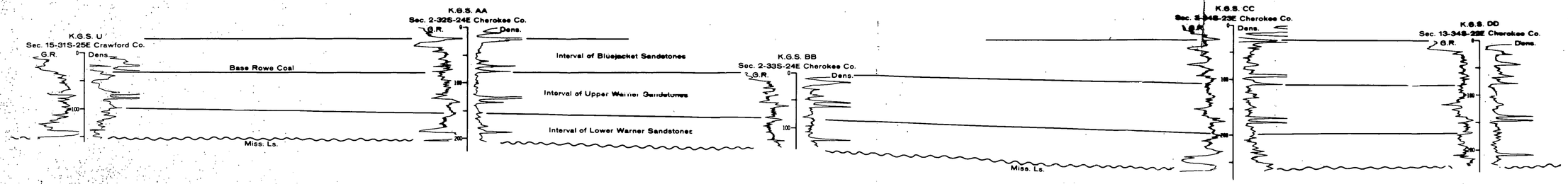
Kansas Geological Survey

S.E. KANSAS
HEAVY OILS PROJECT
Stratigraphic Cross-Section A'-A''

½ mile
0.8 km.
HORIZ. SCALE

W.J. Ebanks, Jr. June 1977

FIGURE 9

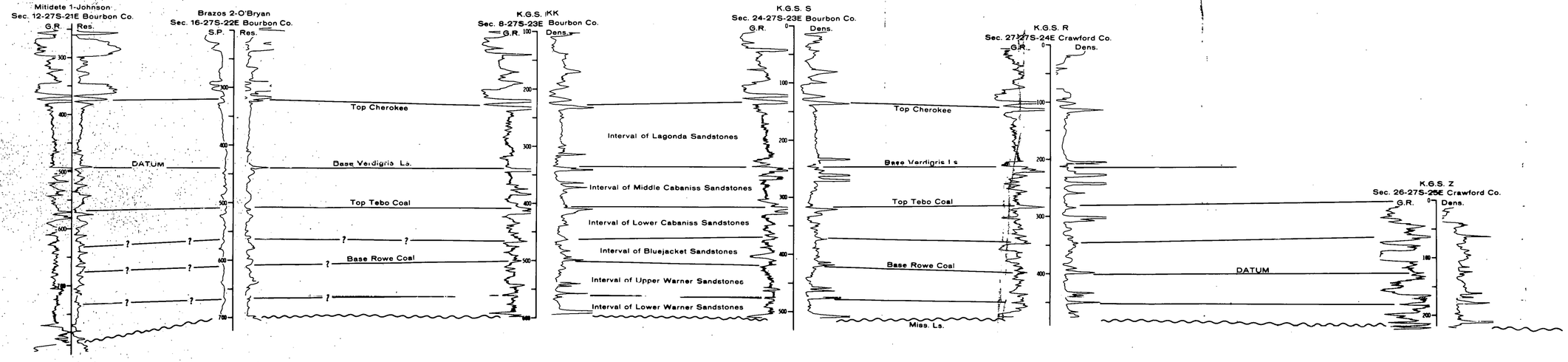


Kansas Geological Survey

S.E. KANSAS
HEAVY OILS PROJECT
Stratigraphic Cross-Section A''-A'''

½ mile
0.8 km.
HORIZ. SCALE

W.J. Ebanks, Jr. June 1977



Kansas Geological Survey

S.E. KANSAS
HEAVY OILS PROJECT
Stratigraphic Cross-Section B-B'

½ mile
0.8 km.
HORIZ. SCALE

W.J. Ebanks, Jr. June 1977

FIGURE 10

between the Cabaniss and Krebs formations, actually at the top of a radioactive black shale which is probably within the upper Cherokee, or Cabaniss, section and which is called here the lower Cabaniss marker (the so-called "Seville Limestone" which separates the Cherokee into its upper and lower divisions is probably not continuous with its type location in Illinois, but may be represented in southeastern Kansas by any one of two or three thin, argillaceous limestones at about this stratigraphic position - thus the choice here of the shale marker above these limestones and interbedded sandstones); 5)Base of the Rowe Coal, as traced from its type locality in southeastern Crawford County, near well location T (Fig. 1); 6)Base of an unnamed, but very persistent, coal bed which occurs 30 to 50 feet above the Mississippian unconformable surface in most of the study area and which is called here the lower Warner marker; 7)Top of the Mississippian limestone, or at the top of the first occurrence of chert and limestone in well cuttings at the base of the Cherokee (this may, in some locations, actually be a few inches or feet above the top of the Mississippian Limestone itself, in a zone of residual chert and shale). Because of changes in the types of sediments originally deposited over the tri-state study area, these markers are not all traceable from Missouri to Oklahoma. Other subdivisions of the subsurface section may have to be used to map sandstone occurrences in these areas outside of southeastern Kansas.

Lower Warner Sandstone. - In the interval between the Mississippian surface and the lower Warner marker is the Lower Warner Sandstone. This sandstone is probably equivalent to the Warner Sandstone of Oklahoma (Howe, 1956; Scruton, 1950). Figure 5, a map of sandstone thickness, depicts the distribution of the Lower Warner Sandstone. Its thickness

varies from zero in most of the western two thirds of the study area to twenty feet in a few places along the Missouri-Kansas border; in one area, in northeastern Crawford County, it is as thick as thirty feet.

In most locations where it was encountered, the Lower Warner Sandstone lies just above a coal bed in the Riverton Shale. The amount of dark shale beneath the sandstone and coal depends on the amount of local erosional relief on the post-Mississippian unconformity. For instance, in hole D (24-27S-25E) (Cross Section A-A') the sandstone and coal were deposited almost in contact with a high area in the underlying limestone, whereas, in hole G (27-29S-25E) (Cross Section A'-A") there is a dark shale section almost 60 feet thick beneath the coal where a deep depression in the Mississippian occurs.

Although the basal contact usually is sharp and the top is gradational with overlying siltstone, both may be gradational. Internal structure of the Lower Warner Sandstone is quite variable and includes large-scale cross bedding as well as ripple cross beds and horizontal laminae. Beds in which fragments of pre-existing clay ironstone or shale are included occur in the sandstone, not always at the base.

The Lower Warner Sandstone is classified as a sublitharenite or lithic graywacke (Pettijohn, et al, 1972), because the most common mineral is quartz, but there is also an abundance of grains of pre-existing rock (lithic grains) and fair amounts (21-28%) of fine matrix. Carbonaceous matter is an important component of these sands, in the form of carbonized woody fragments and disseminated fine particles which are associated with clay and silt in laminae and are scattered through layers of coarser sand. The grain size of the sandstones is very-fine or fine sand size. They are well sorted except for the clay and silt matrix, and are partially cemented by silica in most cases.

Porosity and permeability of the Lower Warner Sandstone are quite variable. These parameters are indicated on core logs in Appendix D and average values for each sandstone discussed are shown in Table 1. As only oil-bearing sandstone cores were analyzed, these values may not be truly representative. Variability of the data is so great, that there is as much variation among samples in one core as there is among those from different cores. Cleaner, less shaly sands typically have permeabilities in the range of 100 md., while the permeability of shalier sands is less than 10 md. Values of porosity are mostly less than 20 per cent. From the nature of sandstone distribution and the textural variations in each sandstone, it may be expected that the permeability is influenced by rock fabric. Horizontal permeability should be greater than vertical permeability, and permeability in the direction of elongation of these sands should be greater than permeability across this trend, at any one location.

Upper Warner Sandstone. - The Upper Warner Sandstone occurs in the interval between the lower Warner marker and the Rowe Coal. This sandstone is equivalent stratigraphically to the sandstone called "Warner" in Missouri, but is younger than the Warner Sandstone of the type-area in Oklahoma. It has not been recognized at the surface in Kansas, but, possibly, some of the sandstone previously mapped as Bluejacket Sandstone in Kansas is, in reality, this sandstone. Further studies will resolve this problem and, it is hoped, an appropriate name can be assigned to this unit, which is the most important oil-bearing Cherokee sandstone in western Missouri. For purposes of this report, the name Upper Warner Sandstone will be applied to this stratigraphic unit.

Figure 6 illustrates the trends in thickness and distribution of this sandstone. Its maximum thickness is greater than that of any other sandstone encountered in the study area, thickness ranging from zero to more than forty-five feet in southeastern Bourbon County.

As with the Lower Warner Sandstone, areas of greatest thickness are along the Missouri-Kansas border, and the sand is distributed westward from there in very irregular, lobe-like trends. The trends in thickness are less affected by irregularities in the surface of the Mississippian Limestone than are those of the underlying sandstone, but some influence by the Mississippian is noted, especially in northern Bourbon County.

The Upper Warner Sandstone thickens both by addition of sandstone at the top of the section and by erosion downward into previously deposited beds. In several locations, this sandstone is in almost direct contact with a thin coal bed at its base, as in hole N (see core logs, Appendix D). In areas of thicker sandstone, the lower contact is sharp and the contact with overlying siltstones and shales is gradational. In areas farther westward and southward, both contacts are gradational.

Internal structures in the Upper Warner Sandstone include large- and small-scale cross bedding, horizontal lamination, rare organic burrows, casts of plant remains, wavy shale lamination, and thin zones of siderite cementation. The Upper Warner Sandstone is classified as a sublitharenite, but in a few sections contains little enough matrix to qualify as a litharenite or quartz wacke (Pettijohn, et al, 1972).

Quartz is the most important constituent of these sands, but, rock fragments and clay matrix are also significant. Carbonaceous fragments and plant remains are conspicuous in some portions of the sandstone.

The predominant grain size is very-fine or fine sand size; medium size sand grains were logged in one core. In cores in which the basal contact is sharp, there may be a gradation in grain size from slightly coarser, at the base, to finer upward.

Porosity and permeability of the Upper Warner Sandstone are as variable among samples from one well as among samples from different wells, in most cases. Where this variability exists, higher permeabilities are in the range of 100 md., and lower values are 10 md or lower. An exception is the sand in hole Q, which has permeability of 100-300 md. throughout and porosity higher than 25% in most samples. Table 1 compares these parameters with those in other sandstone zones. The comments made above concerning directional permeability in the Lower Warner Sandstone apply also to those parts of the Upper Warner in which there is a change in texture and type of internal structures.

Bluejacket Sandstones. - The Upper and Lower Bluejacket Sandstones occur between the Rowe Coal and the lower Cabaniss marker shale. Both sandstones occur in only certain of the wells in the area of study. More often, one or the other, not both sandstones, occurs in a well. The two Bluejacket sandstones, where both are present, are separated by a thin interval of shale and limestone which sometimes also includes a very thin coal. The Lower Bluejacket, as described here, with these overlying beds, most closely fits the description of the "Bluejacket Sandstone" of Kansas and Missouri (Howe, 1956; Searight, et al, 1953), but correlations established in the course of this study, based on well logs, suggest that it is the Upper Bluejacket, as described here, which is most likely to be continuous at the surface with the Bluejacket Sandstone at its type locality in Oklahoma (Howe, 1951).

The distinction made here between these two sandstones is most clearly seen in logs of holes D and Z, near the mutual eastern corners of Bourbon and Crawford Counties, Kansas. Figures 7 and 8 depict the distribution and thickness of these sandstones. The Lower Bluejacket is best developed in the eastern and northern parts of the study area where it is as thick as fifteen or twenty feet. The Upper Bluejacket is thinner and less conspicuous in these areas, but it extends much farther southwestward and reaches a thickness of ten to twenty feet in western Cherokee County. These maps of sandstone distribution demonstrate, perhaps more than the maps of other sandstones in the area, the need for considering discontinuity of reservoir rock in assigning potential reserves to areas of oil-bearing sediments.

Commonly, the Lower Bluejacket is in sharp contact with underlying sediments but grades upward into siltstone or shale; whereas the lower contact of the Upper Bluejacket is gradational and its upper contact is fairly abrupt. These relationships are not universal, however, as illustrated by the cross sections A-A"' (Figs. 9-10).

There is less variability in the types of internal structure in these rocks than has been described in lower rocks. Small-scale cross bedding predominates in the sandier intervals, and some large-scale cross beds are present. In less sandy intervals, thin shale laminae and wavy bedding are characteristic.

The Upper and Lower Bluejacket Sandstones are classified, respectively, as lithic arenite to lithic graywacke and as sublithic arenite to lithic graywacke (Pettijohn, et al. 1972). The Lower Bluejacket contains a little more feldspar in some samples than does the Upper Bluejacket. The sand grains in these rocks are of very fine or fine

sand size and are well sorted. Carbonaceous fragments, leaf impressions and casts of fossil woody material are common constituents of these sands. In areas of less sandy deposits, siderite is usually present as small nodules or as cement.

Permeability and porosity of these Bluejacket sandstones are even more variable within and among wells than are these parameters in other sands described above. The reason is that textural variations, that is grain size, sorting, and abundance of matrix and cement are also highly variable from sample-to-sample in these sands. The result is rather poor reservoir-rock quality. As discussed above, the highest degree of oil saturation in these sandstones commonly is in the tightest sand. Table 1 compares the petrophysical features of these sandstones with those of other sandstones discussed here.

Cabaniss Sandstones. - In three wells in the study area, K.G.S. test holes GG and HH in Crawford County and Shell core hole Kan-8 (Sec. 33-26S-24E) in Bourbon County, thick sandstones were encountered in the interval between the lower Cabaniss marker shale and the base of the Verdigris Limestone. On cross section B-B' this interval is subdivided by the Tebo Coal marker into upper and lower correlation units, but, where these sandstones are well developed, this Tebo marker is absent or obscured by the abundance of sandstone.

No attempt to map the extent of these sandstones has been made in this study because of the few wells which encountered them. These sandstones probably are correlative with the intervals of Taft and Chelsea Sandstones in Oklahoma. They are not present in any test hole in the study area east of Range 23E, except in the Shell well mentioned above, and four holes near this Shell test failed to find any sandstone at all

in this section. The low density of wells in the western half of the study area and the obvious lenticularity of these sandstones probably account for their seeming discontinuity.

Contacts of these sandstones with sediments above and below are either sharp or gradational. Conspicuous cross bedding and abundant rounded lithiclasts of shale in the sandstones are common features of these sandstones. Grain-size varies from very-fine to fine sand-size with good sorting. Grain-size, in some sands, decreases upward, and, in some others, it is uniform throughout. The sands in K.G.S. hole GG have very good permeability and good porosity, but an equivalent interval in HH is mostly shale, siltstone, and fine sandy laminae with low porosity and permeability. Calcite cement occurs in small patches throughout these sands.

The composition of the Cabaniss sandstones, which are lithic arenites or graywackes or are sublithic arenites, differs from that of lower sandstones in having a larger proportion of lithic grains. Finely divided carbonaceous matter is disseminated throughout these sediments. It is so abundant that, while drilling through this interval, the carbonaceous matter makes an oil-like scum on the drilling fluid.

Porosity and permeability are quite good in some cores (18-20% and 40-100 md., respectively), but they are much lower in others. In general, the abundance of clay and mica matrix in these sandstones results in poor reservoir-rock quality, but there are oil fields adjacent to the study area on the west from which oil with gravity in the range 21°-30° A.P.I. is produced from sands equivalent to the Cabaniss sandstones described here.

A P P E N D I X C

WELL LOGS AND SAMPLE DESCRIPTIONS

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G	27-29S-25E	54
G-Twin	27-29S-25E	55
H	11-30S-25E	56
I	33-30S-24E	57
K	21-32S-24E	58
L	3-33S-23E	59
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DD	13-34S-22E	76
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KK	8-27S-23E	81

Oil Shows in Wells

○ live-oil show (bleeds) - trace

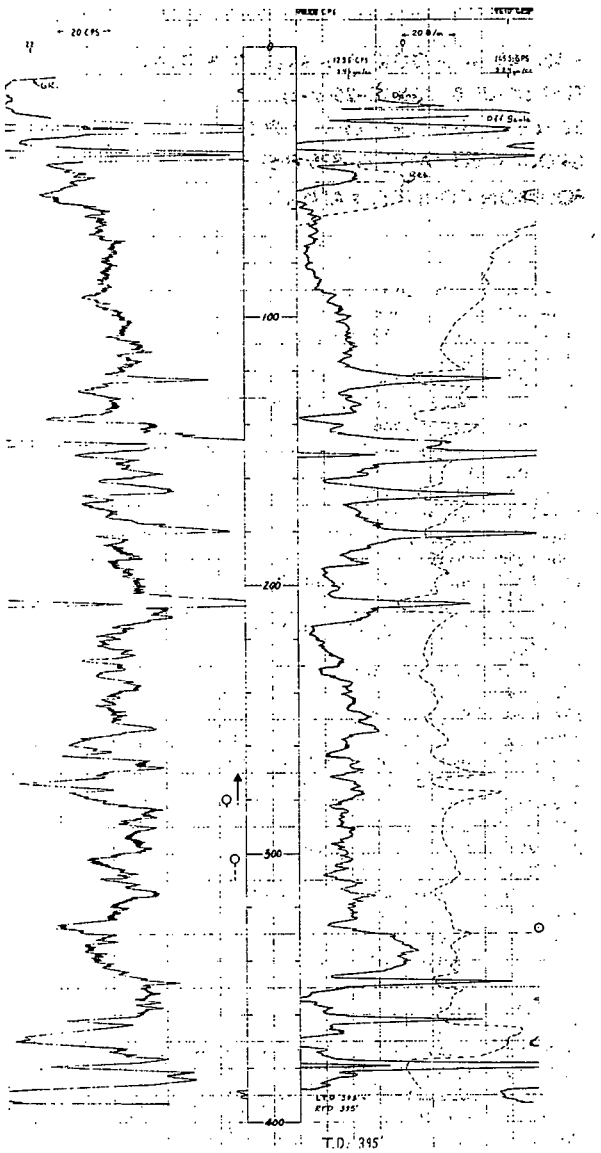
● live-oil show (bleeds) - abundant

△ heavy-oil show (tar-like, smears) - trace

▲ heavy-oil show (tar-like,smears) - abundant

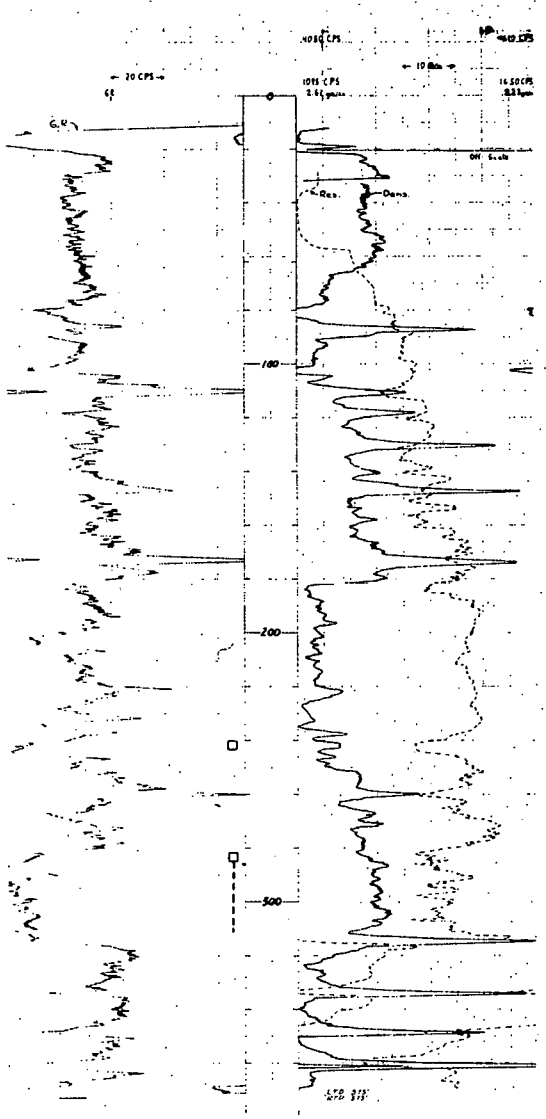
□ dead-oil show (solid, shiny to dull, no smear) - trace

■ dead-oil show (solid, shiny to dull, no smear) - abundant



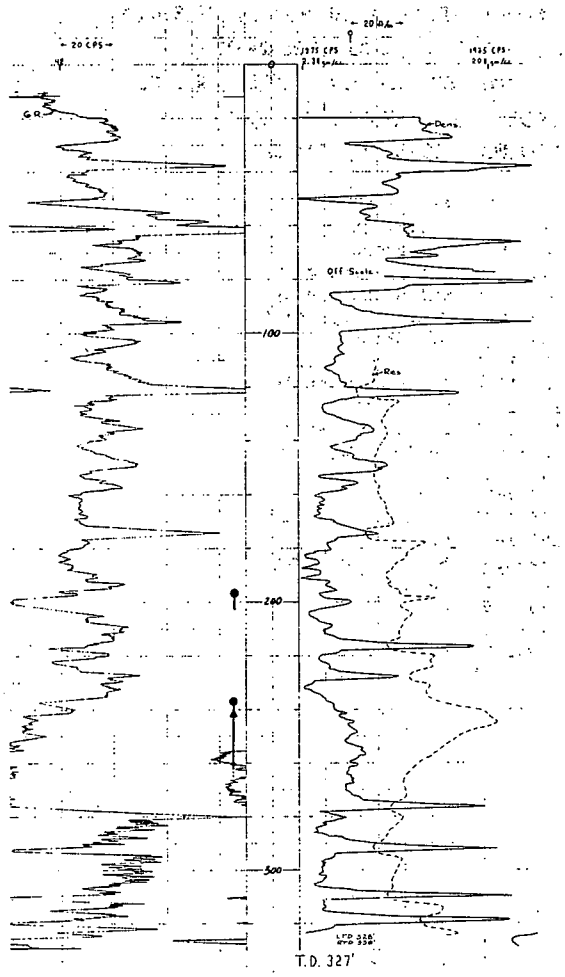
KANSAS GEOLOGICAL SURVEY (E.R.D.A.)
TEST HOLE A (BB 24-25-35-1)
SE SW SE Sec. 35 - T.24S. - R.25E.
GROUND ELEVATION: 808 FEET
BOURBON COUNTY, KANSAS

0- 14'	Alluvium
14- 28'	Limestone
28- 31'	Shale, black
31- 32'	Coal
32- 40'	Limestone
40- 43'	Shale, black
43- 45'	Coal
45- 70'	Sandstone
70- 85'	Siltstone
85-122'	Shale, gray
122-123'	Coal
123-128'	Limestone
128-134'	Shale, gray
134-140'	Limestone
140-150'	Shale, black
150-152'	Coal
152-164'	Shale, gray
164-166'	Coal
166-180'	Shale, gray
180-181'	Coal
181-206'	Shale, gray
206-207'	Coal
206-260'	Shale, greenish gray
260-264'	Limestone
264-268'	Shale, greenish gray
268-282'	Sandstone
282-300'	Shale, dark gray, silty
300-314'	Sandstone, with shale lamin
314-346'	Shale, dark gray to black
346-347'	Coal
347-360'	Shale, gray
360-362'	Coal
362-378'	Sandstone
378-379'	Coal
379-388'	Shale, black
388-392'	Limestone
392-395'	Chert
TD 395'	



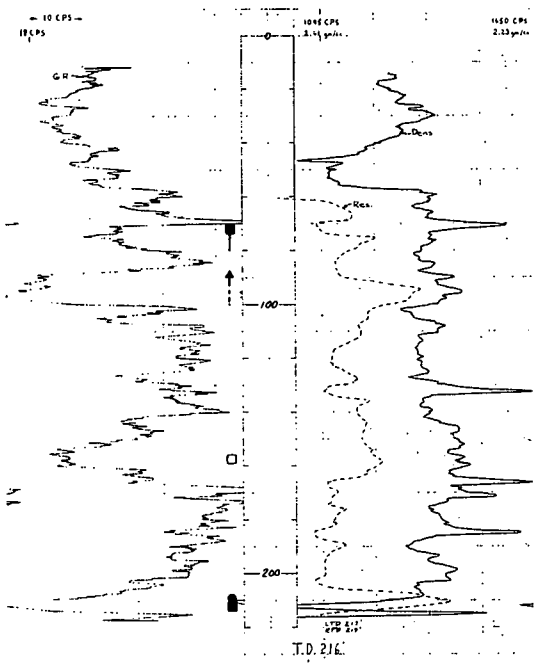
KANSAS GEOLOGICAL SURVEY (E.R.D.A.)
TEST HOLE B (BB 25-25-9-1)
SE SE SW Sec. 9-T.25S.-R.25E
GROUND ELEVATION: 825 FEET
BOURBON COUNTY, KANSAS

0- 8'	Alluvium
8- 12'	Limestone
12- 18'	Shale, dark gray
18- 20'	Coal
20- 28'	Sandstone
24- 78'	Shale, gray, silty
78- 80'	Limestone
80- 86'	Shale, gray
86- 88'	Coal
88-101'	Shale, gray
101-104'	Limestone
104-108'	Shale, gray
108-110'	Coal
110-128'	Shale, gray, sandy
128-130'	Coal
130-146'	Shale, gray, sandy
146-148'	Coal
148-172'	Shale, gray
172-174'	Coal
174-200'	Shale, gray
200-204'	Sandstone
204-233'	Siltstone, very shaley
233-236'	Limestone
236-237'	Coal
237-250'	Sandstone
250-260'	Shale, dark gray
260-262'	Coal
262-280'	Shale, greenish gray
280-314'	Sandstone
314-316'	Coal
316-333'	Shale, gray, silty
333-335'	Coal
335-347'	Shale, black
347-349'	Coal
349-359'	Shale, very dark gray, sandy
359-361'	Coal
361-368'	Siltstone, greenish gray
368-373'	Chert
TD 373'	



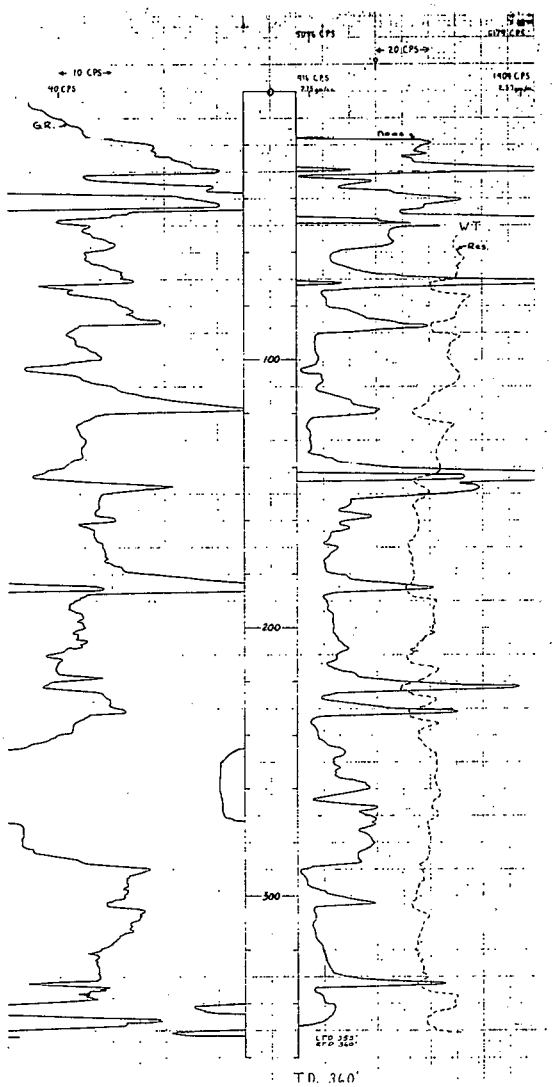
KANSAS GEOLOGICAL SURVEY (E.R.D.A.)
TEST HOLE C (BB 26-25-10-1)
SW SW SW Sec. 10-T.26S.-R.25E.
GROUND ELEVATION: 870 FEET
BOURBON COUNTY, KANSAS

0- 20'	Alluvium
20- 29'	Shale, gray
29- 31'	Limestone
31- 37'	Shale, gray
37- 38'	Coal
38- 50'	Shale, gray
50- 52'	Limestone
52- 58'	Shale, black
58- 60'	Coal
60- 78'	Shale, gray
78- 80'	Limestone
80- 82'	Coal
82- 95'	Shale, gray
95- 97'	Coal
97-120'	Shale, gray
120-122'	Coal
122-160'	Shale, gray, silty
160-193'	Siltstone, sandy
193-194'	Coal
194-215'	Sandstone, silty
215-216'	Coal
216-220'	Shale, dark gray
220-276'	Sandstone, shaley
276-277'	Coal
277-296'	Shale, dark gray
292-293'	Coal
293-309'	Shale, black
309-310'	Coal
310-318'	Shale, black
318-320'	Coal
320-324'	Shale, black
324-328'	Limestone
328-330'	Chert
TD 330'	



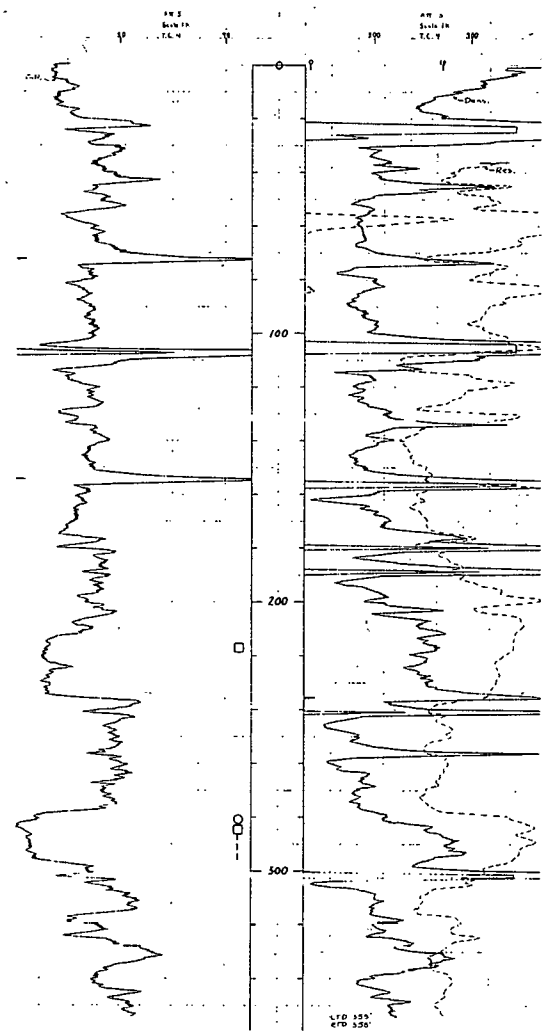
KANSAS GEOLOGICAL SURVEY (E.R.D.A.)
TEST HOLE D (BB 27-25-24-1)
NW NW NW Sec. 24 - T.27S. - R.25E.
GROUND ELEVATION: 798 FEET
BOURBON COUNTY, KANSAS

0- 40'	Alluvium
40- 43'	Shale, gray
43- 50'	Limestone
50- 68'	Shale, dark gray
68- 79'	Siltstone, sandy
79- 86'	Shale, gray, silty
86- 87'	Limestone
87-101'	Sandstone, silty
101-115'	Siltstone, shaley
115-124'	Shale, gray
124-130'	Sandstone, shaley
130-141'	Shale, gray
141-164'	Sandstone
164-165'	Coal
165-182'	Shale, dark gray
182-184'	Coal
184-203'	Shale, dark gray
203-214'	Sandstone
214-215'	Coal
215-218'	Shale, dark gray
218-219'	Chert
TD 219'	



KANSAS GEOLOGICAL SURVEY (E.R.D.A.)
TEST HOLE F (CR 28-25-28-1)
SW SE SE Sec. 28 - T.28S. - R.25E.
GROUND ELEVATION: 906 FEET
CRAWFORD COUNTY, KANSAS

0- 20'	Alluvium
20- 31'	Shale, gray, silty
31- 38'	Limestone
38- 40'	Coal
40- 50'	Shale, black, silty
50- 52'	Coal
52- 70'	Siltstone, shaley to sandy
70- 74'	Shale, dark gray
74- 84'	Siltstone
84-100'	Shale, black, calcareous
100-114'	Siltstone, shaley to sandy
114-120'	Shale, dark gray to black
120-189'	Shale, gray with silty zones
189-222'	Siltstone, very shaley
222-224'	Coal
224-248'	Shale, gray
248-289'	Sandstone
289-290'	Coal
290-304'	Shale, black
304-306'	Coal
306-334'	Shale, dark gray
334-336'	Coal
336-342'	Shale, silty
342-348'	Sandstone
348-352'	Shale, black
352-360'	Limestone
TD 360'	

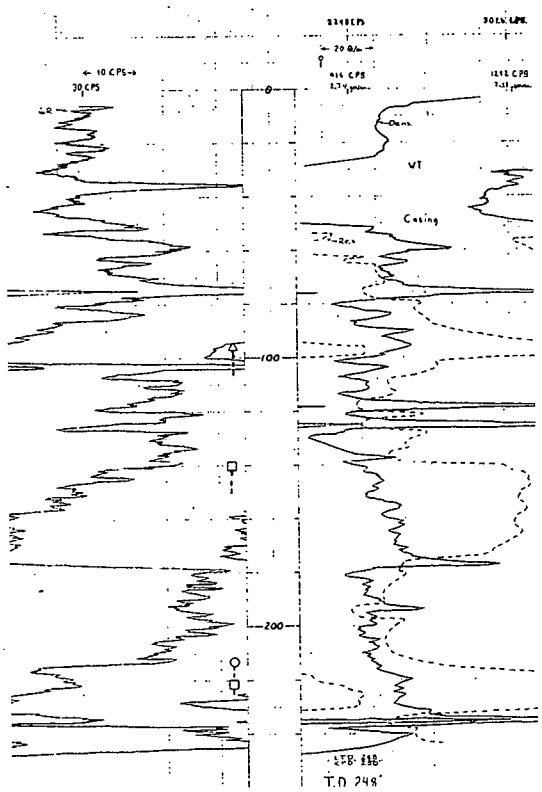


KANSAS GEOLOGICAL SURVEY (E.R.D.A.)
TEST HOLE G (CR 29-25-27-1)
NW NE NE Sec. 27 - T.29S. - R.25E.
GROUND ELEVATION: 946 FEET
CRAWFORD COUNTY, KANSAS

0- 10'	Alluvium
10- 15'	Sandstone
15- 22'	Shale
22- 24'	Limestone
24- 25'	Coal
25- 43'	Shale
43- 44'	Coal
44- 48'	Shale
48- 49'	Limestone
49- 54'	Shale
54- 60'	Sandstone
60- 73'	Shale
73- 74'	Coal
74-103'	Shale
103-105'	Coal
105-118'	Shale
118-120'	Sandstone
120-127'	Shale
127-133'	Sandstone
133-134'	Shale
134-136'	Coal
136-154'	Shale
154-156'	Coal
156-178'	Shale
178-180'	Coal
180-189'	Shale
189-190'	Coal
190-193'	Shale
193-202'	Sandstone
202-203'	Coal
203-233'	Sandstone
233-235'	Coal
235-242'	Shale
242-244'	Coal
244-258'	Shale
258-260'	Coal
260-278'	Shale
278-300'	Sandstone
300-301'	Coal
301-356'	Shale
356-358'	Chert
TD 358'	

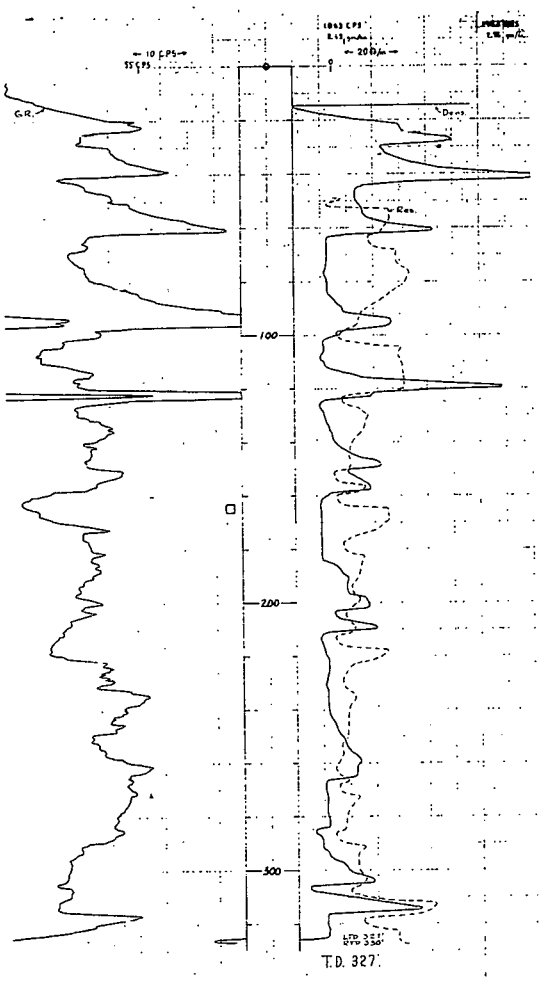
KANSAS GEOLOGICAL SURVEY (E.R.D.A.)
TEST HOLE G-TWIN (CR 29-25-27-2)
NW NE NE Sec. 27-T.29S.-R.25E.
GROUND ELEVATION: 946 FEET
CRAWFORD COUNTY, KANSAS
(No well log run)

0- 10'	Alluvium
10- 15'	Sandstone
15- 22'	Shale
22- 24'	Limestone
24- 25'	Coal
25- 43'	Shale
43- 44'	Coal
44- 48'	Shale
48- 49'	Limestone
49- 54'	Shale
54- 60'	Sandstone
60- 73'	Shale
73- 74'	Coal
74-104'	Shale
104-107'	Coal
107-109'	Shale
TD 109	



KANSAS GEOLOGICAL SURVEY (E.R.D.A.)
TEST HOLE H (CR 30-25-11-1)
SW NW NW Sec. 11 - T.30S. - R.25E.
GROUND ELEVATION: 914 FEET
CRAWFORD COUNTY, KANSAS

0- 10'	Alluvium
10- 15'	Shale, gray
15- 20'	Limesotne
20- 29'	Shale, gray
29- 30'	Coal
30- 48'	Shale, dark gray
48- 58'	Sandstone
58- 60'	Coal
60- 72'	Shale, black
72- 77'	Limestone
77- 78'	Coal
80- 85'	Shale, greenish gray
85-108'	Sandstone
108-117'	Shale, gray
117-119'	Coal
119-124'	Shale, gray
124-126'	Coal
126-135'	Shale, gray, silty
135-176'	Sandstone
176-178'	Coal
178-193'	Shale, dark gray
193-194'	Shale, dark gray
194-214'	Shale, dark gray
214-236'	Sandstone
236-238'	Coal
238-246'	Shale, gray
246-250'	Chert
TD 250'	

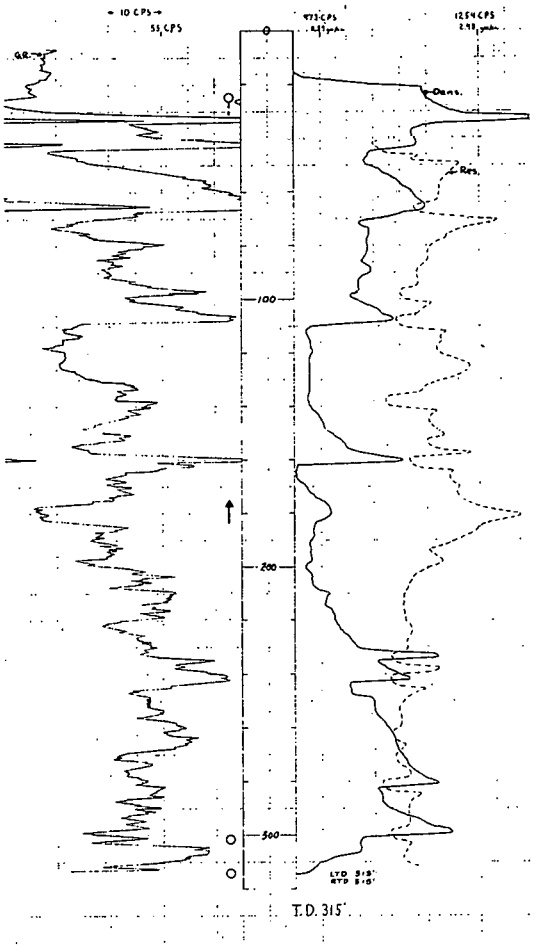


KANSAS GEOLOGICAL SURVEY (E.R.D.A.)
TEST HOLE I (CR 30-24-33-1)
NE NE NW Sec. 33 - T.30S. - R.24E.
GROUND ELEVATION: 936 FEET
CRAWFORD COUNTY, KANSAS

0- 10'	Alluvium
10- 18'	Sandstone
18- 26'	Shale, black
26- 28'	Coal
28- 42'	Shale, gray
42- 44'	Coal
44- 62'	Shale, dark gray
62- 64'	Coal
64- 68'	Shale, gray, silty
68- 78'	Sandstone
78- 94'	Shale, gray
94- 95'	Coal
95-102'	Shale, light brown
102-114'	Sandstone
114-118'	Shale, gray
118-120'	Coal
120-148'	Shale, gray
148-149'	Coal
149-158'	Shale, black
158-176'	Sandstone
176-201'	Shale, gray to black
201-202'	Coal
202-220'	Sandstone, shaley
220-248'	Shale, gray to black
248-255'	Shale, gray, silty
255-264'	Shale, dark gray
264-265'	Coal
265-284'	Shale, dark gray
284-286'	Coal
286-304'	Shale, dark gray, silty
304-305'	Coal
305-316'	Shale, black, sandy
316-324'	Shale, black
324-330'	Chert
TD 330'	

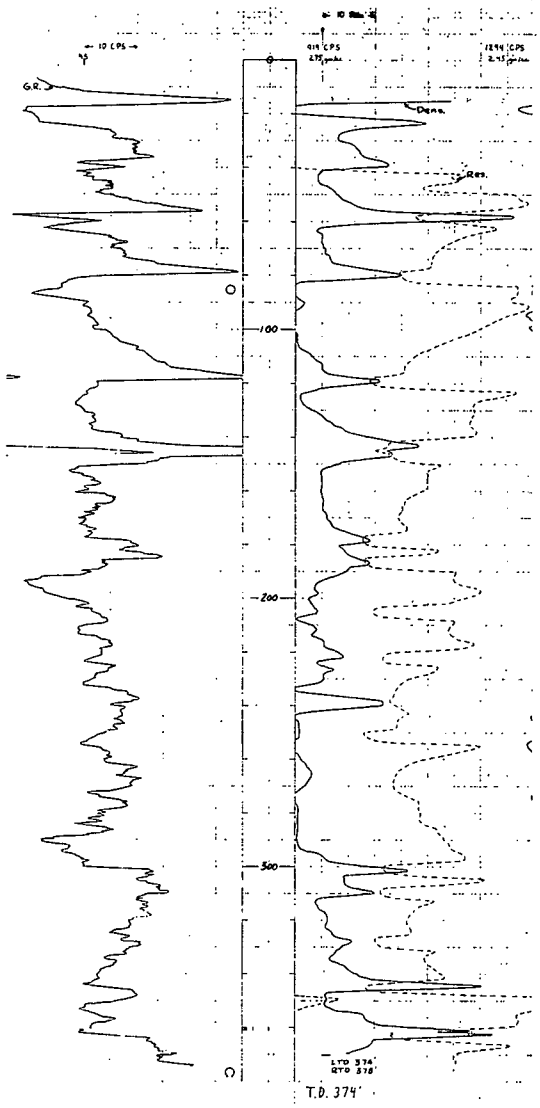
KANSAS GEOLOGICAL SURVEY (E.R.D.A.)
TEST HOLE K (CK 32-24-21-1)
NW NW NW Sec. 21 - T.32S. - R.24E.
GROUND ELEVATION: 925 FEET
CHEROKEE COUNTY, KANSAS
(No well log run)

0-18'	Soil
18-42'	Shale
42-43'	Coal
43-48'	Shale
48-60'	Sandstone
60-62'	Shale
TD 62'	



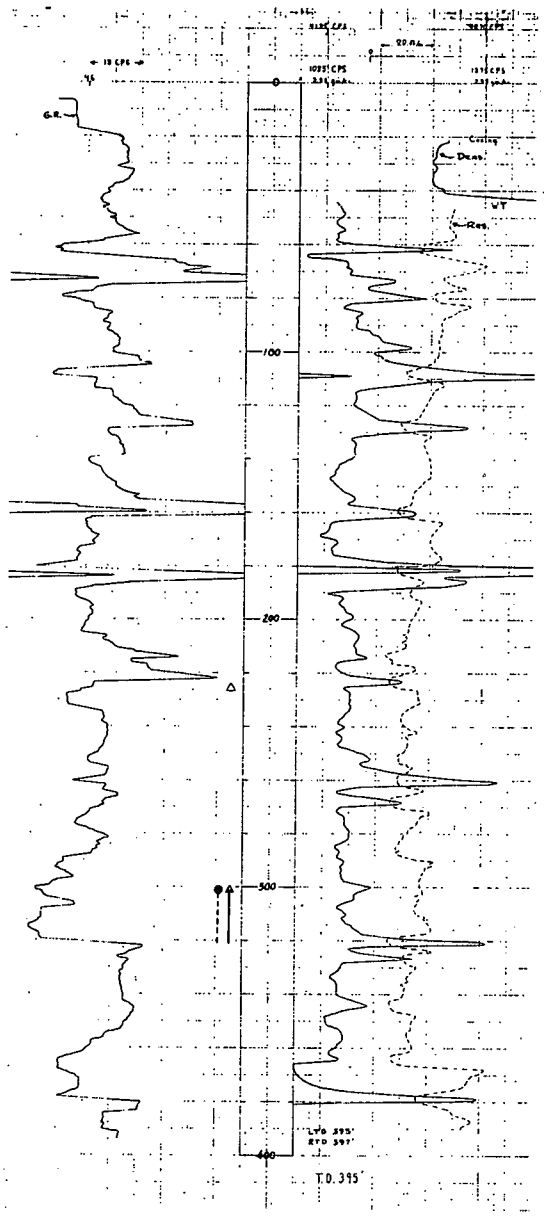
KANSAS GEOLOGICAL SURVEY (E.R.D.A.)
TEST HOLE L (CK 33-23-3-1)
SW SW SW Sec. 3 - T.33S. - R.23E.
GROUND ELEVATION: 920 FEET
CHEROKEE COUNTY, KANSAS

0- 18'	Alluvium
18- 20'	Shale, gray
20- 21'	Coal
21- 30'	Sandstone
30- 38'	Shale, dark gray to black
38- 39'	Coal
40- 66'	Shale, dark gray to black
65- 67'	Coal
67- 78'	Sandstone, shaley
78-105'	Shale, gray
105-106'	Coal
106-120'	Shale, gray, sandy
120-130'	Sandstone
130-146'	Shale, gray to black
146-158'	Sandstone, very shaley
158-172'	Shale, gray, silty
172-192'	Sandstone, shaley
192-232'	Shale, gray
232-234'	Coal
234-280'	Shale, dark gray
280-282'	Coal
282-298'	Shale, gray
298-299'	Coal
299-304'	Sandstone
304-312'	Shale, dark gray
312-315'	Chert
TD 315'	



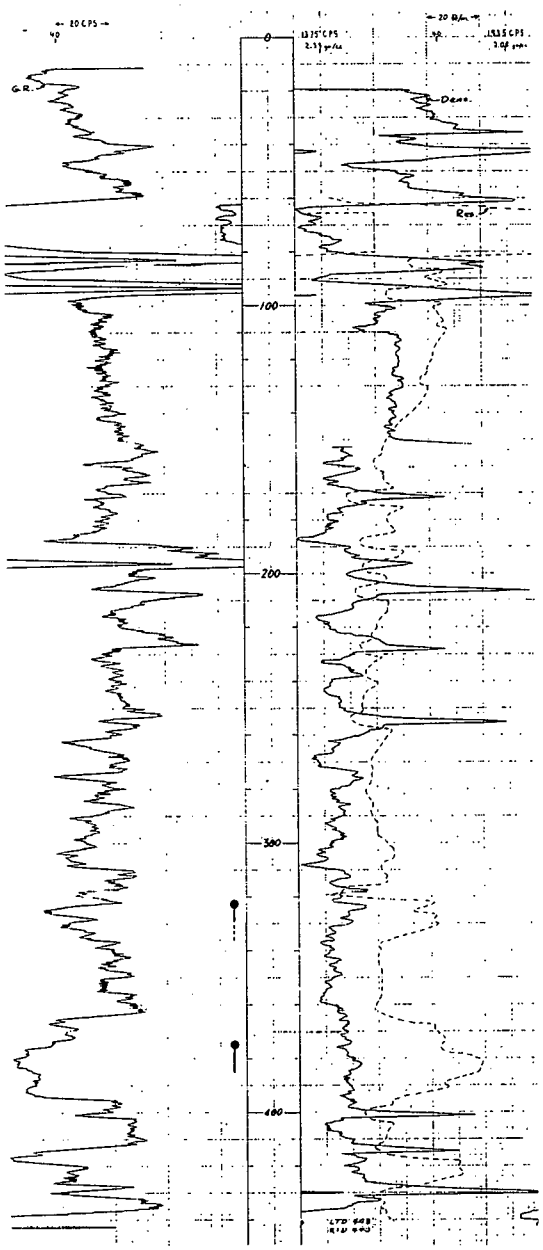
KANSAS GEOLOGICAL SURVEY (E.R.D.A.)
TEST HOLE M (CK 32-23-5-1)
NW NW NE Sec. 5 - T.32S. - R.23E.
GROUND ELEVATION: 900 FEET
CHEROKEE COUNTY, KANSAS

0- 13'	Alluvium
13- 17'	Shale, black
17- 21'	Sandstone
21- 23'	Coal
23- 36'	Shale, dark gray
36- 38'	Coal
38- 56'	Shale, gray to dark gray
56- 58'	Coal
58- 77'	Shale, gray to dark gray
77- 79'	Coal
79- 82'	Shale, gray
82- 90'	Sandstone
90-100'	Siltstone, very shaley
100-106'	Shale, gray
106-107'	Coal
107-117'	Shale, gray
117-119'	Coal
120-140'	Siltstone, very shaley
140-142'	Coal
142-177'	Shale, gray to dark gray
177-178'	Coal
178-184'	Shale, light brown
184-185'	Coal
185-195'	Shale, gray
195-202'	Siltstone, sandy to shaley
202-204'	Coal
204-236'	Shale, gray
236-238'	Coal
238-285'	Shale, gray
285-299'	Sandstone
299-300'	Coal
300-307'	Shale, gray
307-309'	Coal
309-325'	Shale, gray
325-327'	Coal
327-342'	Shale, light gray to gray
342-344'	Coal
344-360'	Shale, dark gray
360-362'	Coal
362-375'	Shale, black, sandy
375-378'	Chert
TD 378;	



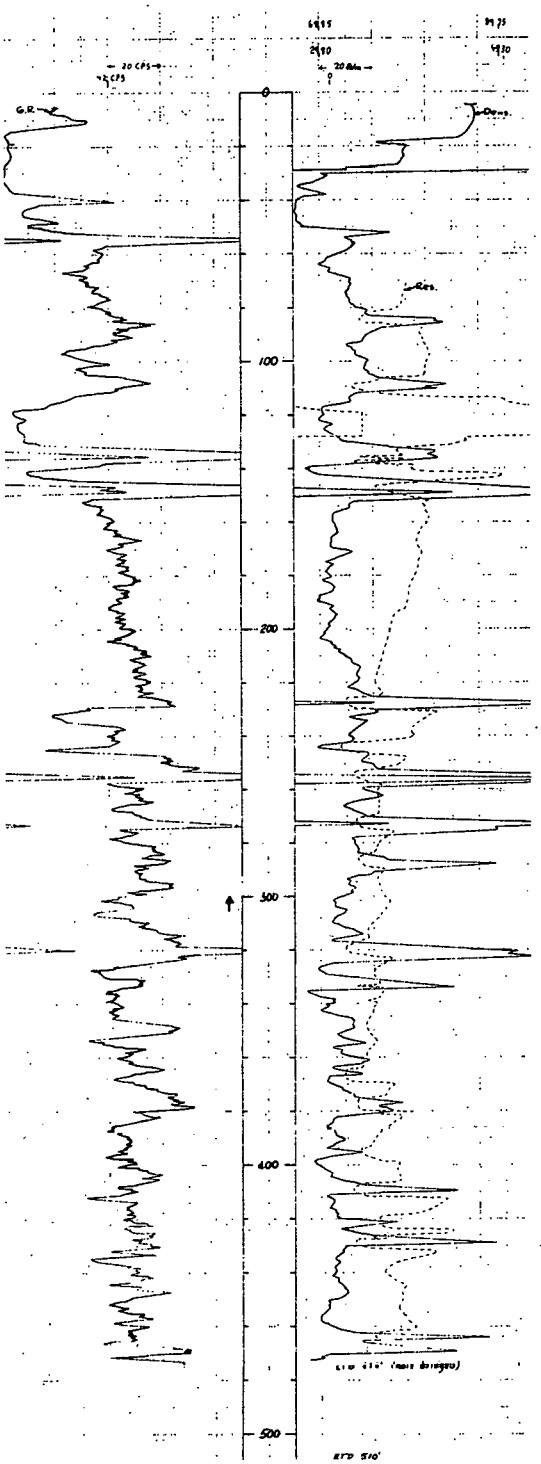
KANSAS GEOLOGICAL SURVEY (E.R.D.A.)
TEST HOLE N (CR 29-24-34-1)
NW NE NW Sec. 34 - T.29S. - R.24E.
GROUND ELEVATION: 958 FEET
CRAWFORD COUNTY, KANSAS

0- 15'	Alluvium
15- 60'	Shale, light gray
60- 62'	Coal
62- 64'	Limestone
64- 72'	Shale, gray
72- 76'	Shale, black
76- 78'	Shale, gray
78- 80'	Coal
80- 96'	Shale, gray, silty
96- 98'	Limestone
98-106'	Shale, dark gray
106-108'	Coal
108-129'	Shale, gray silty
129-130'	Coal
130-156'	Shale, gray
156-159'	Shale, black
159-179'	Shale, gray, silty
179-181'	Coal
181-212'	Shale, gray, silty zones
212-213'	Coal
213-228'	Shale, gray to black
228-259'	Siltstone, sandy to shaley
259-260'	Coal
260-265'	Siltstone, shaley
265-267'	Coal
267-278'	Siltstone, shaley
280-288'	Shale, gray
288-290'	Coal
290-322'	Sandstone
322-324'	Coal
324-328'	Shale, gray
328-329'	Coal
329-343'	Shale, dark gray to black
343-345'	Coal
345-364'	Shale, dark gray
364-378'	Sandstone
378-379'	Coal
379-386'	Shale, gray
386-397'	Chert
TD 397'	



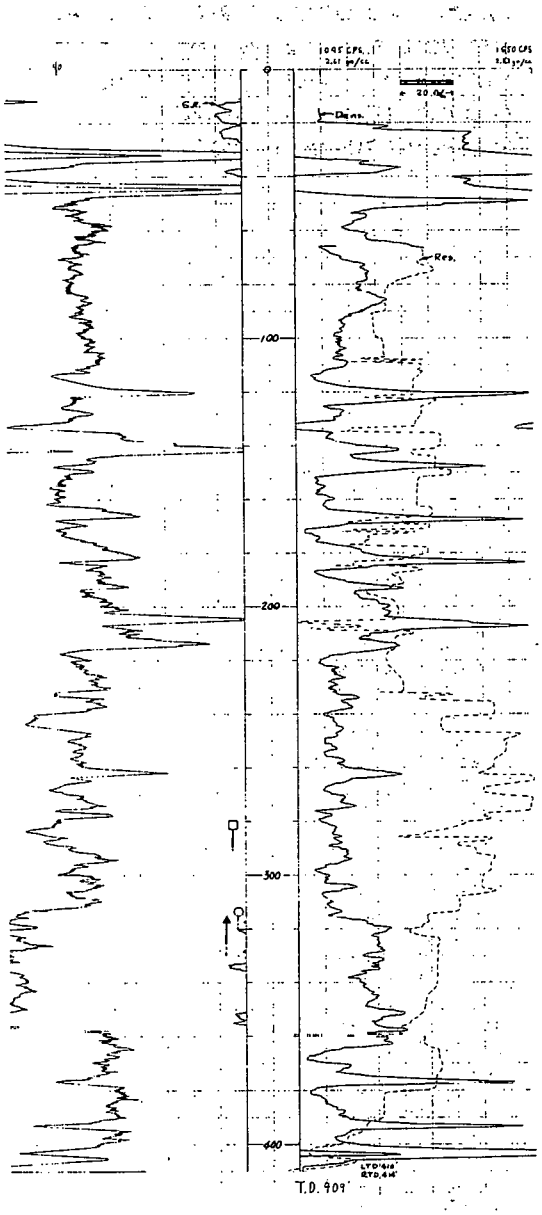
KANSAS GEOLOGICAL SURVEY (E.R.D.A.)
TEST HOLE O (BB 24-25-22-1)
NE NE NE Sec. 22-T.24S.-R.25E.
GROUND ELEVATION: 894 FEET
BOURBON COUNTY, KANSAS

0- 5'	Alluvium
5- 12'	Limestone, tan
12- 15'	Shale, black
15- 45'	Shale
45- 60'	Shale, silty
60- 82'	Limestone, light brown
82- 85'	Shale, black
85- 87'	Coal
87- 96'	Limestone
96-170'	Siltstone & Shale
170-172'	Coal
172-185'	Shale
185-190'	Limestone
190-196'	Shale, black
198-204'	Shale, gray
204-206'	Coal
206-226'	Siltstone, very shaley, carbonaceous
226-228'	Coal
228-232'	Siltstone, very shaley
232-253'	Shale, gray
253-255'	Coal
255-275'	Shale, greenish gray
275-280'	Sandstone
280-300'	Shale, gray
300-308'	Siltstone
308-310'	Limestone, light brown
310-323'	Shale, gray
323-337'	Sandstone
337-365'	Shale, black to dark gray
365-398'	Sandstone
398-401'	Coal
401-414'	Shale, dark gray
414-416'	Coal
416-426'	Sandstone
426-428'	Shale, black to dark gray
428-429'	Coal
429-440'	Shale, black
440-442'	Sandstone
442-445'	Chert, white
TD 445'	



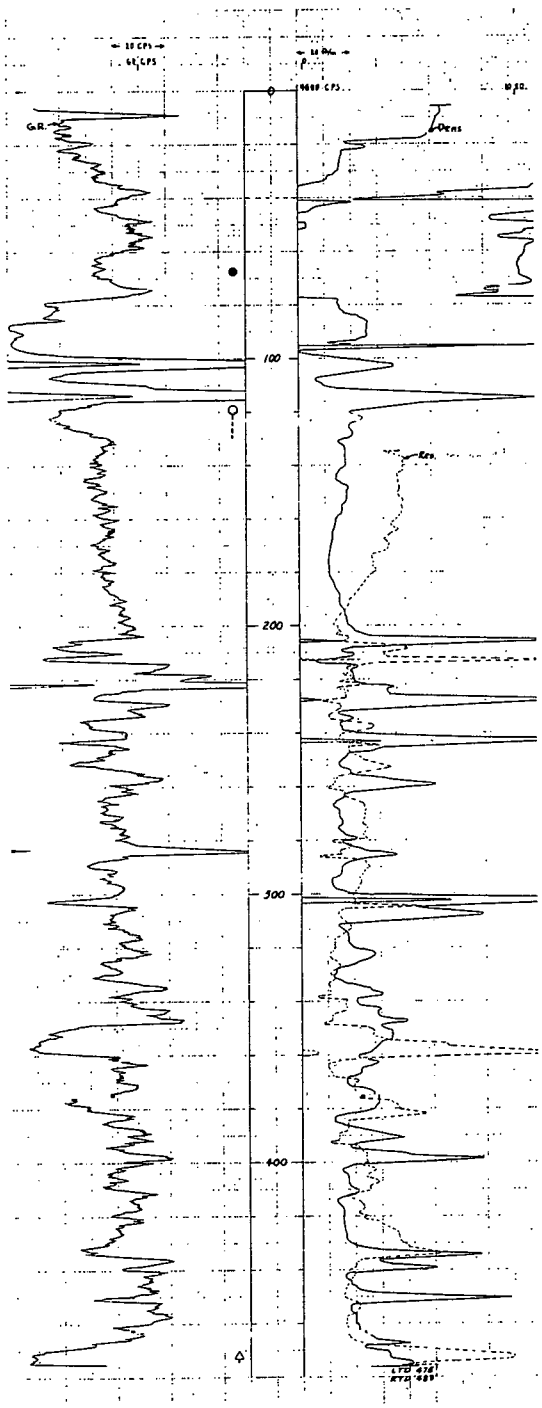
KANSAS GEOLOGICAL SURVEY (E.R.D.A.)
TEST HOLE P (BB 27-24-3-1)
NW NW NW Sec. 3 - T.27S. - R.24E.
GROUND ELEVATION: 932 FEET
BOURBON COUNTY, KANSAS

0- 10'	Alluvium
10- 12'	Coal
12- 53'	Limestone
53- 95'	Shale
95-110'	Sandstone
110-112'	Coal
112-118'	Shale
118-135'	Limestone
135-140'	Shale
140-145'	Limestone
145-152'	Shale
152-153'	Coal
153-160'	Shale
160-175'	Sandstone
175-225'	Shale
225-227'	Coal
227-233'	Shale
233-238'	Limestone
238-242'	Shale
242-248'	Limestone
248-277'	Shale
277-278'	Coal
278-300'	Shale
300-301'	Coal
301-310'	Sandstone
310-368'	Shale
368-369'	Coal
369-370'	Coal
370-395'	Shale
395-398'	Limestone
398-412'	Shale
412-430'	Sandstone
430-433'	Shale
433-434'	Coal
434-465'	Sandstone
465-467'	Coal
467-472'	Shale
472-473'	Coal
473-488'	Shale
489-500'	Shale
500-505'	Sandstone
505-506'	Coal
506-508'	Shale
508-510'	Limestone
TD 510'	



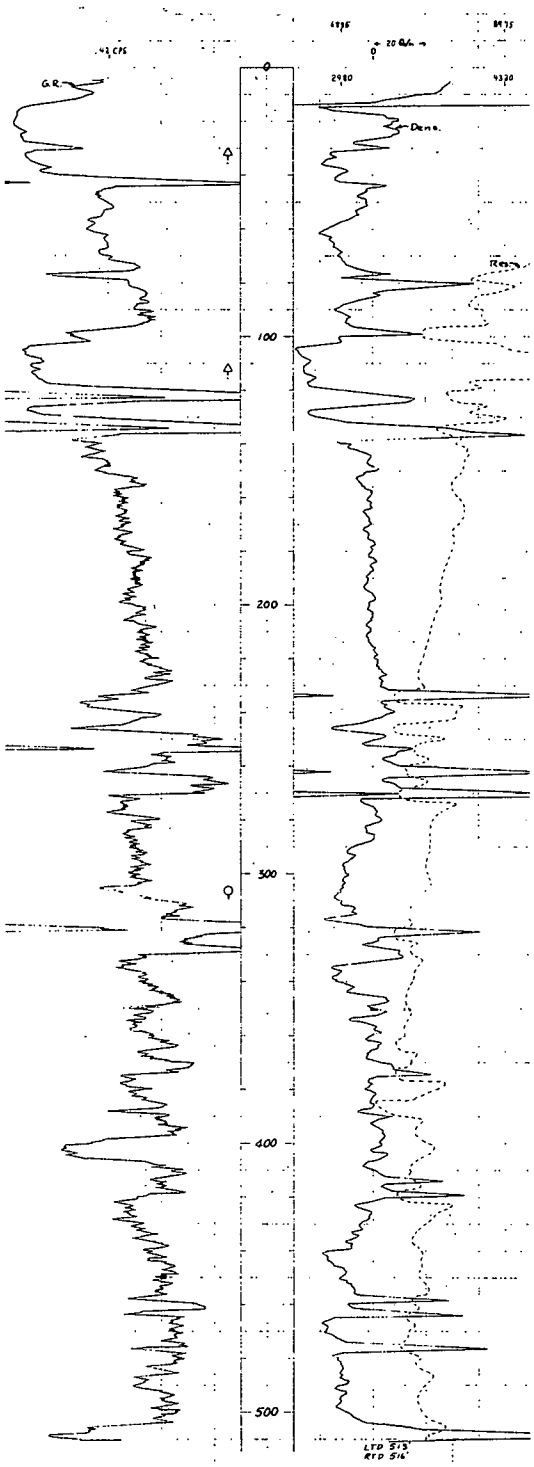
KANSAS GEOLOGICAL SURVEY (E.R.D.A.)
TEST HOLE Q (BB 25-25-26-1)
NE SE SW Sec. 26 - T.25S. - R.25E.
GROUND ELEVATION: 875 FEET
BOURBON COUNTY, KANSAS

0- 12'	Alluvium
12- 13'	Coal
13- 29'	Limestone
29- 35'	Shale, black
35- 36'	Coal
36- 44'	Limestone
44- 45'	Coal
45- 48'	Shale, black
48- 84'	Siltstone, shaley
84-119'	Shale, greenish gray
119-121'	Coal
121-131'	Shale, light gray
131-133'	Limestone
133-145'	Shale, black
145-147'	Coal
147-165'	Shale, gray
165-167'	Coal
167-182'	Shale, gray
182-184'	Coal
184-206'	Shale, gray
206-208'	Shale, black
208-235'	Shale, dark gray
235-250'	Sandstone, very silty
250-278'	Shale, dark gray, silty
278-292'	Sandstone, silty
292-293'	Coal (trace)
293-313'	Shale, dark gray
313-356'	Sandstone
356-358'	Coal
358-375'	Shale, dark gray
375-376'	Coal
376-392'	Shale, black
392-394'	Coal
394-402'	Shale, black
402-404'	Coal
404-406'	Shale, black
406-410'	Limestone
410-414'	Chert
TD 414'	



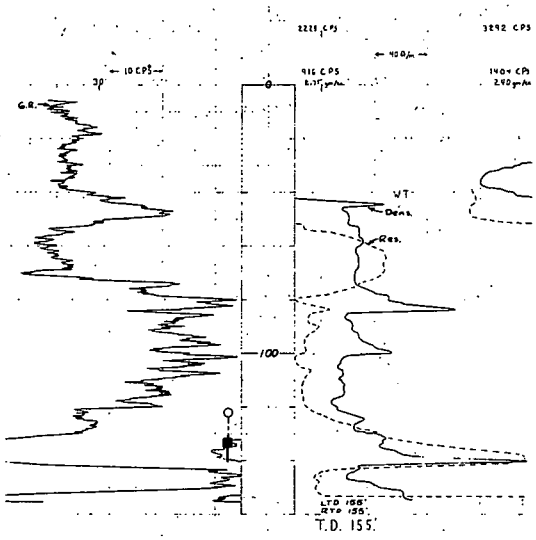
KANSAS GEOLOGICAL SURVEY (E.R.D.A.)
TEST HOLE R (CR 27-24-27-1)
NE NE NE Sec. 27 - T.27S. - R.24E.
GROUND ELEVATION: 979 FEET
CRAWFORD COUNTY, KANSAS

0- 9'	Limestone
9- 34'	Shale
34- 35'	Coal
35- 65'	Shale
65- 76'	Sandstone
75- 77'	Coal
77- 88'	Shale
88-103'	Limestone
103-106'	Shale, black
106-112'	Limestone
112-116'	Shale
116-117'	Coal
117-120'	Shale
120-140'	Sandstone
140-204'	Shale
204-206'	Coal
206-212'	Limestone
212-228'	Shale
228-229'	Coal
229-242'	Shale
242-243'	Coal
243-253'	Shale
253-260'	Limestone
260-262'	Coal
262-268'	Shale
268-280'	Sandstone
280-286'	Shale
286-287'	Coal
287-292'	Shale
292-300'	Sandstone
300-304'	Coal
304-312'	Shale
312-313'	Coal
313-343'	Shale
343-344'	Coal
344-352'	Shale
352-364'	Sandstone
364-365'	Limestone
365-378'	Shale
378-386'	Sandstone
386-388'	Coal
388-402'	Shale
402-403'	Coal
403-420'	Shale
420-440'	Sandstone
440-442'	Coal
442-454'	Shale
454-455'	Coal
455-470'	Shale
470-475'	Sandstone
475-477'	Coal
477-482'	Shale
482-483'	Chert
TD 483'	



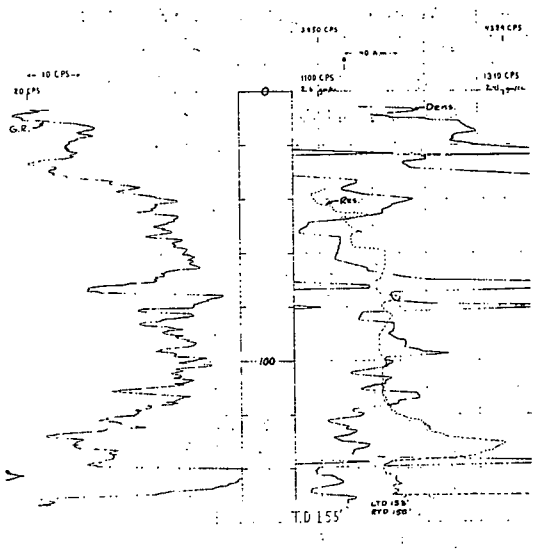
KANSAS GEOLOGICAL SURVEY (E.R.D.A.)
TEST HOLE S (BB 27-23-24-1)
SW SW SE Sec. 24 - T.27S. - R.23E.
GROUND ELEVATION: 927 FEET
BOURBON COUNTY, KANSAS

0- 10'	Alluvium
10- 14'	Limestone
14- 15'	Coal
15- 44'	Limestone
44- 76'	Shale
76- 77'	Coal
77- 78'	Shale
78- 82'	Limestone
82-103'	Shale
103-122'	Limestone
122-125'	Shale
125-126'	Coal
126-130'	Shale
130-135'	Limestone
135-138'	Shale
138-139'	Coal
139-143'	Shale
143-144'	Limestone
144-165'	Sandstone
165-237'	Shale
237-238'	Coal
238-242'	Siltstone
242-248'	Limestone
248-263'	Shale
263-264'	Coal
264-274'	Shale
274-283'	Sandstone
283-305'	Shale
305-315'	Sandstone
315-324'	Shale
324-326'	Coal
326-378'	Shale
378-379'	Coal
379-393'	Shale
393-395'	Limestone
395-404'	Shale
404-411'	Sandstone
411-415'	Shale
415-416'	Coal
416-425'	Shale
425-428'	Sandstone
428-462'	Shale
462-463'	Coal
463-476'	Coal
476-478'	Coal
478-488'	Shale
488-492'	Sandstone
492-503'	Shale
503-508'	Sandstone
508-510'	Shale
510-512'	Coal
512-514'	Shale
514-515'	Sandstone
515-516'	Chert
TD 516'	



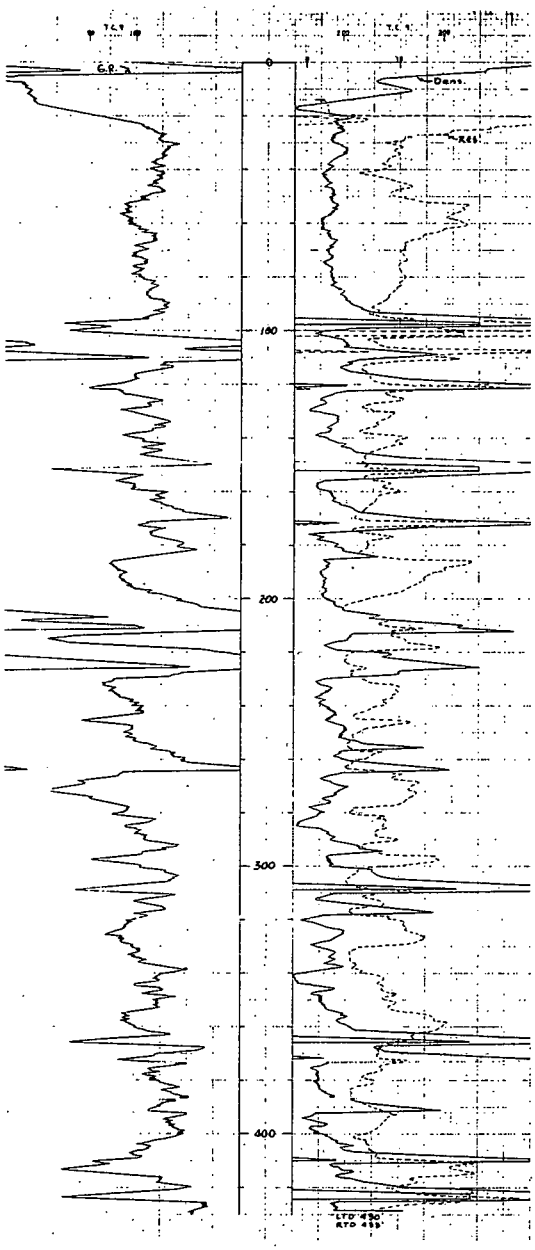
KANSAS GEOLOGICAL SURVEY (E.R.D.A.)
TEST HOLE T (CR 30-25-26-1)
SW SW SW Sec. 26-T.30S.-R.25E.
GROUND ELEVATION: 932 FEET
CRAWFORD COUNTY, KANSAS

0- 45'	Mine spoils
45- 46'	Coal
46- 73'	Sandstone, carbonaceous
73- 83'	Shale, gray
83- 85'	Coal
85- 99'	Shale, gray to black
99-101'	Coal
101-120'	Shale, black
120-142'	Sandstone, silty
142-143'	Coal
143-151'	Shale, black
151-155'	Chert
TD 155'	



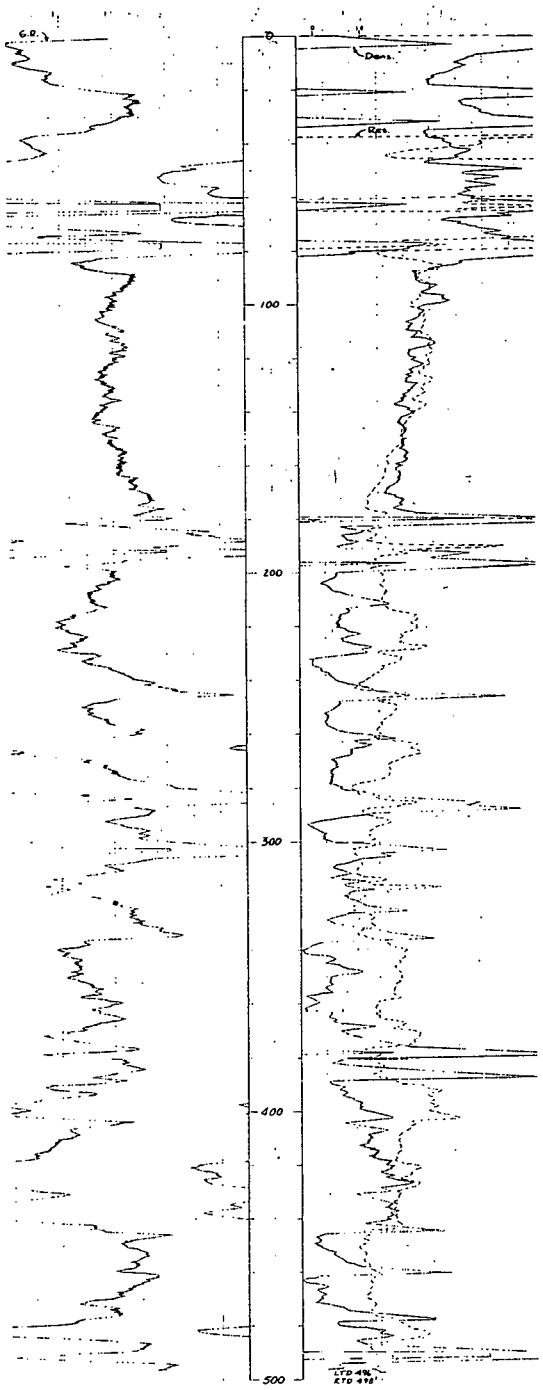
KANSAS GEOLOGICAL SURVEY (E.R.D.A.)
TEST HOLE U (CR 31-25-15-1)
NE NE SE Sec. 15-T.31S.-R.25E.
GROUND ELEVATION: 919 FEET
CRAWFORD COUNTY, KANSAS

0- 25'	Alluvium
21- 23'	Coal
23- 34'	Shale, gray
34- 35'	Coal
35- 48'	Shale, dark gray
48- 52'	Sandstone
52- 74'	Shale, dark gray
74- 76'	Coal
76- 82'	Shale, dark gray
82- 84'	Coal
84-118'	Shale, dark gray
118-134'	Sandstone, carbonaceous
134-136'	Coal
136-150'	Shale, black
150-153'	Chert
TD 153'	



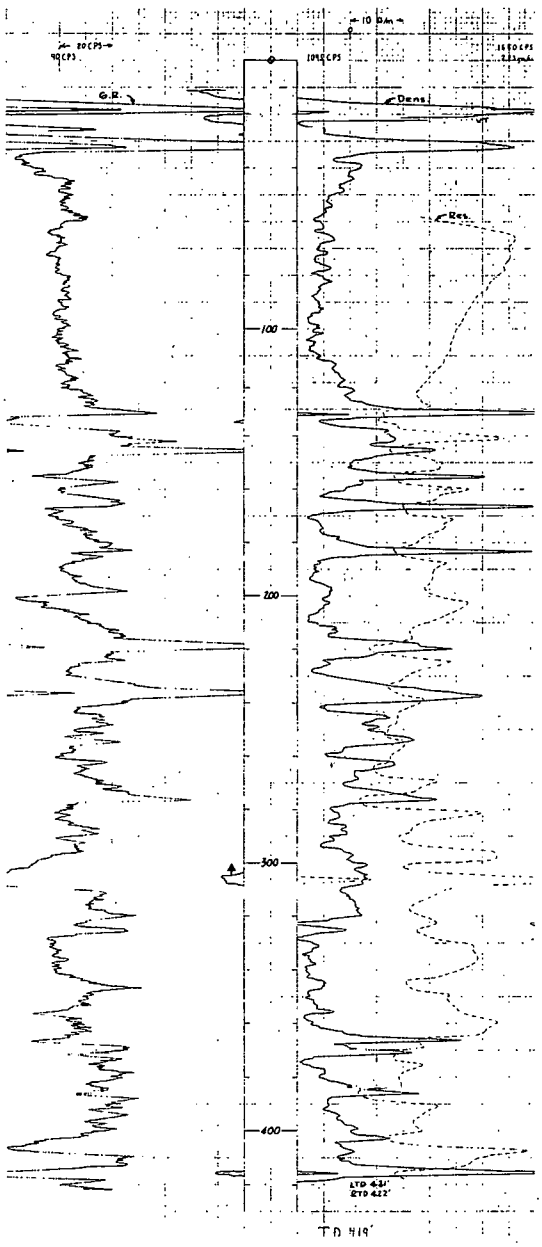
KANSAS GEOLOGICAL SURVEY (E.R.D.A.)
TEST HOLE V (CR 30-24-8-1)
NW NW NW Sec. 8 - T.30S. - R.24E.
GROUND ELEVATION: 935 FEET
CRAWFORD COUNTY, KANSAS

0- 2'	Alluvium
2- 4'	Shale, black
4- 10'	Limestone
10- 20'	Sandstone
20- 97'	Shale
97- 99'	Coal
99-102'	Limestone
102-112'	Shale
112-114'	Coal
114-133'	Shale
133-134'	Coal
134-152'	Shale
152-154'	Coal
154-172'	Shale
172-173'	Coal
173-177'	Limestone
177-215'	Shale
215-223'	Sandstone
223-238'	Shale
238-239'	Coal
239-258'	Shale
258-259'	Coal
259-268'	Shale
268-278'	Sandstone
278-283'	Shale
283-285'	Limestone
285-311'	Shale
311-312'	Coal
312-338'	Shale
338-339'	Coal
339-350'	Shale
350-368'	Shaley Sandstone
368-369'	Coal
369-392'	Shale
392-393'	Coal
393-412'	Shale
412-413'	Coal
413-417'	Sandstone
417-432'	Shale
432-433'	Chert
TD 433'	



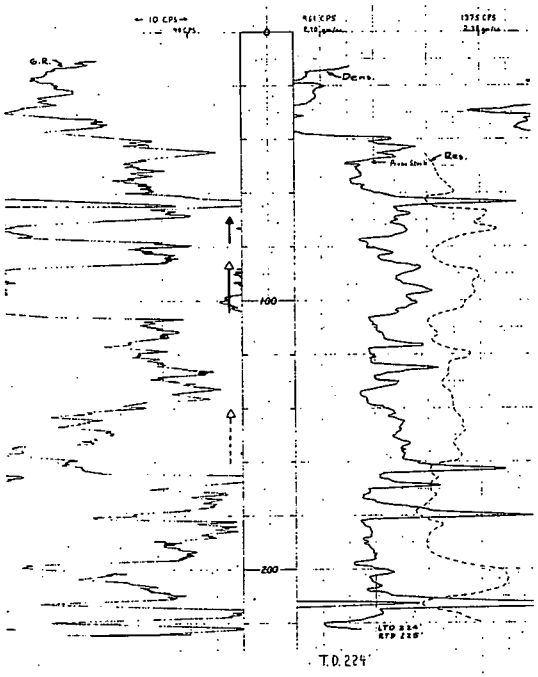
KANSAS GEOLOGICAL SURVEY (E.R.D.A)
TEST HOLE X (CR 29-24-3-1)
NW NW NW Sec. 3-T.29S.-R.24E.
GROUND ELEVATION: 994 FEET
CRAWFORD COUNTY, KANSAS

0- 15'	Alluvium
15- 23'	Shale
23- 25'	Coal
25- 32'	Shale
32- 34'	Coal
34- 48'	Shale
48- 63'	Limestone
63- 66'	Shale
66- 75'	Limestone
75- 81'	Shale
81- 82'	Coal
82-182'	Shale
182-183'	Coal
183-184'	Limestone
184-197'	Shale
197-198'	Coal
198-203'	Shale
203-204'	Limestone
204-215'	Shale
215-228'	Sandstone
228-229'	Coal
229-245'	Shale
245-246'	Coal
246-263'	Shale
263-275'	Sandstone
275-287'	Shale
287-288'	Coal
288-302'	Shale
302-303'	Coal
303-316'	Shale
316-317'	Limestone
317-319'	Coal
319-364'	Shale
364-373'	Sandstone
373-384'	Shale
384-385'	Coal
385-387'	Shale
387-397'	Sandstone
397-398'	Coal
398-437'	Sandstone
437-438'	Coal
438-457'	Shale
457-458'	Coal
458-484'	Shale
484-488'	Sandstone
488-493'	Shale
493-496'	Shale
496-498'	Chert
TD 498'	



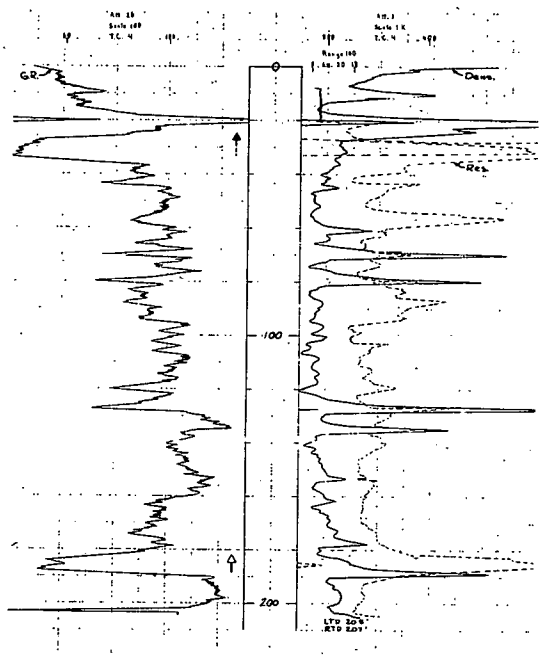
KANSAS GEOLOGICAL SURVEY (E.R.D.A.)
TEST HOLE Y (CR 28-24-16-1)
NE NE NE Sec. 16-T.28S.-R.24E.
GROUND ELEVATION: 939 FEET
CRAWFORD COUNTY, KANSAS

0- 5'	Alluvium
5- 16'	Limestone
16- 20'	Black Shale
20- 30'	Limestone
30- 34'	Black Shale
34- 35'	Coal
35- 40'	Sandstone, greenish gray
40- 45'	Siltstone, greenish gray
45-129'	Shale, greenish gray to gray
129-130'	Coal
130-133'	Shale, dark gray
133-138'	Limestone
138-154'	Shale, black
154-156'	Coal
156-164'	Shale, gray to black
164-168'	Limestone
168-182'	Shale, gray to black
182-184'	Coal
184-198'	Shale, gray
198-210'	Sandstone
210-224'	Shale, dark gray
224-226'	Coal
226-232'	Sandstone
232-268'	Shale, gray
268-269'	Coal
269-278'	Shale, gray
278-310'	Sandstone, shaley
310-324'	Shale, gray
324-325'	Coal
325-328'	Shale, gray
328-342'	Sandstone, shaley
342-352'	Shale, gray, silty
352-366'	Sandstone
366-367'	Coal
367-369'	Shale, brown
369-371'	Coal
371-385'	Shale, gray
385-386'	Coal
386-402'	Shale
402-408'	Sandstone
408-410'	Coal
410-416'	Shale, gray
416-418'	Coal
418-422'	Chert
TD 422'	



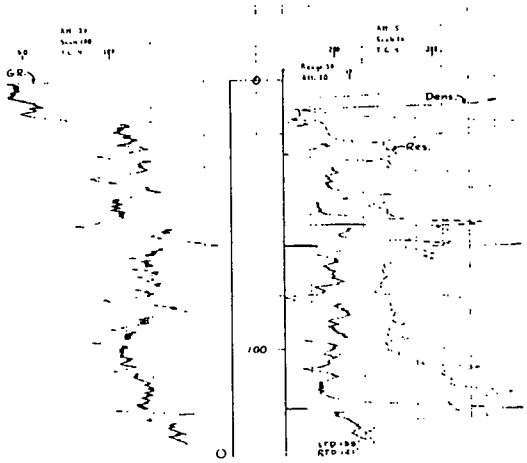
KANSAS GEOLOGICAL SURVEY (E.R.D.A.)
TEST HOLE Z (CR 27-25-26-1)
NE NE SE Sec. 26 - T.27S. - R.25E.
GROUND ELEVATION: 804 FEET
CRAWFORD COUNTY, KANSAS

0- 18'	Alluvium
18- 20'	Coal
20- 31'	Sandstone
31- 32'	Coal
32- 36'	Limestone
36- 64'	Shale, black
64- 66'	Coal
66- 70'	Shale, gray
70- 78'	Sandstone
78- 86'	Shale, dark gray
86-105'	Sandstone
105-116'	Shale, gray
116-117'	Coal
117-124'	Shale, gray
124-125'	Coal
125-138'	Shale, dark gray
138-162'	Sandstone
162-164'	Coal
164-168'	Shale, gray
168-169'	Coal
169-178'	Shale, black
178-180'	Coal
180-196'	Shale, dark gray
196-204'	Sandstone
204-210'	Shale, gray
210-212'	Coal
212-218'	Shale, black
218-220'	Limestone
220-225'	Chert
TD 225'	



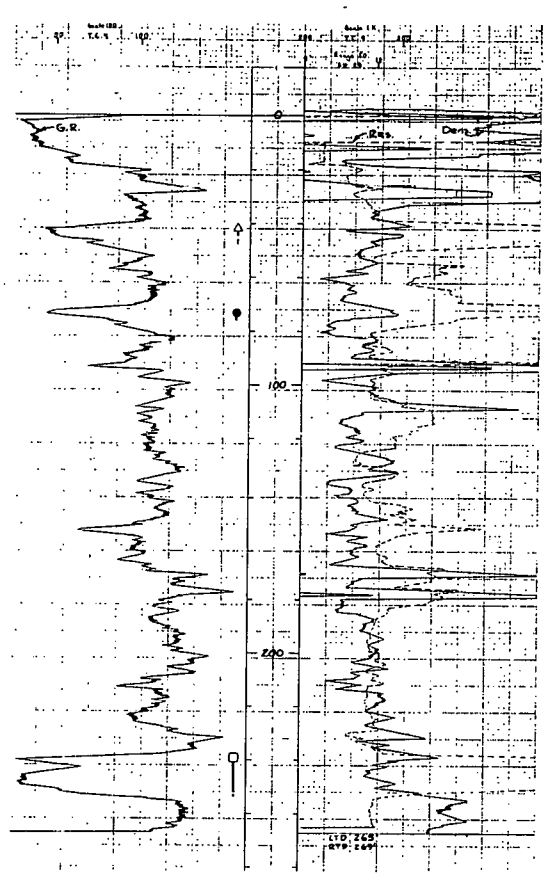
KANSAS GEOLOGICAL SURVEY (E.R.D.A.)
TEST HOLE AA (CK 32-24-2-1)
NW SW SW Sec. 2 - T.32S. - R.24E.
GROUND ELEVATION: 916 FEET
CHEROKEE COUNTY, KANSAS

0- 16'	Alluvium
16- 22'	Shale
22- 24'	Coal
24- 30'	Clay
30- 37'	Sandstone
37- 44'	Shale
44- 45'	Coal
45- 58'	Shale
58- 60'	Sandstone
60- 62'	Coal
62- 68'	Shale
68- 70'	Coal
70- 84'	Shale
84- 85'	Coal
85- 89'	Sandstone
89- 90'	Coal
90-114'	Shale
114-115'	Coal
115-127'	Shale
127-128'	Coal
128-137'	Shale
137-138'	Coal
138-180'	Shale
180-181'	Coal
181-187'	Sandstone
187-205'	Shale
205-207'	Limestone
TD 207'	



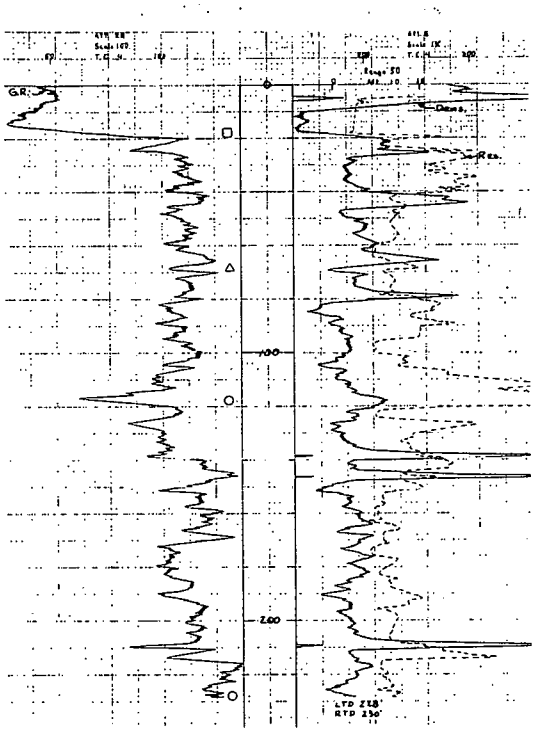
KANSAS GEOLOGICAL SURVEY (E.R.D.A.)
TEST HOLE BB (CK 33-24-2-1)
NW SW SW Sec. 2-T.33S.-R.24E.
GROUND ELEVATION: 898 FEET
CHEROKEE COUNTY, KANSAS

0- 18'	Alluvium
18- 37'	Shale
37- 45'	Sandstone
45- 54'	Shale
54- 56'	Coal
56- 63'	Shale
63- 65'	Coal
65- 95'	Shale
95-100'	Siltstone
100-118'	Shale
118-120'	Coal
120-133'	Shale
133-134'	Coal
134-140'	Shale
140-141'	Chert
TD 141'	



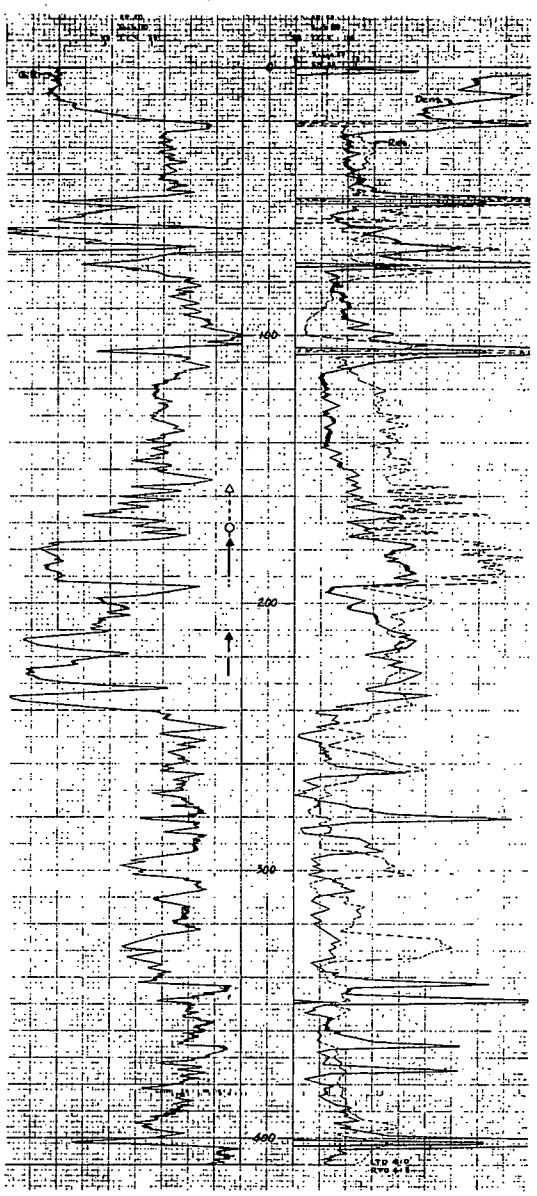
KANSAS GEOLOGICAL SURVEY (E.R.D.A.)
TEST HOLE CC (CK 34-23-3-1)
SE SE SW Sec. 3 - T.34S. - R.23E.
GROUND ELEVATION: 872 FEET
CHEROKEE COUNTY, KANSAS

0- 22'	Alluvium
22- 27'	Shale
27- 28'	Coal
28- 39'	Shale
39- 47'	Sandstone
47- 54'	Shale
54- 55'	Coal
55- 70'	Shale
70- 80'	Sandstone
80- 91'	Shale
91- 92'	Coal
92-105'	Shale
105-107'	Coal
107-153'	Shale
153-155'	Sandstone
155-169'	Shale
169-172'	Coal
172-178'	Shale
178-182'	Coal
182-235'	Shale
235-268'	Sandstone
268-269'	Chert
TD 269'	



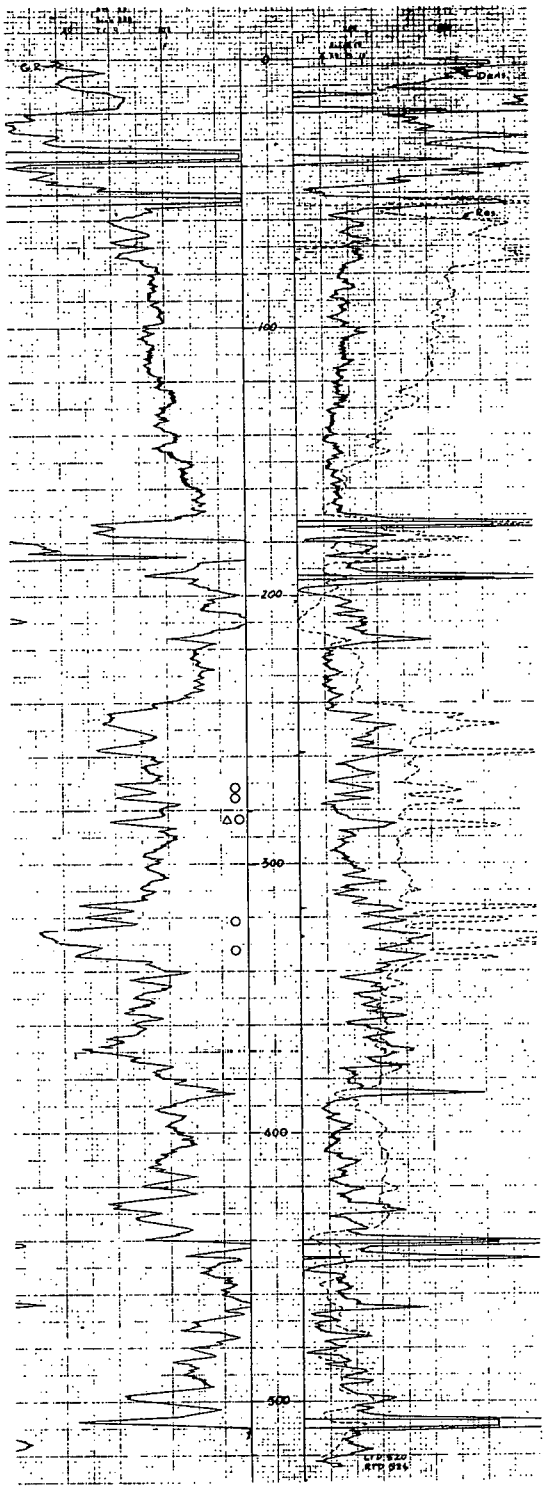
KANSAS GEOLOGICAL SURVEY (E.R.D.A.)
TEST HOLE DD (CK 34-22-13-1)
NW NW NW Sec. 13 - T.34S. - R.22E.
GROUND ELEVATION: 824 FEET
CHEROKEE COUNTY, KANSAS

0- 15'	Alluvium
15- 20'	Sandstone
20- 22'	Coal
22- 48'	Shale
48- 51'	Sandstone
51- 66'	Shale
66- 70'	Sandstone
70- 84'	Shale
84- 85'	Coal
85-115'	Shale
115-120'	Sandstone
120-138'	Shale
138-139'	Coal ?
139-144'	Shale
144-152'	Coal
152-168'	Shale
168-169'	Coal
169-229'	Shale
229-230'	Limestone
TD 230'	



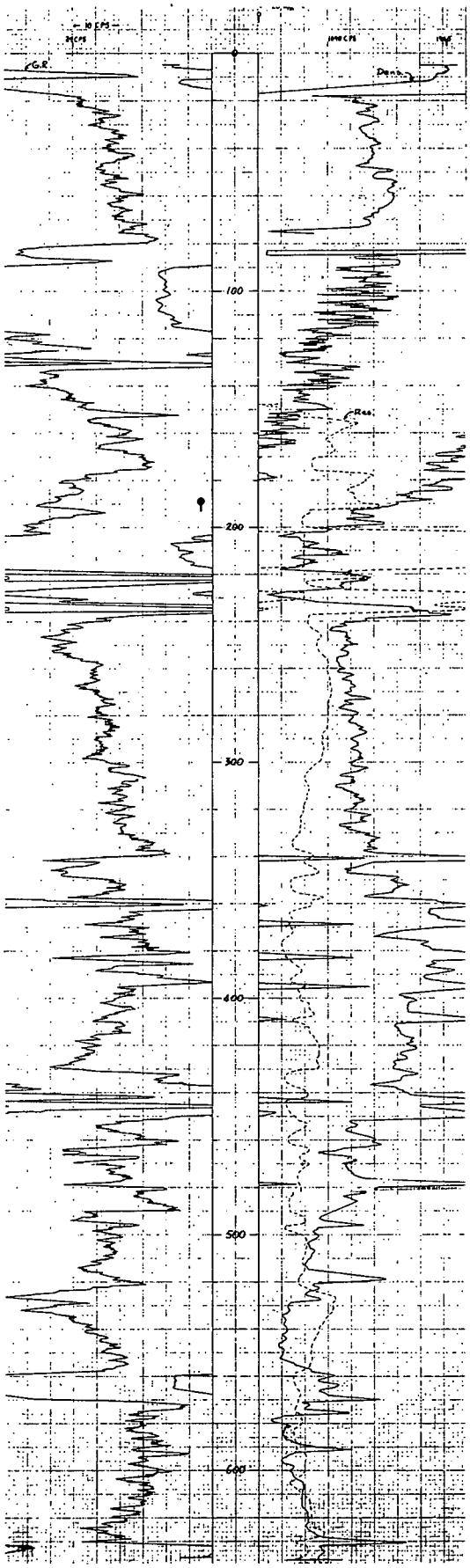
KANSAS GEOLOGICAL SURVEY (E.R.D.A.)
TEST HOLE GG (CR 30-23-32-1)
SW SW SW Sec. 32 - T.30S. - R.23E.
GROUND ELEVATION: 881 FEET
CRAWFORD COUNTY, KANSAS

0- 22'	Alluvium
22- 49'	Shale
49- 51'	Coal
51- 53'	Shale
53- 60'	Limestone
60- 74'	Shale
74- 75'	Coal
75-110'	Shale
110-112'	Coal
112-133'	Shale
133-135'	Coal
135-145'	Shale
145-238'	Sandstone
238-239'	Coal
239-248'	Shale
248-250'	Limestone
250-262'	Shale
262-263'	Coal
263-282'	Shale
282-283'	Coal
283-295'	Shale
295-296'	Coal
296-303'	Sandstone
303-325'	Shale
325-335'	Sandstone
335-342'	Shale
342-343'	Coal
343-376'	Shale
376-378'	Coal
378-397'	Shale
397-400'	Sandstone
400-402'	Coal
402-411'	Shale (black)
411-413'	Chert
TD 413'	



KANSAS GEOLOGICAL SURVEY (E.R.D.A.)
TEST HOLE HH (CR 29-23-32-1)
SE SE SE Sec. 32 - T.29S. - R.23E.
GROUND ELEVATION: 938 FEET
CRAWFORD COUNTY, KANSAS

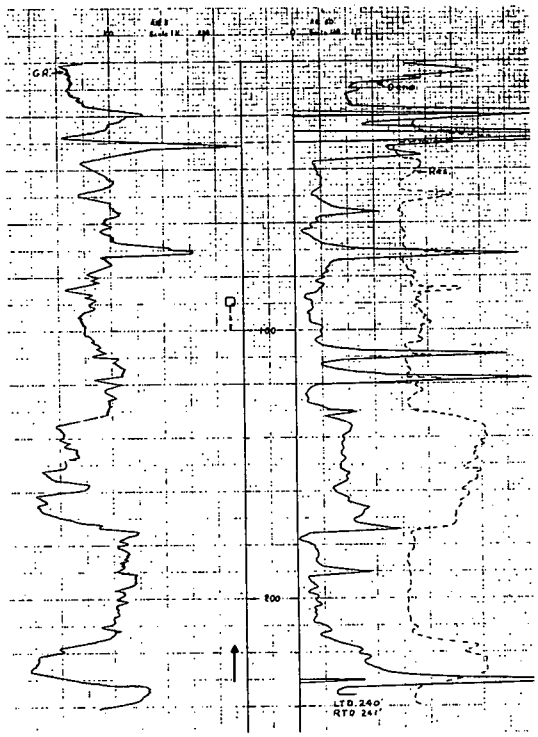
0- 11'	Alluvium
11- 22'	Shale
22- 38'	Limestone
38- 42'	Shale
42- 53'	Limestone
53- 57'	Shale, black
57- 59'	Limestone?
59- 80'	Sandstone, very shaley
80-170'	Shale
170-172'	Coal
172-177'	Shale
177-184'	Limestone
184-233'	Shale
233-234'	Coal
234-240'	Shale
240-374'	Sandstone, shaley
374-375'	Coal
375-383'	Shale
383-385'	Coal
385-440'	Shale, sandy
440-443'	Shale
443-445'	Coal
445-462'	Shale
462-463'	Coal
463-474'	Shale
474-475'	Coal
475-496'	Shale
496-503'	Sandstone
503-508'	Shale
508-510'	Coal
510-524'	Shale, pyritic
524-526'	Limestone
TD 526'	



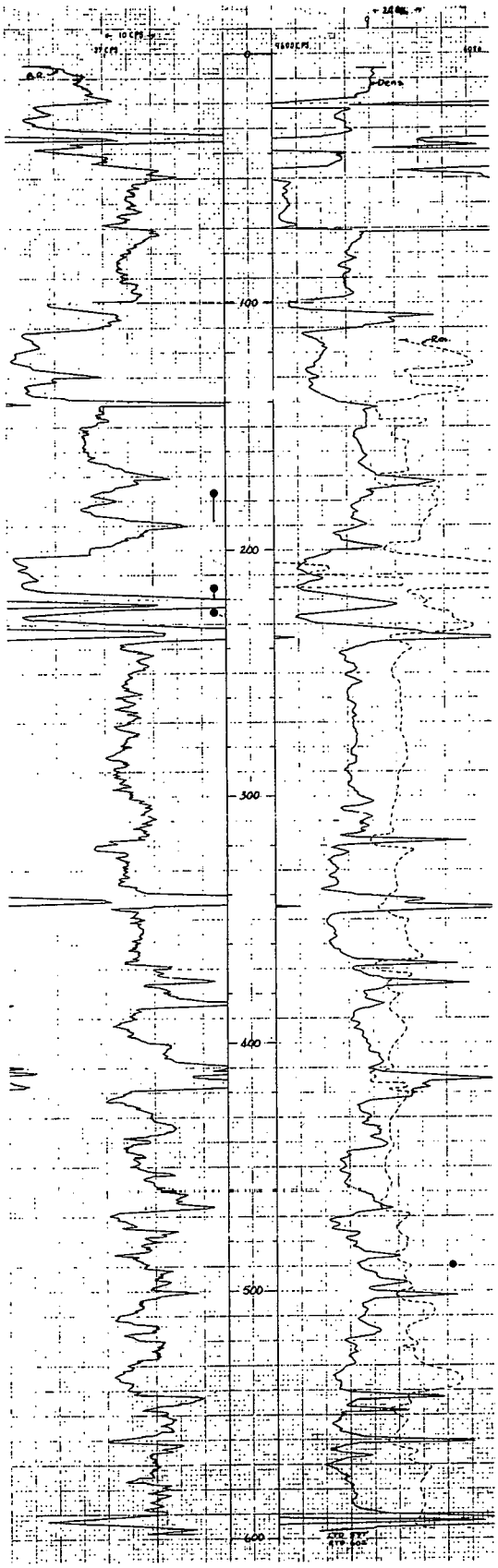
KANSAS GEOLOGICAL SURVEY (E.R.D.A.)
TEST HOLE II (CR 28-22-24-1)
SE SE NE Sec. 24 - T.28S. - R.22E.
GROUND ELEVATION: 988 FEET
CRAWFORD COUNTY, KANSAS

0- 4'	Alluvium
4- 21'	Limestone (weathered)
21- 83'	Shale
83- 87'	Limestone
87- 89'	Coal
89- 93'	Shale
93-132'	Limestone
132-153'	Shale
153-154'	Coal
154-178'	Shale
178-194'	Sandstone
194-195'	Coal
195-200'	Shale
200-218'	Limestone
218-228'	Shale, black
228-237'	Limestone
237-245'	Shale
245-260'	Sandstone
260-340'	Shale
340-342'	Coal
342-344'	Shale
344-348'	Limestone
348-368'	Shale
368-370'	Coal
370-394'	Shale
394-399'	Limestone
399-407'	Shale
407-408'	Coal
408-420'	Shale
420-433'	Sandstone
433-447'	Shale
447-449'	Coal
449-450'	Limestone
450-468'	Shale
468-470'	Limestone
470-493'	Shale
493-495'	Coal
495-525'	Shale
525-540'	Sandstone
540-560'	Shale
560-568'	Sandstone
568-570'	Coal
570-576'	Shale
576-578'	Coal
578-603'	Shale
603-604'	Coal
604-612'	Shale
612-614'	Sandstone
614-632'	Shale
632-633'	Coal
633-642'	Shale
642-645'	Chert
TD 645'	

KANSAS GEOLOGICAL SURVEY (E.R.D.A.)
TEST HOLE JJ (CR 30-25-14-1)
SE NE NW Sec. 14 - T.30S. - R.25E.
GROUND ELEVATION: 928 FEET
CRAWFORD COUNTY, KANSAS



0- 20'	Alluvium
20- 28'	Shale
28- 30'	Coal
30- 37'	Shale
37- 42'	Sandstone
42- 43'	Coal
43- 56'	Shale
56- 59'	Coal
59- 74'	Shale
74- 76'	Coal
76- 84'	Shale
84-105'	Sandstone
105-112'	Shale
112-113'	Coal
113-120'	Shale
120-125'	Sandstone
125-137'	Shale
137-138'	Coal
139-172'	Sandstone
172-173'	Coal
173-189'	Shale
189-191'	Coal
191-213'	Shale
213-214'	Coal
214-230'	Sandstone
230-231'	Coal
231-240'	Shale
240-241'	Chert
TD 241'	



KANSAS GEOLOGICAL SURVEY (E.R.D.A.)
TEST HOLE KK (BB 27-23-8-1)
SW SE SW Sec. 8-T.27S.-R.23E.
GROUND ELEVATION: 945 FEET
BOURBON COUNTY, KANSAS

0- 5'	Alluvium
5- 20'	Shale
20- 38'	Limestone
38- 42'	Shale
42- 48'	Limestone
48-103'	Shale
103-140'	Limestone
140-179'	Shale
179-190'	Sandstone
190-202'	Shale
202-203'	Coal
203-222'	Limestone
222-226'	Shale
226-228'	Sandstone
228-233'	Limestone
233-238'	Shale
238-240'	Coal
240-320'	Shale
320-321'	Coal
321-342'	Shale
342-344'	Limestone
344-372'	Shale
372-374'	Coal
374-382'	Shale
382-383'	Coal
383-412'	Shale
412-413'	Coal
413-420'	Shale
420-430'	Sandstone
430-468'	Shale
468-469'	Coal
469-477'	Shale
477-479'	Limestone
479-488'	Shale
488-490'	Coal
490-495'	Sandstone
495-498'	Shale
498-499'	Coal
499-530'	Shale
530-543'	Sandstone
543-544'	Coal
544-552'	Shale
552-553'	Coal
553-565'	Shale
565-567'	Coal
567-585'	Shale
585-595'	Sandstone
595-597'	Shale
597-599'	Coal
599-600'	Shale
600-602'	Chert
TD 602'	

APPENDIX D

CORE GRAPHS AND ANALYSES

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Well No.	Location	Page No.
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D	24-27S-24E	87-88
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L	3-33S-23E	91-92
N	34-29S-24E	93-94
Q	26-25S-25E	95-96
T	26-30S-25E	97-98
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CC	3-34S-23E	101-102
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HH	32-29S-23E	95-96
JJ	14-30S-25E	105-106

Key to Symbols

K -- permeability (md.)

ϕ -- porosity (% B.V.)

So -- oil saturation (% ϕ)

Sw -- water saturation (% ϕ)

μ -- arith. mean

σ -- standard deviation (note that std. dev. for permeability is not valid - no normal distribution)

-- Sandstone

-- Shale

-- Siltstone

-- Coal

-- limestone

-- root traces (fossil)

-- cross-bedding

-- burrowed

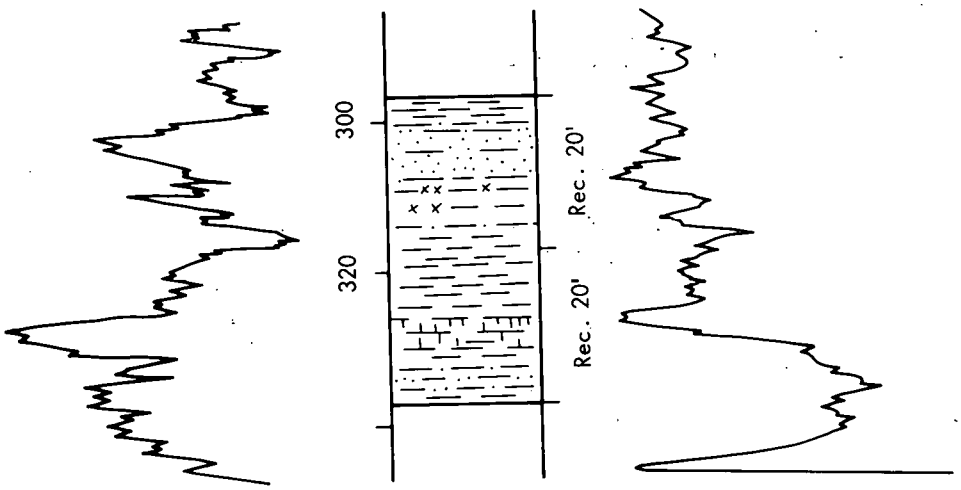
-- siderite (bed or nodules)

-- pebbles

-- wavy bedding

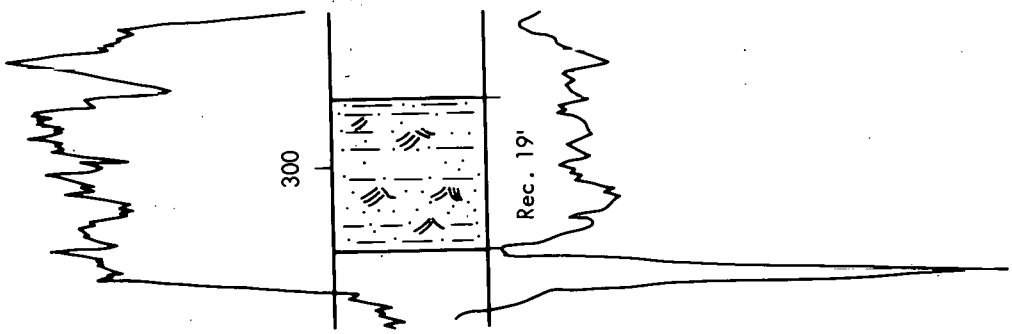
A

Sec. 35 T.24S. R.25E.



B

Sec. 9 T.25S. R.25E.



A

Sec. 35-T.24S.-R.25E.

Upper Warner Sandstone

No Core Analyzed - no oil shows.

B

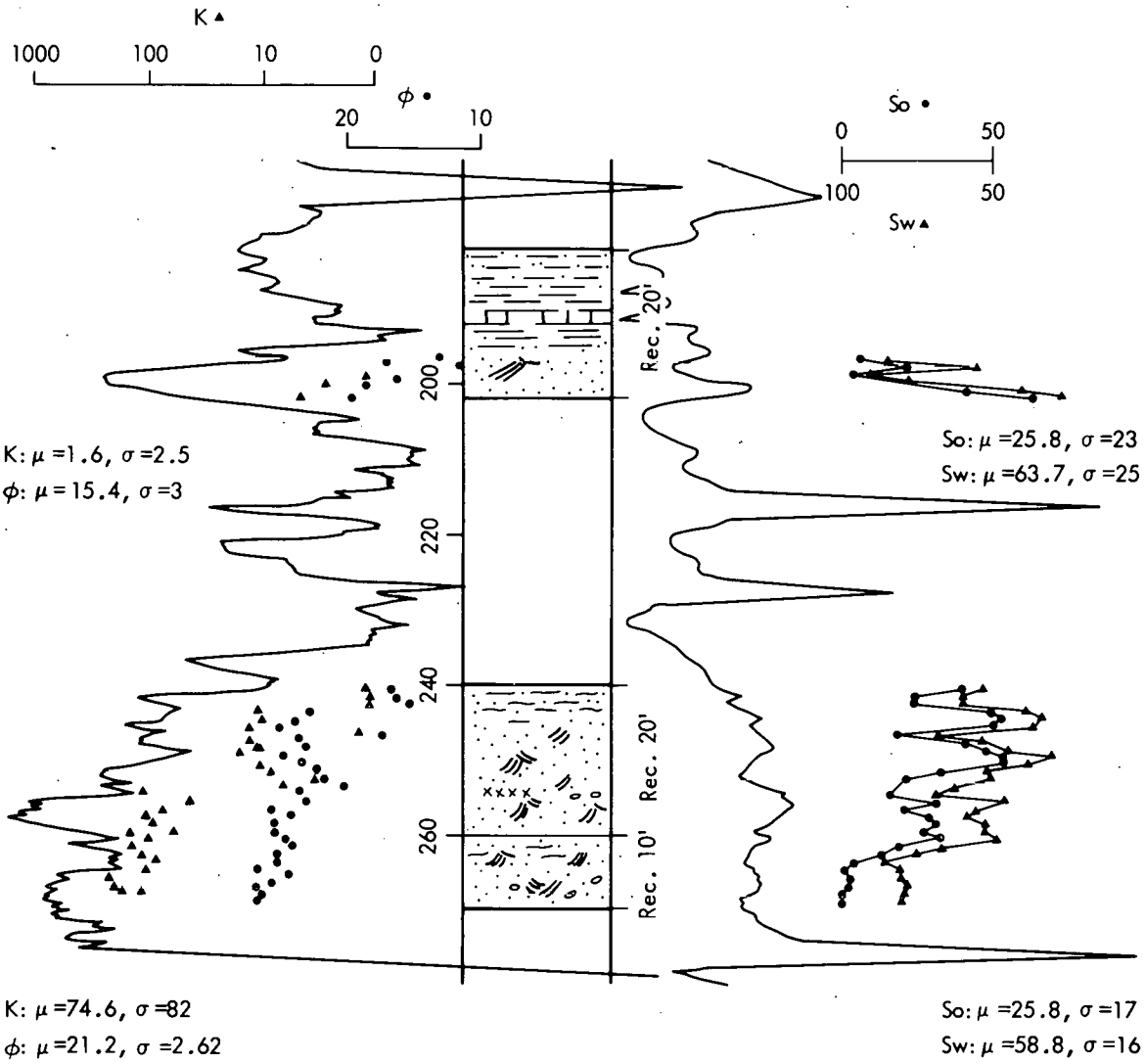
Sec. 9-T.25S.-R.25E.

Upper Warner Sandstone

No Core Analyzed - trace of dead oil throughout.

C

Sec. 10 T.26S. R.25E.



C

Sec. 10-T.26S.-R.25E.

Lower Bluejacket Sandstone

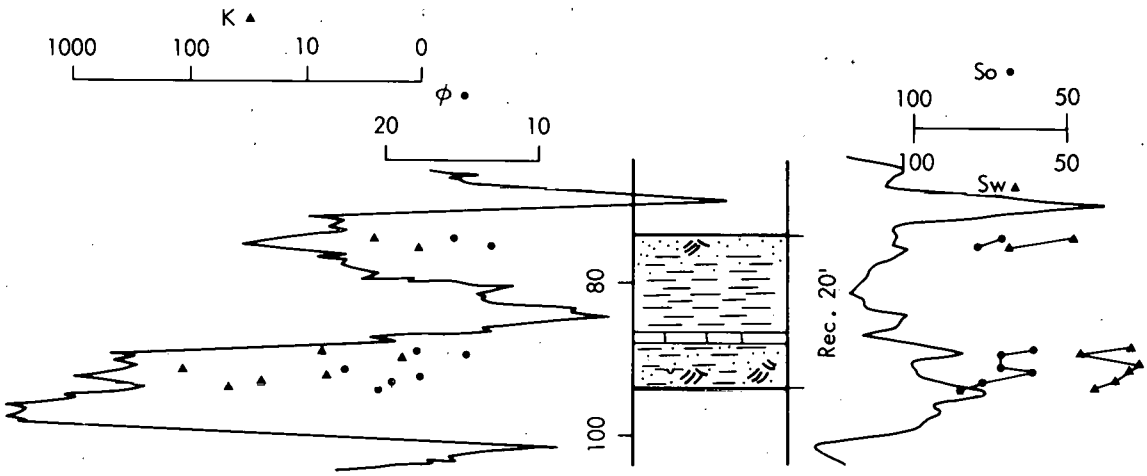
Sample No.	Depth, Feet	Effective Porosity Percent	Percent Saturation Oil	Water	Total	Oil Content Bbls./A Ft.	Perm., Mill.
1	196.4	12.8	6	85	91	60	Imp.
2	197.2	15.2	23	55	78	271	Imp.
3	198.5	11.3	3	91	94	26	Imp.
4	199.5	15.5	18	78	96	217	0.19
5	200.5	18.2	42	46	88	593	3.9
6	201.8	19.4	63	27	90	948	5.7

Upper Warner Sandstone

7	240.5	15.7	40	53	93	487	0.65
8	241.5	15.4	24	61	85	287	0.35
9	242.5	14.2	24	61	85	264	0.24
10	243.5	21.0	49	39	88	799	15.
11	244.5	22.0	53	33	86	905	13.
12	245.5	23.0	50	36	86	892	20.
13	246.5	16.2	17	76	93	214	1.3
14	247.5	21.9	36	54	90	612	20.
15	248.5	21.2	48	45	93	790	16.
16	249.5	22.8	54	30	84	955	25.
17	250.5	21.3	54	38	92	893	11.
18	251.5	20.6	33	54	87	528	9.4
19	252.5	20.3	21	50	71	331	3.5
20	253.5	18.8	17	64	81	248	9.0
21	254.5	21.9	16	68	84	272	107.
22	255.5	21.6	31	46	77	520	67.
23	256.5	23.6	20	60	80	366	82.
24	257.5	22.2	28	59	87	482	107.
25	258.5	23.4	31	52	83	563	94.
26	259.5	23.2	27	53	80	486	75.
27	260.5	22.8	33	48	81	584	101.
28	261.5	22.6	18	66	84	316	191.
29	262.5	23.1	13	75	88	233	116.
30	263.5	23.1	4	86	90	72	91.
31	264.5	22.6	1	80	81	18	105.
32	265.5	21.3	2	80	82	33	305.
33	266.5	22.7	2	78	80	35	284.
34	267.5	23.4	1	79	80	18	186.
35	268.5	23.2	1	80	81	18	108.

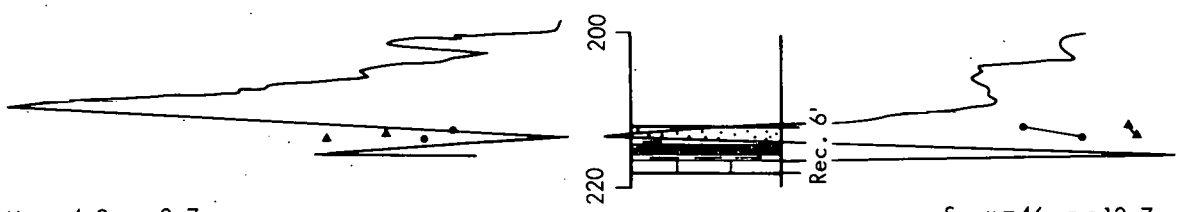
D

Sec. 24 T.27S. R.24E.



K: μ=27.9, σ=38.0
ϕ: μ=17.6, σ=3.1

So: μ=27.4, σ=8
Sw: μ=41, σ=13.8



K: μ=4.9, σ=3.7
ϕ: μ=16.5, σ=1.2

So: μ=46, σ=12.7
Sw: μ=29.5, σ=.7

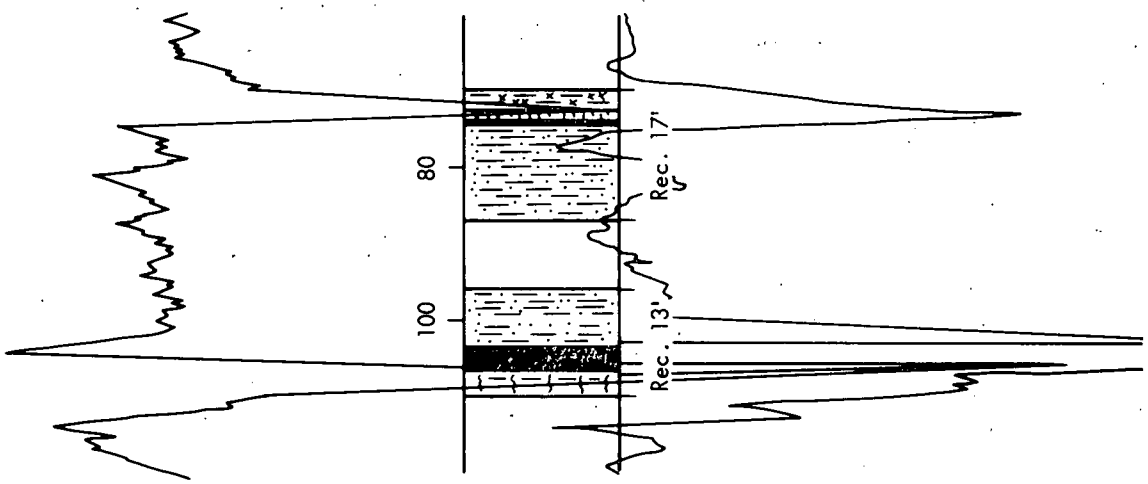
D

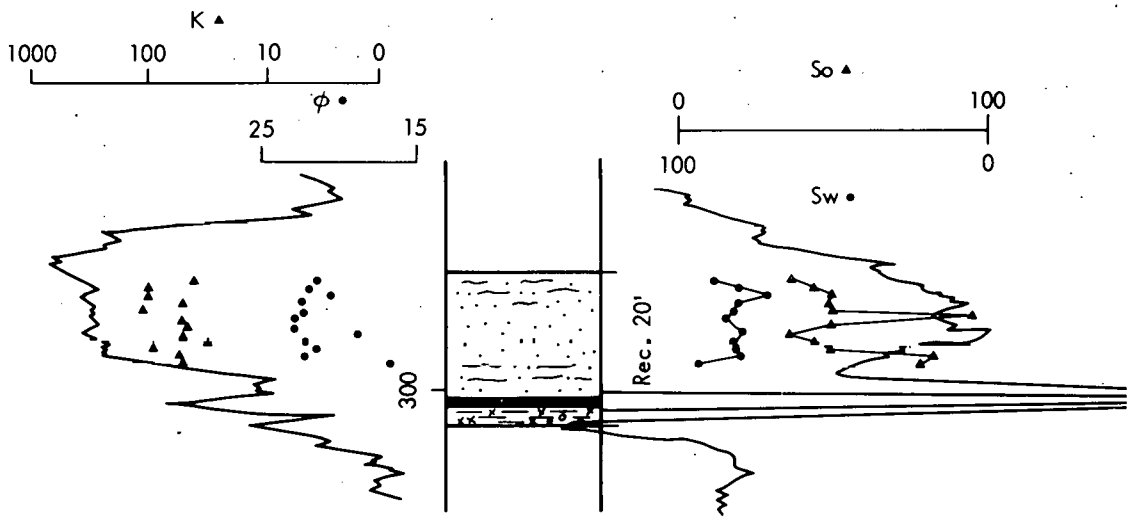
Sec. 24-T.27S.-R.24E.

Sample No.	Depth, Feet	Effective Porosity Percent	Percent Saturation Oil	Water	Total	Oil Content Bbls./A Ft.	Perm., Mill.
Upper Bluejacket Sandstone							
1	74.5	15.6	28	49	77	339	3.3
2	75.5	13.0	23	69	92	232	Imp.
Lower Bluejacket Sandstone							
3	88.5	17.9	39	32	71	542	8.0
4	89.5	14.8	27	46	73	310	1.3
5	90.5	22.6	27	26	53	474	107.
6	91.5	17.6	38	30	68	519	7.8
7	92.5	19.3	22	35	57	329	40.
8	93.5	20.1	15	41	56	234	56.
Lower Warner Sandstone							
9	212.5	15.6	37	30	67	448	2.3
10	213.5	17.3	55	29	74	738	7.5

G

Sec. 27 T.29S. R.25E.





K: μ=82.5, σ=21.39
ϕ: μ=21.4, σ=1.83

So: μ=17.5, σ=5.2
Sw: μ=45.5, σ=19.9

G

Sec. 27-T.29S.-R.25E.

Lower Cabaniss Sandstone

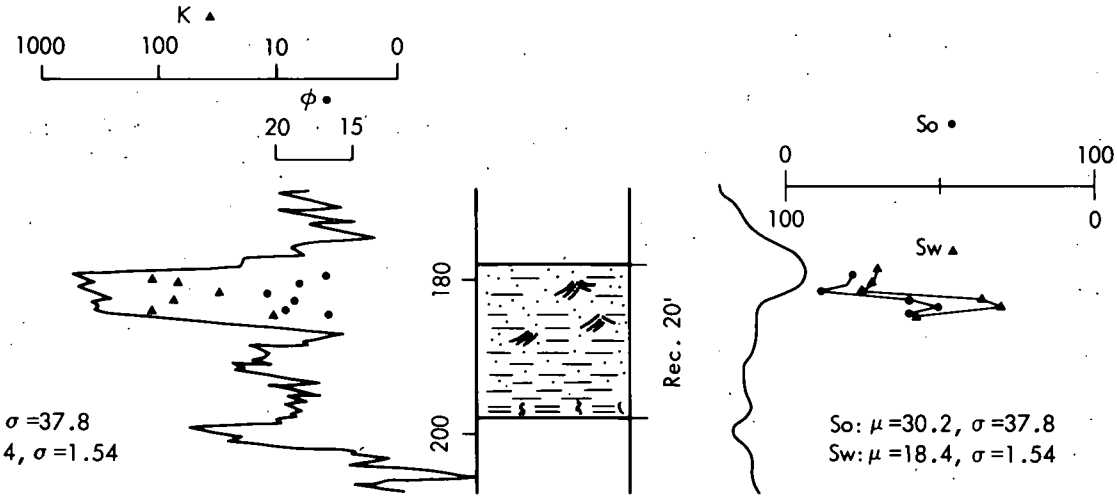
No core analyzed - Sandstone not present;
Weir-Pittsburg Coal: 104'-107'

Lower Warner Sandstone

Sample No.	Depth, Feet	Effective Porosity Percent	Percent Saturation Oil	Water	Total	Oil Content Bbls./A Ft.	Perm., Mill.
1	285.5	21.5	12	64	76	201	69.
2	286.5	22.0	19	56	75	325	108.
3	287.5	20.6	28	52	80	448	110.
4	288.5	22.4	19	54	73	330	79.
5	289.5	22.4	18	52	70	314	122.
6	290.5	22.8	15	4	19	267	76.
7	291.5	22.9	17	52	69	303	60.
8	292.5	18.8	20	65	85	292	73.
9	293.5	22.2	18	57	75	311	53.
10	294.5	21.6	18	52	70	302	94.
11	295.5	22.4	20	16	36	348	78.
P-12	296.4	-	-	-	-	-	68.
12	296.6	16.8	6	22	28	78	-

L

Sec. 3 T.33S. R.23E.

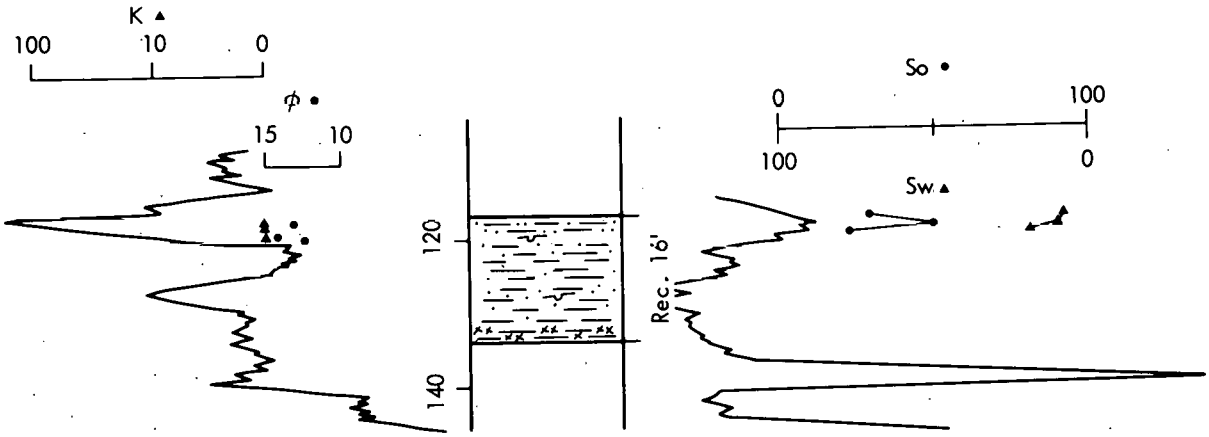


K: μ=76, σ=37.8
ϕ: μ=18.4, σ=1.54

So: μ=30.2, σ=37.8
Sw: μ=18.4, σ=1.54

DD

Sec. 13 T.34S. R.22E.



K: μ=0.0, σ=0.0
ϕ: μ=13.2, σ = .95

So: μ=23.7, σ=11.5
Sw: μ 35.7, σ=5.5

L

Sec. 3-T.33S.-R.23E.

Upper Warner interval - "Stray" sand

Sample No.	Depth, Feet	Effective Porosity Percent	Percent Saturation Oil	Water	Total	Oil Content Bbls./A Ft.	Perm., Mill.
1	178.5	16.8	22	72	94	288	103.
2	179.5	18.4	21	73	94	300	80.
3	180.5	20.6	11	77	88	176	56.
4	181.5	18.8	40	36	76	585	88.
5	182.5	19.2	48	30	78	716	118.
6	183.5	16.5	39	60	99	500	12.

DD

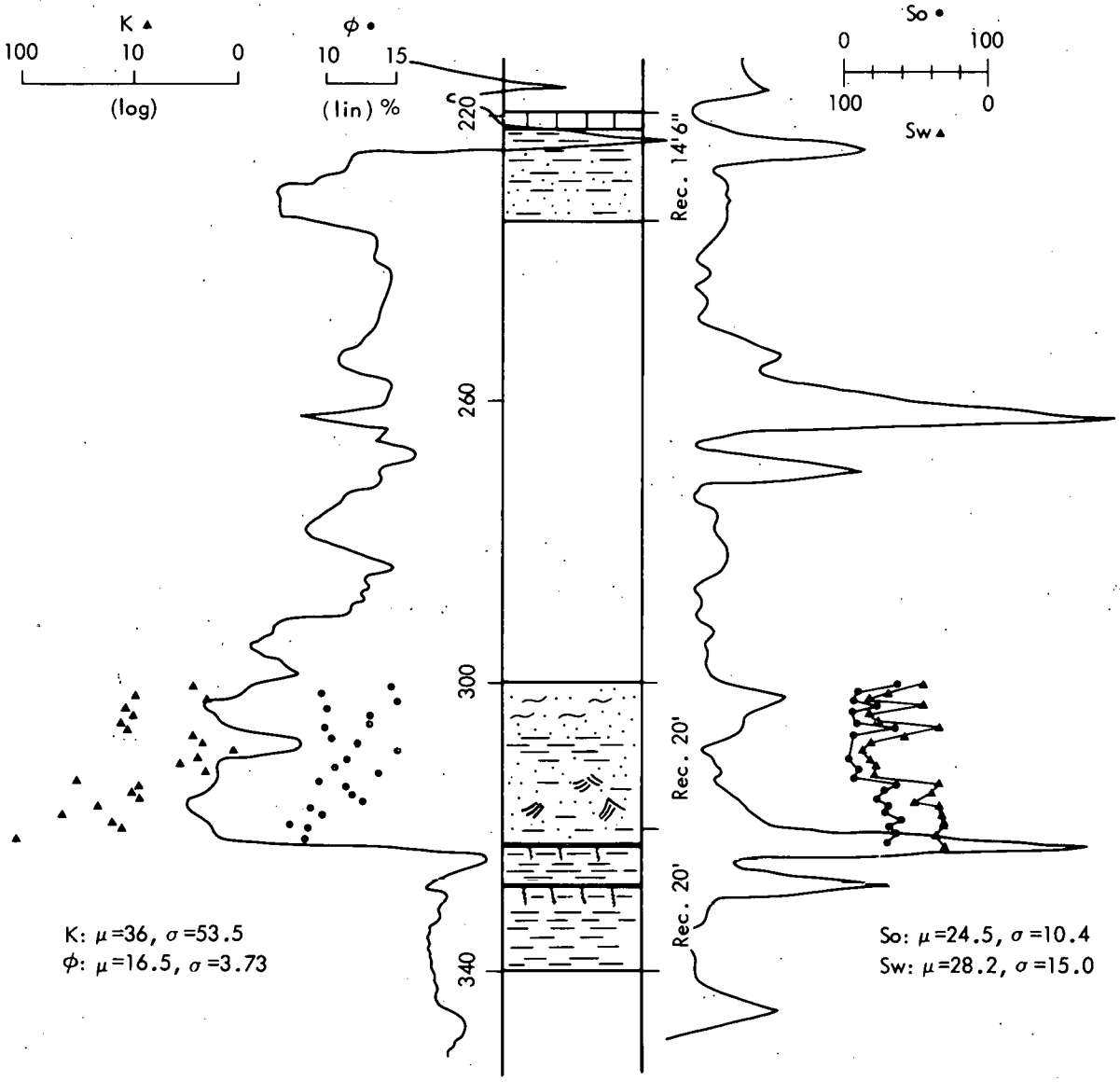
Sec. 13-T.34S.-R.22E.

Upper Warner Sandstone

Sample No.	Depth, Feet	Effective Porosity Percent	Percent Saturation Oil	Water	Total	Oil Content Bbls./A Ft.	Perm., Mill.
1	117.5	13.2	28	8	36	287	Imp.
2	118.5	14.2	51	10	61	563	Imp.
3	119.5	12.3	23	20	43	220	Imp.

N

Sec. 34 T.29S. R.24E.



N
Sec. 34-T.29S.-R.24E.

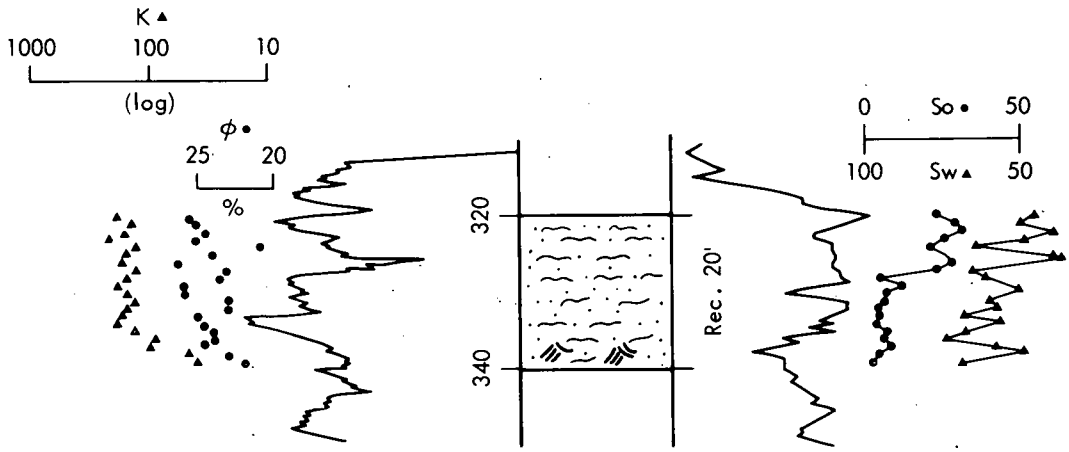
Upper Bluejacket Sandstone
No core analyzed - trace of heavy-oil in top one-half foot

Upper Warner Sandstone
No shows in upper part of sandstone

Sample No.	Depth, Feet	Effective Porosity Percent	Percent Saturation Oil	Water	Total	Oil Content Bbls./A Ft.	Perm., Mill.
1	300.5	15.5	36	49	85	434	3.8
2	301.5	20.6	6	72	78	96	11.
3	302.5	15.0	4	87	91	47	2.2
4	303.5	20.2	23	43	66	361	18.
5	304.5	17.0	3	87	90	40	16.
6	305.5	17.2	7	80	87	82	20.
7	306.5	20.1	32	35	67	501	19.
8	307.5	19.7	2	73	75	31	3.8
9	308.5	17.9	2	86	88	28	2.8
10	309.5	15.0	3	91	94	35	0.35
11	310.5	18.9	4	86	90	59	3.0
12	311.5	19.2	10	84	94	149	5.1
13	312.5	16.2	4	83	87	50	2.6
14	313.5	20.5	37	35	72	590	55.
15	314.5	18.6	27	45	72	390	10.
16	315.5	18.2	20	54	74	282	12.
17	316.5	17.4	30	49	79	452	9.9
18	317.5	21.1	29	36	65	475	37.
19	318.5	20.2	39	33	72	613	73.
20	319.5	21.4	30	36	66	499	28.
21	320.5	20.2	36	40	76	565	18.
22	321.5	20.2	30	36	66	470	116.

Q

Sec. 26 T.25S. R.24E.



K: μ =228, σ =97.7

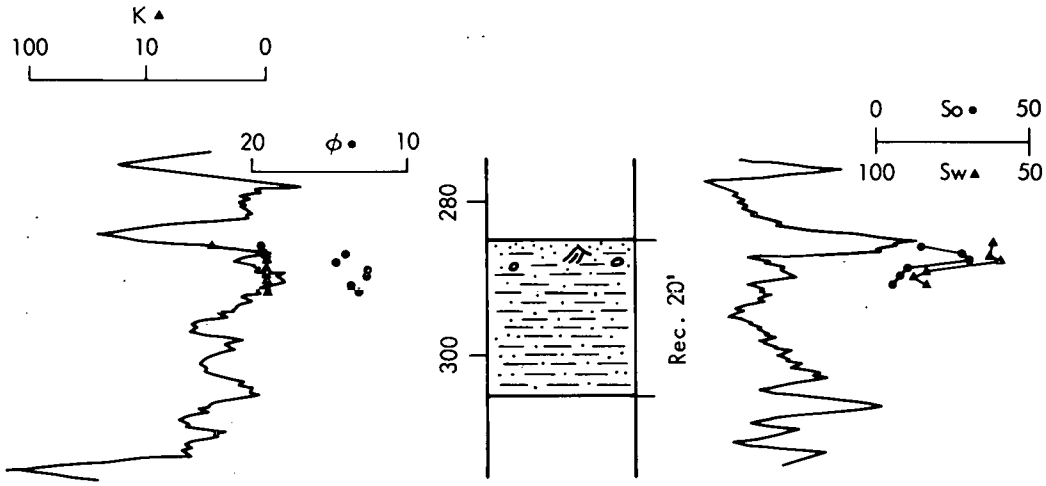
ϕ : μ =24.4, σ =1.42

So: μ =13.1, σ =10.4

Sw: μ =56, σ =10.9

HH

Sec. 32 T.29S. R.23E.



K: μ =6.5, σ =42.25

ϕ: μ =14.6, σ =2.48

So: μ =16.7, σ =11.2

Sw: μ =73.5, σ =12.8

Q

Sec. 26-T.25S.-R.25E.

Upper Warner Sandstone

Trace of live oil show in top two feet of core; fair heavy-oil show: 315'-320'; bottom of sand not cored, no show of oil in samples

Sample No.	Depth, Feet	Effective Porosity Percent	Percent Saturation Oil	Water	Total	Oil Content Bbls./A Ft.	Perm., Mill.
1	320.5	25.8	21	46	67	421	334.
2	321.5	25.2	28	49	77	548	218.
3	322.5	24.4	31	39	70	588	296.
4	323.5	25.4	24	50	74	474	407.
5	324.5	21.0	20	65	85	326	169.
6	325.5	24.6	26	40	66	497	296.
7	326.5	26.4	27	38	65	554	300.
8	327.5	23.2	22	67	89	397	177.
9	328.5	23.8	4	61	65	74	244.
10	329.5	26.1	12	54	66	244	324.
11	330.5	26.0	6	52	58	121	250.
12	331.5	23.0	5	60	65	89	192.
13	332.5	23.1	3	58	61	54	244.
14	333.5	25.4	3	69	72	59	300.
15	334.5	24.6	3	56	59	57	319.
16	335.5	25.2	7	69	76	137	168.
17	336.5	24.1	6	75	81	112	99.
18	337.5	24.3	8	57	65	151	109.
19	338.5	23.1	3	49	52	54	65.
20	339.5	22.2	2	70	72	34	51.

HH

Sec. 32-T.29S.-R.23E.

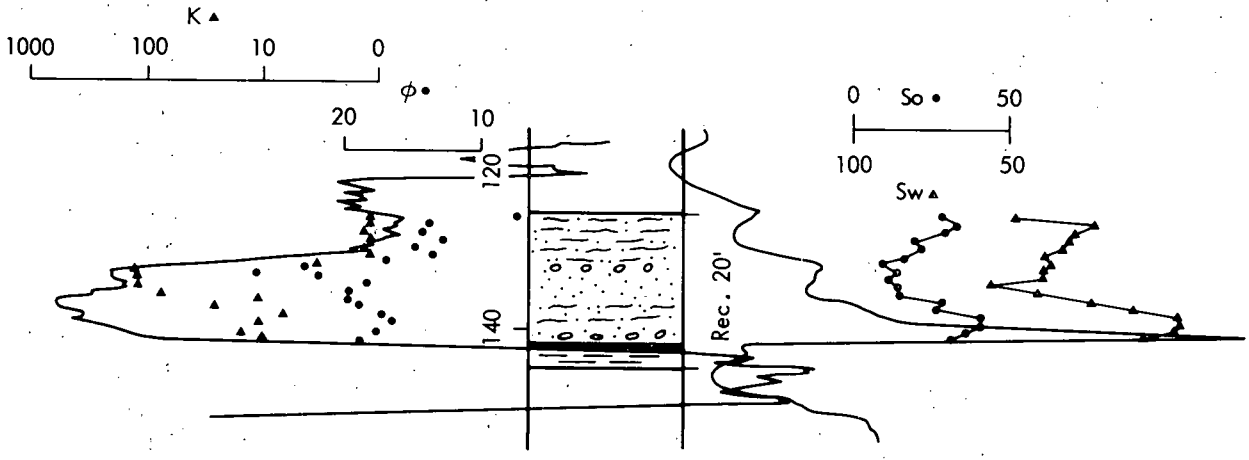
Lower Cabaniss Sandstone

Sandstone stringers only - see log

1	285.5	19.5	15	63	78	227	39.
2	286.5	14.0	29	64	93	315	Imp.
3	287.5	14.6	32	59	91	363	Imp.
4	288.5	12.7	10	84	94	99	Imp.
5	289.5	13.8	8	88	96	86	Imp.
6	290.5	13.1	6	83	89	61	Imp.

T

Sec. 26 T.30S. R.25E.

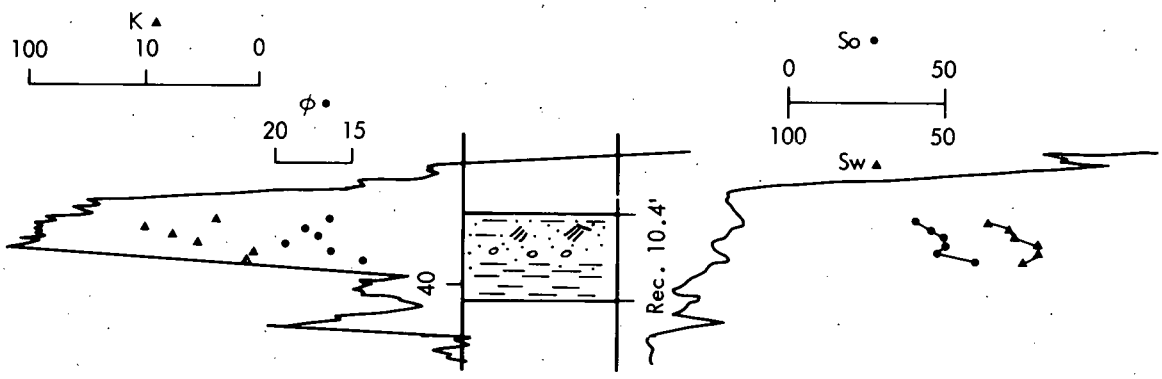


K: μ=36, σ=53.5
ϕ: μ=16.5, σ=3.73

So: μ=24.5, σ=10.5
Sw: μ=28.24, σ=15.2

AA

Sec. 2 T.32S. R.25E.



K: μ=3.97, σ=3.8
ϕ: μ=17.0, σ=1.54

So: μ=49.5, σ=6.22
Sw: μ=25.0, σ=6.36

T

Sec. 26-T.30S.-R.25E.

Lower Warner Sandstone

Trace of live oil show: 120'-124'; Good oil show: 124'-125'

Sample No.	Depth, Feet	Effective Porosity Percent	Percent Saturation Oil	Water	Total	Oil Content Bbls./A Ft.	Perm., Mill.
1	125.5	7.9	28	48	76	172	0.19
2	126.5	13.1	33	22	55	336	0.17
3	127.5	13.7	28	29	57	298	0.84
4	128.5	12.3	20	30	50	192	0.22
5	129.5	14.1	22	32	54	241	0.87
6	130.5	12.9	16	39	55	160	0.57
7	131.5	17.3	8	36	44	107	4.3
8	132.5	22.5	14	38	52	245	153.
9	133.5	21.5	11	39	50	184	135.
10	134.5	18.1	14	56	70	197	128.
11	135.5	19.3	15	40	55	224	84.
12	136.5	19.5	29	23	52	440	10.
13	137.5	18.8	27	14	41	394	42.
14	138.5	17.1	41	6	47	545	7.2
15	139.5	16.8	41	5	46	535	11.
16	140.5	17.6	36	7	43	493	25.
17	141.5	18.6	33	16	49	477	10.

AA

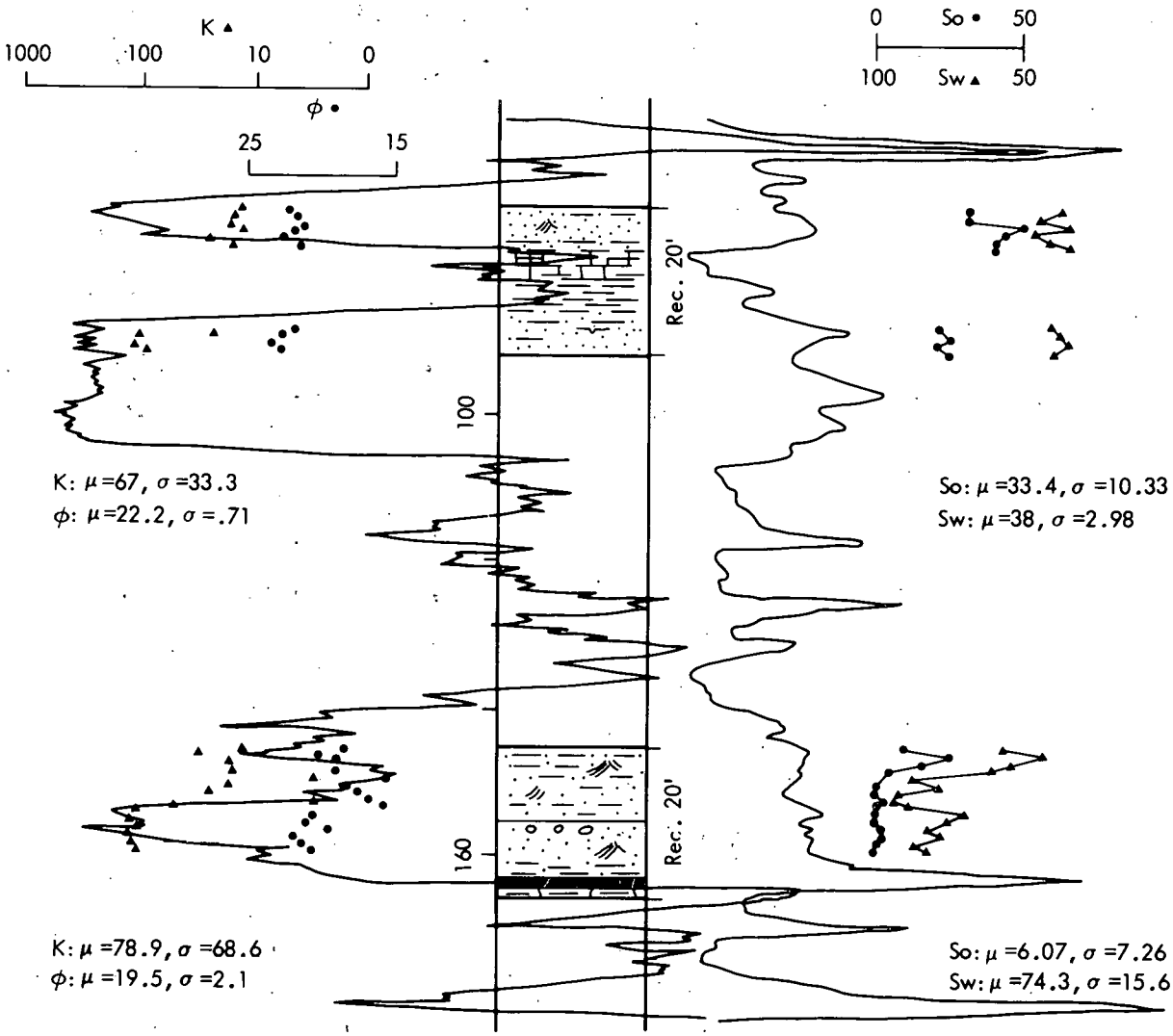
Sec. 2-T.32S.-R.24E.

Upper Bluejacket Sandstone

Sample No.	Depth, Feet	Effective Porosity Percent	Percent Saturation Oil	Water	Total	Oil Content Bbls./A Ft.	Perm., Mill.
1	31.5	16.7	41	36	77	532	2.6
2	32.5	18.0	47	27	74	658	10.
3	33.5	17.2	50	26	76	669	6.5
4	34.5	19.2	51	19	70	761	4.2
5	35.5	16.2	48	19	67	605	0.24
6	36.5	14.7	60	23	83	686	0.30

Z

Sec. 26 T.27S. R.25E.



Z
Sec. 26-T.27S.-R.25E.

Upper Bluejacket Sandstone

Sample No.	Depth, Feet	Effective Porosity Percent	Percent Saturation Oil	Water	Total	Oil Content Bbls./A Ft.	Perm., Mill.
1	72.5	22.4	32	37	69	556	20.
2	73.5	21.6	32	44	76	536	24.
3	74.5	21.1	51	35	86	835	28.
4	75.5	22.0	44	36	80	751	17.
5	76.5	22.7	41	40	81	722	43.
6	77.5	21.4	41	35	76	681	25.

Lower Bluejacket Sandstone
Bottom of sand not cored; trace of heavy-oil in samples 93'-105'

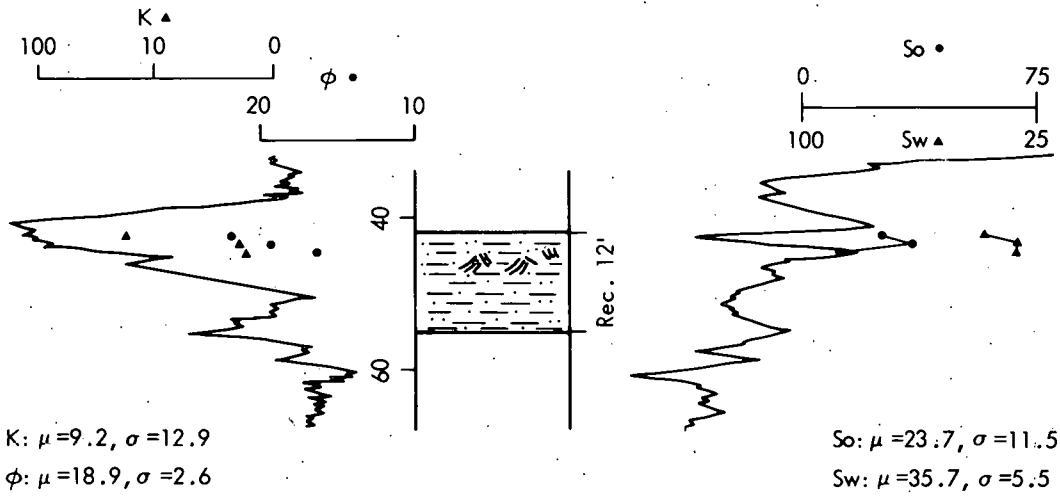
7	88.5	21.9	22	40	62	374	39.
8	89.5	22.8	25	38	63	442	119.
9	90.5	23.3	22	35	57	398	156.
10	91.5	22.8	24	40	64	425	90.

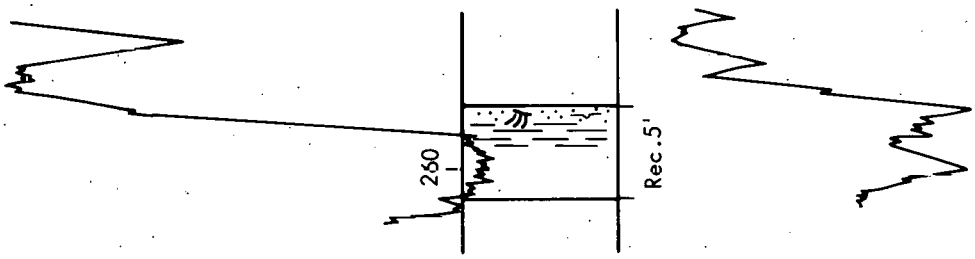
Upper Warner Sandstone
Trace of heavy-oil show: 140'-144'

11	145.5	18.1	12	55	67	169	18.
12	146.5	20.0	27	40	67	419	51.
13	147.5	18.7	17	54	71	247	28.
14	148.5	18.8	7	60	67	102	21.
15	149.5	16.2	3	87	90	38	3.5
16	150.5	19.0	2	77	79	30	28.
17	151.5	18.2	2	91	93	28	43.
18	152.5	17.6	4	93	97	55	3.4
19	153.5	16.5	2	87	89	27	71.
20	154.5	21.2	2	69	71	33	147.
21	155.5	21.8	2	75	77	34	191.
22	156.5	20.2	3	82	85	47	114.
23	157.5	22.7	4	77	81	71	191.
24	158.5	22.3	2	86	88	35	172.
25	159.5	21.5	2	82	84	33	101.

CC

Sec. 3 T.34S. R.23E.





CC
Sec. 3-T.34S.-R.23E.

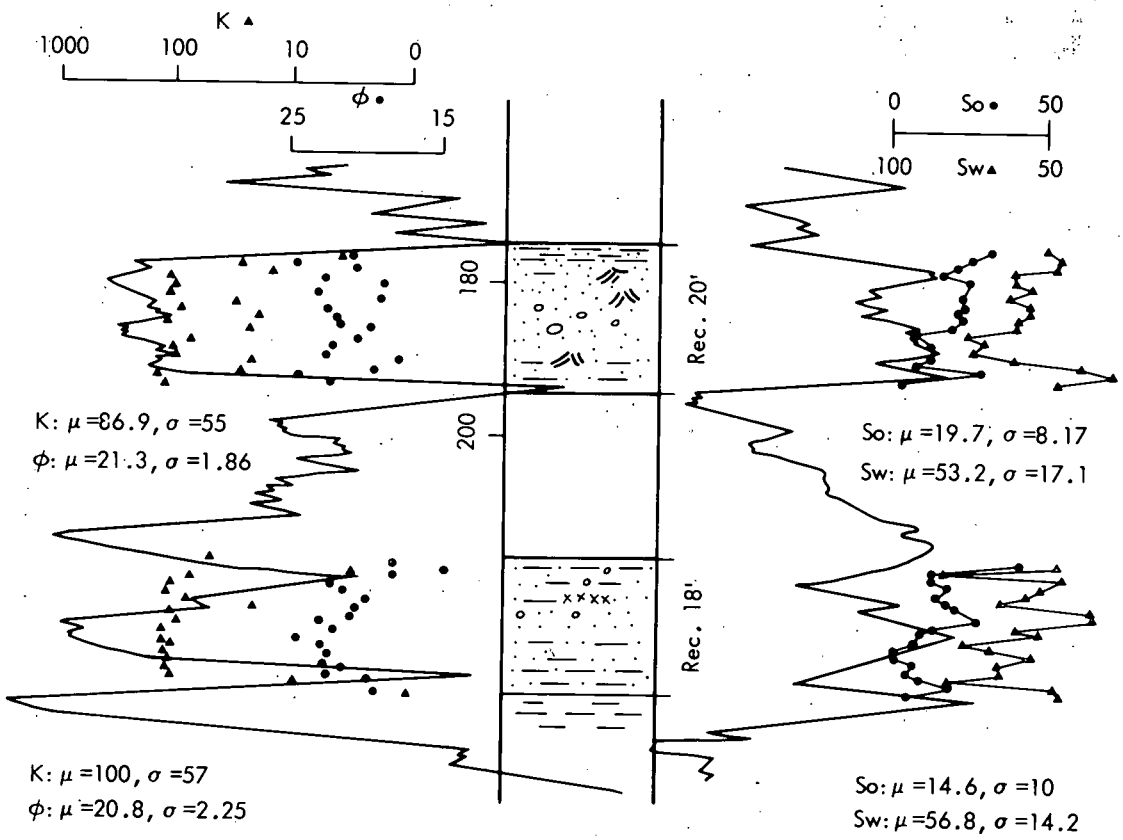
Upper Bluejacket Sandstone
Trace of heavy-oil stain: 40'-42'

Sample No.	Depth, Feet	Effective Porosity Percent	Percent Saturation Oil	Water	Total	Oil Content Bbls./A Ft.	Perm., Mill.
1	42.5	21.4	24	42	66	399	24.
2	43.5	19.2	35	32	67	521	1.9
3	44.5	16.2	12	33	45	151	1.6

Lower Warner Sandstone
Traces of dead oil in samples: 238'-250'; core not analyzed, traces of dead oil in core 250'-254'.

GG

Sec. 32 T.30S. R.23E.



GG
Sec. 32-T.30S.-R.23E.

Lower Cabaniss Sandstones

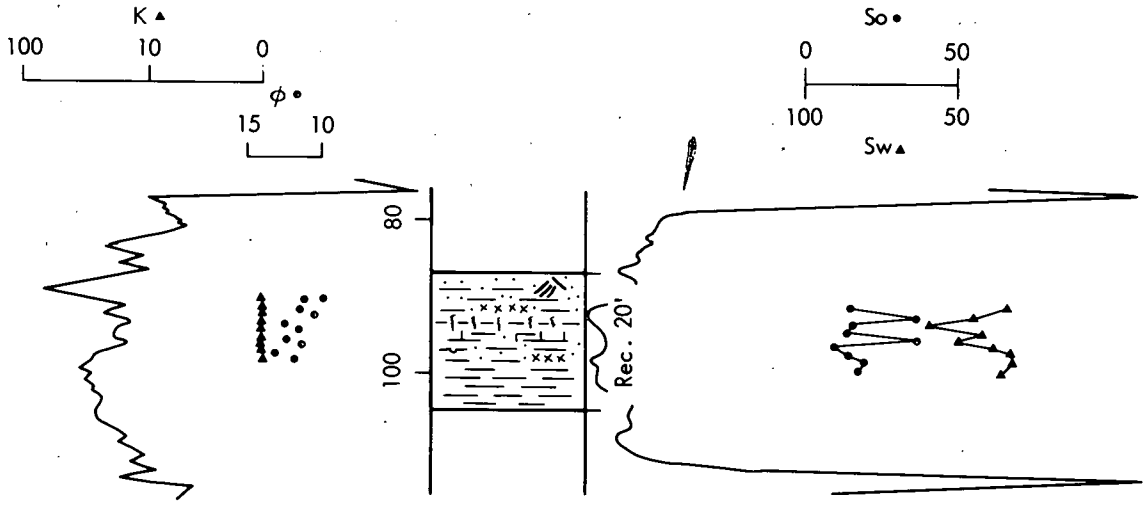
Traces of heavy-oil in broken-sandy interval 156'-174'.

Sample No.	Depth, Feet	Effective Porosity Percent	Percent Saturation Oil	Water	Total	Oil Content Bbls./A Ft.	Perm., Mill.
1	176.5	20.8	32	49	81	518	4.8
2	177.5	24.4	26	45	71	493	48.
3	178.5	20.6	21	46	67	336	23.
4	179.5	22.6	16	61	77	281	135.
5	180.5	18.7	29	60	89	422	102.
6	181.5	23.1	25	55	80	449	133.
7	182.5	19.0	23	62	85	340	53.
8	183.5	22.4	24	55	79	418	94.
9	184.5	21.9	22	55	77	375	31.
10	185.5	21.7	23	59	82	388	145.
11	186.5	19.9	24	60	84	371	39.
12	187.5	20.4	8	76	84	127	83.
13	188.5	22.0	13	70	83	222	116.
14	189.5	22.6	14	74	88	246	128.
15	190.5	17.9	13	60	73	181	29.
16	191.5	19.4	8	39	47	120	49.
17	192.5	24.3	30	28	58	567	202.
18	193.5	22.1	4	46	50	69	149.
Good heavy-oil show in samples 211'-216'.							
19	216.5	18.1	43	49	92	605	73.
20	217.5	14.7	14	82	96	160	3.5
21	218.5	18.1	14	43	57	197	84.
22	219.5	22.0	19	51	70	325	101.
23	220.5	21.6	15	55	70	251	135.
24	221.5	19.9	19	65	84	294	88.
25	222.5	20.5	22	35	57	351	36.
26	223.5	20.9	29	34	63	471	127.
27	224.5	22.8	14	58	72	248	92.
28	225.5	21.9	10	52	62	170	169.
29	226.5	24.4	9	76	85	171	169.
30	227.5	22.6	3	67	69	35	137.
31	228.5	22.2	3	54	57	52	162.
32	229.5	22.5	8	65	73	140	143.
33	230.5	21.2	6	64	70	99	149.
34	231.5	22.1	10	81	91	172	133.
35	232.3	19.8	20	47	67	308	9.5
36	233.5	19.3	6	45	51	90	Imp.

Bottom of sandstone not cored; no show of oil in samples.

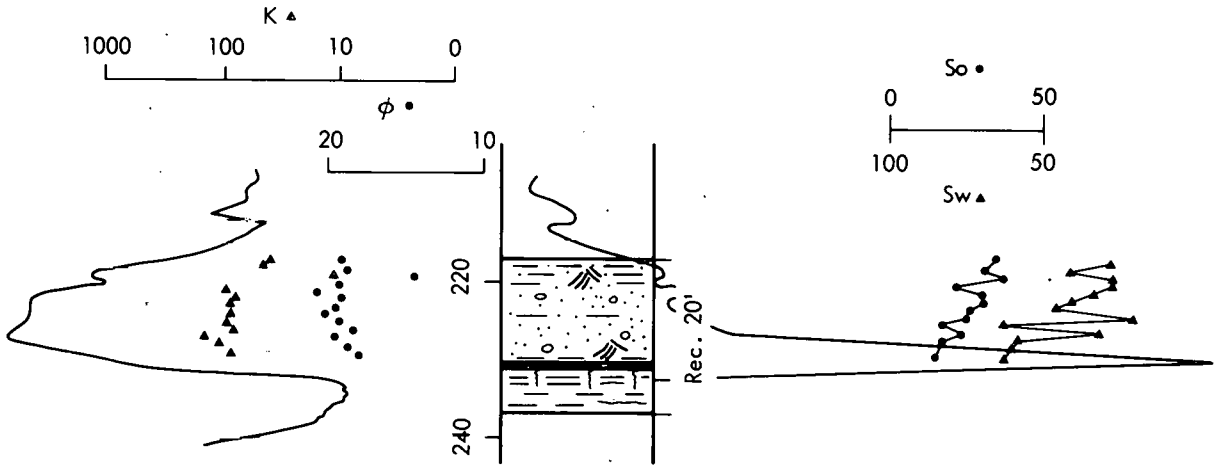
JJ

Sec. 14 T.30S. R.25E.



K: μ=0.0, σ=0.0
ϕ: μ=11.7, σ=.76

So: μ=21.0, σ=9.0
Sw: μ=41.6, σ=9.4



K: μ=106, σ=68
ϕ: μ=19.4, σ=1.73

So: μ=25.2, σ=6.9
Sw: μ=42.2, σ=15.1

JJ
Sec. 14-T.30S.-R.25E.

Lower Bluejacket interval

Sample No.	Depth, Feet	Effective Porosity Percent	Percent Saturation Oil	Water	Total	Oil Content Bbls./A Ft.	Perm., Mill.
1	91.5	11.1	15	35	50	129	Imp.
2	92.5	11.2	36	45	81	314	Imp.
3	93.5	10.6	16	60	76	132	Imp.
4	94.5	12.4	14	43	57	135	Imp.
5	95.5	11.5	37	52	89	331	Imp.
6	96.5	12.3	19	38	57	182	Imp.
7	97.5	11.3	14	33	47	123	Imp.
8	98.5	13.0	20	33	53	202	Imp.
9	99.5	11.8	18	35	53	165	Imp.
Lower Warner Sandstone							
10	217.5	19.0	33	30	53	488	68.
11	218.5	18.8	31	42	73	453	70.
12	219.5	14.3	37	27	64	411	12.
13	220.5	19.1	22	28	50	327	11.
14	221.5	20.8	30	33	63	485	147.
15	222.5	19.1	31	43	74	459	95.
16	223.5	20.5	26	49	75	414	109.
17	224.5	21.0	25	20	45	408	101.
18	225.5	20.7	17	63	80	274	111.
19	226.5	19.7	24	32	56	368	94.
20	227.5	20.6	18	59	77	288	277.
21	228.5	19.9	17	60	77	263	167.
22	229.5	19.2	16	62	78	239	113.

A P P E N D I X E

Locations of Samples Analyzed for Organic-Geochemical Characteristics

Core Samples:

Bourbon Co., Kan.

Core O	NE NE NE	22-24S-25E
Core Q	NE SE SW	26-25S-25E
Core C	SW SW SW	10-26S-25E
Core D	NW NW NW	24-27S-25E

Cherokee Co., Kan.

Core AA	NW SW SW	2-32S-24E
Core L	SW SW SW	3-33S-23E
Core DD	NW NW NW	13-34S-22E
Core CC	SE SE SW	3-34S-23E

Crawford Co., Kan.

Core Z	NE NE SE	26-27S-25E
Core HH	SE SE SE	32-29S-23E
Core N	NW NE NW	34-29S-24E
Core G	NW NE NE	27-29S-25E
Core GG	SW SW SW	32-30S-23E
Core H	SW NW NW	11-30S-25E
Core JJ	SE NE NW	14-30S-25E
Core T	SW SW SW	26-30S-25E

Outcrop Samples:

Riverton	NE 23-34S-24E	Cherokee Co., Kan.
Iantha	SW 11-32N-32W	Barton Co., Mo.
Bellamy	SW 24-34N-30W	Vernon Co., Mo.

Oil Samples:

HMC-J3-1-2	NW 17-35S-23E	Cherokee Co., Kan.	155-160'
MO.D.N.R.-20-C	SW 5-34N-32W	Vernon Co., Mo.	79-88'
ERDA Bartlett	SE 16-34S-20E	Labette Co., Kan.	295-360'

APPENDIX F

Organic-Geochemical Characteristics of Cherokee Oil Sands.

Core	Depth	% Bitumen	% H.C.	Sat/Aro	Sat.	Aro.	NSO's	Asphalt.
Bourbon Co.								
O	322-336	0.1	57	1.5	34	23	22	21
O	365-395	0.1	66	1.5	40	26	19	15
Q	320-328	2.0	61	1.1	32	29	14	25
C	246-249	2.5	71	1.3	40	31	15	14
C	252-258	2.7	82	1.4	48	34	7	11
D	89- 94	2.2	65	1.2	35	30	14	21
Cherokee Co.								
AA	31- 34	2.8	71	1.6	44	27	11	18
AA	34- 37	2.4	78	1.4	46	32	15	7
L	178-184	3.0	66	1.3	37	29	14	20
DD	117-120	1.4	77	1.7	49	28	17	6
CC	42- 45	2.2	65	0.8	29	36	18	17
Crawford Co.								
Z	72- 78	2.9	71	1.4	42	29	12	17
Z	87- 92	1.7	65	1.2	35	30	22	13
Z	145-148	2.1	74	1.6	46	28	16	10
HH	285-286	1.6	74	1.4	43	31	18	8
N	311-320	2.2	77	1.4	45	32	16	7
G	287-290	1.7	76	1.4	44	32	11	13
G	290-293	1.8	67	1.3	38	29	14	19
G	293-296	1.1	73	1.6	45	28	11	16
GG	177-180	2.3	75	1.2	42	33	16	9
GG	185-190	1.3	67	1.2	36	31	23	10
GG	191-193	0.5	69	1.2	38	31	16	15
GG	216-218	1.0	68	1.3	38	30	17	15
GG	224-225	1.3	51	1.3	29	22	12	37
GG	227-228	0.02	50	1.8	32	18	13	37
	(oil-water contact @ 227')							
H	140-178	0.1	61	1.4	36	25	5	34
H	213-235	0.2	75	1.7	47	28	13	12
JJ	217-223	2.2	73	1.4	43	30	13	14
JJ	223-225	2.0	72	1.5	43	29	12	16
JJ	226-230	1.4	75	1.4	44	31	16	9
T	131-134	0.5	76	1.5	45	31	17	7

APPENDIX G

Organic-Geochemical Analytical Techniques

The organic-geochemical methods of analysis employed in this study are modifications of techniques described in a compilation by Davis and Bray, 1969 (Analyses of oil and cap rock from Challenger (Sigsbee) Knoll, in Initial reports of the deep sea drilling project, v. 1, chp. 22: Washington, D.C., U.S. Gov't. Print. Off., p. 415-500).

Definitions:

As used in this report, the term, "bitumen," means the organic matter which is extractable from a rock sample with hydrocarbon solvent, as described below; and the amount of bitumen is expressed as a percentage, by weight, of the whole rock samples. "Hydrocarbons" refers to the saturate and aromatic hydrocarbon compounds only, and is expressed as percentage, by weight, of the extracted samples. Non-hydrocarbon compounds include the nitrogen-sulfur-oxygen (NSO) heterocyclic compounds and the asphaltene compounds, which are also reported as percentages, by weight, of the extracted samples.

Extraction of Oil Sand Samples:

The oil sand samples were gently crushed to less than ¼-inch; ten-gram samples were extracted with a 9 to 1 mixture of benzene and methanol for 6 hours in a Soxhlet extraction apparatus. The extract solution was concentrated under vacuum at 35°C with a Buchler flash evaporator; the concentrated extract solution was brought to dryness under a stream of dry nitrogen in tared 6-dram vials.

Asphaltene Stripping:

Asphaltene fractions were separated from the benzene-methanol extracts by adding 10 ml of n-pentane to the extract, mixing briefly in an ultrasonic water-bath, and filtering after four hours through a ½-inch cake of Hyflo Super Cel in fritted-glass funnels. The n-pentane soluble filtrates were collected in tared-vials and brought to dryness under nitrogen; the asphaltenes on the filter cake were washed into tared vials with benzene-methanol and brought to dryness under nitrogen.

Hydrocarbon Group Separation:

The n-pentane soluble oil fractions were separated into saturated hydrocarbon, aromatic hydrocarbon, and nitrogen-, sulfur-, and oxygen-containing heterocyclic (NSO's) fractions by elution-column chromatography on silica gel and alumina by successive elutions with n-pentane, benzene, and 1:1 benzene-methanol; each fraction was collected in tared beakers and brought to dryness under nitrogen.

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