

**KANSAS GEOLOGICAL SURVEY
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Potential Oil Recovery and Stratigraphic
Relations of Kansas Oil Shales

by

Dale G. Schlinsog

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Potential Oil Recovery and Stratigraphic
Relations of Kansas Oil Shales

by

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B.S. University of Wisconsin-Parkside, 1980

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ABSTRACT

Dark organic-rich shales are present throughout much of the stratigraphic column of Kansas. Some of these shales yield considerable amounts of shale oil when assayed.

One hundred forty samples from 37 shale units were tested for potential oil recovery. Fischer assay results indicate yields ranging from trace amounts to 23.3 gallons of oil per ton of shale.

Differences in oil recovery are directly related to the type and amount of organic matter within a shale. Vitrinite is the dominant maceral in the Upper Cretaceous and Pennsylvanian dark shales tested. The Lower Permian and Upper Ordovician shales are essentially devoid of any organic material. The Devonian-Mississippian Chattanooga Shale contains equally small amounts of phytoplankton and vitrinite.

Seven potentially economic low grade mixed oil shales are present in the Middle and Upper Pennsylvanian strata of Kansas: the "V", Excello, Little Osage, Anna, Tacket Formation, Eudora, and Heebner shales. Shale oil, phosphate, uranium, and mineable coals if extracted concurrently from these units would reduce extraction costs and might form an economic window for potential exploitation of these oil shales.

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INTRODUCTION

The rapid increase in the price of crude oil in recent years has stimulated interest toward finding and exploiting substitutes for this commodity. Considerable interest in the United States is focused on the oil shales of the Green River Formation in Colorado, Utah, and Wyoming. Although this is the case, there exist several other areas in the United States, including Kansas, that contain oil shales.

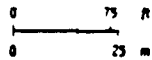
Oil shale was defined by Gavin (1924) as follows: "Oil shale is a compact, laminated rock of sedimentary origin, yielding over 33 percent of ash and containing organic matter that yields oil when distilled, but not appreciably when extracted with ordinary solvents for petroleum." Within the present study, all oil shales are dark colored and yield several gallons of oil per ton of shale by conventional destructive distillation methods.

Dark organic-rich shales are present throughout much of the stratigraphic column of Kansas (Fig. 1). These shales are mainly dark, marine shales that vary in fossil abundances. Most of the shales are classified as core or offshore shales (Heckel, 1977) in the typical Kansas cyclothem. Others were deposited during longer high sea level stands not related to cyclothem deposits. Environmental conditions necessary for the formation of

Figure 1. Stratigraphic distribution of samples. (stratigraphic column modified from Zeller, 1968)

EXPLANATION

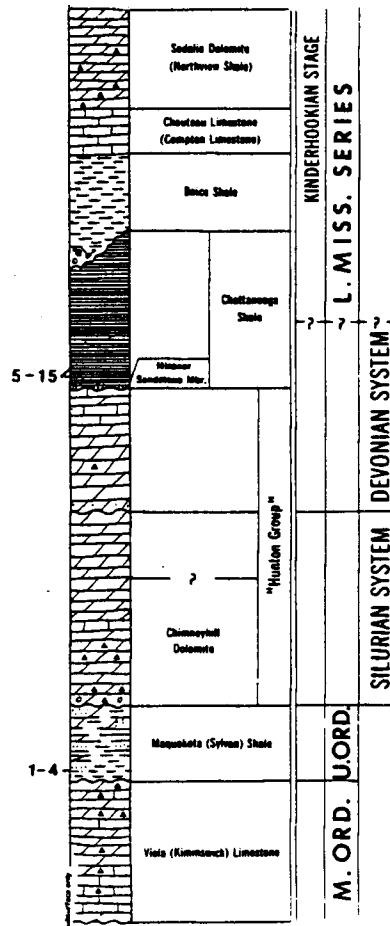
	Limestone		Black shale
	Cross-bedded limestone		Calcareous shale
	Oolitic limestone		Chalk
	Cherty limestone		Shale with concretions
	Shaly limestone		Glaucconite
	Sandy limestone		Underclay
	Dolomitic limestone		Coal or lignite
	Dolomite		Sand and gravel, conglomerate, or "mortar beds"
	Cherty dolomite		Sandstone or sand
	Shaly dolomite		Undifferentiated sandstone or siltstone
	Sandy dolomite		Siltstone
	Gypsum or anhydrite		Cross-bedded sandstone or siltstone
	Bentonite		Shale or claystone
	Unconformity		Reddish color (used as overlay on other symbols)



Approximate Thickness

Sample Nos.

STRATIGRAPHY



MIDDLE & LOWER PENNSYLVANIAN SERIES

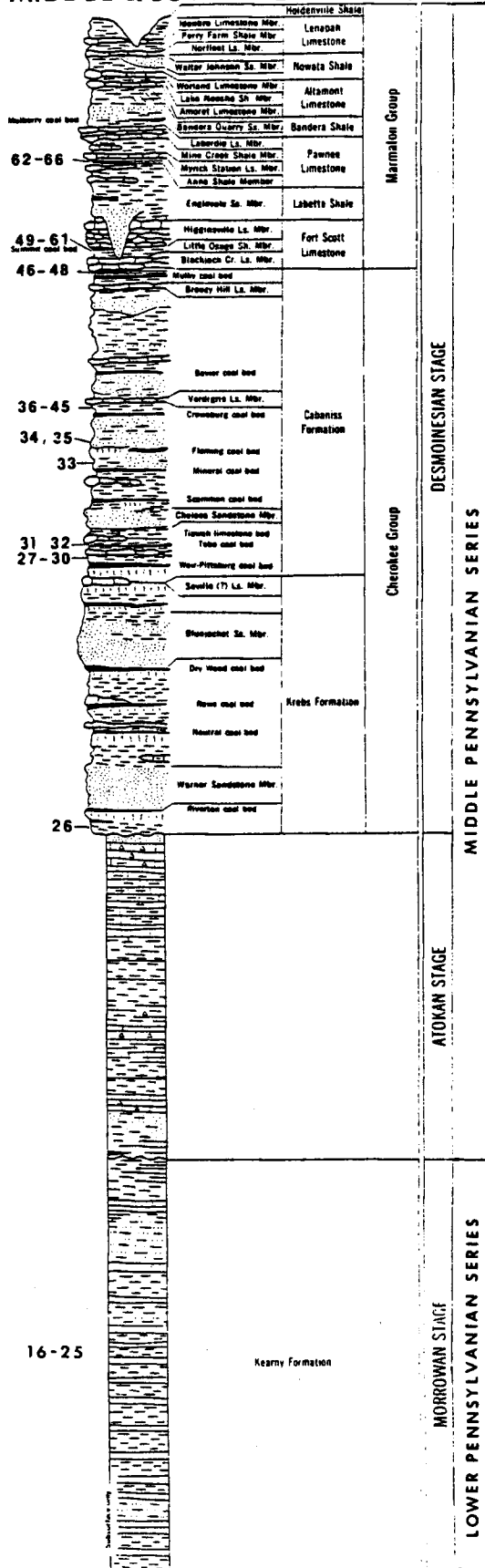
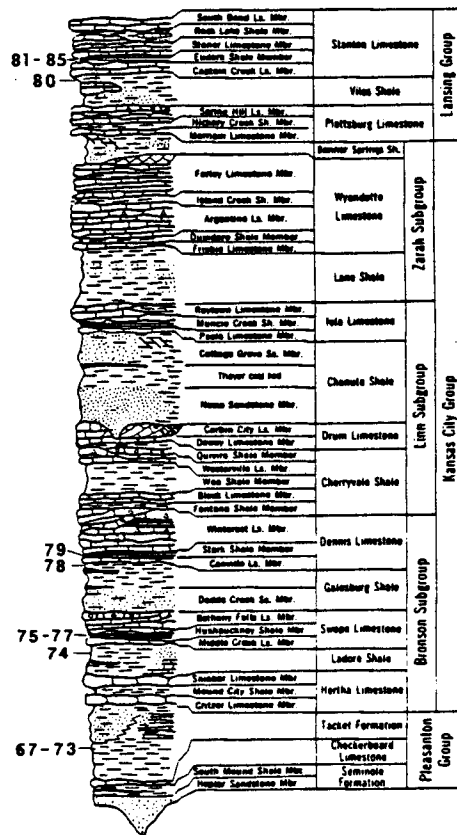


FIG.1 (cont.)

UPPER PENNSYLVANIAN SERIES

MISSOURIAN STAGE



UPPER PENNSYLVANIAN SERIES

VIRGILIAN STAGE

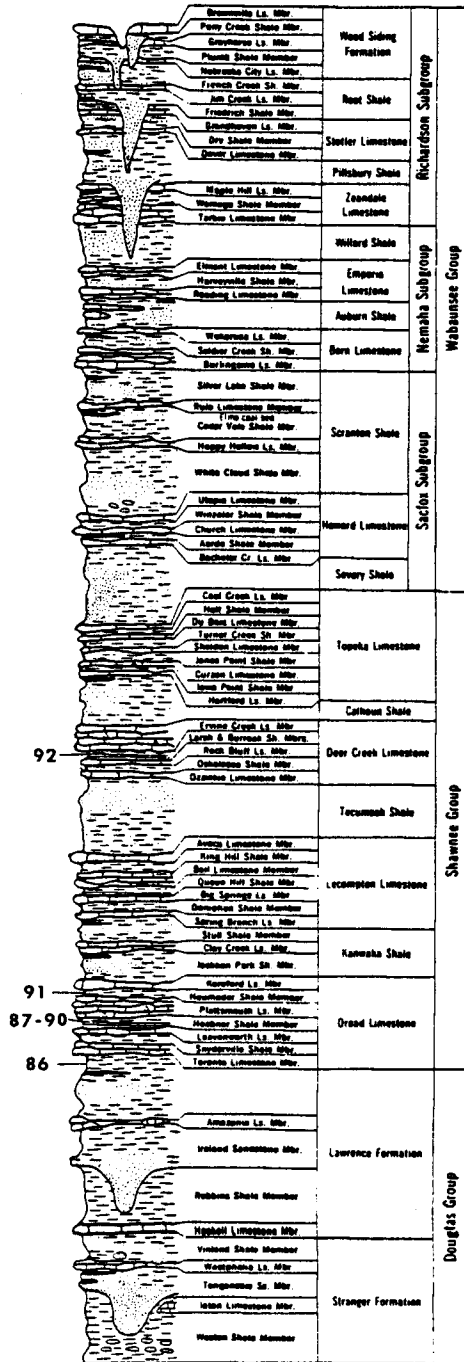
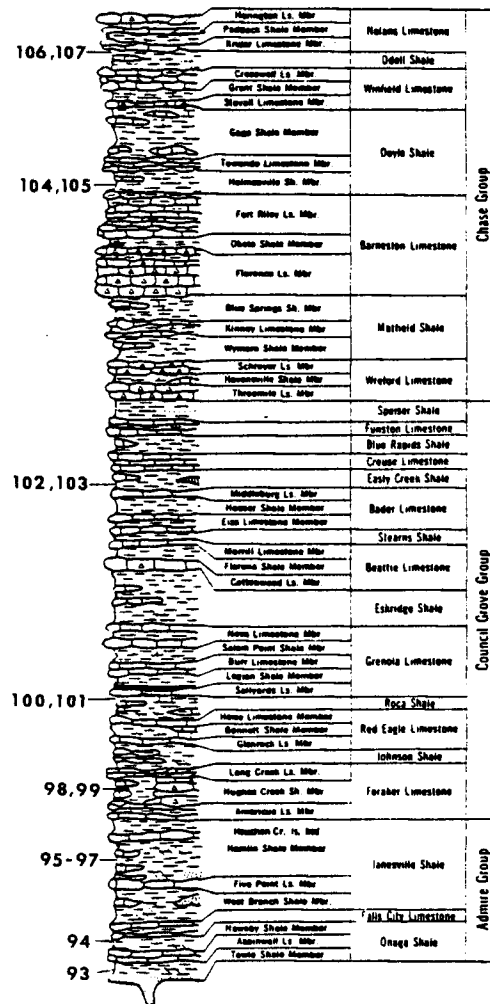


FIG. 1 (cont.)

LOWER PERMIAN SERIES

GEARYAN STAGE



oil shales include abundant organic productivity, early development of anoxic conditions, and the absence of destructive organisms.

Kansas oil shales considered to be potentially economic must fulfill the following criteria: (1) be at least 1 meter thick, (2) yield a minimum of 10 gallons of oil per ton of shale, and (3) satisfy an arbitrary overburden thickness to shale thickness ratio of 20:1 or less. Another economically important feature of some oil shales is stratigraphic proximity to strippable coal beds. Kansas shales that meet these requirements are primarily Middle and Upper Pennsylvanian deposits present in the southeastern part of the state.

The purposes of this investigation are:

- (1) To reassess the potential oil yield of Kansas oil shales from assays which utilize the Modified Fischer Retort Method. Modern techniques which increase the oil yield from shales make earlier analyses largely obsolete.
- (2) To assess the potential economic value of the Upper Cretaceous Sharon Springs Shale Member of the Pierre Shale as an oil shale. This unit will be evaluated from assay results and petrographic examination.
- (3) To evaluate a number of dark-colored Kansas shales with considerable thickness which were not previously tested for potential oil recovery.
- (4) To analyze the green Lower Permian shales of Kansas for potential oil yield.

(5) To give a detailed evaluation of stratigraphic and physical similarities of Kansas oil shales from field data, assays, and petrographic examinations. This will provide the means of comparing similarities between oil yields, stratigraphy, and physical properties of the shales.

(6) To test the viability of the use of coal, phosphate, and uranium as an economic window in aiding the recovery of oil shales. This will be evaluated through the interpretation of the oil recovery results, petrology of organic material, data from previous studies, and field observations.

PREVIOUS WORK

Few studies exist that evaluate Kansas shales for potential oil recovery. A study by Runnels et al. (1952) determined the extent and shale oil yield of black platy to fissile shales from 37 locations in Kansas. The shales analyzed in their study yielded from trace amounts to a maximum of 22.8 gallons of oil per ton of shale. The specific gravity of the recovered oil and gross heating values (British Thermal Units per pound of shale) of these shales were also determined.

The Runnels et al. (1952) study was the foundation for a more recent investigation of Kansas oil shales sponsored by the Kansas Energy Office (Angino et al., 1981). This study focused on the feasibility of using coal as an "economic aid" to making Kansas oil shales economically recoverable. This study also showed that the amount of oil shale available for extraction is 33.2×10^9 tons with reserves of oil estimated at 33.5×10^8 barrels at 75 percent recovery.

Numerous studies have focused on the geochemistry (Baker, 1962; James, 1970; James and Baker, 1971; Gill et al., 1972; Murphy et al., 1972; Cubitt, 1979), stratigraphy (Jewett, 1945; Howe, 1956; Emery, 1962; Jewett et al., 1965), and depositional environments (Elias, 1937; Hattin, 1962, 1965; Heckel, 1975, 1977, 1978, 1979; Malinky,

1980) of dark organic-rich shales in Kansas. These studies did not, however, involve the potential oil recovery of these shales.

METHODS

Sampling Procedures

Thirty-seven shale units sampled at 68 locations form the basis of this study (Figs. 2-4; Appendix D). Most of the shales have a thickness of a least 1 meter and predominant dark color (descriptions of representative measured sections are given in Appendix E). Several shales were omitted from this study because previous analyses (Runnels et al., 1952) indicated an absence of recoverable oil.

All of the sampled shales crop out in Kansas except the Chattanooga Shale, Maquoketa Shale, and black shales of the Kearny Formation. These occur only in the subsurface in Kansas. The cores used were from the core library of the Kansas Geological Survey.

Outcrop sampling was done by spot sampling or where possible by channeling. Vertical channel samples were taken over 0.3 to 0.6 meter intervals. If the outcrop was more than 3 meters thick, samples were taken 1.5 meters apart. Samples were obtained by trenching to depths ranging from a few centimeters to a meter. Later the samples were air dried at room temperature.

Sampling locations were selected from a review of the appropriate literature (Jewett, 1945; Runnels et al., 1952; Hattin, 1965; Gill et al., 1972; Cubitt, 1979;

Figure 2. Locations of cored sections of
the Maquoketa Shale ○ , Chattanooga Shale ● ,
Kearny Formation *, and black shale in the
Fort Scott Limestone ◉ .

Figure 3. Distribution of outcrops of Middle and Upper Pennsylvanian rocks in eastern Kansas and parts of adjoining states. Sampled locations are indicated by dots. (after Moore, 1949)

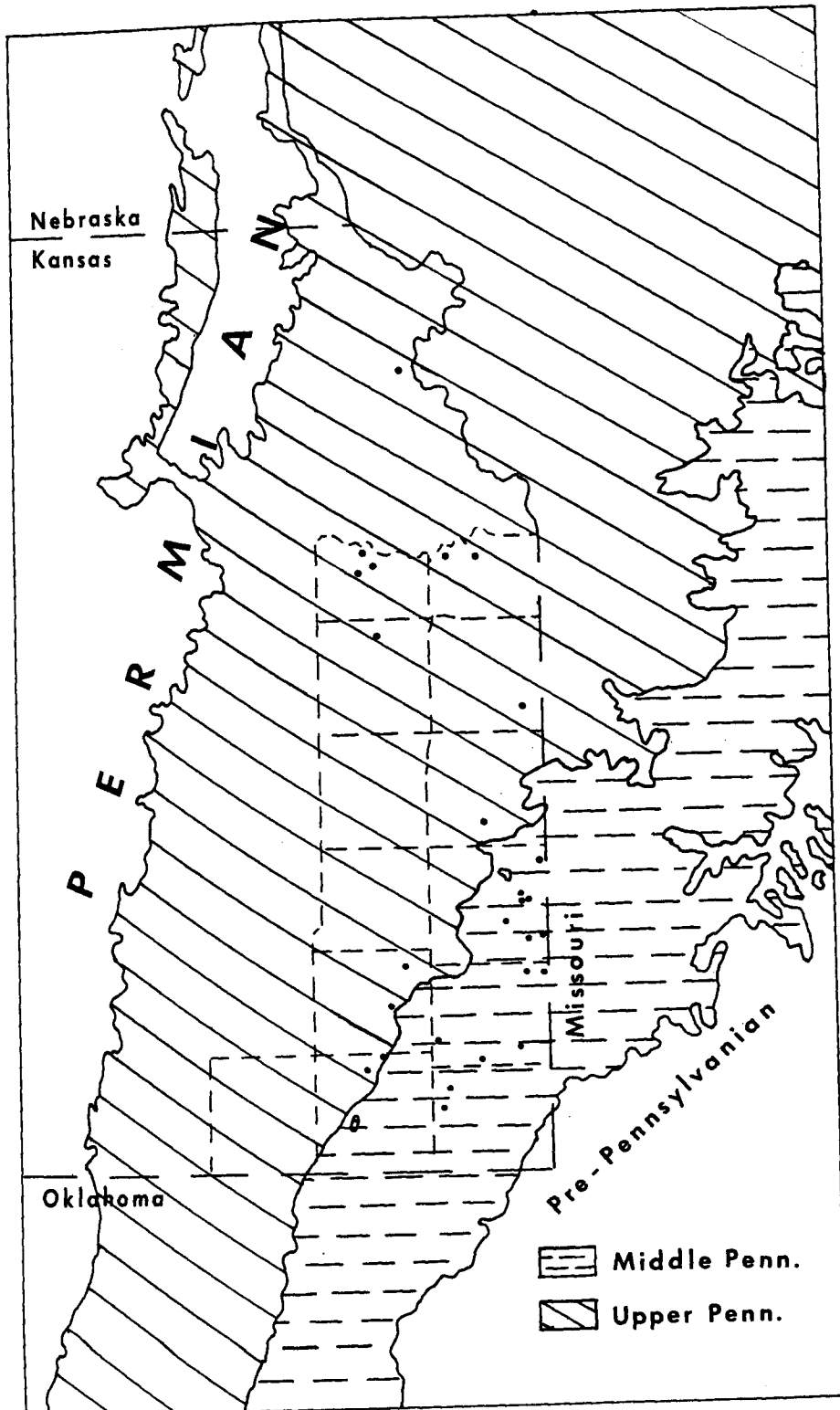
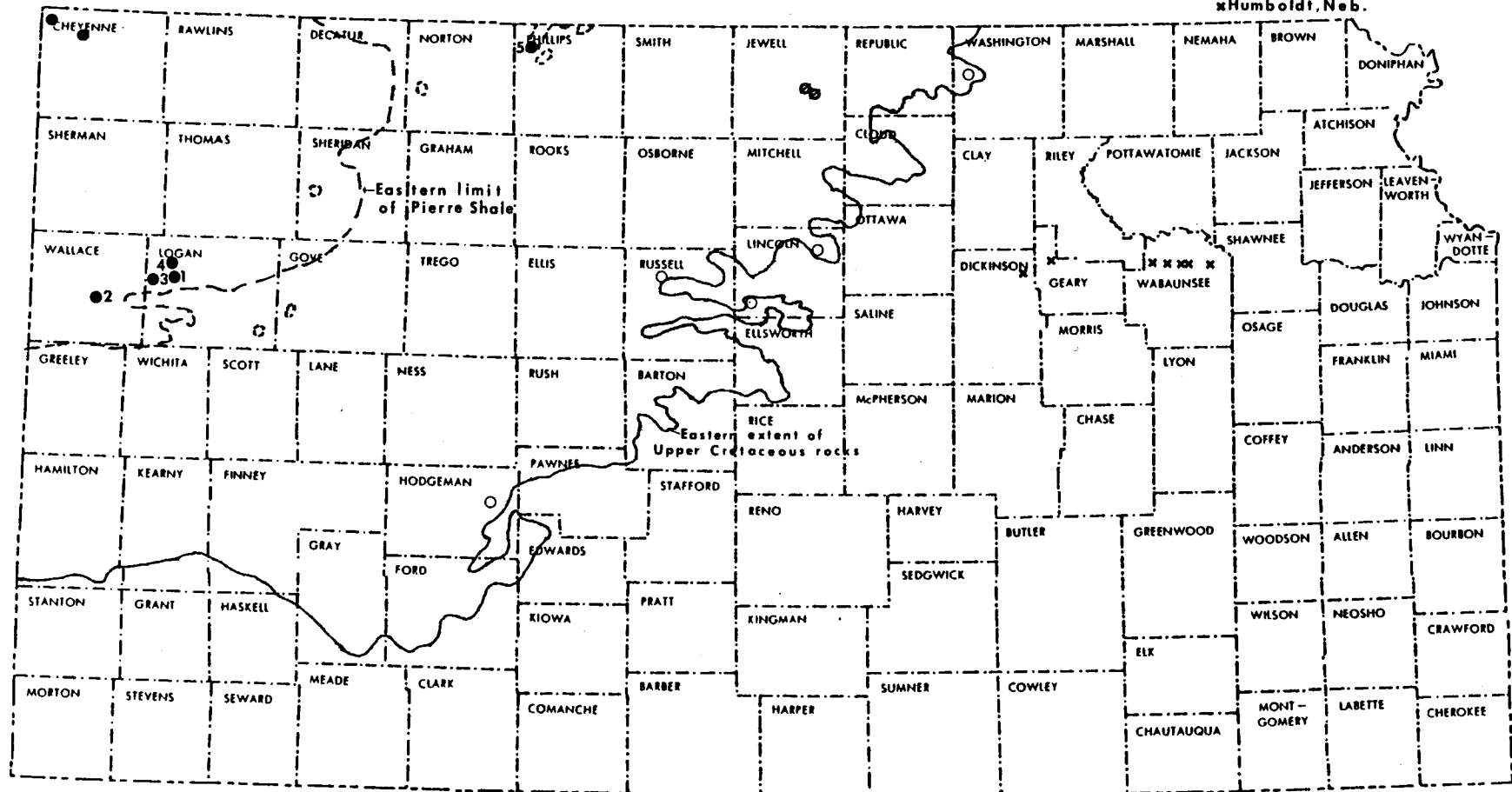


Figure 4. Eastern extent of outcropping Upper Cretaceous rocks and locations of measured and sampled sections of the Pierre Shale ●, Carlile Shale ●, and Graneros Shale ○. Also included are the Lower Permian sampled locations * .
(modified from Merriam, 1963)

x Humboldt, Neb.



Heckel et al., 1978,1979) and from field reconnaissance. Dr. L. L. Brady of the State Geological Survey of Kansas provided field assistance in locating several of the Middle Pennsylvanian shales associated with known coal beds.

Analytical Techniques

All oil shale assays were done at the Laramie Energy Technology Center of the U. S. Department of Energy in Laramie, Wyoming. Before a shale was assayed using the Modified Fischer Retort Method, a preliminary rapid oil-yield test (Stanfield, 1953) was performed to evaluate the sample. This method involves placing a crushed (passing an 8-mesh per inch screen) 3-gram shale sample in a test tube and heating it for 5 minutes at 600°C. The presence of oil is indicated by: (1) odor, (2) appearance of oil condensate or white to brown vapors below the water zone, or (3) a dark ring on the test tube walls in the refluxing zone due to carbonization of the oil. An oil yield estimate is made by comparing results with those from samples of known oil yields. This test is suitable for estimating oil yields of 3 gallons of oil per ton of shale or less.

Shales that had estimated yields greater than 3 gallons per ton were assayed by the U. S. Bureau of Mines Fischer Retort Method (U. S. Department of Energy, 1979), which measures the quantities of oil, water, gas plus loss (calculated amount of evolved gas not condensed at 0°±3°C

plus experimental error), and spent shale present in an oil shale sample. With this procedure, samples are crushed to pass an 8-mesh screen, then a 95±10 gram sample is placed in a cast aluminum-alloy retort. The retort is heated to 500°C and held there for 40±5 minutes. Vapors distilled from the sample are cooled and the condensate is collected. The condensate is then centrifuged to separate the oil and water. Measured water volume is converted to its weight equivalent and subtracted from the oil plus water weight. The uncondensable gas weight (gas plus loss) is calculated by subtracting the condensate fraction (oil plus water weight) from total weight loss. The relative density (specific gravity) of the oil is also determined; tests are run at 37.8°C/37.8°C (oil temperature/water temperature) and then converted to 15.6°C/15.6°C. The tendency of the samples to coke was also noted.

Hand samples were used to determine color, general composition, relative grain size, degree of induration, lamination and bedding, stratification and parting, and accessory components for classification. The nomenclature used for the classification follows Potter et al. (1980, p. 1-125). The Geological Society of America rock-color chart (Goddard et al., 1979) was used to determine dry sample colors.

Ten Kansas shale samples were supplied to geologists N. R. Sherwood and Dr. A. C. Cook of the University of

Wollongong, New South Wales, Australia, for petrographic examinations. Vitrinite (huminite) reflectances were measured using a microphotometer. The instrument was calibrated against standards of 1.726 percent (GGG garnet), 0.917 percent (YAG garnet) and 0.413 percent (spinel) reflectance. Maceral (organic matter) and mineral compositions were determined as visual approximations in white reflected light and UV/violet light excitation (fluorescence mode).

STRATIGRAPHY OF SAMPLED SECTIONS

Upper Ordovician

The Upper Ordovician Maquoketa Shale consists of gray dolomitic shale and gray silty dolomite and is present in the subsurface from southeastern Kansas where it is 10 m. thick to northeastern Kansas where it reaches a thickness of 50 m. The Maquoketa Shale is unconformably overlain by the Silurian Chimney Hill Dolomite of the Hunton Group and unconformably underlain by the Middle Ordovician Viola Limestone (Fig. 1).

Undifferentiated Upper Devonian and Lower Mississippian

Upper Devonian-Lower Mississippian rocks in eastern Kansas are present only in the subsurface and consist primarily of carbonate rocks with two intervening shales (Fig. 1). These shales occur at the base of rocks of the Kinderhookian Stage and consist of the Chattanooga Shale, present in eastern Kansas, and the Boice Shale present only in northeastern Kansas. The sampled sections of Chattanooga Shale vary in thickness from 5 to 60 m.

Lower Pennsylvanian

The Lower Pennsylvanian strata of the Morrowan Stage (Fig. 1) are present only in southwest Kansas and occur approximately 1525 meters below the surface. The Morrowan Stage is represented by the 185 m. (600 ft.; all cited thicknesses have been converted from feet to meters)

thick Kearny Formation, a predominantly marine deposit consisting of limestone, sandstone, and shale (McManus, 1959).

Middle Pennsylvanian

The Middle Pennsylvanian rocks of Kansas have been subdivided into the Atokian and Desmoinesian Stages (Fig. 1). The Desmoinesian Stage is further subdivided into the Cherokee and Marmaton Groups.

The Cherokee Group consists of two formations. The lowermost Krebs Formation is predominantly shale with varying amounts of sandstone, limestone, underclay, and coal (Zeller, 1968). It has a thickness of 60 to 75 m. The Cabaniss is similarly composed principally of shale with varying amounts of sandstone, limestone, underclay, and coal and has a thickness of approximately 70 m. (Zeller, 1968). The Croweburg and Mulky coals of the Cabaniss Formation are overlain respectively by black organic-rich shales referred to as the "V" shale and Excello shale in this study. The Excello Shale is recognized as a formal unit in Missouri and Oklahoma.

The conformably overlying Marmaton Group is composed of approximately 75 m. of shale, limestone, sandstone, and coal (Jewett, 1945). It includes four limestone and four shale formations. Shale members of the Fort Scott Limestone and Pawnee Limestone were studied.

Upper Pennsylvanian

Upper Pennsylvanian rocks present in outcrop in the

eastern part of Kansas (Fig. 3) consist of approximately 650 m. (Moore, 1949) of cyclically deposited limestone and shale. Limestone formations have thicknesses of 5 to 15 m. and shale formations 15 to 30 m.

The Upper Pennsylvanian stratigraphic section (Fig. 1) is comprised of the Missourian and Virgilian Stages. The Missourian Stage is subdivided into the Pleasanton, Kansas City, and Lansing Groups and the Virgilian Stage is subdivided into the Douglas, Shawnee, and Wabaunsee Groups.

The lowest rock unit assigned to the Missourian Stage in Kansas is the Pleasanton Group, which consists of 10 to 40 m. of shale with some sandstone, limestone, and coal (Jewett et al., 1965). The Kansas City Group conformably overlies the Pleasanton Group and includes six limestone formations separated by six shale formations. The total thickness of this group is approximately 110 m. (Merriam, 1963). The thin black shales within the Kansas City Group examined in this study also serve as stratigraphic marker beds.

The rocks of the Lansing Group situated at the top of the Missourian Stage of the Upper Pennsylvanian (Fig. 1) are composed of two thick limestone formations separated by one shale formation. The Lansing Group conformably overlies the Kansas City Group and has an average thickness of about 25 m. (Zeller, 1968). The Vilas Shale and Eudora Shale Member of the Stanton Limestone (Fig. 1) were examined in this study.

The Douglas Group is the lowest rock unit of the Virgilian Stage in Kansas and is subdivided into the Stranger and Lawrence Formations (Fig. 1). These deposits are largely clastic rocks that range in thickness from 75 m. in northern Kansas to 120 m. in southern Kansas (O,Conner, 1963). They are interpreted as chiefly non-marine deposits separating the largely marine deposits of the Lansing and Shawnee Groups (Moore et al., 1951).

The Shawnee Group consists of four limestone and three shale formations (Fig. 1). The average total thickness of this group is 105 m. Several thin black shale units examined in this study are present within the limestone formations.

Lower Permian

Lower Permian rocks in Kansas are subdivided into the Gearyan (Fig. 1) and Cimarronian Stages. The Gearyan Stage is further subdivided into the Admire, Council Grove, and Chase Groups.

The Admire Group, with a total thickness of 40 m., consists of two limestone formations separated by a shale formation (Zeller, 1968). Conformably overlying the Admire Group is the Council Grove Group, which is comprised of seven limestone and seven shale formations and has a total thickness of 100 m. (Zeller, 1968). Shales make up a much greater percentage of this group than the limestones. The conformably overlying Chase Group consists of seven alternating (cyclic) largely shale-and-limestone

formations similar to the Council Grove Group. The colored shales are mainly red, green, and varicolored. This group has an average thickness of 100 m.

Upper Cretaceous

The Upper Cretaceous in Kansas is subdivided into the Colorado and Montana Groups (Fig. 1). These groups are comprised of approximately 760 m. of marine shales and limestones (Zeller, 1968).

The Colorado Group consists of the Graneros Shale, Greenhorn Limestone, Carlile Shale, and Niobrara Chalk (Fig. 1). The Graneros Shale is largely composed of pro-delta silty clay and offshore clay and ranges in thickness from approximately 10 m. in central Kansas to 20 m. in western Kansas (Hattin, 1965). The marine deposits of the Carlile Shale (Hattin, 1962) conformably rest on the Greenhorn Limestone and are conformably overlain by the Niobrara Chalk.

The Montana Group consists of the Pierre Shale, a marine, dark-colored noncalcareous shale (Fig. 1). In extreme northwestern Kansas, the Pierre Shale attains a thickness of approximately 490 m. (Merriam, 1963). The Pierre Shale contains five shale members which include the Sharon Springs, Weskan, Lake Creek, Salt Grass and Beecher Island. The Sharon Springs Shale Member is approximately 45 m. thick and has gained special attention due to its color, organic matter content, high radioactivity (Gill et al., 1972), and potential oil yield (Runnels et al., 1952).

RESULTS OF INVESTIGATIONS

The thirty-seven shale units analyzed for potential shale oil yield were selected on the basis of color, thickness, lateral extent, and in some cases, association with coal beds. Lithostratigraphic units and collection stations (sites) are listed in Appendix D. The results of the oil shale assays using the Modified Fischer Retort Method are summarized in Table 1. These results include weight percent of the oil, water, spent shale and gas plus loss, as well as gallons of oil and water per ton of shale and specific gravity of the shale oil. Samples showed no tendency to coke. The accuracy of the results was tested by analyzing several samples in triplicate. Most of these samples yielded results within one weight percent.

Figure 5 illustrates average oil and water yields, gas plus loss, and spent shale determined from the analyses of Kansas oil shales. Averages of weight percent were determined for all shales analyzed in this study. The largest shale oil reserves are present in Middle and Upper Pennsylvanian strata. Average water and average gas plus loss values vary throughout the shales sampled.

Another important factor concerning this study is the net energy return after retorting. Burger (1973, cited in Hutton et al., 1980) estimated that at least

Table 1: Oil shale assay by Modified Fischer Retort Method

Sample Number	Weight Percent				Gallons per ton		Specific Gravity
	Oil	Water	Spent Shale	Gas + Loss*	Oil	Water	
1	0.0	1.3	98.3	0.4	trace	3.0	-
2	0.0	1.7	97.3	1.0	trace	4.0	-
3	0.0	1.9	97.2	0.9	trace	4.6	-
4	0.0	2.0	97.0	1.0	trace	4.8	-
5	1.8	1.4	95.7	1.1	4.6	3.4	0.920
6	1.0	1.4	96.9	0.7	2.7	3.4	"
7	1.9	1.4	95.8	0.9	5.0	3.4	"
8	1.2	1.4	96.3	1.1	3.1	3.4	"
9	0.2	1.7	97.5	0.6	0.4	4.1	"
10	0.0	1.5	98.1	0.4	trace	3.6	-
11	0.0	1.5	97.9	0.6	trace	3.6	-
12	0.0	2.1	96.3	1.6	trace	5.0	-
13	0.0	1.5	98.0	0.5	trace	3.7	-
14	0.0	1.6	97.2	1.2	trace	3.8	-
15	0.0	1.7	97.3	1.0	trace	4.1	-
16	0.0	2.5	96.7	0.8	trace	6.0	-
17	0.0	2.7	96.5	0.8	trace	6.5	-
18	0.0	3.3	95.6	1.1	trace	7.9	-
19	0.0	3.1	95.6	1.3	trace	7.4	-
20	0.0	3.1	96.2	0.7	trace	7.4	-
21	0.5	3.0	95.4	1.1	1.3	7.2	0.920
22	0.0	1.7	97.0	1.3	trace	4.0	-
23	0.0	3.6	95.8	0.6	0.1	8.6	0.920
24	0.0	3.2	95.4	1.4	trace	7.8	-
25	0.0	3.5	95.4	1.1	trace	8.3	-
26	0.0	2.3	97.0	0.7	trace	5.4	-
27	No results - bad weight loss on all runs						
28	0.0	4.5	94.0	1.5	trace	10.8	-
29	0.2	2.2	95.9	1.7	0.4	5.3	0.920
30	0.8	4.0	94.2	1.0	2.0	9.6	"
31	3.8	1.9	91.6	2.7	9.9	4.6	0.924
32	0.0	3.8	95.0	1.2	trace	9.2	-
33	0.0	2.2	96.0	1.8	trace	5.2	-
34	0.0	3.4	95.5	1.1	trace	8.1	-
35	0.0	1.9	97.8	0.3	trace	4.5	-
36	0.0	2.4	97.1	0.5	trace	5.8	-
37	0.8	2.3	96.1	0.8	2.1	5.5	0.920
38	0.0	2.2	97.4	0.4	trace	5.4	-
39	0.0	2.8	96.9	0.3	trace	6.8	-
40	3.1	3.0	92.1	1.8	8.1	7.2	0.918
41	0.2	1.9	97.5	0.5	0.6	4.4	0.920
42	0.8	2.4	95.8	1.0	2.1	5.8	"
43	0.4	3.3	95.7	0.6	1.1	7.9	"
44	0.0	3.0	96.0	1.0	trace	7.3	-

Table 1: (cont.)

Sample Number	Weight Percent				Gallons per ton		Specific Gravity
	Oil	Water	Spent Shale	Gas + Loss*	Oil	Water	
45	4.9	2.4	90.1	2.6	13.0	5.8	0.913
46	0.0	3.2	96.4	0.4	trace	7.7	-
47	4.8	2.3	90.7	2.2	12.6	5.5	0.922
48	2.9	2.6	92.7	1.8	7.5	6.2	0.923
49	0.4	5.8	92.7	1.1	0.9	13.9	0.920
50	0.0	3.0	96.5	0.5	trace	7.1	-
51	6.1	3.0	87.7	3.2	15.8	7.2	0.927
52	6.1	2.5	88.7	2.7	15.7	6.0	0.929
53	9.0	2.3	85.4	3.3	23.3	5.6	0.922
54	1.5	3.2	94.6	0.7	3.9	7.7	0.920
55	2.3	3.0	93.4	1.3	6.3	7.2	0.898
56	6.7	2.1	86.3	4.9	17.4	5.1	0.918
57	0.0	4.0	93.7	2.3	trace	9.5	-
58	0.8	5.7	90.5	3.0	2.1	13.7	0.920
59	2.0	3.1	93.8	1.1	5.2	7.4	"
60	0.5	1.9	96.4	1.2	1.3	4.6	"
61	1.9	2.8	94.4	0.9	5.0	6.7	"
62	0.2	3.0	95.5	1.3	0.6	7.2	"
63	7.0	5.4	85.6	2.0	18.3	12.9	0.918
64	3.0	3.6	91.8	1.6	7.9	8.6	0.912
65	0.0	2.2	96.6	1.2	trace	5.3	-
66	4.9	3.5	88.3	3.3	12.8	8.4	0.914
67	1.2	1.6	96.3	0.9	3.1	3.8	0.920
68	0.1	4.0	94.7	1.2	0.2	9.6	"
69	1.2	2.8	94.8	1.2	3.2	6.7	0.920
70	0.3	3.8	94.0	1.9	0.8	9.1	0.920
71	1.7	1.6	95.3	1.4	4.3	3.8	"
72	5.3	1.7	90.0	3.0	14.0	4.1	0.903
73	0.0	2.8	96.2	1.0	trace	6.6	-
74	0.0	1.7	97.3	1.0	trace	4.1	-
75	0.0	3.6	95.9	0.5	trace	8.6	-
76	7.3	4.5	84.3	3.9	18.6	10.8	0.943
77	2.2	6.5	88.8	2.5	5.6	15.6	0.937
78	0.0	2.6	96.8	0.6	trace	6.3	-
79	1.9	7.0	87.7	3.4	4.8	16.8	0.920
80	0.0	2.6	97.0	0.4	trace	6.1	-
81	4.3	5.0	88.3	2.4	10.8	12.0	0.945
82	0.0	3.7	96.3	0.0	trace	8.8	-
83	6.7	4.8	85.7	2.8	16.4	11.4	0.970
84	2.9	6.1	88.6	2.4	7.5	14.6	0.920
85	5.9	6.0	84.2	3.9	15.0	14.4	0.942
86	0.0	2.9	96.6	0.5	trace	7.0	-
87	4.2	6.0	87.5	2.3	10.5	14.4	0.960
88	3.4	7.0	87.4	2.2	8.5	16.8	0.954

Table 1: (cont.)

Sample Number	Weight Percent				Gallons per ton		Specific Gravity
	Oil	Water	Spent Shale	Gas + Loss*	Oil	Water	
89	4.0	5.0	87.7	3.3	10.0	12.0	0.953
90	3.2	6.0	88.0	2.8	8.0	14.4	0.945
91	0.0	1.7	96.5	1.8	trace	4.1	-
92	3.6	6.0	87.6	2.8	9.1	14.4	0.941
93	0.0	2.2	97.1	0.7	trace	5.3	-
94	0.0	1.8	97.8	0.4	trace	4.2	-
95	0.0	2.0	97.4	0.6	trace	4.9	-
96	0.0	1.4	98.1	0.5	trace	3.5	-
97	0.0	2.6	96.6	0.8	trace	6.2	-
98	0.0	5.5	93.6	0.9	trace	13.1	-
99	0.0	2.9	96.2	0.9	trace	7.0	-
100	0.0	5.5	94.2	0.3	trace	13.2	-
101	0.0	5.5	94.1	0.4	trace	13.1	-
102	0.0	2.4	97.3	0.3	trace	5.7	-
103	0.0	1.8	97.5	0.7	trace	4.4	-
104	0.0	3.7	95.7	0.6	trace	8.8	-
105	0.0	4.0	95.5	0.5	trace	9.7	-
106	0.0	2.2	97.4	0.4	trace	5.4	-
107	0.0	1.8	96.4	1.8	trace	4.3	-
108	0.0	4.5	94.9	0.6	trace	10.7	-
109	0.0	5.8	92.6	1.6	trace	14.0	-
110	0.0	5.7	92.8	1.5	trace	13.6	-
111	0.0	4.9	93.8	1.3	trace	11.8	-
112	0.0	1.1	98.4	0.5	trace	2.7	-
113	0.0	4.8	93.0	2.2	trace	11.4	-
114	0.0	7.1	90.8	2.1	trace	17.0	-
115	0.1	2.7	95.7	0.6	0.4	8.9	0.920
116	0.0	6.8	91.8	1.4	trace	16.2	-
117	0.0	6.9	92.0	1.1	trace	16.5	-
118	0.0	7.6	90.6	1.8	trace	18.3	-
119	0.0	5.6	94.0	0.4	trace	13.4	-
120	0.0	4.8	93.5	1.7	trace	11.4	-
121	0.3	4.8	94.0	0.9	trace	11.5	-
122	0.0	12.7	83.0	4.3	trace	30.4	-
123	0.9	7.5	88.6	3.0	2.2	18.0	0.920
124	0.6	8.3	87.7	3.4	1.6	19.9	"
125	0.9	9.0	87.5	2.6	2.2	21.6	"
126	0.0	5.6	93.2	1.2	trace	13.5	-
127	0.0	8.8	88.6	2.6	trace	21.1	-
128	0.0	6.8	91.1	2.1	trace	16.2	-
129	0.0	7.3	89.6	3.1	trace	17.6	-
130	0.1	7.0	91.2	1.7	0.3	16.8	0.920
131	0.0	7.9	90.5	1.6	trace	18.9	-

Table 1: (cont.)

Sample Number	Weight Percent				Gallons per ton		Specific Gravity
	Oil	Water	Spent Shale	Gas + Loss*	Oil	Water	
132	0.0	6.0	93.6	0.4	trace	14.3	-
133	0.0	6.0	92.6	1.4	trace	14.4	-
134	0.0	5.5	94.4	0.1	trace	13.1	-
135	0.0	6.7	92.0	1.3	trace	16.1	-
136	No results - bad weight loss on all runs						
137	0.0	4.5	94.4	1.1	trace	10.9	-
138	0.0	5.2	94.4	0.4	trace	12.4	-
139	0.0	4.7	94.5	0.8	trace	11.2	-
140	0.0	4.3	94.5	1.2	trace	10.3	-

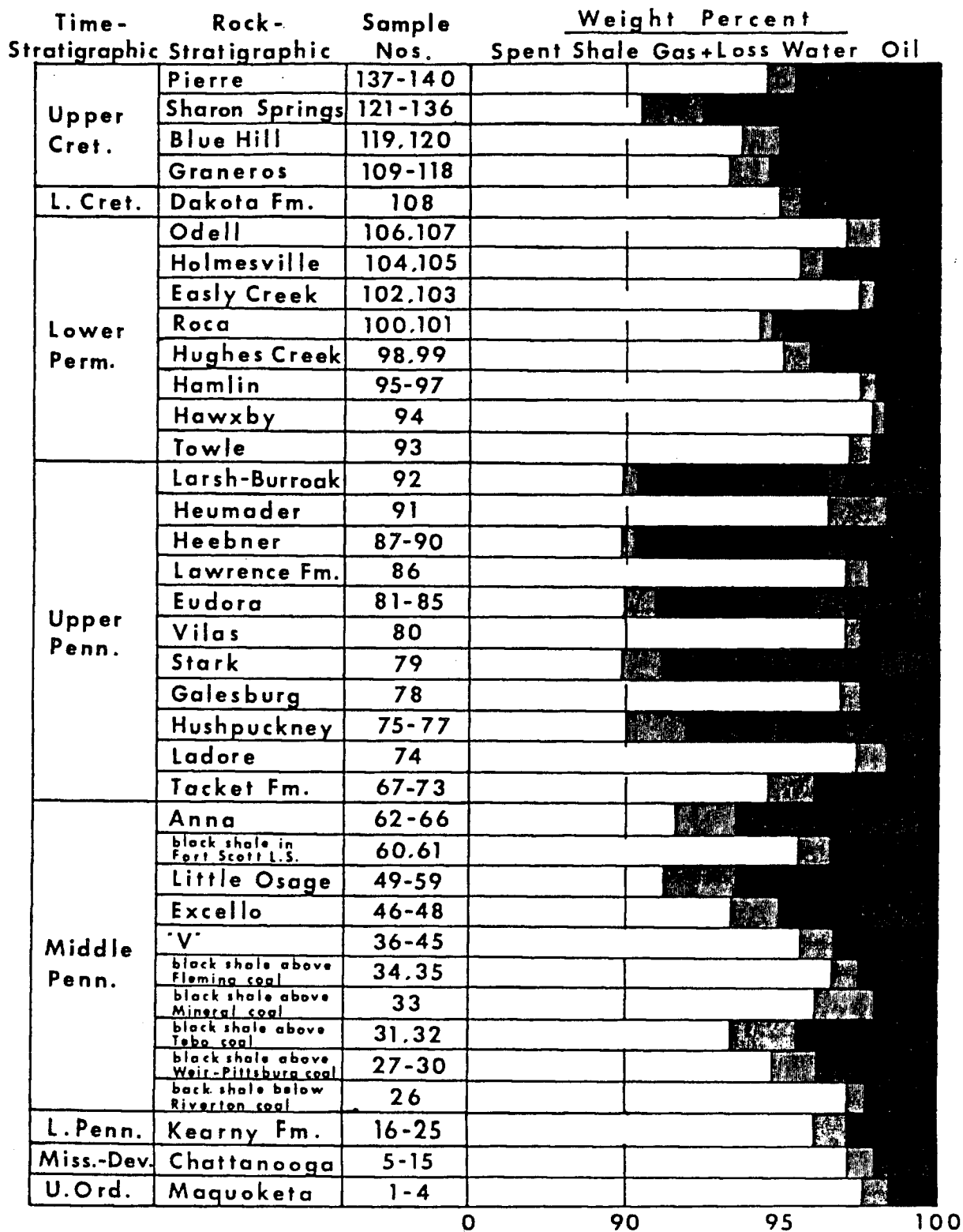
Samples showed no tendency to coke.

All assays were done by DOE, Laramie, Wyoming

0.920 = estimate of specific gravity; assumed median value (Smith, 1963).

* evolved gases not condensed at 0^o+3^o C plus experimental error.

Figure 5. Graphic representation of average oil (red) and water (blue) yields, gas plus loss (green), and spent shale (white) of Kansas oil shales as determined from assays. (scale expanded from 90 to 100 percent)



2.5 percent by weight of kerogen (insoluble organic matter) is necessary to obtain an energy return from an oil shale after pyrolysis. Kansas shales that contain at least 2.5 percent by weight of extractable kerogen include the Larsh-Burroak Shale, Heebner Shale, Eudora Shale, Hushpuckney Shale, Tacket Formation shale, Anna Shale, Little Osage Shale, Excello shale, "V" shale and the unnamed black shale above the Tebo coal.

Although none of the shales yielded extremely high amounts of oil, some are more economically attractive than others. Seven of the shales tested displayed economic potential and may be sources for future exploitation. Three factors used to determine potential include: (1) oil yields greater than 10 gallons per ton of shale, (2) considerable lateral extent and (3) minimum vertical thickness of 1 meter. Stratigraphic proximity to coal beds was also considered where applicable. The shales satisfying these requirements are the Heebner, Eudora, Tacket Formation, Anna, Little Osage, Excello, and "V" shales. These can be characterized by total thickness at sample locations, lithologies and thickness of oil-bearing units, and oil yield.

The total thickness of the Heebner Shale (Plate II) is 2.0 m. at the sample locations, but the unit thickens southward of these areas. The oil-bearing unit is a black clayshale ranging in thickness from 0.9 to 1.2 m. It yields from 8.0 to 10.5 gallons of oil per ton of shale.

The Eudora Shale (Plate I) is approximately 2.0 m. thick. The oil-bearing black clayshale is 0.3 to 1.5 m. thick. This unit is absent, however, where it overlies the algal mound buildups in southeastern Kansas (Heckel, 1975). The black clayshale produces from 7.5 to 16.4 gallons of oil per ton of shale. A gray bedded claymud overlies the the black clayshale and was also tested. It yielded only trace amounts of oil.

The Tacket Formation is composed of two shales separated by a thin limestone and varies in thickness throughout southeastern Kansas. The examined upper shale (Plates VII and VIII) ranged in thickness from 3.3 to 4.4 m. and produced from trace amounts to 14.0 gallons of oil per ton of shale.

The Anna Shale (Plate V) ranges in thickness from 0.6 to 1.5 m. It consists of a thin basal bedded claymud yielding trace amounts of oil, a black claystone which yields 7.9 to 18.3 gallons of oil per ton of shale, and a thin upper clayshale which yields 0.6 gallons per ton.

The Little Osage Shale (Plates III and IV) ranges from 1.2 to 3.7 m. in thickness (Jewett, 1945). The upper 1.2 to 1.5 m. of this member is composed of a black claystone-clayshale. It has the largest oil yield of all the samples, ranging from trace amounts to 23.3 gallons of oil per ton of shale.

The Excello shale (Plate III), the upper unit in the Cherokee Group, is between 0.8 and 1.4 m. thick. It

produces from trace amounts to 12.6 gallons of oil per ton of shale.

For this study the "V" shale (Plate VI) was considered to include all the strata between the Verdigris Limestone and Croweburg coal. The "V" shale is 3.8 to 4.5 m. thick and is composed of three shale units separated by two limestone units. The two uppermost shale units yielded from trace amounts to 1.1 gallons of oil per ton of shale and the lowermost shale unit produced 2.1 and 13.0 gallons per ton.

Several additional shales yield considerable amounts of shale oil, but do not fulfill all three the requirements defining an economic oil shale. These shales are the Larsh-Burroak, Stark, and Hushpuckney Shales, an unnamed black shale above the Tebo coal, and the Chattanooga Shale.

Other shales analyzed yielded minor amounts of oil, but had considerable thickness. These shales include the Sharon Springs Shale, an unnamed black shale above the Weir-Pittsburg coal, and black shales of the Kearny Formation. The remaining shales analyzed yielded only trace amounts of oil.

The specific gravities of the oil recovered from the shales tested was also determined. Values ranged from 0.898 (Little Osage Shale) to 0.970 (Eudora Shale). These correspond to degrees API gravity of 26 to 15, which indicates heavy oil.

Petrographic Results

Results of the petrographic examinations of ten Kansas shales for vitrinite reflectances and volumetric composition by N. Sherwood and A. Cook of Wollongong University (personal communication, 1982) are presented in Tables 2 and 3. Measurable vitrinite is present in only six of the ten samples and is usually micrinitized. Some vitrinite present in the Sharon Springs, Stark, and Little Osage Shales (Table 2) fluoresces upon UV/violet light excitation. The vitrinite reflectance percentages indicate a coal rank range from peat to subbituminous for the samples tested. These values are unusually low for shales suspected to be source rocks for petroleum generation (Baker, 1962; Hatch and Leventhal, 1981). Hutton and Cook (1980) have determined that the presence of alginite causes a significant lowering of reflectance values. The absence of any appreciable amounts of alginite in these shales, however, makes this conclusion impractical.

Cherokee coals from Bourbon, Crawford and Cherokee Counties, Kansas have vitrinite reflectances of 0.59 to 0.70 percent (Sherwood and Cook, personal communication, 1982) as compared to 0.37 for the stratigraphically associated Little Osage Shale from Bourbon County. This indicates high-volatile bituminous coal ranking for the coals, while the Little Osage Shale and other Pennsylvanian shales indicate a range for low subbituminous coal rank. These differences are basically unexplained in this study.

Table 2. Vitrinite (huminite) reflectance values for ten Kansas shales.

<u>Litho- stratigraphic Unit</u>	<u>Sample No.</u>	<u>Vitrinite Reflectance %</u>	<u>Range of Reflectance</u>	<u>No. of Readings</u>
Sharon Springs Shale	130a	0.19	0.16-0.25	14
	130b	0.17	0.10-0.25	31
Blue Hill Shale	119	No Measurable Vitrinite		
Roca Shale	100	No Measurable Vitrinite		
Hamlin Shale	95	No Measurable Vitrinite		
Heebner Shale	87	0.37	0.23-0.47	21
Eudora Shale	81	0.40	0.32-0.46	24
Stark Shale	79	0.38	0.30-0.45	22
Little Osage Shale	53	0.37	0.29-0.41	24
Chattanooga Shale	7	0.46	0.30-0.53	19
Maquoketa Shale	1	No Measurable Vitrinite		

Table 3. Volumetric composition and fluorescence colors of organic matter from ten Kansas shales

<u>Samp. No.</u>	<u>Organic and Mineral Components</u>	<u>Dominant Fluorescence colors</u>	<u>% by Volume</u>
130a	dinoflagellates/ acritarchs	dull,medium,bright orange; dull,medium,bright yellow; medium bright green	1
	alginate A (poss. Botryococcus-related)	bright yellow	<0.1
	sporinite	medium orange;med. yellow	<0.1
	liptodetrinite	dull,medium,bright orange; dull,medium,bright yellow; medium green	
	bitumen/resinite	bright yellow	<0.1
	vitritinite	medium brownish orange	10-15
	inertinite		0.1-0.5
	shell & other in- organic fossil frags.		<0.1
	clay/silt-sized mineral matter		80-85
	pyrite/other highly reflect. mineral matter		3-5
130b	dinoflagellates/ acritarchs	dull,medium orange; dull,medium yellow	1
	sporinite	med. orange;bright yellow	<0.1
	liptodetrinite	dull,medium orange; dull,medium yellow	1
	vitritinite	medium brownish orange.	15-20
	inertinite		0.1-0.5
	clay/silt-sized mineral matter		80-85
	shell & other in- organic fossil frags.		<0.1
	pyrite/other highly reflect. mineral matter		2
119	dinoflagellates/ acritarchs	dull,medium orange	<0.1
	liptodetrinite	dull,medium orange; medium yellow	<0.1
	vitritinite+inertinite		1
	clay/silt-sized mineral matter		98
	pyrite/other highly reflect. mineral matter		1

Table 3. (cont.)

100	vitroinite+inertinite		<0.1
	liptodetrinite	medium orange	<0.1
	clay/silt-sized		99
	mineral matter		
	pyrite/other highly		1
	reflect. mineral matter		
95	vitroinite+inertinite		<0.1
	clay/silt-sized min.		99
	matter (mainly carbonate)		
	pyrite/other highly		0.1-0.5
	reflect. mineral matter		
87	dinoflagellates/	medium orange	<0.1
	acritarchs		
	alginate B	medium, dull orange	<0.1
	liptodetrinite	dull, medium orange	0.1-0.5
	vitroinite		30-35
	inertinite		3
	clay/silt-sized		60-65
	mineral matter		
	pyrite/other highly		2-3
	reflect. mineral matter		
81	dinoflagellates/	medium orange	0.1-0.5
	acritarchs		
	sporinite	medium orange	<0.1
	alginate B	medium orange	<0.1
	liptodetrinite	dull, medium orange	1
	vitroinite		25-30
	inertinite		0.1-0.5
	shell & other in-		<0.1
	organic fossil frags.		
	clay/silt-sized		65-70
	mineral matter		
	pyrite/other highly		5
	reflect. mineral matter		
79	dinoflagellates/	medium orange	<0.1
	acritarchs		
	alginate B	medium orange	<0.1
	liptodetrinite	dull, medium orange	1
	bitumen/resinite	medium orange; med. yellow	<0.1
	vitroinite	dull brown (micrinitized)	25
	inertinite		4
	shell & other in-		0.1-0.5
	organic fossil frags.		
	clay/silt-sized		70
	mineral matter		
	pyrite/other highly		2-3
	reflect. mineral matter		

Table 3. (cont.)

53	dinoflagellates/ acritarchs	dull, medium orange; dull medium bright yellow	1
	sporinite	medium orange	<0.1
	alginate B	medium orange	<0.1
	liptodetrinite	dull, medium, bright orange; dull, medium, bright yellow	1
	bitumen/resinite	bright orange; med. yellow	0.1-0.5
	vitroinite	dull brown	25
	inertinite		10
	shell & other in- organic fossil frags.		0.1-0.5
	clay/silt-sized mineral matter		55-65
	authigenic carbonate		1
	pyrite/other highly reflect. mineral matter		3-4
7	<u>Tasmanites</u> /other tasmanitids	medium, bright yellow	1
	dinoflagellates/ acritarchs	medium orange; medium, bright yellow	1
	liptodetrinite	dull, medium orange	1-2
	vitroinite		1-2
	inertinite		<0.1
	clay/silt-sized mineral matter		80-90
	pyrite/other highly reflect. mineral matter		5-10
1	dinoflagellates/ acritarchs	medium yellow	<0.1
	liptodetrinite	medium yellow	1
	vitroinite+inertinite		<0.1
	clay/silt-sized mineral matter		85-95
	distinct carbonate		5-15
	pyrite/other highly reflect. mineral matter		0.1-0.5

The organic matter, resolved largely by examination in reflected UV/violet light fluorescence mode, includes vitrinite, inertinite, liptodetrinite, dinoflagellates/acritarchs, Tasmanites/other tasmanitids, bitumen/resinite, alginite A, alginite B, and sporinite (see Appendix A for definitions). Volumetric composition and fluorescence colors of organic matter along with various mineral components are listed in Table 3.

The remaining components identified petrographically are similar to those described from hand samples. These components include clay/silt-sized mineral matter, pyrite/other highly reflecting mineral matter, authigenic carbonate, and shell and other inorganic fossil fragments. Other clay-sized minerals are included in clay/silt-sized mineral matter.

DISCUSSION OF RESULTS

Reassessment of Oil Yields from Kansas Oil Shales

Oil shale assays by retorting techniques modified and improved over the past thirty years have increased the shale oil recovered from samples tested. These advances in technology have pointed up the need for current re-evaluation of Kansas oil shales. Earlier studies, too, were based on limited samples, limiting the accuracy of the results. It was felt that the present extensive sampling program would improve estimates of potential shale oil yield.

Comparisons between the 14 reassessed shales and previously reported values (Runnels et al., 1952) appear in Table 4. The most notable differences involve increases in the new data for average oil yield of the Eudora and Anna Shales and maximum oil yields of the sampled units.

All Eudora Shale samples tested in the present study, except one, are from the black clayshale-claystone portion of the Eudora Shale. The sample that came from the overlying gray bedded claymud unit yielded only trace amounts of oil. If this value is omitted, the average oil yield of the Eudora Shale would be 12.43 gallons per ton, an increase of 6.56 gallons per ton from the original reported average.

A gray bedded claymud sample of the Anna Shale also

Table 4. Comparison of oil yields of Kansas oil shales determined in present study with those of Runnels et al. (1952).

Lithostratigraphic Unit	Shale Oil Yields, Gallons Per Ton	
	Present Study	Runnels et al. Study
Pierre Shale	1) trace 2) trace 3) trace 4) trace Avg.=trace	1) trace 2) 0.0 3) 0.0 4) 0.0 Avg.=0.0
Sharon Springs Shale	1) 2.2 2) 1.6 3) 2.2 4) 0.3 remaining 12 samples = trace Avg.=0.81 (3 trace)	1) trace 2) trace 3) heavy trace 4) 6.95 5) 5.75 Avg.=2.54
Heebner Shale	1) 10.5 2) 8.5 3) 10.0 4) 8.0 Avg.=9.25	1) 19.65 Avg.=19.65
Eudora Shale	1) 10.8 2) trace 3) 16.4 4) 7.5 5) 15.0 Avg.=9.94	1) 7.43 2) 4.31 Avg.=5.87
Ladore Shale	1) trace Avg.=trace	1) slight trace Avg.=slight trace
Tacket Formation shale (Pleasanton Shale)	1) 3.1 2) 0.2 3) 3.2 4) 0.8 5) 4.3 6) 14.0 7) trace Avg.=3.66	1) 0.0 2) trace 3) 0.72 4) 1.68 5) 8.39 6) 7.19 7) 2.16 8) 1.68 9) 0.0 10) 2.64 11) 6.47 12) 2.64 13) 1.44 14) 9.83 15) 1.92 Avg.=3.12
Anna Shale	1) 0.6 2) 18.3 3) 7.9	1) 9.35 2) 3.12 3) 5.03

Table 4. (cont.)

<u>Lithostratigraphic Unit</u>	<u>Shale Oil Yields, Gallons Per Ton</u>	
	<u>Present Study</u>	<u>Runnels et al. Study</u>
Anna Shale (cont.)	4) trace 5) 12.8 Avg.=7.92	Avg.=5.83
Little Osage Shale	1) trace 7) 6.3 2) 3.9 8) 17.4 3) 15.8 9) trace 4) 15.7 10) 2.1 5) 23.3 11) 5.2 6) 0.9 Avg.=8.24	1) 12.2 2) 11.98 3) 7.43 Avg.=10.54
Excello shale	1) trace 2) 12.6 3) 7.5 Avg.=6.7	1) 4.31 2) 4.55 3) 9.11 Avg.=5.99
"V" shale	1) 0.6 2) 2.1 3) 1.1 4) trace 5) 13.0 Avg.=3.36	1) 9.6 2) 2.88 Avg.=6.24
Black shale above Fleming coal	1) trace 2) trace Avg.=trace	1) 3.83 2) 0.0 Avg.=1.92
Black shale above Mineral coal	1) trace Avg.=trace	1) 2.64 2) trace Avg.=1.32
Black shale above Tebo coal	1) 9.9 2) trace Avg.=4.95	1) 3.83 2) 0.0 Avg.=1.92
Black shale below Riverton coal	1) trace Avg.=trace	1) trace 2) 0.0 3) trace Avg.=trace

yielded only trace amounts of oil. If this value were omitted, the average oil yield of the Anna Shale would be 9.9 gallons per ton, an increase of 4.07 gallons per ton from the previous average. This would also result in an increase in the estimated reserves of 1.4×10^8 barrels (Angino et al., 1981) to 2.5×10^8 barrels, based on the technique used by Angino et al. (1981).

Oil shale reserves of the Eudora and Heebner Shales were not estimated due to insufficient data. The Eudora Shale was sampled only in Douglas, Johnson, and Franklin Counties and the Heebner Shale only in Douglas County, therefore, any southward extension of outcrop and oil yield values would be hypothetical. Since average oil yields of the other shales were relatively similar, the remaining reserve estimates were not recalculated.

Specific gravities of the recovered oil and gas plus loss values also showed differences (Table 5). Smaller previous values for specific gravity suggest that only lighter fractions of the organic matter present were recovered. Both the light and heavy fractions were recovered in the current study.

Major differences are related to improved analytical techniques. In the previous study, the retort was heated by a gas burner to a maximum temperature of 500°C and maintained for 20 minutes. Modern techniques involve the use of an electric heater with coils evenly spaced around the retort. A constant temperature of $500 \pm 5^{\circ}\text{C}$ is main-

Table 5. Comparison of average specific gravities of recovered shale oil and average gas plus loss values of select Kansas oil shales as determined in the present study with those determined by Runnels et al. (1952).

<u>Lithostratigraphic Unit</u>	<u>Specific Gravity</u>		<u>Gas Plus Loss (Wt. %)</u>	
	<u>Runnels et al. (25°C)</u>	<u>Present (15.6°C)</u>	<u>Runnels et al.</u>	<u>Present</u>
Heebner Shale	0.66	0.953	1.6	2.7
Eudora Shale	0.64	0.944	1.9	2.9
Tacket Formation shale	0.62	0.918	0.9	1.5
Anna Shale	0.59	0.915	1.7	2.3
Little Osage Shale	0.65	0.919	1.7	3.1
Excello shale	0.61	0.923	2.2	2.0
"V" shale	0.64	0.918	0.8	1.4

tained for 40±5 minutes. Appropriate temperature and length of heating are necessary to maintain uniform results. The longer retort period and revised heating apparatus apparently enhance oil yields, gas plus loss values, and specific gravities of recovered oil.

Specific gravity measurements were taken at 25°C in the previous study. The higher 37.8°C temperature used in the present study was necessary to obtain sufficient fluidity for accurate measurements.

Some of these differences may also be attributed to different sampling locations. Most of the exact locations used by Runnels et al. (1952) have been reclaimed, extensively weathered, or grown over and were thus either unsuitable, unattainable, or not sampled for the present study.

Oil Shale Potential of the Sharon Springs Shale

The Upper Cretaceous Sharon Springs Shale Member of the Pierre Shale crops out in Logan and Wallace Counties in western Kansas and in a fault block in Phillips County (Fig. 4). In a previous study (Runnels et al., 1952) this shale was sampled at one locality in Wallace County and tested for oil yield. The presence of some recoverable shale oil and the great vertical and lateral extent of this shale (Gill et al., 1972) make it an appealing potential shale oil source.

In this study, partial sections of the Sharon Springs

Shale were measured and sampled at 5 locations (Fig. 4). The poor quality and limited number of exposures restricted sampling. Seventeen samples of this shale were analyzed for potential shale oil yield.

No complete sections of the Sharon Springs Shale are exposed in western Kansas. Subsurface measurements, however, indicate a total thickness of 68 meters. Three informal units comprise the Sharon Springs Shale: a lower dark soft shale unit, a middle organic rich unit, and an upper hard phosphatic shale unit (Gill et al., 1972). The mineralogy of the Sharon Springs Shale consists largely of clay minerals, with some quartz, pyrite, dolomite, calcite, and organic matter.

The lower dark soft shale unit was sampled at locations 1, 4, and 5 (Fig. 4) and has an average exposed thickness of 9.5 meters. This unit consists of brownish gray (5YR 4/1), brownish black (5YR 2/1), and grayish black (N2), soft, bedded claymud-laminated claymud. The upper part of the exposures are stained yellow from weathering and oxidation.

Seven samples from the lower dark soft shale unit were assayed for potential oil yield. Only trace amounts of oil were recovered.

The middle organic-rich shale unit was examined and sampled at locations 2 and 3 (Fig. 4) where it ranges in thickness from 4.6 to 10.7 meters. This unit consists of olive black (5Y 2/1) and brownish black (5YR 2/1), papery

to fissle, resistant, clayshale. Septarian concretions (up to 5.8 m. in diameter), limonite, jarosite, selenite gypsum, bentonite layers, fish scales and bones, and plant debris are present. Eight samples were tested for recoverable shale oil and were found to yield from trace amounts to 2.2 gallons of oil per ton of shale (Table 1). Sixteen to twenty percent of organic matter is present; unusually high values for such low oil yields. The organic matter present is comprised mainly of vitrinite (huminite) with minor amounts of dinoflagellates/acritarchs and liptodetrinite and traces of other organic matter (Table 2). The vitrinite is partially derived from higher plants with the remainder of uncertain origin. Brown or red algae are possible sources for some of the vitrinite. The absence of significant amounts of sporinite is unusual for vitrinite-rich shale where the vitrinite is from higher plants. Therefore, the humic matter in these shales may be derived from a combination of higher plants and algae. Most of the shale oil yielded upon retorting, probably is derived from the vitrinite. A similar situation exists for coal, which also has considerable humic matter (vitrinite), but insignificant oil yield.

The upper slightly phosphatic shale unit from location 2 (Fig. 4) is approximately 1.1 meters thick. It consists of brownish gray (5YR 4/1) and brownish black (5YR 2/1), platy, moderately hard, clayshale. Phosporite nodules, limonite, bentonite beds, fish scales and bones,

and small limestone concretions are present. Two assayed samples yielded only trace amounts of oil.

The Sharon Springs Shale Member of the Pierre Shale comprises a large volume of low grade mixed oil shale, but oil yields are not large enough for economic interest.

Kansas Shales Previously Untested for Oil Yield

Twenty-three previously untested shale units, meeting earlier specified qualifications, were analyzed for oil yield (Table 6). Six of these shales were sampled from cores and the remaining 18 from outcrops. Only 6 Pennsylvanian shales and 1 Devonian-Mississippian sample produced any measurable amounts of oil (Table 1). Three of these units were sampled from outcrops: (1) Larsh-Burroak Shale, (2) Stark Shale, and (3) Hushpuckney Shale; and four were sampled from cores: (1) a black shale in the Fort Scott Limestone (may be correlative to Little Osage Shale in southeastern Kansas), (2) black shale above the Weir-Pittsburg coal, (3) black shales of the Kearny Formation and (4) Chattanooga Shale.

The Larsh-Burroak Shale is approximately 1.3 meters thick at the sample location with only 0.6 meters of black clayshale exposed. It yielded 9.1 gallons of oil per ton of shale when assayed.

The Stark Shale is approximately 0.9 meters thick at the sample location. This unit is composed of black clayshale that grades upward into a gray bedded claymud.

Table 6. Kansas shales previously untested for oil yield
(see Fig. 1 for further classification).

<u>Lithostratigraphic Units</u>	<u>Sample Numbers</u>
Upper Cretaceous	
Blue Hill Shale	119,120
Graneros Shale	109-118
Lower Cretaceous	
Dakota Formation shale	108
Lower Permian	
Odell Shale	106,107
Holmesville Shale	104,105
Easley Creek Shale	102,103
Roca Shale	100,101
Hughes Creek Shale	98,99
Hamlin Shale	95-97
Hawxby Shale	94
Towle Shale	93
Upper Pennsylvanian	
Larsh-Burroak Shale	92
Heumader Shale	91
Lawrence Formation shale	86
Vilas Shale	80
Stark Shale	79
Galesburg Shale	78
Hushpuckney Shale	75-77
Middle Pennsylvanian	
Black shale in Fort Scott Limestone	60,61
Black shale above Weir-Pittsburg coal	27-30
Lower Pennsylvanian	
Kearny Formation shales	16-25
Mississippian-Devonian	
Chattanooga Shale	5-15
Upper Ordovician	
Maquoketa Shale	1-4

The black clayshale portion is approximately 0.6 meters thick and yields 4.8 gallons of oil per ton of shale.

The Hushpuckney Shale, the most prolific oil-bearing unit of the previously untested shales, yields a maximum of 18.6 gallons of oil per ton of shale. A thickness of 1.4 meters is exposed at the sample locations. The black oil-producing clayshale makes up only the middle 0.6 to 0.8 meters of the Hushpuckney Shale.

Although these shales have relatively high oil yields, insufficient thickness and the lack of any coal bed associations eliminates them as potential sources for shale oil exploitation.

The black shale of the Fort Scott Limestone was sampled at depths of 1363 m. (4473 ft.) and 1365 m. (4479 ft.) below the surface in western Kansas (Appendix D and Fig. 2). A thickness of 2.7 meters was present in the core. This shale yielded 1.3 and 5.0 gallons of oil per ton of shale.

The black shale above the Weir-Pittsburg coal was sampled at core depths of 7.0 m. (24 ft.) and 8.5 m. (28 ft.) below the surface. Although the sampled intervals were only 1.9 meters thick, this shale crops out in southeastern Kansas and averages 5.3 meters in thickness.

Ten core samples of black shales of the Kearny Formation were taken at depths between 1543 m. (5063 ft.) and 1855 m. (6085 ft.) below the surface in southwestern Kansas (Appendix D and Fig. 2). These shales range in

thickness from 0.6 m. to 27.4 m. and yield from trace amounts to 1.3 gallons of oil per ton of shale.

The Chattanooga Shale was also examined. Subsurface thickness ranges from 0 m. in central Kansas to over 61 m. in the northeastern part of the state. The samples analyzed yielded from trace amounts to 5.0 gallons of oil per ton of shale.

Only the black shale overlying the Weir-Pittsburg coal is accessible for mining. Unfortunately, meager amounts of recoverable shale oil make it unsuitable for exploitation.

Lower Permian Green Shales

The Lower Permian green shales of Kansas contain organic material (Elias, 1937), but have never been examined for potential oil yield. These shales crop out from northeast to southeast across the central portion of Kansas (Fig. 4). The green shales examined in this study include: (1) from the Admire Group, the Towle Shale Member and Hawxby Shale Member of the Onaga Shale and Hamlin Shale Member of the Janesville Shale; (2) from the Council Grove Group, the Roca Shale and Easley Creek Shale; and (3) from the Chase Group, the Holmesville Shale Member of the Doyle Shale and Odell Shale (Fig. 1). These calcareous claystones and clayshales have a minimum thickness of 3 meters and although each is considered a green shale, there are distinct contrasts in hue, value,

and chroma (Appendix C).

The green color of these shales results from deposition in a zone of effective reduction where red ferric iron is converted to the green ferrous state due to the reducing action of organic matter (Elias, 1937). The amount of carbon present in shales is also an important color control (Potter et al., 1980, p. 53-58). Once the Fe^{3+} has been converted to Fe^{2+} the coloration (pigmentation) is by organic carbon. Thus, shale color is regulated by the amount of Fe^{3+} and organic carbon, both of which are measurable.

Iron oxides make up from 2.8 to 6.6 percent of the oxides present in these shales (Cubitt, 1979), a sufficient quantity of iron to produce a green or red color.

All 13 of the shale samples assayed yielded only trace amounts of oil. This is due to the absence of significant amounts of organic matter. These shales are composed largely of clay/silt-sized mineral matter with minor amounts of pyrite and other iron related minerals and minor amounts of organic matter (Table 3).

Stratigraphic and Physical Similarities of Kansas Oil Shales

Stratigraphic Similarities of Middle and Upper Pennsylvanian and Lower Permian Shales

Upper and Middle Pennsylvanian and Lower Permian rocks of Kansas exhibit a cyclic nature, which has been interpreted to result from alternating transgressions and

regressions of the Permian and Pennsylvanian seas (Moore, 1936, 1949, 1964). The basic cyclothem contains, in ascending order: (1) an outside, nearshore shale, (2) a middle transgressive limestone, (3) a core, offshore shale, (4) an upper regressive limestone, and (5) an outside, nearshore shale (Heckel, 1975, 1977).

All seven of the most prolific oil-bearing shales tested have been stratigraphically classified as core shales. These shales were typically deposited in anoxic environments below the base of the photic zone with somewhat restricted circulation and a large influx of organic material (Heckel, 1977). These conditions were ideal for preservation of organic matter. The coals underlying two of the potentially economic oil shales contradict the theory of offshore deposition and suggest deviations in the proposed model.

Three additional shales are also considered to be offshore core shales and although oil yields were significant, limited thickness makes them economically unsuitable.

All green or gray shales tested from the Pennsylvanian and Permian Systems are outside, nearshore shales. These mudshales and mudstones are largely devoid of organic material, which accounts for the minimal oil yields.

Physical Similarities

Petrology of Organic Material: The organic matter present in ten selected Kansas shales, as determined largely by

N. Sherwood and Dr. A. Cook of the University of Wollongong, is usually disseminated throughout the matrix (Table 3). The organic composition, determined from examinations using normal reflected light and reflected light fluorescence modes, is dominantly vitrinite in the Middle and Upper Pennsylvanian samples and the Upper Cretaceous Sharon Springs Shale. The Upper Ordovician Maquoketa Shale and two Lower Permian shales contain minor amounts of organic material. The Devonian-Mississippian Chattanooga Shale contains small equal amounts of phytoplankton and vitrinite.

Optical properties of the organic matter most closely resemble those of vitrinite, which is probably derived largely from higher plants. Unfortunately, dinoflagellates, sporinite, resinite, and other exinite macerals, usually found with vitrinite are rare. Some of the organic matter identified as vitrinite may therefore be of algal origin.

The large percentage of vitrinite present in the examined shales is uncommon in rich oil shales and is the possible explanation of the examined samples that show a high organic content, but low oil yields. However, the Cretaceous and Pennsylvanian shales can be classified as mixed oil shales (Hutton et al., 1980), which are marine shales containing a variety of organic matter. The Devonian-Mississippian Chattanooga Shale can also be classified as a low grade mixed oil shale, but minor amounts of tasmanitid macerals present also allow it to

be classified as low grade tasmanite (Hutton et al., 1980).

Vitrinite Reflectance: The vitrinite reflectance values for the Upper Cretaceous Sharon Springs Shale show a value range equivalent to values for a rank of peat to a low rank-brown coal stage (Table 2). The Pennsylvanian and Devonian-Mississippian Chattanooga Shale samples range in rank from the high rank-brown coal stage to subbituminous stage (Table 2).

These shales are considered immature on the coal-rank scale with various maturation indices (Dow, 1978). If the organic matter consists of greater quantities of algal material, then the vitrinite reflectances would tend to be lower (Hutton and Cook, 1980) and maturation of these shales would be greater than indicated.

Partings: Parting is the tendency of a rock to split along laminations or bedding, a tendency enhanced by weathering (Potter et al., 1980, p. 16). Thin partings are common in rocks containing abundant organic material and clay minerals and small amounts of sand- and silt-sized grains. A preferred orientation of platy minerals also promotes partings.

There is little relation between shale oil yield and parting thickness in Kansas oil shales. Shales that produce oil range from papery (0.05 mm. or less) to slabby (1 to 30 cm.) with the platy (1 to 5 mm.) to slabby shales (following Potter et al., 1980, p. 16) yielding the most oil. These oil shales are classified

as clayshales, claystones, clayshale-claystones, and claystone-clayshales based on parting thickness and percentage of clay-size constituents. Bedded claymud, mudshale-mudstone samples yielded only trace amounts of shale oil.

Middle and Upper Pennsylvanian oil shales contain relatively large amounts of organic matter along with clay/silt-sized mineral matter, but are not thinly parted. The absence of fine partings is largely due to the resistance of the rock units. The abundance of phosphorite nodules, lenses, and lamina within claystone and clayshale portions appears to stabilize these shales. Authigenic carbonate may also serve as a cement which tends to hold the units together. Overlying limestone units may protect the shales from weathering. The shales themselves form barriers to fluid flow, thus the altering effects of groundwater are greatest at the boundaries of shale units instead of within the shale units.

Only the Upper Cretaceous Sharon Springs Shale with its abundant organic carbon and clay content (Gill et al., 1972), exhibits the parting characteristics noted earlier. Color: Shale oil yield is directly related to the type and abundance of organic carbon, which in turn is the controlling factor in shale color. The Kansas shales tested for recoverable oil range in color from various shades of green to black (N1) based on the Geological Society of America rock color chart (Goddard et al., 1979).

Most of the Pennsylvanian shales and the Devonian-Mississippian Chattanooga Shale, although not specifically tested for organic carbon, appear from petrographic examinations to contain large amounts of organic matter. They are largely dark gray (N3) to black (N1) and yield varying amounts of oil. Shales lighter than dark gray (N3) yield only minor amounts of oil.

Grayish black (N2) to black (N1) shales have the greatest oil yields, but also include shale that yield only trace amounts of oil. This is thought to be a result of the type and abundance of organic matter present, weathering, or diagenesis. The degree of oxidation occurring during diagenesis is not readily reflected in shale color. The presence of calcite in some of these shales may also be a cause of the dark colors (Hosterman and Whitlow, 1981).

The Upper Cretaceous Graneros and Blue Hill Shales are generally dark gray (N3), but produce only trace amounts of oil when assayed. The Graneros Shale contains considerable organic carbon in certain units (Hattin, 1965), while the Blue Hill Shale contains a very small amount of organic material (Table 3). This suggests that the Graneros Shale is composed largely of non-oil producing organic matter or has undergone some diagenesis. Also, the small amount of organic matter in the Blue Hill Shale may be sufficient for its coloration.

Iron is another important factor in shale coloration.

In the absence of organic matter, shales containing iron will take on a red color when oxidized and a green color when reduced. In anoxic environments where organic material is abundant, all of the iron present is reduced to the ferrous (Fe^{2+}) state. This allows for takeover of coloration (pigmentation) by the organic matter present in the organic-rich shales (Potter et al., 1980, p. 53-58).

Accessory Minerals and Components: Phosphorite nodules and lamina (Plate IX) are present in all of the seven potentially economic oil shales (Table 7) and many of the other dark gray to black shales tested for oil yield. Phosphorite deposition typically occurs in equatorial marine waters where phosphate rich bottom waters reach the concentration for phosphate ion saturation. At this concentration phosphorite either precipitates directly or replaces existing carbonate material (Manheim et al., 1975; Heckel, 1977; Malinky, 1980). This usually occurs at the sediment-water interface and is facilitated by a decrease in pressure and an increase in temperature, Eh, and pH (Manheim et al., 1975).

Uranium is also found in the seven economically attractive oil shales (Table 7). The uranium, phosphate, and humic organic material found in the black Pennsylvanian shales of Kansas are genetically interrelated (Swanson, 1960). Phosphorous, derived largely from plants, precipitated in combination with calcium and fluorine

Table 7. Oil yield and phosphate and uranium contents of potentially economic oil shales from Kansas. Phosphate and uranium contents of phosphorite nodules are also listed. (phosphate and uranium content of the shales are from Swanson (1960) and Runnels (1949); phosphate and uranium content of phosphorite nodules are from Runnels et al. (1953))

Lithostratigraphic Unit	Oil Yield Gallons Per Ton*	Total Phosphate (P_2O_5)		Percent Uranium (U_3O_8)	
		Shale	Nodules	Shale	Nodules
Heebner Shale	Avg. = 9.25	—	31.95	Avg.=0.005	0.017
Eudora Shale	Avg. = 12.43	0.81	—	Avg.=0.005	—
Tacket Formation shale	Avg. = 4.27	Avg.=2.22	27.22	—	0.011
Anna Shale	Avg. = 13.00	2.30	34.10	Avg.=0.005	0.020
Little Osage Shale	Avg. = 10.07	Avg.=2.24	30.88	0.004	0.029
Excello shale	Avg. = 6.70	Avg.=3.20	Avg.=27.45	Avg.=0.006	Avg.=0.015
"V" shale	Avg. = 2.96	2.62	—	—	—

* average is determined from black clayshale-claystone portions of units

to form phosphorite. Uranium as UO_2 can substitute for PO_4 , and U^{4+} can substitute for calcium in the carbonate-fluorapatite structure, or become adsorbed on humic organic material.

Pyrite and other highly reflecting minerals are present in all the shales examined petrographically (Table 3), but are largely indistinguishable in hand samples. The presence of pyrite indicates strongly reducing conditions at the sediment-water interface or within the sediment (Potter et al., 1980, p. 48).

Gypsum was not readily evident in the high oil-yield shales, however, gypsum was present in large concentrations in all the low oil-yield Upper Cretaceous shales. Organic carbon, pyrite, and gypsum in the Upper Cretaceous Graneros Shale are genetically interrelated (Hattin, 1965).

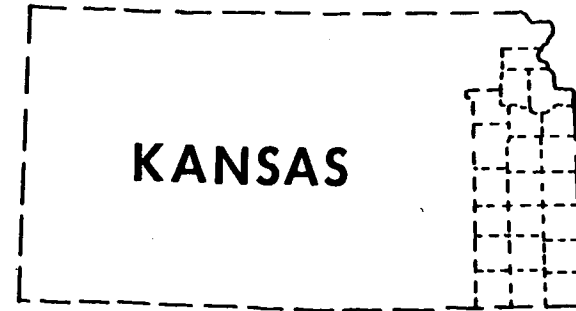
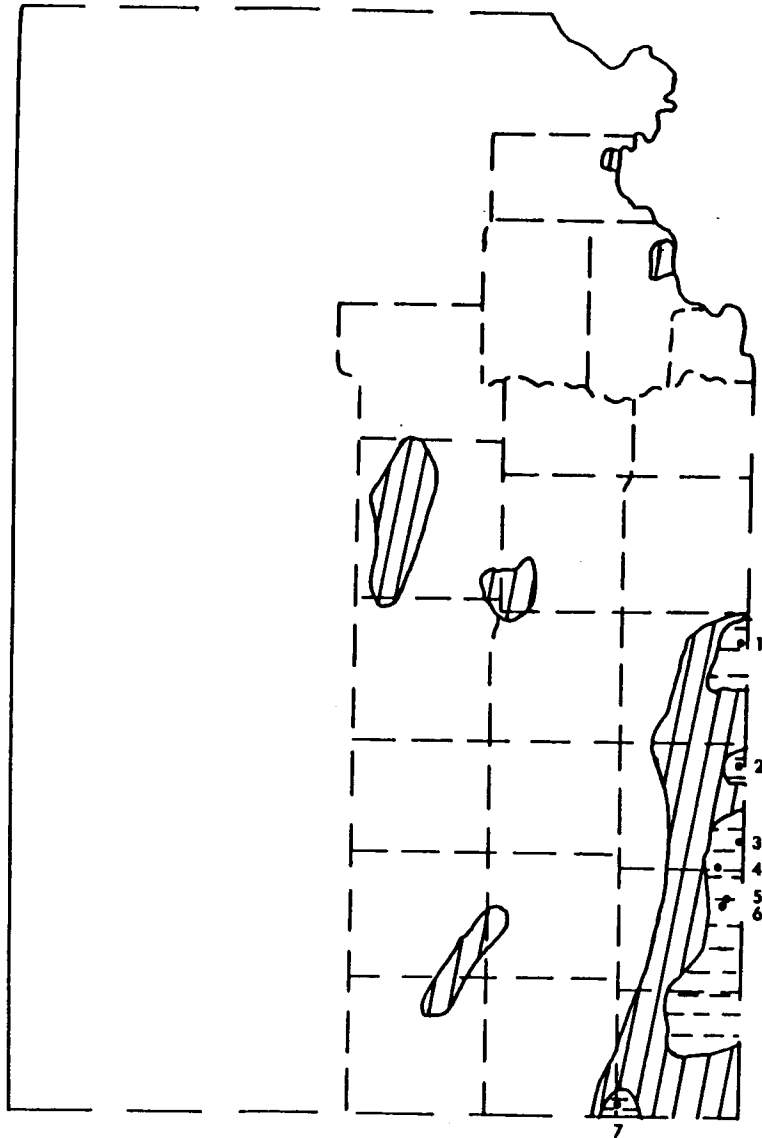
Limonite and other iron hydroxides are commonly present in the outcropping shales. These minerals are directly related to weathering and have no significant relation to the presence of organic material.

Application of the Economic Window Concept

Considerable amounts of coal are currently being strip-mined in southeastern Kansas (Fig. 6). Extraction costs are high since thick black shale-limestone overburden must first be removed to recover the coal. The economic window concept (Angino et al., 1981) refers to

Figure 6. Location of active and inactive Kansas coal mines. (modified from Brady et al., 1976)

<u>Mine Names</u>	<u>Coal Being Mined</u>
1) Midway Mine (P&M Coal Mining Co.)	Mulberry coal
2) Fulton Mine (Bills Coal Co.)	Mulky coal
3) Ft. Scott Mine (Bills Coal Co.)	Croweburg, Fleming, and Bevier coals
4) Mine # 1 (Pat's Coal Co.)	Bevier coal
5) Croweburg Mine (Alternate Fuels, Inc.)	Mineral coal
6) Mine # 22 (Clemens Coal Co.)	Mineral and Croweburg coals
7) Chetopa Mine (Bills Coal Co.)	Mineral coal



Inactive Coal Fields



Active Coal Fields



Location of Active Coal Mines

the cost reduction of both black shale and coal extraction by utilizing formerly unusable oil shale overburden. Unfortunately, most of the black shales that overlie (or underlie) mineable coals do not yield significant amounts of oil upon retorting. Those shales that lend support to the economic window concept are the Little Osage, Excello, and "V" shales (Appendix B). The Little Osage Shale (2.5 m.) and Excello shale (1.0 m.) together with the Higginsville (5.0 m.) and Blackjack Creek (3.0 m.) Limestones comprise the overburden of the Mulky coal (0.3 m.) (Schoewe, 1959, and Brady et al., 1976).

Although these shales will theoretically produce economically recoverable amounts of oil, the associated limestones complicate extraction. Two problems that reduce the attractiveness of exploiting the black shale overburden are the great thickness of the overlying limestones and the repetition of thin limestone stringers within some of the shales.

These limitations, however, do not eliminate the potential for shale oil recovery in southeastern Kansas. The limestone overburden could be quarried and used for road metal or rip-rap. The inorganic material within the oil shales could be used in manufacturing cement, building bricks, mineral wool, alumina, filter for acid manufacturing, and various molded articles (Runnels et al., 1952).

The uranium and phosphate present in these shales

also may be valuable products when extracted in combination with the oil. The uranium content in samples of the Heebner, Eudora, Tacket Formation, Anna, Little Osage, Excello, and "V" shales are listed in Table 7 along with oil yield, total phosphate of shale, total phosphate of phosphorite nodules within the shale, and percent uranium found in the phosphorite nodules.

Phosphorite nodules and dispersed phosphate are present in all economically attractive Kansas oil shales (Plate IX). One or more of 3 types of nodules are present: (1) highly calcareous and fossiliferous nodules, (2) gray to black, granular nodules, and (3) septarian nodules (Malinky, 1980). In general, these phosphorite nodules contain 0.01 to 0.03 percent uranium, whereas, the raw shales contain an average of only 0.005 percent. This suggests that the phosphorite nodules are the major uranium-bearing components in most of these shales, in line with the expected geochemical theory. Total phosphate (as P_2O_5) in the raw shales ranged from 0.81 to 3.20 percent, while total phosphate in the nodules ranged from 27.22 to 34.10 percent. Consequently, these nodular phosphates could be a potential source of fertilizers for a localized market (Rose and Hardy, 1967).

Phosphorite nodules comprise a maximum of 5 percent of the total shale. Although previous attempts to separate the shale and nodules have been unsuccessful (Rose and Hardy, 1967), removal of the nodules would

increase phosphate recovery by 10 times and uranium recovery by 3 times.

In summary, the optimum economic window for efficient usage of these oil shales would involve the early removal of phosphate and uranium, followed by retorting of the shale for oil. The spent shale could then be used for lightweight road metal or discarded. The initial oil shale extraction costs would be offset in some cases by the presence of strippable coals or limestones.

Economic Factors of Oil Shale Development

Economic factors important in the exploitation of oil shales are: (1) extraction and processing of the oil shale, (2) hydrologic considerations, and (3) environmental considerations. Kansas oil shales that are potentially economic crop out in southeast Kansas. These shale are overlain by rock units which gradually increase in thickness westward. Overburden is not so thick that surface mining techniques are precluded. Limitations on mining would involve oil yield and thickness of the oil shales.

Coal is mined from the surface by strip-mining procedures in Kansas. These would be the same procedures used for mining oil shales and can be used to recover up to 90 percent or more of the total shale present in the mine area (Office of Technology Assessment, 1980).

Processing of Kansas oil shales would most likely

be done by surface retorting techniques. These techniques are very similar to the Modified Fischer Retort Method previously discussed, but on a much larger scale.

Another procedure that has recently been introduced is the Institute of Gas Technology HYTORTTM process (Matthews et al., 1981). This process allows for recoveries of 2 to 2.5 times those of conventional retorting. Samples yielding from 10 to 15 gallons of oil per ton of shale from Fischer assays will yield 25 to 30 gallons per ton using this method. This process is still in the experimental stages, but has been proven technologically and economically feasible. Samples of Kansas oil shales were not tested by this procedure, but theoretically would show large increases in oil yield if processed in such a manner. The crude oil derived by either method would have to be further processed and refined before a final useable product would be obtained.

Three limiting factors are common to all modern retorting processes: (1) energy has to be used to produce further energy, (2) only 70 percent or less of the organic matter found in oil shales can be liberated during the retorting process, and (3) large volumes of expanded shale are a byproduct of retorting (Yen and Chilingar, 1976, p. 7). This spent shale has to be moved and stored in such a manner that any undesirable leachates not be introduced into the groundwater or local drainage systems.

Other hydrologic and environmental constraints that would arise if Kansas oil shales were to become economic to process would be availability of water for processing, air and water pollution problems, and land reclamation requirements (Angino et al., 1981).

CONCLUSIONS

1. This study provides a comprehensive and detailed assessment of Kansas oil shales and serves as a guideline for future evaluations. Thirty-seven shale units were examined in the study.
2. Potential oil recovery of previously tested Kansas oil shales by the Modified Fischer Retort Method indicates greater average oil yields, gas plus loss values, and specific gravities of recovered shale oil than were obtained in earlier studies. Increases are attributed to improved techniques and modern equipment. Oil yields range from trace amounts to 23.3 gallons of oil per ton of shale, gas plus loss values from 0.0 to 4.9 percent by weight, and specific gravities of the shale oil from 0.898 to 0.970.
3. The Upper Cretaceous Sharon Springs Shale Member of the Pierre Shale is a low grade mixed oil shale. Oil recovery ranges from trace amounts to 2.2 gallons of oil per ton of shale. The oil is derived from organic matter which is largely vitrinite with minor amounts of associated phytoplankton. Although there are extensive reserves of this shale, the low oil yield discourages future development for shale oil.

4. Of the twenty-three Kansas shales previously untested for oil yield, only seven yield more than trace amounts of oil. None of these are considered potentially economical due to low oil yields and, in most cases, insufficient unit thickness.

5. Previously untested Lower Permian green shales of Kansas contain very small amounts of organic matter and yield essentially no shale oil when assayed. Therefore, these shales are not classified as oil shales.

6. The possible extraction of phosphate and uranium along with shale oil increases the economic attractiveness of Kansas oil shales. Mineable coals are also associated with oil shales in several stratigraphic intervals and could serve as economic windows for reducing extraction costs of both commodities. In addition, oil shales with economic potential must have oil yields greater than 10 gallons of oil per ton of shale, large lateral extent, and a minimum thickness of 1 meter. Seven low grade mixed oil shales in Kansas satisfy these requirements: the "V", Excello, Little Osage, and Anna shales of Middle Pennsylvanian age and the Tacket Formation, Eudora, and Heebner shales of Upper Pennsylvanian age.

7. The high oil-yield (greater than 5 gallons per ton) Kansas oil shales are dark gray (N3) to black (N1) and have partings with variable thicknesses. The parting

characteristics show little relation to oil yield or organic content. All of the seven potentially economic oil shales contain genetically related phosphorite nodules, uranium, and humic organic matter. Large quantities of vitrinite and small amounts of exinite are present in these shales. This is unusual in oil shales.

8. Vitrinite reflectances indicate a very low rank maturity for the shales studied. These anomalous values may be due to the variety of vitrinite present.

9. The type and amount of organic matter prohibits high oil yield from these shales, with the possible exception of the Devonian-Mississippian Chattanooga Shale, which is a low grade mixed oil shale or a low grade tasmanite.

10. Extraction of Kansas oil shales for shale oil is not economically feasible at this time. Improved extraction techniques and processing methods in the future may increase interest in these shales.

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REFERENCES

- Angino, E., Berg, J., Dellwig, L., Stanley, B. and Walters, R., 1981, Kansas oil shale: Kansas Energy Office, 42 p.
- Baker, D.R., 1962, Organic geochemistry of the Cherokee Group in southeastern Kansas and northeastern Oklahoma: Am. Assoc. Petroleum Geologists Bull. v. 46, p. 1621-1642.
- Brady, L.L., Adams, D.B. and Livingston, N.D., 1976, An evaluation of the strippable coal reserves in Kansas: Kansas Geol. Survey Min. Resource Series No. 5, 40 p.
- Cook, A.C. and Kantsler, A.J. (Eds.), 1980, Oil shale petrology workshop: Wollongong, N.S.W., Keiraville Kopiers, 100 p.
- Cubitt, J., 1979, The geochemistry, mineralogy and petrology of Upper Paleozoic shales in Kansas: Kansas Geol. Survey Bull. 217, 117 p.
- Dow, W.G., 1978, Petroleum source beds on continental slopes and rises: Am. Assoc. Petroleum Geologists Bull., v. 62, p. 1584-1606.
- Ebanks, W.J., James, G.W. and Livingston, N.D., 1977, Evaluation of heavy oil and tar sands in Bourbon, Crawford and Cherokee Counties, Kansas: Kansas Geol. Survey Final Report No. BERG/R1-77/20 under contract No. E-76-S-02-2997 with the U.S. Dept. of Energy, 110 p.
- Elias, M.K., 1937, Depth of deposition of the Big Blue (Late Paleozoic) sediments in Kansas: Geol. Soc. America Bull., v. 48, p. 403-432.
- Emery, P.A., 1962, Stratigraphy of the Pleasanton Group in Bourbon, Neosho, Labette, and Montgomery Counties, Kansas: Unpublished M.S. thesis, Dept. of Geol., Univ. of Kansas, 55 p.
- Gavin, M.J., 1924, Oil shale: Washington D.C., Government Printing Office, 201 p.

- Gill, J.R., Cobbon, W.A. and Schultz, L.G., 1972, Stratigraphy and composition of the Sharon Springs Member of the Pierre Shale in western Kansas: U.S. Geol. Survey Prof. Paper 723, 50 p.
- Goddard, E.N., Trask, P.D., Deford, R.K., Rove, O.N., Singewald, Jr., J.T. and Overbeck, R.M., 1979, Rock-color chart: Geol. Soc. America, Boulder, Colorado.
- Haq, B.U. and Boersma, A. (Eds.), 1978, Introduction to marine micropaleontology: New York, Elsevier North Holland, Inc., 376 p.
- Hatch, J.R. and Leventhal, J.S., 1981, Geochemistry of organic-rich shales and coals from Middle Pennsylvanian Cherokee Group and lower part of Marmaton Group, Oklahoma, Kansas, Missouri, and Iowa (abs.): Am. Assoc. Petroleum Geologists Bull., v. 65, no. 5, p. 936.
- Hattin, D.E., 1962, Stratigraphy of the Carlile Shale (Upper Cretaceous), in Kansas: Kansas Geol. Survey Bull. 156, 155 p.
- , 1965, Stratigraphy of the Graneros Shale (Upper Cretaceous), central Kansas: Kansas Geol. Survey Bull. 178, 183 p.
- Heckel, P.H., 1975, Stratigraphy and depositional framework of the Stanton Formation in southeastern Kansas: Kansas Geol. Survey Bull. 210, 45 p.
- , 1977, Origin of phosphatic black shale facies in Pennsylvanian cyclothems of mid-continent North America: Am. Assoc. Petroleum Geologists Bull., v. 61, no. 7, p. 1045-1068.
- , 1978, Upper Pennsylvanian cyclothem limestone facies in eastern Kansas: Kansas Geol. Survey Guidebook Series No. 2, 79 p.
- , Brady, L.L., Ebanks, Jr., W.J. and Pabian, R.K., 1979, Pennsylvanian cyclic platform deposits of Kansas and Nebraska: Kansas Geol. Survey Guidebook Series No. 4, 79 p.
- and Baesemann, J.F., 1975, Environmental interpretation of conodont distribution in Upper Pennsylvanian (Missourian) megacyclothems in eastern Kansas: Am. Assoc. Petroleum Geologists Bull., v. 59, no. 3, p. 486-509.

- Hosterman, J.W. and Whitlow, S.I., 1981, Munsell color value as related to organic carbon in Devonian shale in Appalachian Basin: Am. Assoc. Petroleum Geologists Bull., v. 65, p. 333-335.
- Howe, W.B., 1956, Stratigraphy of pre-Marmaton Desmoinesian (Cherokee) rocks in southeastern Kansas: Kansas Geol. Survey Bull. 123, 132 p.
- Hutton, A.C. and Cook, A.C., 1980, Influence of alginite on the reflectance of vitrinite from Joadja, N.S.W., and some other coals and oil shales containing alginite: Fuel, v. 59, p. 711-714.
- , Kantsler, A.J., Cook, A.C. and McKirdy, D.M., 1980, Organic matter in oil shales: Aust. Petrol. Explor. Assoc. J., v. 20, p. 44-67.
- James, G.W., 1970, Stratigraphic geochemistry of a Pennsylvanian black shale (Excello) in the mid-continent and Illinois basin: Unpublished PhD thesis, Rice Univ., 92 p.
- and Baker, D.R., 1971, Organic geochemistry of a Pennsylvanian black shale (Excello) in the mid-continent and Illinois basin, in short papers on research in 1971: Kansas Geol. Survey Bull. 204, pt. 1, p. 3-10.
- Jewett, J.M., 1945, Stratigraphy of the Marmaton Group, Pennsylvanian, in Kansas: Kansas Geol. Survey Bull. 58, 148 p.
- , Emery, P.A. and Hatcher, D.A., 1965, The Pleasanton Group (Upper Pennsylvanian) in Kansas: Kansas Geol. Survey Bull. 175, pt. 4, 11 p.
- Malinky, J.M., 1980, Depositional environment of the Eudora Shale (Missourian, Upper Pennsylvanian) near Tyro, Kansas: Unpublished M.S. thesis, Ohio Univ., 98 p.
- Manheim, F., Rowe, G.T. and Jipa, D., 1975, Marine phosphorite formation off Peru: Jour. Sed. Petrology, v. 45, p. 243-251.
- Matthews, R.D., Janka, J.C. and Dennison, J.M., 1981, New insights into Devonian oil shale resource of eastern United States (abs.): Am. Assoc. Petroleum Geologists Bull., v. 65, no. 5, p. 954.

- McManus, D.A., 1959, Stratigraphy and depositional history of the Kearny Formation (Lower Pennsylvanian) in western Kansas: Unpublished PhD thesis, Dept. of Geol., Univ. of Kansas, 150 p.
- Merriam, D.F., 1963, The geologic history of Kansas: Kansas Geol. Survey Bull. 162, 317 p.
- Moore, R.C., 1936, Stratigraphic classification of the Pennsylvanian rocks of Kansas: Kansas Geol. Survey Bull. 22, 256 p.
- , 1949, Divisions of the Pennsylvanian System in Kansas: Kansas Geol. Survey Bull. 83, 203 p.
- , 1964, Paleocological aspects of Kansas Pennsylvanian and Permian cyclothems: in, Merriam, D.F. (Ed.) Symposium on cyclic sedimentation: Kansas Geol. Survey Bull. 169, p. 287-380.
- , Frye, J.C., Jewett, J.M., Lee, W. and O'Connor, H.G., 1951, The Kansas rock column: Kansas Geol. Survey Bull. 89, 132 p.
- Murphy, M.E., Narayanan, S., Gould, G., Lawler, S., Noonan, J., Prentice, D., 1972, Organic geochemistry of some Upper Pennsylvanian and Lower Permian Kansas shales, in short papers on research in 1971: Kansas Geol. Survey Bull. 204, pt. 1, p. 19-25.
- O'Connor, H.C., 1963, Changes in Kansas stratigraphic nomenclature: Am. Assoc. Petroleum Geologists Bull., v. 47, p. 1873-1877.
- Office of Technology Assessment, Congress of the United States, 1980, An assessment of oil shale technologies: Washington, D.C., U.S. Government Printing Office, 517 p.
- Potter, P.E., Maynard, J.B. and Pryor, W.A., 1980, Sedimentology of shale: New York, Springer-Verlag, 303 p.
- Rose, K.E. and Hardy, R.G., 1967, Recovery of phosphate from the Cabaniss and Pleasanton Shales of Kansas: Kansas Geol. Survey Bull. 187, pt. 4, 12 p.
- Runnels, R.T., 1949, Preliminary report on phosphate-bearing shales in eastern Kansas: Kansas Geol. Survey Bull. 82, pt. 2, p. 37-48.
- , Kulstead, R.O., McDuffee, C. and Schleicher, J.A., 1952, Oil shale in Kansas: Kansas Geol. Survey Bull. 96, pt. 3, p. 157-184.

- , Schleicher, J.A. and Van Nortwick, H.S., 1953, Composition of some uranium-bearing phosphate nodules from Kansas shales: Kansas Geol. Survey Bull. 102, pt. 3, p. 93-104.
- Schoewe, W.H., 1959, Coal reserves of the Cherokee Group in eastern Kansas. I. Mulky Coal: Kansas Geol. Survey Bull. 134, pt. 5, p. 181-222.
- Sherwood, N.R. and Cook, A.C., 1982, Dept. of Geology, University of Wollongong, N.S.W., Australia, personal communication.
- Smith, J.W., 1963, Stratigraphic change in organic composition demonstrated by oil specific gravity-depth correlation in Tertiary Green River oil shales, Colorado: Am. Assoc. Petroleum Geologists Bull., v. 47, no. 5, p. 804-813.
- Stanfield, K.E., 1953, Estimating oil yield of lean oil shale: Anal. Chemistry, v. 25, no. 10, p. 1552-1553.
- Swanson, V.E., 1960, Oil yield and uranium content of black shales: U.S. Geol. Survey Prof. Paper 356-A, 44 p.
- United States Department of Energy, 1979, Standard method of test for oil shale (resource evaluation by the U.S.B.M. Fischer Assay Procedure): Laramie Wyoming, rough draft, 20 p.
- Yen, T.F. and Chilingarian, G.V. (Eds.), 1976, Oil shale: New York, Elsevier Scientific Publishing Company, 292 p.
- Zeller, D.E. (Ed.), 1968, The stratigraphic succession in Kansas: Kansas Geol. Survey Bull. 189, p. 21-58.

PLATES

Plate I. Sketch and photograph (pick-axe for scale) of Section 1 (Appendix E) illustrating the sampled intervals and oil yields of the Eudora Shale. Oil yields are listed and graphically represented (1 mm. = 1 gallon per ton) with sample numbers listed beneath yields.

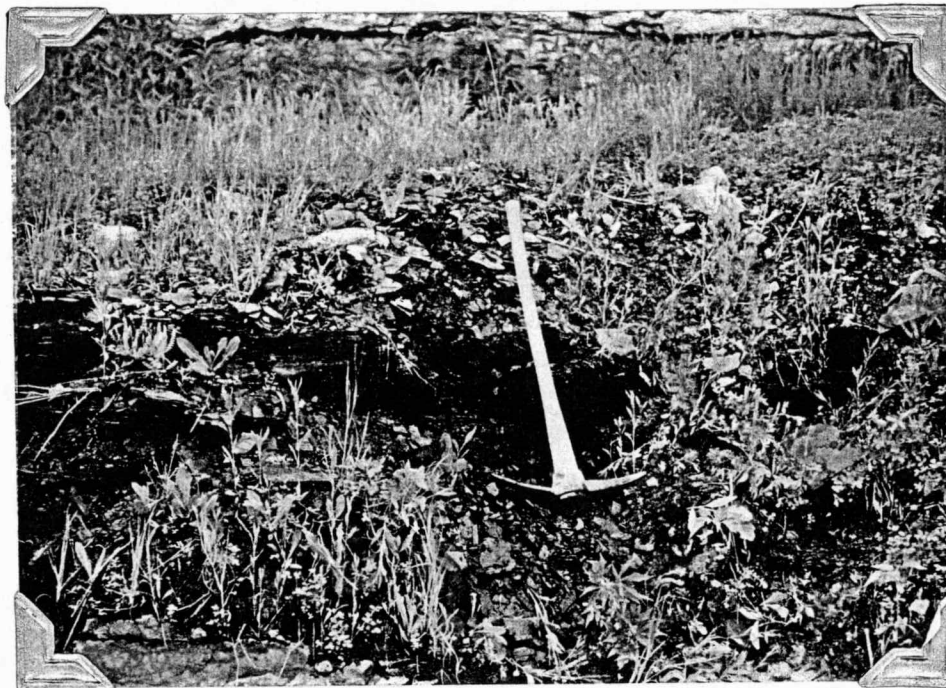
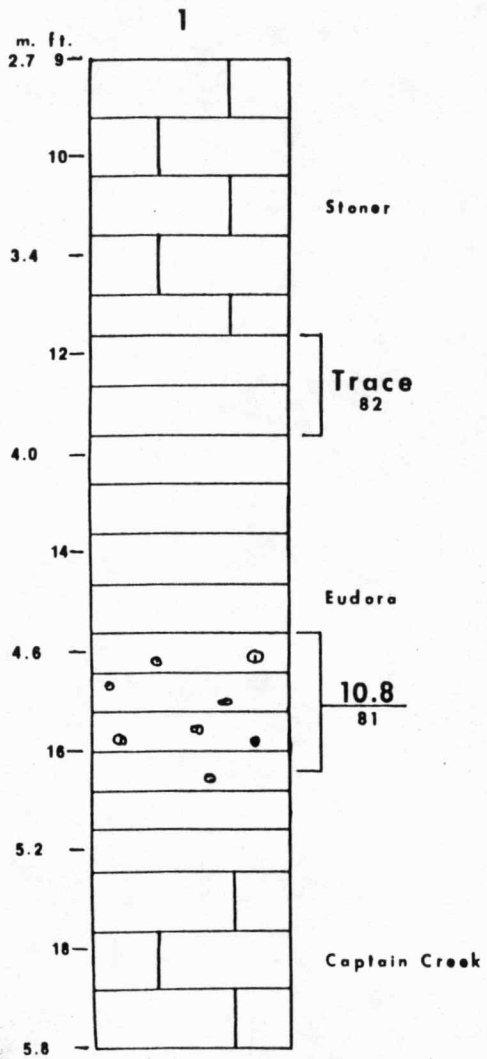


Plate II. Sketch and photograph (5 ft. staff) of Section 2 (Appendix E) illustrating the sampled interval and average oil yield of the Heebner Shale. Average oil yield is listed and graphically represented (0.65 mm. = 1 gallon per ton) with sample numbers listed beneath yield.

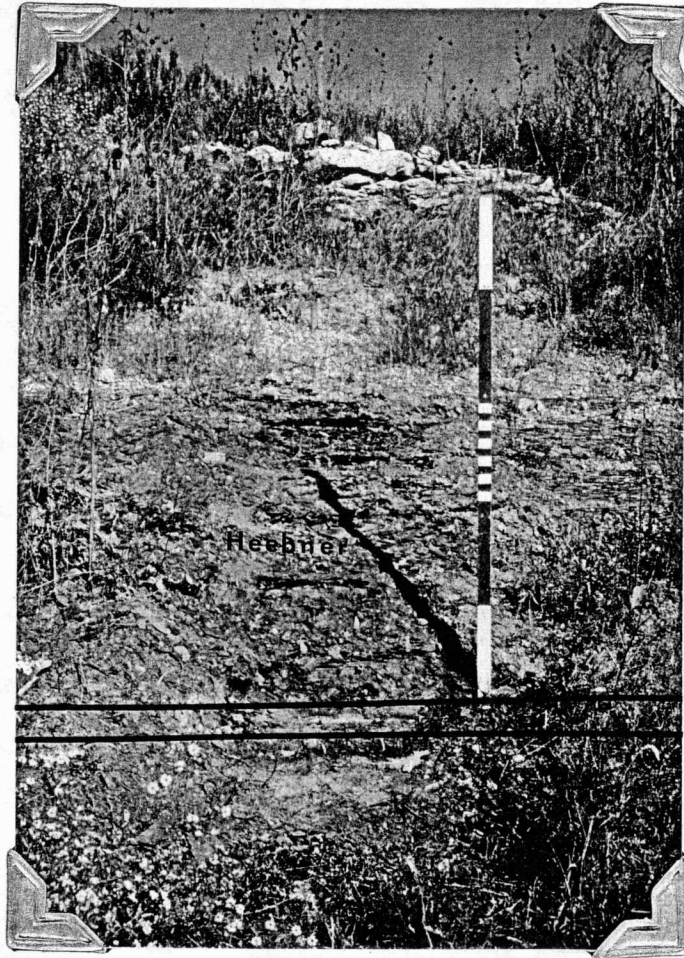
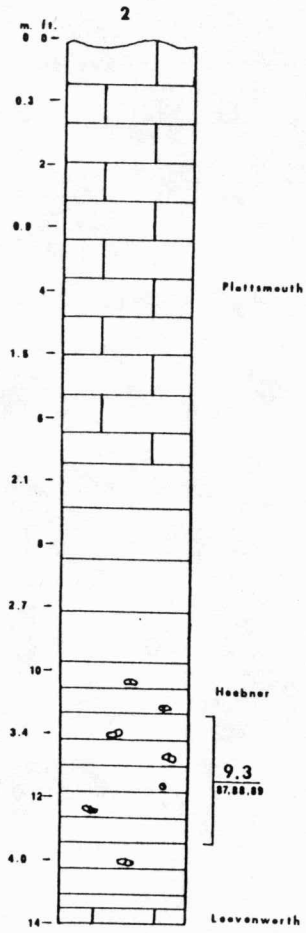


Plate III. Sketch and photograph (crouched man is approximately 3.5 ft.) of Section 3 (Appendix E) illustrating the sampled intervals and oil yields of the Little Osage and Excello Shales. Oil yields are listed and graphically represented (0.65 mm. = 1 gallon per ton) with sample numbers listed beneath yields.

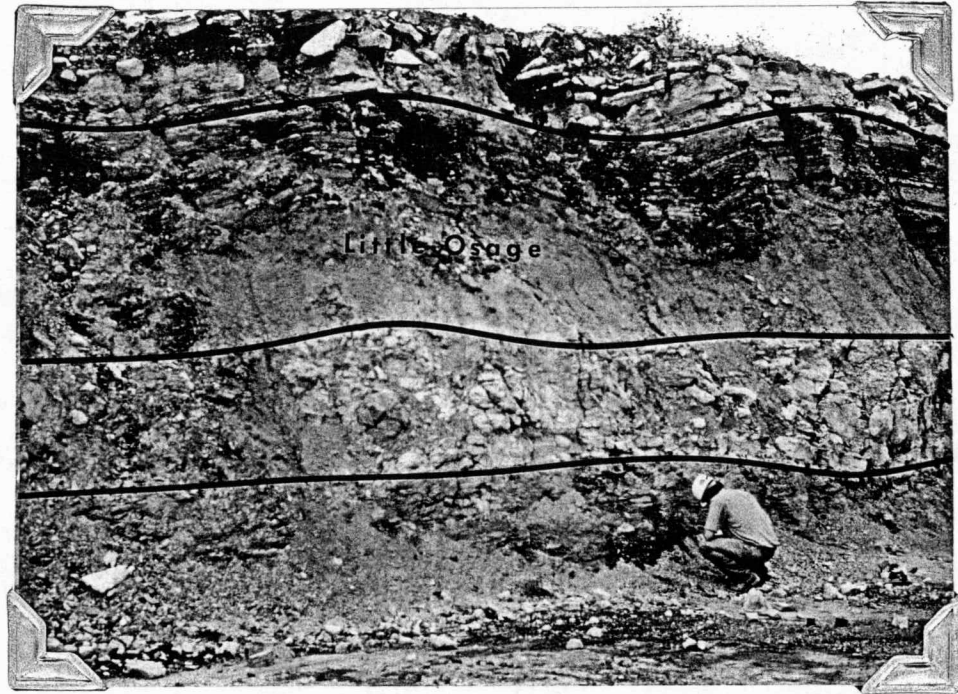
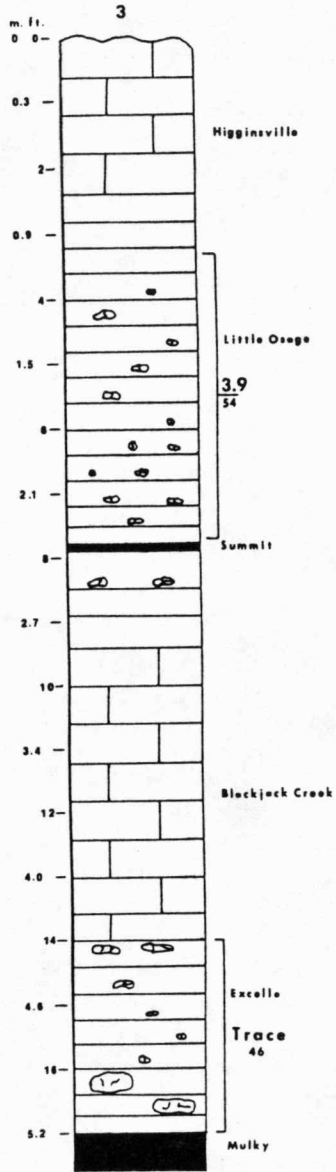


Plate IV. Sketch and photograph (5 ft. staff) of Section 6 (Appendix E) illustrating the sampled intervals and oil yields of the Little Osage Shale. Oil yields are listed and graphically represented (1 mm. = 1 gallon per ton) with sample numbers listed beneath yields.

6

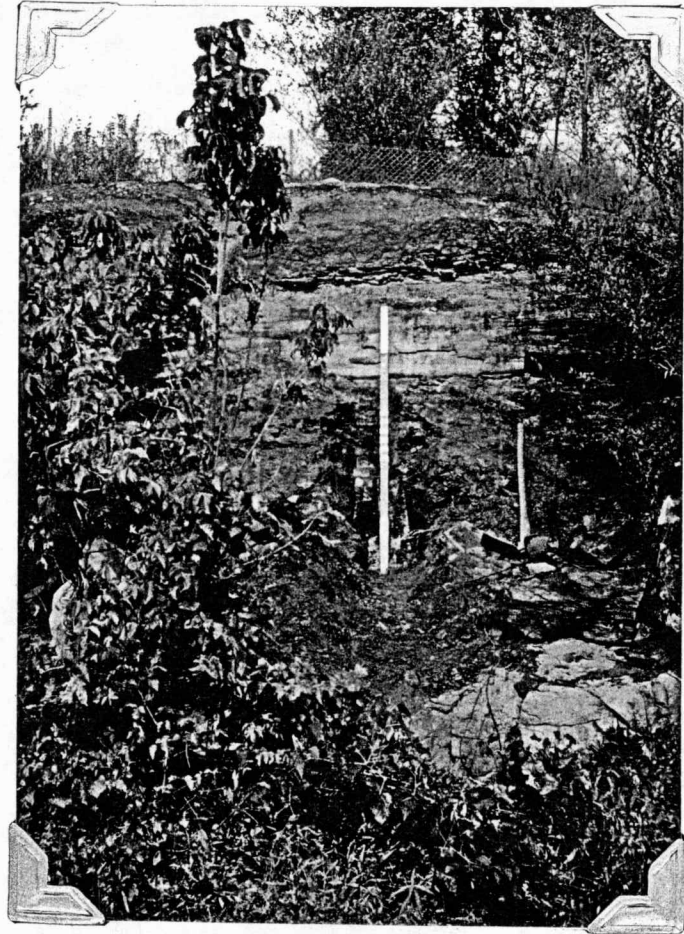
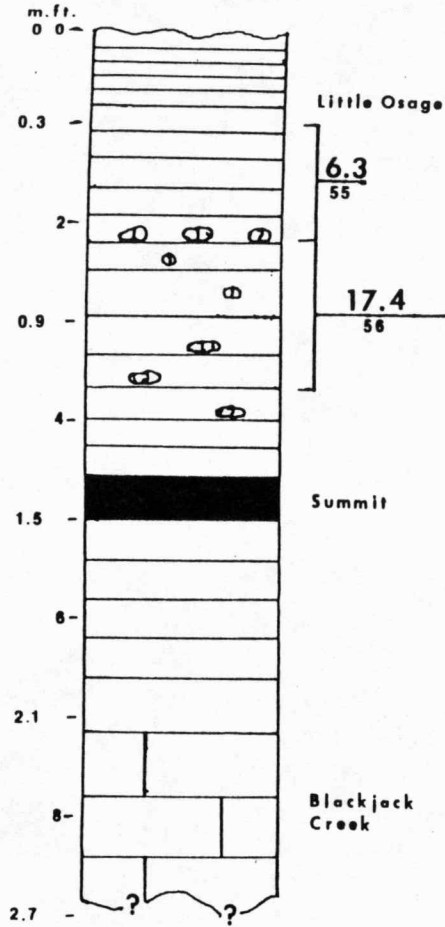


Plate V. Sketch and photograph (staff divided into 1 ft. intervals) of Section 7 (Appendix E) illustrating the sampled intervals and oil yields of the Anna Shale. Oil yields are listed and graphically represented (1 mm. = 1 gallon per ton) with sample numbers listed beneath yields.

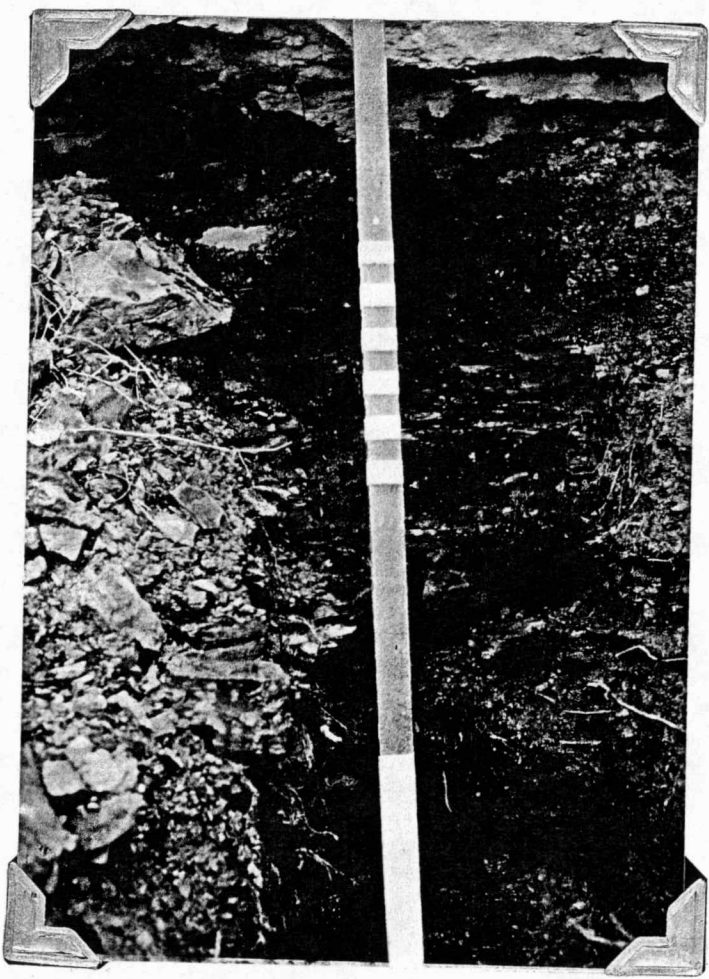
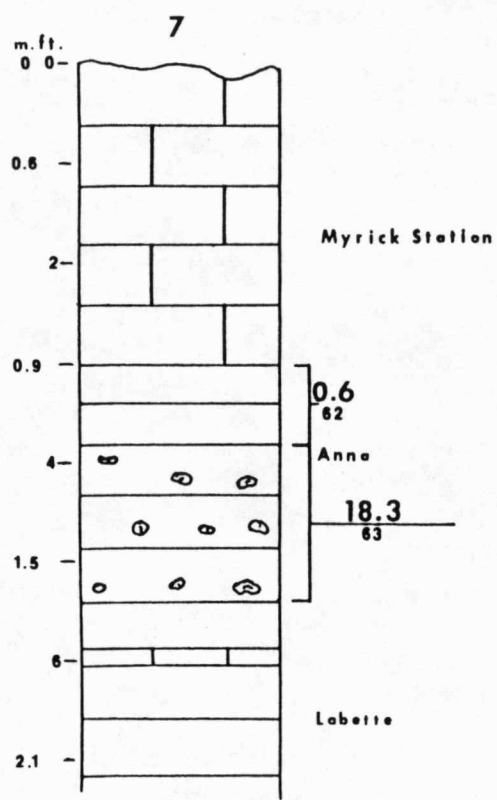


Plate VI. Sketch and photograph (man is approximately 6 ft. tall) of Section 8 (Appendix E) illustrating the sampled intervals and oil yields of the "V" Shale and the black shale above the Fleming Coal. Oil yields are listed and graphically represented (0.65 mm. = 1 gallon per ton) with sample numbers listed beneath yields.

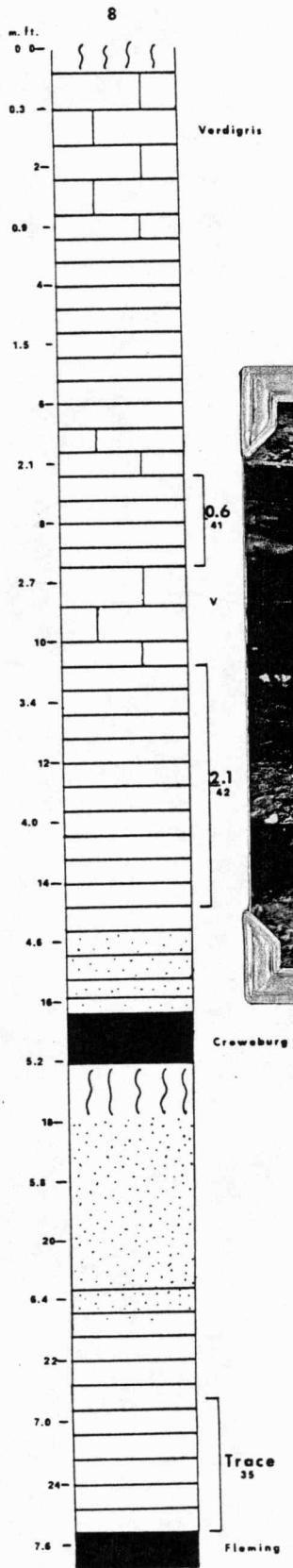


Plate VII. Sketch and photograph (5 ft. staff) of Section 11 (Appendix E) illustrating the sampled intervals and oil yields of the Tacket Formation Shale. Oil yields are listed and graphically represented (0.65 mm. = 1 gallon per ton) with sample numbers listed beneath yields.

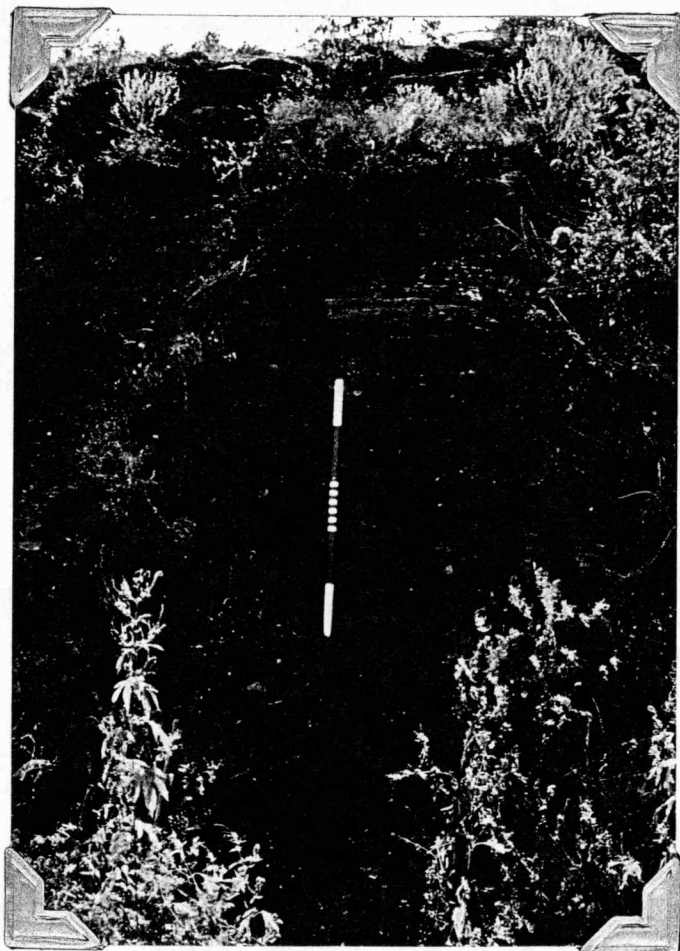
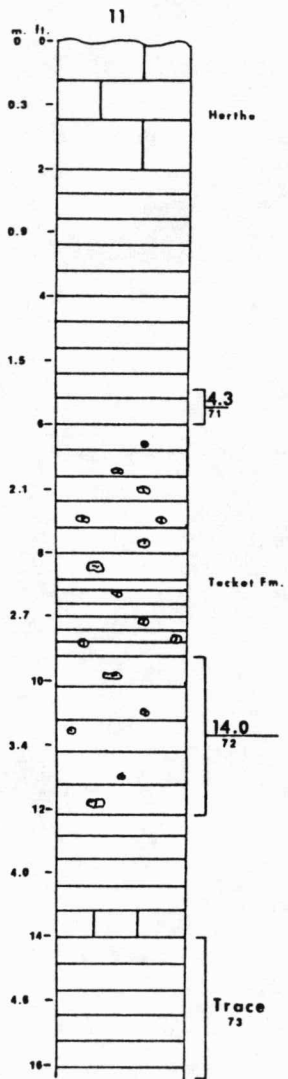


Plate VIII. Sketch and photograph (5 ft. staff) of Section 13 (Appendix E) illustrating the sampled intervals and oil yields of the Tacket Formation Shale. Oil yields are listed and graphically represented (1 mm. = 1 gallon per ton) with sample numbers listed beneath yields.

13

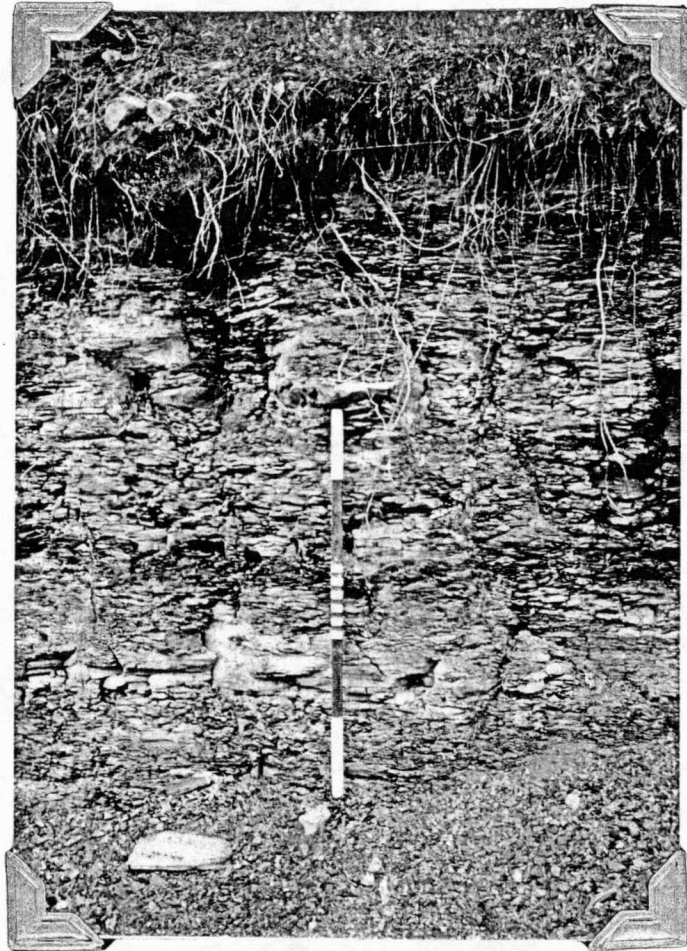
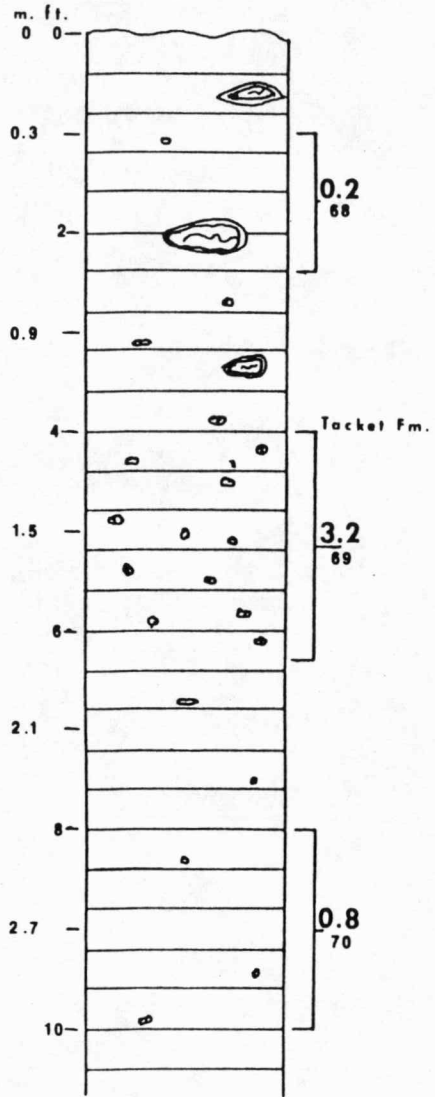
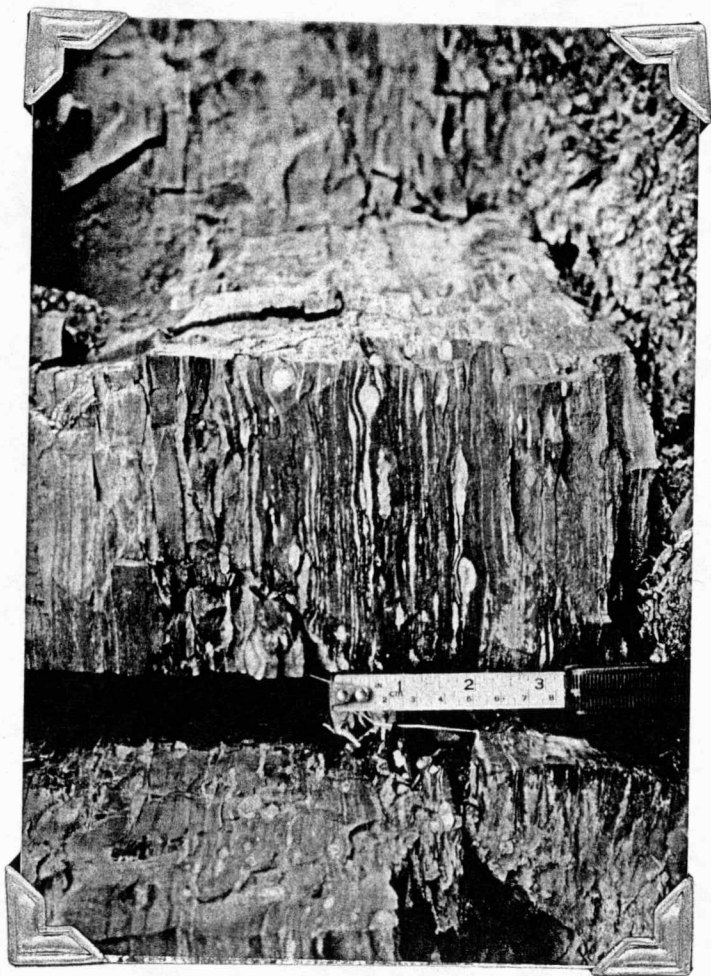


Plate IX. Phosphorite nodules and lamina present in the Little Osage Shale, Section 4 (Appendix E).



APPENDICES

Appendix A. Definitions of Organic Terms (after Haq and Boersma, 1978; Cook and Kanstler, 1980; Hutton et al., 1980)

Vitrinite: material consisting largely of woody and cellulosic debris, derived from higher plant matter or possibly brown or red algae

Inertinite (micrinite): material of various origins which has undergone extensive oxidation prior to deposition

Liptodetrinite: mechanically degraded exinite or comminuted dinoflagellates/acritarchs (less than 3-5 microns in diameter)

Dinoflagellates: unicellular, biflagellate algae, preserved as thin-walled alginite, usually cysts and processes, commonly associated with higher plant remains

Acritarchs: affinities are unknown, but thought to be unicellular phytoplankton, preserved as cysts

Tasmanites: thick-walled spherical algae

Tasmanitids: unicellular, thick-walled algae, characterized by numerous, fine, radial canals, which may pass through the cell wall

Bitumen: natural substances composed of a mixture of hydrocarbons substantially free from oxygenated bodies

Resinite: derived from resins, waxes, fats and other oily secretions similar to those found in bark, wood and leaves

Alginite A: discrete colonial algal bodies as lensoidal alginite (largely green algae)

Alginite B: finely banded lamellar alginite (green or blue-green algae)

Sporinite: outer membrane of spores and pollen grains from higher plants

Appendix B. Stratigraphic Cross-Sections of Selected Kansas Oil Shales.

The logs used for these sections were obtained from the Kansas Geological Survey log library and from the heavy oil-tar sand study (Ebanks et al., 1977).

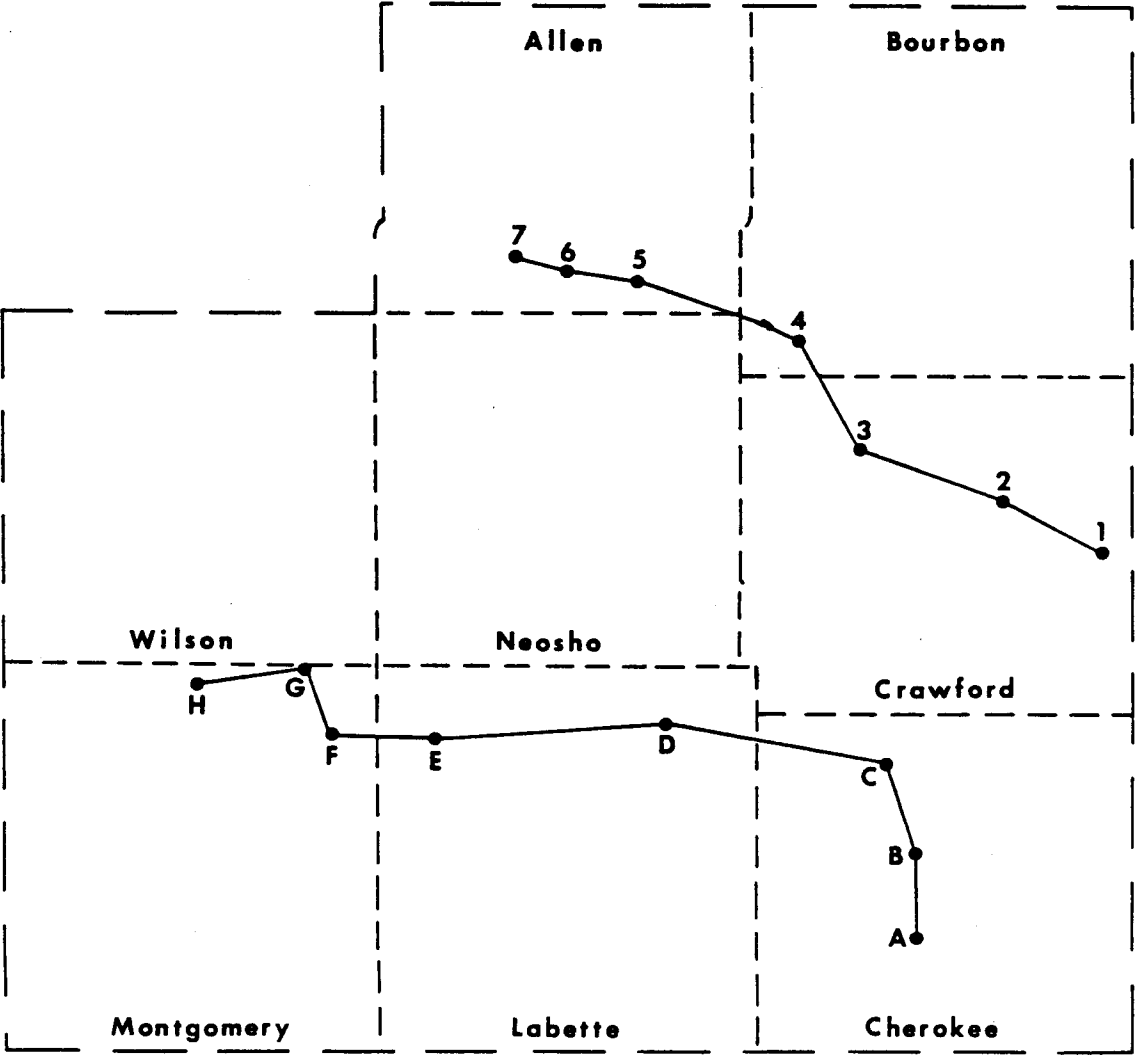
The following southeast to northwest cross-sections (Fig. 7; Plates X and XI, in back pocket) across southeastern Kansas illustrate Middle Pennsylvanian coals and Middle and Upper Pennsylvanian oil shales with limited overburden. These rocks have a gentle westward dip and crop out in southeastern Kansas allowing present day strip-mining of the coals and possible future exploitation of the oil shales.

Correlations between sections (Plates X and XI) illustrate the relative thickness and lateral extent of the Tacket Formation shale, Anna Shale, Little Osage Shale, Excello shale, and "V" shale. Correlations are based on two markers, the top of the Cherokee Group or base of the Fort Scott Limestone and the base of the Rowe coal.

Radioactivity of these black shales produces a distinctive peak on the gamma ray logs. Low density values are produced by associated coals. Both of these features provide important correlative information.

Stratigraphic relations between several coals

Figure 7. Location map of stratigraphic
cross-sections of selected Kansas oil shales.



associated with black shales are also illustrated in
these sections (Plates X and XI).

Appendix C. Generalized Descriptions of Shales not appearing in Appendix E (classification follows Potter et al. (1980) and Goddard et al. (1979); mineral percentages, where listed, from Cubitt (1979).

<u>Sample Nos.</u>	<u>Descriptions</u>
1-4	Maquoketa Shale Dolomitic claystone-clayshale, medium gray (N5), platy-slabby, hard (well indurated), composed of largely clay/silt-sized grains, mica flakes present, 4.6 to 7.3 m. in thickness
5-15	Chattanooga Shale Claystone, grayish black (N2) to medium gray (N5), slabby or greater, well indurated, composed of clay/silt-sized grains, pyrite present as nodules and lenses, mica present along partings, 3.1 to 61.0 m. thick
16-25	Kearny Formation shale Calcareous claystone-clayshale, grayish black (N2) to medium dark gray (N4), platy to slabby, hard, but brittle, composed of approximately 70 to 90% clay-size grains and 10 to 30% silt-size grains, some mica present and a few brachiopod fragments noted, thickness varies from 1.2 to 27.4 m.
26	Black shale below Riverton coal Claystone-clayshale, grayish black (N2), platy to slabby, moderately hard, composed largely of clay-size grains, 1.7 m. thick
77-80	Black shale above Weir-Pittsburg coal Claystone-clayshale, grayish black (N2), platy-slabby, moderately hard, composed mainly of clay-size grains, 3.1 m. thick
31 & 32	Black shale above Tebo (Pilot) coal Claystone-clayshale, grayish black (N2) to dark gray (N3), platy to slabby, moderately hard to hard, approximately 90 to 95% clay-size grains and 5 to 10% silt-size grains, small concretions (possible phosphorite nodules) present, limonite staining along fractures, gypsum (selenite) present along partings, 2.0 m. thick with 0.2 m. limestone present 0.3 m. above coal

Appendix C. (cont.)

<u>Sample Nos.</u>	<u>Descriptions</u>
74	Ladore Shale Mudshale, medium light gray (N6), platy-flaggy, moderately hard, composed of approximately 50-65% clay-size grains and 35-50% silt-size grains, some plant debris present 10.7 m. exposed
75-77	Hushpuckney Shale Clayshale, medium dark gray (N4), platy to flaggy, moderately hard, composed of largely clay-size grains, <u>orbiculoidea</u> brachiopods present, mica visible, 1.4 m. thick
78	Galesburg Shale Mudshale, medium gray (N5) to medium dark gray (N4), platy-flaggy, hard, composed of 50-65% clay-size and 35-50% silt-size grains, some mica present, 1.8 m. exposed
79	Stark Shale Clayshale, black (N1), papery to platy, well indurated, composed largely of clay-size grains, phosphorite nodules are present along with selenite and limonite staining, 0.9 m. thick
80	Vilas Shale Mudshale-mudstone, medium dark gray (N4), platy to slabby, moderately hard, composed of 50-65% clay-size and 35-50% silt-size grains, mica present, plant fragments scattered throughout sample, 3.1 m. exposed
86	Lawrence Formation shale Mudstone, medium gray (N5), partings not apparent (massive), hard, composed of 50-65% clay-size and 35-50% silt-size grains, thickness unknown
91	Heumader Shale Medium gray (N5), other information unknown (received sample in powdered form)
92	Larsh-Burroak Shale Clayshale, grayish black (N2), papery to platy, well indurated, composed of largely clay-size grains, limonite staining on fractures, 1.5 m. thick

Appendix C. (cont.)

<u>Sample Nos.</u>	<u>Descriptions</u>
93	Towle Shale Calcareous claystone, grayish yellow green (5GY 7/2), slabby or greater, hard, composed largely of clay-size grains, 2.7 m. thick
94	Hawxby Shale Calcareous claystone, medium gray (N5) to olive gray (5Y 4/1), slabby or greater, hard, composed of clay/silt size material, 3.1 m. thick
95-97	Hamlin Shale Calcareous clatstone-clayshale, grayish yellow green-dusky yellow green (5GY 6/2), platy-slabby, relatively hard, 90-95% clay-size and 5-10% silt-size grains, composed of 20% qtz., 32% calcite, 4% dolomite and 44% undifferentiated clay minerals, 4.6 m. thick
98 & 99	Hughes Creek Shale Bedded claymud, dark gray (N3), partings not evident, relatively soft, contains mainly of clay-size material, composed of 18% qtz., 28% calcite, 8% dolomite, 46% undifferentiated clay minerals, 9.1 m. thick
100 & 101	Roca Shale Calcareous claystone, grayish green (10GY 5/2), partings not evident, hard, composed of clay/silt-size grains, 4.5 m. thick
102 & 103	Easley Creek Shale Calcareous claystone-clayshale, grayish yellow green (5GY 7/2) to grayish olive (10Y 4/2), platy-slabby, hard, contains more than 80% clay-size material, composed of 33% qtz., 10% calcite, 6% dolomite, 51% undifferentiated clay minerals, 7.6 m. of alternating red, green and gray shales
104 & 105	Holmesville Shale Claystone, dusky yellow green (5GY 5/2), wide partings, relatively hard, mainly composed of clay-size material, 2.4 m. thick

Appendix C. (cont.)

<u>Sample Nos.</u>	<u>Descriptions</u>
106 & 107	Odell Shale Claystone-clayshale, dusky yellow green (5GY 5/2), platy-slabby, relatively hard, contains 80-95% clay-size and 5-20% silt-size material, composed of 48% qtz., 5% calcite, 15% dolomite, 32% undifferentiated clay minerals, 4.6 m. of alternating red and green shale present
108	Dakota Formation shale Bedded claymud, dark gray (N3), flaggy-slabby, soft, composed largely of clay-size material, 1.2 m. exposed
109-117	Graneros Shale Laminated claymud-bedded claymud, dark gray (N3) to brownish black (5YR 2/1), fissile to slabby, soft (nonindurated), composed of greater than 80% clay-size grains, some fish scales present, selenite and limonite are present along partings, average thickness of 9.0 m.
119 & 120	Blue Hill Shale Laminated claymud-bedded claymud, dark gray (N3), fissile to slabby, soft, contains more than 85% clay-size material, 18.3 m. exposed
121,132-136	Sharon Springs Shale Dark soft shale unit Bedded claymud, dark gray (N3) to olive black (5Y 2/1), slabby or greater, composed of essentially all clay-size grains, contains bentonite layers, 9.5 m. exposed
122,123,125, 127-131	Organic-rich shale unit Clayshale, brownish black (5YR 2/1) to olive black (5Y 2/1), papery to fissile, resistant, composed of largely clay-size material, selenite, septarian concretions, phosphorite nodules, bentonite layers and macerated fish fragments are present, 4.6 m. and 27.4 m. exposed at sampling locations

Appendix C (cont.)

<u>Sample Nos.</u>	<u>Descriptions</u>
124 & 126	Phosphatic shale unit Clayshale, olive gray-olive black (5Y 3/1), fissile to platy, moderately hard, composed mainly of clay-size material, contains several layers of dark bluish-gray weathering phosphorite nodules, bentonite layers, limonite staining on partings, fish scales, and other fish remains, 3.1 m. and 4.0 m. exposed at sampling locations
137-140	Unnamed shale member of the Pierre Shale Bedded claymud, dark gray (N3) to brownish black (5YR 2/1), slabby or greater, soft, weathers easily, contains greater than 90% clay-size material, some cephalopods are present, 30.5 m. exposed

Appendix D: Sample-Collecting Stations

Sample no.	Sample Collection Station	Lithostratigraphic Unit	Location Township/Range
1	Core, Wabaunsee Co. Depth: 3207 ft.	Maquoketa Shale	SW NE SW, s.33, T.13S.,R.10E.
2	Core, Rice Co. Depth: 3316 ft.	"	NW NW NW, s.27, T.21S.,R.9W.
3	Core, Stafford Co. Depth: 3719 ft.	"	CW 1/2 NE, s.11, T.24S.,R.11W.
4	Core, Stafford Co. Depth: 3725 ft.	"	CW 1/2 NE, s.11, T.24S.,R.11W.
5	Core, Greenwood Co. Depth: 2174.5 ft.	Chattanooga Shale	SW NE NE, s.15, T.23S.,R.12E.
6	Core, Greenwood Co. Depth: 2161 ft.	"	SW NE NE, s.15, T.23S.,R.12E.
7	Core, Greenwood Co. Depth: 2320 ft.	"	NE SW NE, s.20, T.23S.,R.12E.
8	Core, Greenwood Co. Depth: 2315 ft.	"	NE SW NE, s.20, T.23S.,R.12E.
9	Core, McPherson Co. Depth: 3315 ft.	"	NW SW, s.16, T.21S.,R.1W.
10	Core, McPherson Co. Depth: 3308 ft.	"	NW SW, s.16, T.21S.,R.1W.
11	Core, Harvey Co. Depth: 3485 ft.	"	NE NW SW, s.17, T.22S.,R.3W.
12	Core, Harvey Co. Depth: 3438 ft.	"	NE NW SW, s.17, T.22S.,R.3W.
13	Core, Reno Co. Depth: 3775 ft.	"	SE C SW, s.27, T.24S.,R.5W.
14	Core, Reno Co. Depth: 3770 ft.	"	SE C SW, s.27, T.24S.,R.5W.
15	Core, Wabaunsee Co. Depth: 2978 ft.	"	SW NE SW, s.33, T.13S.,R.10E.
16	Core, Morton Co. Depth: 5065 ft.	Kearny Fm. shale	NW NE, s.9, T.33S.,R.41W.
17	Core, Morton Co. Depth: 5070 ft.	"	NW NE, s.9, T.33S.,R.41W.
18	Core, Stevens Co. Depth: 5955 ft.	"	CE SW, s.10, T.33S.,R.38W.
19	Core, Stevens Co. Depth: 5965 ft.	"	CE SW, s.10, T.33S.,R.38W.
20	Core, Stevens Co. Depth: 5975 ft.	"	CE SW, s.10, T.33S.,R.38W.
21	Core, Stevens Co. Depth: 5985 ft.	"	CE SW, s.10, T.33S.,R.38W.
22	Core, Stevens Co. Depth: 6085 ft.	"	CE SW, s.10, T.33S.,R.38W.

Appendix D: (cont.)

Sample no.	Sample Collection Station	Lithostratigraphic Unit	Location Township/Range
23	Core, Seward Co. Depth: 5825 ft.	Kearny Fm. shale	CE SE, s.16, T.34S.,R.32W.
24	Core, Seward Co. Depth: 5835 ft.	"	CE SE, s.16, T.34S.,R.32W.
25	Core, Seward Co. Depth: 5845 ft.	"	CE SE, s.16, T.34S.,R.32W.
26	Core, Crawford Co. Depth: 234 ft.	black shale below River- ton coal	SE NE NE, s.30, T.30S.,R.25E.
27	Core, Crawford Co. Depth: 24 ft.	black shale above Weir- Pittsburg coal	SE NE NE, s.30, T.30S.,R.25E.
28	Core, Crawford Co. Depth: 28 ft.	"	SE NE NE, s.30, T.30S.,R.25E.
29	Core, Crawford Co. Depth: 24 ft.	"	SE NE NE, s.30, T.30S.,R.25E.
30	Core, Crawford Co. Depth: 28 ft.	"	SE NE NE, s.30, T.30S.,R.25E.
31	Abandoned coal mine, Crawford Co.	black shale above Tebo coal	NW NW NW, s.2, T.28S.,R.25E.
32	Abandoned coal mine, Crawford Co.	"	NW NW NW, s.2, T.28S.,R.25E.
33	Clemens Mine #22 (Coal Mine), Craw- ford Co.	black shale above Miner- al coal	NE SW SE, s.4, T.28S.,R.25E.
34	Clemens Mine #22 (Coal mine), Craw- ford Co.	black shale above Flem- ing coal	NE SW SE, s.4, T.28S.,R.25E.
35	Bills Coal Comp. (Coal mine), Bourbon Co.	"	NW SE, s.23, T.26S.,R.25E.
36	Core, Cherokee Co. Depth: 44ft.	"V"shale	SE SW SE, s.8, T.32S.,R.22E.
37	Core, Cherokee Co. Depth: 28 ft.	"	SE SW SE, s.8, T.32S.,R.22E.
38	Core, Cherokee Co. Depth: 33 ft.	"	SE SW SE, s.8, T.32S.,R.22E.
39	Core, Cherokee Co. Depth: 38 ft.	"	SE SW SE, s.8, T.32S.,R.22E.
40	Core, Cherokee Co. Depth: 43 ft.	"	SE SW SE, s.8, T.32S.,R.22E.
41	Bills Coal Comp. (Coal mine), Bourbon Co.	"	NW SE, s.23, T.26S.,R.25E.
42	Bills Coal Comp. (Coal mine), Bourbon Co.	"	NW SE, s.23, T.26S.,R.25E.

Appendix D: (cont.)

Sample no.	Sample Collection Station	Lithostratigraphic Unit	Location Township/Range
43	Clemens Mine #22 (Coal mine), Crawford Co.	"V"shale	NW SW SE, s.4, T.28S.,R.25E.
44	Clemens Mine #22 (Coal mine), Crawford Co.	"	NW SW SE, s.4, T.28S.,R.25E.
45	Clemens Mine #22 (Coal mine), Crawford Co.	"	NW SW SE, s.4, T.28S.,R.25E.
46	Fulton Mine (Coal mine), Bourbon Co.	Excello shale	NE SE, s.2, T.24S.,R.25E.
47	Bradbury Bros. Mine (Bills Coal Comp.; Coal Mine), Bourbon Co.	"	SW NE NW, s.28, T.26S.,R.25E.
48	Bradbury Bros. Mine (Bills Coal Comp.; Coal mine), Bourbon Co.	"	SW NE NW, s.28, T.26S.,R.25E.
49	Bradbury Bros. Mine (Bills Coal Comp.; Coal mine), Bourbon Co.	Little Osage Shale	SW NE NW, s.28, T.26S.,R.25E.
50	Rock quarry near Fort Scott, Bourbon Co.	"	SW NW NE, s.19, T.25S.,R.25E.
51	Rock quarry near Fort Scott, Bourbon Co.	"	SW NW NE, s.19, T.25S.,R.25E.
52	Rock quarry near Fort Scott, Bourbon Co.	"	SW NW NE, s.19, T.25S.,R.25E.
53	Rock quarry near Fort Scott, Bourbon Co.	"	SW NW NE, s.19, T.25S.,R.25E.
54	Fulton Mine (Coal mine), Bourbon Co.	"	NE SE, s.2, T.24S.,R.25E.
55	Stream cut W side of Highway 69, Fort Scott, Bourbon Co.	"	SW SW NE, s.31, T.25S.,R.25E.
56	Stream cut W side of Highway 69, Fort Scott, Bourbon Co.	"	SW SW NE, s.31, T.25S.,R.25E.
57	Road cut S side of Highway 54, Bourbon Co.	"	CE NW SE, s.27, T.25S.,R.25E.
58	Road cut N side of Highway 160, Crawford Co.	"	SE SE SW, s.16, T.31S.,R.23E.
59	Road cut N side of Highway 160, Crawford Co.	"	SE SE SW, s.16, T.31S.,R.23E.
60	Core, Thomas Co. Depth: 4473 ft.	black shale within Fort Scott Ls.	NE SE NW, s.16, T.7S.,R.32W.

Appendix D: (cont.)

Sample no.	Sample Collection Station	Lithostratigraphic Unit	Location Township/Range
61	Core, Thomas Co. Depth: 4479 ft.	black shale within Fort Scott Ls.	NE SE NW, s.16, T.7S.,R.32W.
62	Jubilee Quarry, Bourbon Co.	Anna Shale	NE SE SW, s.16, T.26S.,R.24E.
63	Jubilee Quarry, Bourbon Co.	"	NE SE SW, s.16, T.26S.,R.24E.
64	Creek bank, Crawford Co.	"	NW NW NE, s.23, T.30S.,R.21E.
65	Creek bank	"	NW NW NE, s.23, T.30S.,R.21E.
66	Crawford Co. Ditch cut N side of Highway 59, Labette Co.	"	SE SW SW, s.3, T.33S.,R.20E.
67	Road cut S side of Highway 57, Neosho Co.	Tacket Fm. shale	NE NE NE, s.20, T.29S.,R.20E.
68	Road cut S side of Highway 57, Neosho Co.	"	NE NE NE, s.20, T.29S.,R.20E.
69	Road cut S side of Highway 57, Neosho Co.	"	NE NE NE, s.20, T.29S.,R.20E.
70	Road cut S side of Highway 57, Neosho Co.	"	NE NE NE, s.20, T.29S.,R.20E.
71	Road cut, Country Club entrance, High- way 160, Labette Co.	"	NW NE NE, s.21, T.31S.,R.19E.
72	Road cut, Country Club entrance, High- way 160, Labette Co.	"	NW NE NE, s.21, T.31S.,R.19E.
73	Road cut, Country Club entrance, High- way 160, Labette Co.	"	NW NE NE, s.21, T.31S.,R.19E.
74	Road cut W side of Highway 69, Linn Co.	Ladore Shale	C 1/2, s.31, T.19S.,R.25E.
75	Road cut W side of Highway 69, Linn Co.	Hushpuckney Shale	C 1/2, s.31, T.19S.,R.25E.
76	Road cut SE side of Highway 52, Linn Co.	"	SW NE NE, s.23, T.22S.,R.23E.
77	Road cut SE side of Highway 52, Linn Co.	"	SW NE NE, s.23, T.22S.,R.23E.

Appendix D: (cont.)

Sample no.	Sample Collection Station	Lithostratigraphic Unit	Location Township/Range
78	Road cut N side of Highway 59, Neosho Co.	Galesburg Shale	NE NE, s.24, T.27S.,R.20E.
79	Road cut N side of Highway 59, Neosho Co.	Stark Shale	NE NE, s.24, T.27S.,R.20E.
80	Road cut S side of Highway 10, Johnson Co.	Vilas Shale	SE SE, s.36, T.12S.,R.21E.
81	Road cut S side of Highway 10, Johnson Co.	Eudora Shale	SE SE, s.36, T.12S.,R.21E.
82	Road cut S side of Highway 10, Johnson Co.	"	SE SE, s.36, T.12S.,R.21E.
83	Road cut N side of Highway 10, Douglas Co.	"	SE SE SW, s.3, T.13S.,R.21E.
84	Road cut S side of Highway 10, Johnson Co.	"	SW NW SE, s.5, T.13S.,R.23E.
85	Buildex Quarry, Ottawa, Franklin Co.	"	" , s. T.16S.,R.19E.
86	Core, Douglas Co.	Lawrence Fm. shale	NE, s.2, T.13S.,R.19E.
87	Road cut E side of Clinton Lake, Douglas Co.	Heebner Shale	SE NE NW, s.20, T.13S.,R.19E.
88	Road cut E side of Clinton Lake, Douglas Co.	"	SE NE NW, s.20, T.13S.,R.19E.
89	Road cut E side of Clinton Lake, Douglas Co.	"	SE NE NW, s.20, T.13S.,R.19E.
90	Road cut, 7th St., Lawrence, Douglas Co.	"	NW NW NW, s.36, T.12S.,R.19E.
91	Page Airways Underground Storage, Atchison Co.	Heumader Shale	" , s.7, T.6S.,R.21E.
92	Road cut N side of Highway 70, Douglas Co.	Larsh-Burrook Shale	NE NW, s.22, T.12S.,R.18E.
93	Road ditch S of Humboldt, NE, along N-105	Towle Shale	W NW, s.27, T.2N.,R.13E
94	Road cut N side of Highway 70, Wabaunsee Co.	Hawxby Shale	SW SW SW, s.27, T.11S.,R.12E.

Appendix D: (cont.)

Sample no.	Sample Collection Station	Lithostratigraphic Unit	Location Township/Range
95	Road cut N side of Highway 70, Wabaunsee Co.	Hamlin Shale	SW SW SW, s.26, T.11S.,R.11E.
96	Road cut N side of Highway 70, Wabaunsee co.	"	SW SW SW, s.26, T.11S.,R.11E.
97	Road ditch S of Humboldt, NE, along N-105	"	W NW, s.27, T.2N.,R.13E.
98	Road ditch S of Humboldt, NE, along N-105	Hughes Creek Shale	W NW, s.27, T.2N.,R.13E.
99	Road cut N side of Highway 70, Wabaunsee Co.	"	SE SW SE, s.27, T.11S.,R.11E.
100	Road cut S side of Highway 70, Wabaunsee Co.	Roca Shale	NW NE SE, s.27, T.11S.,R.10E.
101	Road cut S side of Highway 70, Wabaunsee Co.	"	NW NE SE, s.27, T.11S.,R.10E.
102	Road cut N side of Highway 70, Wabaunsee Co.	Easley Creek Shale	SE SE NE, s.30, T.11S.,R.10E.
103	Road cut N side of Highway 70, Wabaunsee Co.	"	SW NE, s.30, T.11S.,R.10E.
104	Road cut W side of Highway 77, Geary Co.	Holmesville Shale	C NW NW, s.27, T.11S.,R.5E.
105	Road cut W side of Highway 77, Geary Co.	"	C SW NW, s.27, T.11S.,R.5E.
106	1 mi. N of Chapman, Dickinson Co.	Odell Shale	SE SW, s.17, T.12S.,R.4E.
107	1 mi. N of Chapman, Dickinson Co.	"	SE SW, s.17, T.12S.,R.4E.
108	Gullied slope S side of E-W county road, Hodgeman Co.	Dakota Fm. shale	NE NW, s.25, T.22S.,R.22W.
109	Gullied slope S side of E-W county road, Hodgeman Co.	Graneros Shale	NE NW, s.25, T.22S.,R.22W.
110	Gullied slope S side of E-W county road, Hodgeman Co.	"	NE NW, s.25, T.22S.,R.22W.
111	Road cut E side of Highway 14, Lincoln Co.	"	SW SW, s.30, T.11S.,R.7W.
112	Road cut E side of Highway 14, Lincoln Co.	"	SW SW, s.30, T.11S.,R.7W.

Appendix D: (cont.)

Sample no.	Sample Collection Station	Lithostratigraphic Unit	Location Township/Range
113	Road cut E side of Highway 14, Lincoln Co.	Graneros Shale	SW SW, s.30, T.11S.,R.7W.
114	Ditch cut W side of N-S county road, Ellsworth Co.	"	E NW, s.6, T.15S.,R.10W.
115	Ditch cut W side of N-S county road, Ellsworth Co.	"	E NW, s.6, T.15S.,R.10W.
116	Road cut E side of Highway 281, Russell Co.	"	NW, s.35, T.12S.,R.14W.
117	Road cut E side of Highway 281, Russell Co.	"	NW, s.35, T.12S.,R.14W.
118	Road cut N side of Highway 36, Washington Co.	"	NW, s.12, T.3S.,R.1E.
119	Road cut N side of Highway 36, Jewell Co.	Blue Hill Shale	SE SE SE, s.16, T.3S.,R.7W.
120	Road cut S side of Highway 36, Jewell Co.	"	NE NW NW, s.22, T.3S.,R.7W.
121	Creek bank, Logan Co.	Sharon Springs Shale	SW SE, s.33, T.12S.,R.36W.
122	Gully, Devils Half-acre, Wallace Co.	"	SW SE NW, s.36, T.13S.,R.40W.
123	Gully, Devils Half-acre, Wallace Co.	"	SW SE NW, s.36, T.13S.,R.40W.
124	Gully, Devils Half-acre, Wallace Co.	"	SW SE NW, s.36, T.13S.,R.40W.
125	Gully, Devils Half-acre, Wallace Co.	"	SW SE NW, s.36, T.13S.,R.40W.
126	Gully, Devils Half-acre, Wallace Co.	"	SW SE NW, s.36, T.13S.,R.40W.
127	Exposure on N face of butte, McAllaster Buttes, Logan Co.	"	SE, s.13, T.12S.,R.37W.
128	Exposure on N face of butte, McAllaster Buttes, Logan Co.	"	SE, s.13, T.12S.,R.37W.
129	Exposure on N face of butte, McAllaster Buttes, Logan Co.	"	SE, s.13, T.12S.,R.37W.
130	Exposure on N face of butte, McAllaster Buttes, Logan Co.	"	SE, s.13, T.12S.,R.37W.
131	Exposure on N face of butte, McAllaster Buttes, Logan Co.	"	SE, s.13, T.12S.,R.37W.

Appendix D: (cont.)

<u>Sample no.</u>	<u>Sample Collection Station</u>	<u>Lithostratigraphic Unit</u>	<u>Location Township/Range</u>
132	S bank of N fork of Smoky Hill R., Logan Co.	"	SE, s.20, T.12S.,R.36W.
133	S bank of N fork of Smoky Hill R., Logan Co.	"	SE, s.20, T.12S.,R.36W.
134	S bank of N fork of Smoky Hill R., Logan Co.	"	SE, s.20, T.12S.,R.36W.
135	E bank of Prairie Dog Creek, Phillips Co.	"	E SE, s.24, T.1S.,R.20W.
136	E bank of Prairie Dog Creek, Phillips Co.	"	E SE, s.24, T.1S.,R.20W.
137	N slope of gully, Cheyenne Co.	Pierre Shale	SE NW, s.22, T.1S.,R.42W.
138	N slope of gully, Cheyenne Co.	"	SE NW, s.22, T.1S.,R.42W.
139	E slope of gully, Cheyenne Co.	"	NW, s.1, T.2S.,R.40W.
140	E slope of gully, Cheyenne Co.	"	NW, s.1, T.2S.,R.40W.

Appendix E: Geographic locations and descriptions of measured stratigraphic sections of selected Kansas oil shales.
 (* indicates sampled interval with number)

Section 1 -- SE SE sec.36, T.12 S., R.21 E., Johnson Co.,
 roadcut along Kansas Highway 10

Thickness (ft and m)

Lansing Group

Stanton Limestone (23.8 ft, 7.24 m exposed)

Stoner Limestone Member

Limestone, "packstone", gray, fossiliferous 12 ft, 3.66 m

Eudora Shale Member 5.8 ft, 1.75 m

82 *Bedded clay mud, medium gray (N5), slabby
 (or >), fissle on weathered surface 3.3 ft, 1.0 m

81 *Claystone-clayshale, grayish black (N2),
 flaggy-slabby, contains phosphorite
 nodules 1.0 ft, 0.3 m

Clayshale, grayish black (N2), platy-
 flaggy, calcareous, phosphorite nodules
 not as abundant as in overlying unit 1.0 ft, 0.3 m

Bedded claymud, medium gray (N5), soft 0.5 ft, 0.15 m

Captain Creek Limestone Member

Limestone, "wackestone", gray, fossil-
 iferous 6.0 ft, 1.83 m
 exposed

Section 2 -- SE NE NW sec.20, T.13 S., R.19 E., Douglas Co.,
 roadcut near Clinton Lake

Thickness (ft and m)

Shawnee Group

Oread Limestone (13.5 ft, 4.12 m exposed)

Plattsmouth Limestone Member

Limestone, gray, fossiliferous, wavy-
 bedded, contains chert nodules 6.5 ft, 1.98 m

Heebner Shale Member (6.8 ft, 2.07 m) 6.8 ft, 2.08 m

Bedded claymud, brownish gray (5YR4/1),
 soft 3.2 ft, 0.98 m

Clayshale, grayish black (N2), platy,
 contains phosphorite nodules 1.6 ft, 0.49 m

87,*Clayshale, grayish black (N2), platy,

88, less resistant than overlying unit,

89 fewer phosphorite nodules 2.0 ft, 0.61 m

Leavenworth Limestone Member

Limestone, gray, fossiliferous 0.2 ft, 0.06 m

Section 3 -- NE SE sec.2, T.24 S., R.25 E., Bourbon Co.
 Fulton Mine, Bill's Coal Company

	<u>Thickness (ft and m)</u>
Marmaton Group	
Fort Scott Limestone (13.0 ft, 3.96 m)	
Higginsville Limestone Member	
Limestone, medium light gray, wavy-bedded, fossiliferous.	2.2 ft, 0.67 m
Little Osage Shale Member	6.2 ft, 1.98 m
Bedded claymud, light gray (N7), weathers yellow-orange.	0.3 ft, 0.09 m
54 *Claystone-clayshale, black (N1), flaggy-slabby, calcareous in most areas, thin (mm size) carbonate layers present, contains phosphorite nodules.	3.2 ft, 0.98 m
Coal (Summit)	0.2 ft, 0.06 m
Bedded claymud, light gray (N7), calcareous, contains plant fragments and some phosphorite lenses in upper part of unit.	2.5 ft, 0.76 m
Blackjack Creek Limestone Member	
Limestone, bluish gray, sparsely fossiliferous.	4.6 ft, 1.40 m
Cherokee Group	
Cabaniss Formation (4.2 ft, 1.28 m exposed)	
Excello shale	
46 *Claystone, dark gray (N3), flaggy-slabby, contains phosphorite nodules and calcareous concretions dispersed throughout and brachiopods are present.	2.6 ft, 0.79 m
Coal (Mulky)	1.6 ft, 0.49 m

Section 4 -- SW NW NE sec.19, T.25 S., R.25 E., Bourbon Co.
 rock quarry near Fort Scott, KS

	<u>Thickness (ft and m)</u>
Marmaton Group	
Fort Scott Limestone (25.1 ft, 7.63 m exposed)	
Higginsville Limestone Member (13.5 ft, 4.11 m)	
Limestone, (packstone), light gray, massive, fossiliferous, large crinoid fragments, fusulinids, bryozoans, bivalves, brachiopods noticed.	13.0 ft, 3.96 m
Limestone, yellow-gray, iron stained.	0.5 ft, 0.15 m
Little Osage Shale Member (7.6 ft, 2.30 m)	
Clayshale, dark gray (N3), fissle, calcareous, highly eroded.	0.3 ft, 0.09 m
Limestone, (wackestone), (Houx), grayish-brown, some fossils present.	0.4 ft, 0.13 m
Clayshale, dark gray (N3) fissle-platy,	

Section 4 (cont.)

calcareous.	0.2 ft	0.06 m
Clayshale, dark gray (N3), platy, softer than overlying unit.	0.6 ft,	0.18 m
Clayshale, grayish black (N2), fissle, weathered.	0.5 ft,	0.15 m
51,*Clayshale-claystone, black (N1), platy-		
52, slabby, calcareous, contains small (up		
53 to 4.5 cm diameter) phosphorite nodules,		
phosphate lamina, and thin (mm size)		
carbonate layers.	2.0 ft,	0.61 m
Claymud, medium gray (N5), massive.	0.6 ft,	0.18 m
Coal (Summit)		
Yellow sulfur residue on surface.	0.5 ft,	0.14 m
Bedded claymud, medium light gray (N6), massive calcareous, soft.	2.5 ft,	0.76 m
Blackjack Creek Limestone Member		
Limestone, bluish-gray, coarsely crystalline.	4.0 ft,	1.22 m
	exposed	

Section 5 -- CE NW SE sec.27, T.25 S., R.25 E., Bourbon Co.
roadcut near Fort Scott, KS

	<u>Thickness (ft and m)</u>	
Marmaton Group		
Fort Scott Limestone (8.9 ft, 2.71 m exposed)		
Higginsville Limestone Member		
Limestone, gray, fossiliferous.	2+ ft,	0.61+ m
Little Osage Shale Member (6.8 ft, 2.07 m)	exposed	
Soil covered and overgrown.	2.3 ft,	0.70 m
57 *Claystone, black (N1), flaggy-slabby, contains phosphorite nodules, orbic- uloid brachiopods present.	2.7 ft,	0.82 m
Coal (Summit)	1.3 ft,	0.40 m
Bedded claymud, medium gray (N5), soft.	0.6 ft,	0.18 m
	exposed	

Section 6 -- SW SW NE sec.31. T.25 S., R.25 E., Bourbon Co.
ditch-drainage cut in Fort Scott, KS

	<u>Thickness (ft and m)</u>	
Marmaton Group		
Fort Scott Limestone (9.0 ft, 2.76 m exposed)		
Little Osage Shale Member (7.0 ft, 2.15 m present)		
Limestone, gray, thin.	0.1 ft,	0.03 m
Clayshale, grayish black (N2), fissle, calcareous.	0.3 ft,	0.09 m
Clayshale, medium light gray (N6), papery, calcareous.	0.5 ft,	0.17 m

Section 6 (cont.)

55 *Clayshale, grayish black (N2), platy.	1.1 ft, 0.34 m
56 *Claystone, grayish black (N2), flaggy-slabby, calcareous, thin carbonate layers present, contains phosphorite nodules.	1.7 ft, 0.52 m
Clayshale, medium gray (N5), papery, weathered.	0.7 ft, 0.21 m
Coal (Summit) Sulfur residue on surface.	0.5 ft, 0.15 m
Bedded claymud, light gray (N7), slabby (or >), calcareous.	2.1 ft, 0.64 m
Blackjack Creek Limestone Member Limestone, bluish gray, coarsely crystalline.	2.0 ft, 0.61 m exposed

Section 7 -- NE SE SW sec.16, T.26 S., R.24 E., Bourbon Co.
Jubilee Quarry

	<u>Thickness (ft and m)</u>
Marmaton Group	
Pawnee Limestone (6.0 ft, 1.82 m exposed)	
Myrick Station Limestone	
Limestone, medium gray, fossiliferous.	3.0 ft, 0.91 m
Anna Shale Member (3.0 ft, 0.91 m)	
62 *Clayshale, medium dark gray (N4), fissle.	0.9 ft, 0.27 m
63 *Claystone, black (N1), flaggy-slabby, contains phosphorite nodules and lamina.	1.3 ft, 0.40 m
Bedded claymud-claystone, medium gray (N5), flaggy-slabby, soft.	0.7 ft, 0.21 m
Limestone, gray, silty.	0.1 ft, 0.03 m
Labette Shale	
Mudstone, medium gray (N5), contains fossils (gastropods).	1.0 ft, 0.30 m exposed

Section 8 -- NW SE sec.23, T.26 S., R.25 E., Bourbon Co.
coal mine, Bill's Coal Company

	<u>Thickness (ft and m)</u>
Cherokee Group	
Cabaniss Formation (26.2 ft, 7.98 m exposed)	
Verdigris Limestone Member	
Limestone, medium dark gray, massive, fossiliferous (foraminifera).	3± ft, 0.91 m
"V"shale (12.5 ft, 3.82 m)	
Claystone, grayish black (N2), flaggy-slabby, calcareous, contains a few	

Section 8 (cont.)

	scattered calcareous concretions and some fossils (crinoids, brachiopods).	3.0 ft, 0.91 m
	Limestone, medium dark gray (n4), finely crystalline.	0.7 ft, 0.21 m
41	*Claystone, grayish black (N2), flaggy-slabby, calcareous.	1.5 ft, 0.46 m
	Limestone, medium light gray (N4), finely crystalline.	1.5 ft, 0.46 m
42	*Claystone, grayish black (N2), slabby (or >), calcareous.	4.0 ft, 1.23 m
	Clayshale, dark gray (N3), platy, calcareous.	0.3 ft, 0.09 m
	Mudshale, medium gray (N5), platy.	1.5 ft, 0.46 m
	Coal (Croweburg)	1.0 ft, 0.30 m
	Underclay	0.9 ft, 0.27 m
	Bedded siltstone, tan.	3.0 ft, 0.91 m
35	*Clayshale-laminated claymud, black (N1), platy-flaggy, contains probable phosphorite nodules.	4.5 ft, 1.37 m
	Coal (Flemming)	1.3 ft, 0.40 m
		exposed

Section 9 -- SE NE NW sec.28, T.26 S., R.25 E., Bourbon Co.
Bradbury Brothers Mine, Bill's Coal Company

Thickness (ft and m)

Marmaton Group

	Fort Scott Limestone (16.4 ft, 4.99 m)	
	Higginsville Limestone Member	
	Limestone, gray, thin-bedded.	2± ft, 0.61 m
	Little Osage Shale Member (7.4 ft, 2.25 m)	
	Clayshale, brownish gray (5YR4/1), platy.	0.9 ft, 0.27 m
49	*Claystone-clayshale, brownish black (5YR2/1), ranges from platy to slabby, contains phosphorite nodules and lamina.	4.3 ft, 1.31 m
	Coal (Summit)	0.2 ft, 0.06 m
	Bedded claymud, medium light gray (N6), calcareous.	2.0 ft, 0.61 m
	Blackjack Creek Limestone Member	
	Limestone, gray, coarsely crystalline, contains some fossils.	7.0 ft, 2.13 m

Cherokee Group

	Cabaniss Formation (5.7 ft, 1.74 m exposed)	
	Excello shale (4.6 ft, 1.40 m)	
	Clayshale, brownish gray (5YR4/1), platy-flaggy.	0.3 ft, 0.09 m
48	*Claystone-clayshale, black (N1), flaggy-slabby, contains brachiopods, a few phosphorite nodules, and a few large	

Section 9 (cont.)

	calcareous concretions.	2.3 ft, 0.70 m
47	*Claystone, black (N1), flaggy-slabby, contains phosphorite nodules and lamina, larger calcareous concretions.	2.0 ft, 0.61 m
	Coal (Mulky)	1.1 ft, 0.34 m exposed

Section 10 -- SW SE sec. 4, T.28 S., R.25 E., Crawford Co.
Clemens Mine #22 (coalpit)

		<u>Thickness (ft and m)</u>
Cherokee Group		
Cabaniss Formation (34.2 ft, 10.41 m exposed)		
Verdigris Limestone Member		
	Limestone, medium dark gray, fossiliferous (foraminifera).	2± ft, 0.61 m
	"V"shale (14.7 ft, 4.49 m)	
43	*Clayshale, grayish black (N2), platy-flaggy, calcareous, contains brachiopods (orbiculoidea).	3.2 ft, 0.98 m
	Limestone, medium gray (N4), finely crystalline.	0.6 ft, 0.18 m
44	*Claystone-clayshale, black (N1), flaggy-slabby, calcareous, contains phosphorite nodules.	2.3 ft, 0.70 m
	Limestone, dark gray (N3), finely crystalline.	1.3 ft, 0.40 m
45	*Claystone, grayish black (N2), flaggy-slabby, slightly calcareous, contains phosphorite nodules and a few larger calcareous concretions.	3.3 ft, 1.01 m
	Bedded claymud, medium light gray (N6), soft.	4.0 ft, 1.22 m
	Coal (Croweburg)	1.2 ft, 0.37 m
	Underclay	1.0 ft, 0.30 m
	Bedded claymud, medium light gray (N6), soft.	2.6 ft, 0.79 m
	Limestone, medium gray (N5), finely crystalline.	0.5 ft, 0.15 m
	Bedded claymud, medium gray (N5), iron stained.	1.4 ft, 0.43 m
34	*Laminated claymud-clayshale, grayish black (N2), platy-flaggy, soft.	2.0 ft, 0.61 m
	Coal (Fleming)	0.4 ft, 0.12 m
	Underclay	0.9 ft, 0.27 m
	Bedded siltstone, medium gray (N5).	1.6 ft, 0.49 m
	Mudshale, medium gray (N5), platy-flaggy.	0.4 ft, 0.12 m
33	*Laminated claymud-clayshale, grayish black (N2), platy-flaggy.	4.0 ft, 1.2 m
	Coal (Mineral)	1.5 ft, 0.46 m exposed

Section 11 -- NE NE NE sec.20, T.29 S., R.20 E., Neosho Co.
roadcut near Erie, KS

		<u>Thickness (ft and m)</u>
Kansas City Group		
Hertha Limestone (2 ft, 0.61 m present)		
Critzler Limestone Member		
	Limestone, brownish gray, fossiliferous.	2.0 ft, 0.61 m
Pleasanton Group		
Tacket Formation (14.4 ft, 4.39 m exposed)		
	Clayshale, medium dark gray (N4), platy-flaggy, calcareous.	3.5 ft, 1.07 m
71 *	Clayshale, dark gray (N3), platy, calcareous and noncalcareous zones.	0.8 ft, 0.24 m
	Clayshale, dark gray (N3), platy-flaggy grading down into a 1.8 ft fissle zone, upper 0.7 ft of unit is highly calcareous unit, contains phosphorite nodules.	3.4 ft, 1.04 m
67,*	Claystone-clayshale, grayish black (N2),	
72	flaggy-slabby, contains phosphorite nodules.	2.5 ft, 0.76 m
	Clayshale, medium gray (N5), fissle, calcareous, highly weathered.	1.7 ft, 0.52 m
	Limestone (mudstone), dark gray (N3), finely crystalline.	0.3 ft, 0.09 m
73 *	Claystone-clayshale, dark gray (N3), flaggy-slabby, calcareous.	2.2 ft, 0.67 m

Section 12 -- NW NW NE sec.23, T.30 S., R.21 E., Crawford Co.
creek bank

		<u>Thickness (ft and m)</u>
Marmaton Group		
Pawnee Limestone (7.5 ft, 2.3 m exposed)		
Myrick Station Limestone Member		
	Limestone, medium gray, fossiliferous.	3.0 ft, 0.91 m
Anna Shale Member (4.5 ft, 1.37 m exposed)		
	Clayshale, grayish black (N2), fissle.	1.1 ft, 0.34 m
64 *	Claystone, black (N1), flaggy-slabby, contains phosphorite nodules (up to 2.5 cm diameter) and lamina.	1.3 ft, 0.40 m
	Bedded claymud-claystone, medium gray (N5), slabby, calcareous, soft.	1.3 ft, 0.40 m
65 *	Bedded claymud, dark gray (N3), flaggy-slabby, calcareous, contains fossil debris (Brachiopod fragments).	0.8 ft, 0.25 m

Section 13 -- NW NE NE sec.21, T.31 S., R.19 E., Labette Co.
roadcut at Country Club entrance near Parsons, KS

Thickness (ft and m)

Section 13 (cont.)

Pleasanton Group

Tacket Formation (10.9 ft, 3.32 m exposed)

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|----|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------|
| 68 | *Clayshale, dark gray (N3), to grayish black (N2), platy, calcareous and noncalcareous layers present, contains large calcareous concretions (up to 56 cm in diameter). | 4.0 ft, 1.22 m |
| 69 | *Clayshale, dark gray (N3), platy, calcareous, contains phosphorite nodules. | 2.3 ft, 0.70 m |
| 70 | *Clayshale, dark gray (N3), platy, calcareous and noncalcareous zones present, phosphorite nodules not as abundant as in overlying units. | 4.6 ft, 1.40 m |