SUBSURFACE VIRGILIAN AND LOWER PERMIAN ARKOSIC FACIES, WICHITA UPLIFT-ANADARKO BASIN, OKLAHOMA

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Submitted to the Faculty of the Graduate College
of the Oklahoma State University
in partial fulfillment of the requirements
for the Degree of
MASTER OF SCIENCE
July, 1978

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PREFACE

This thesis studies the distribution and characteristics of the arkosic facies in the Wichita uplift-Anadarko basin area. Electric-logs and sample logs were used to prepare maps and stratigraphic cross sections. Thin sections, core samples, and electric-log correlations were used to study the internal characteristics and make inferences about the depositional environments.

The writer wishes to express appreciation for the guidance of Dr. John W. Shelton and Dr. Zuhair Al-Shaieb. Their helpful suggestions and critical review of the manuscript, along with those of Dr. R. Nowell Donovan and Dr. John Naff are gratefully acknowledged. Information and material for study came from several sources: Oklahoma Geological Survey provided core and well cuttings, Mr. Manderson Miles of Gulf Oil Company provided porosity and permeability data, Mr. George Moore of Union Oil Company provided well cuttings, Mr. John F. Treckman of Shell Oil Company provided core, and the Oklahoma City Geological Society Well Log Library provided access to electric-logs, gamma-ray logs, and sample logs.

Financial support was provided through ERDA contract 76-024-E and Cities Service Oil Company Fellowship. The writer's parents, Edward P. and Barbara L. Hansen deserve special thanks for their encouragement, help, and a lifetime of devotion. Special gratitude is extended to the writer's wife, Carolyn, for her financial support, encouragement, patience, and also for typing this manuscript.

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CHAPTER I

ABSTRACT

The arkosic facies of the Wichita uplift-Anadarko basin area of Oklahoma were deposited as fan-delta complexes. A repetitive sequence of transgressive-regressive couplets, each representing a single fan-delta complex, is present in the Virgilian strata of West Sentinel field. Fan-delta complexes near the Wichita uplift contain, in ascending order, nearshore shallow-marine deposits, coastal or strandline deposits, alluvial fan deposits, and reworked fan-delta deposits. Regressive phases were culminated by coarse-grained alluvial-fan deposits near the Wichita uplift; the shift to transgressive conditions is marked by reworked fan-delta deposits. Transgressive phases were culminated by deposition of nearshore shallow-marine siltstones-shales near the Wichita uplift and limestones basinward. Rock types within the different facies and northward decrease in grain size indicate the Wichita uplift as the source area.

Indications that conditions may be favorable for uranium concentration are high feldspar content, associated faulting, production of hydrocarbons, and abundant carbonaceous material. Combinations of these factors are represented by zones where anomalously high gamma-ray intensities are present.

CHAPTER II

INTRODUCTION

The study area includes 99 townships in parts of Beckham, Caddo, Comanche, Greer, Kiowa, Roger Mills, and Washita Counties in southwestern Oklahoma (Fig. 1). The area corresponds to the northern edge of the Wichita uplift and the southern flank of the Anadarko basin. Stratigraphic units studied range from the Missourian and Virgilian Series of the Pennsylvanian System to the Wolfcampian and Leonardian Series of the Permian System. The rock units have the common characteristic of containing a significant amount of feldspar. Much of the section studied is informally referred to as "granite wash."

Purpose and Methodology

The primary purpose of this investigation is to determine depositional facies of feldspathic units, derived from the Wichita uplift, at relatively shallow depths (5000 feet or less). The geologic setting was determined as a framework for the sedimentologic aspects of the study. Diagenetic overprints were studied from thin-section and x-ray diffraction examinations. Radioactive anomalies were cataloged from the study of gamma-ray logs. All facets of the study were undertaken for the purpose of providing some guidance to efforts related to determining the uranium potential of the "granite wash."

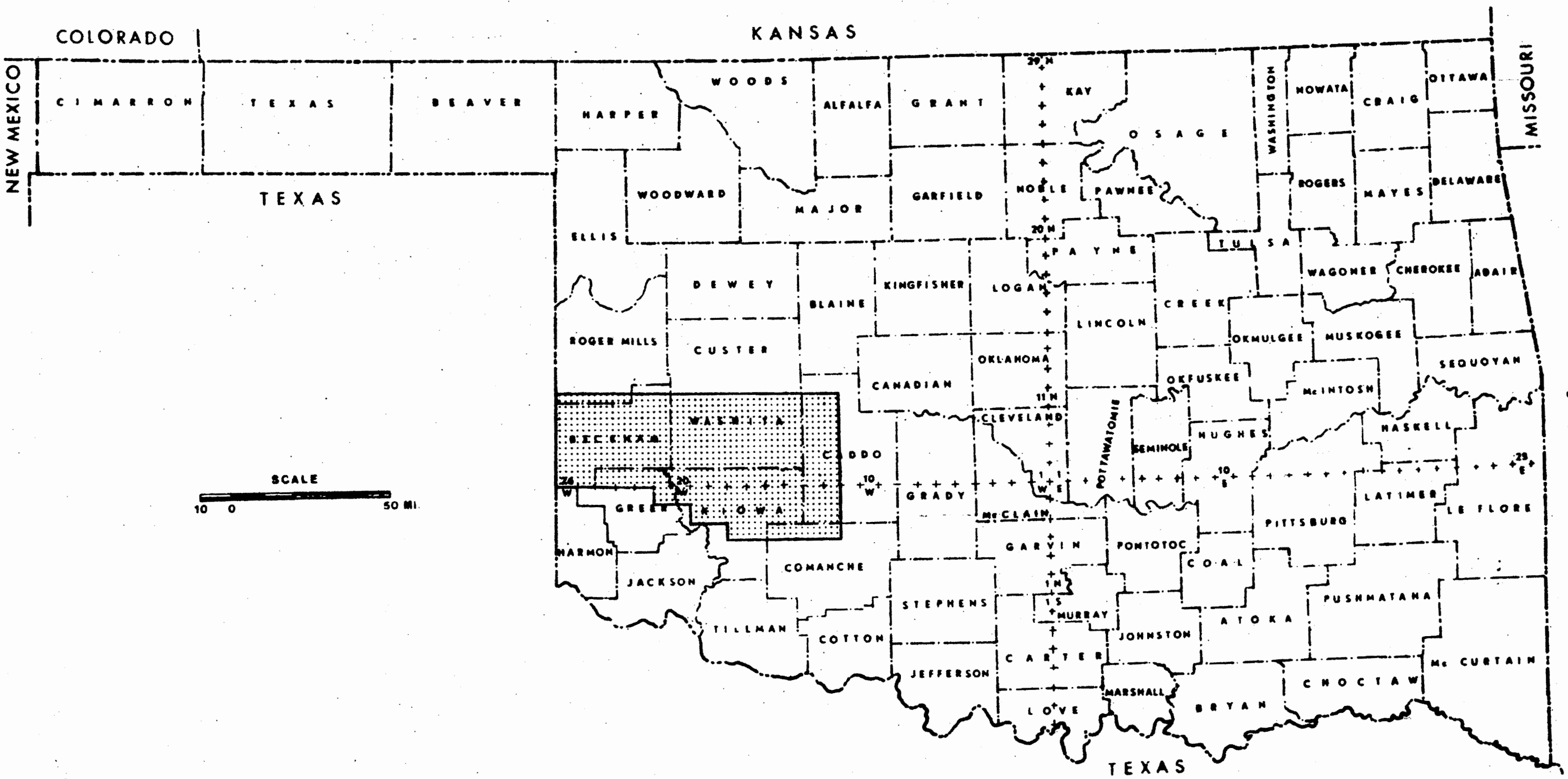

Fig. 1.-Location map of area of study.

A contour map portraying the elevation of the upper boundary of arkosic rock units shows the configuration of beds derived from the igneous rocks of the Wichita uplift. Because petrographic study was limited to core samples, the term "arkosic units" applies to strata in which feldspar is a major constituent. Inasmuch as electric-log correlations are unsuitable for delineation of feldspathic detritus, the first appearance (top) of feldspar in sample logs was used in preparation of the map.

A grid of six cross sections through the study area depicts basement structure, major stratigraphic units, and the upper boundary of arkosic beds. Electric-logs, sample logs, scout data, published cross section of the Pennsylvanian System, and map of basement rocks were used in preparation of the cross sections.

Sandstone percentages and thicknesses of the interval between the top of the arkosic facies and a depth of 5000 feet were mapped to show depositional patterns and volume of strata which potentially may be of interest in uranium exploration. Deflection of at least twenty millivolts on the self-potential log was used in delineating sandstone-conglomerate.

Anomalous gamma-ray intensities within the "granite wash" are cataloged as a matter of information rather than an estimate of uranium-bearing rocks. Some of the anomalies may signify enrichment in uranium, but that interpretation of an anomaly is not necessarily valid.

A detailed sedimentologic study was made of part of the upper Virgilian section in the West Sentinel field area. This interval is representative of porous, arkosic conglomerates in a fault block which is part of the Wichita uplift but which is intermediate in structural position between the uplift and the basin. The section is of further interest because a well in the West Sentinel field contains an interval of anomalously high gamma-ray intensity. Correlation was by means of electric logs, profiles of which were also used in determination of depositional environments. A detailed study of core from the area was used to establish depositional environments and major diagenetic features. Also, uranium concentrations were determined from analysis of selected core samples.

Previous Investigations

Edwards (1959) described the facies changes and petrography of the Pennsylvanian "granite wash" derived from the Wichita Mountains. Regional maps and cross sections of the Anadarko basin prepared by McNeal (1953), Riggs (1957), Gibbons (1962), Adler (1971), and Vozoff (1972) include some data on the "granite wash."

Elk City field, which produces oil and gas from "granite wash", was studied by Beams (1950, 1952), Wilgus (1950), Lang (1950, 1951), and Sneider et al. (1977). The most recent publication describes various environments in which the "granite wash" was deposited. "Granite wash" in the West Sentinel field was described by Gelphman (1959, 1960).

This study is an expansion of previous work presented in reports by Al-Shaieb and Shelton (1976) and Al-Shaieb et al. (1977a).

CHAPTER III

STRUCTURAL FRAMEWORK

General

The Anadarko basin is generally considered to have been part of an aulacogen associated with the Ouachita orogenic belt (Hoffman, Dewey, and Burke, 1974). The earliest stage of its development in Late Proterozoic to Middle Cambrian is marked by extensional, graben-type tectonics and basic intrusions. From Late Cambrian to Mississippian, a large slowly subsiding basin, the Oklahoma basin (Nicholas and Rozendal, 1975), was the site for deposition of carbonates and shale. The final stage of development was the delineation and development of the Anadarko basin during Pennsylvanian and Permian. This stage coincides with the formation of the Ouachita orogenic belt. Northerly to northwesterly compression to form the Ouachita belt was due possibly to subduction, which caused strike-slip faulting in the belt separating the Wichita uplift and Anadarko basin. Although dominant displacement was left-lateral, a considerable vertical component is evidenced by the difference in elevation of the basement in the two provinces. Total vertical displacement is more than 40,000 feet, of which approximately 25,000 feet occurred during Pennsylvanian time (Ham et al., 1969). This large vertical component resulted in the curvature characteristic of steep reverse faults.

The rate of vertical uplift is thought to have been pulsatory, a feature which influenced the rate of sediment supply and basin subsidence and produced transgressions and regressions.

The major faults of the area have been mapped by Harlton (1963, 1972), Ham et al. (1964), and Wroblewski (1967). Many of the faults are reflected by magnetic anomalies delineated in a survey of the area by Geodata International (1976).

Structural Configuration of the "Granite Wash"

The overall configuration of the "granite wash" is the product of two dominant factors. The first factor was the topographic expression of the Wichita uplift. The second factor is the deformation of earlier formed "granite wash" by renewed fault movement. Because this study is of relatively shallow "granite wash" (that which is less than 5000 feet deep), deformation by renewed fault movement is minimal. Permian strata have experienced only minor faulting. The major exception is a trapezoidal fault block north of Hobart. This block was active during the Permian and controlled the sedimentation pattern in that area. On this block the Wellington overlies a very thin section of "granite wash" above the Carlton Rhyolite. In most of the area strike-slip faults do not affect all of the Permian section. Some faults apparently experienced little or no vertical movement during the Permian. The areas where Virgilian strata are less than 5000 feet deep were affected by the fault movement during the Permian.

A map of the top of the "granite wash" may be used to determine the depth to arkosic beds, which may have some uranium potential. Although the top of the "granite wash" is a facies boundary and not a stratigraphic horizon, the upper surface also reflects the influence of Permian structure on sedimentation. The shallowest occurrences of Permian "granite wash" are outcrops of Post Oak Conglomerate in the Wichita Mountains area. The top of the "granite wash" dips gently basinward. In the area north of Hobart and in the Cordell area, contours of the upper surface are convex to the north (Plate I). This configuration reflects the trapezoidal shaped fault blocks north of Hobart which were active through the Wolfcampian. The upper surface dips gently northward within individual fault blocks in the other parts of the study area.

Within the "granite wash," differentiation of Pennsylvanian series can be accomplished using paleontological evidence, mainly fusilinids. Because of marked facies changes, further differentiation over large areas is not possible. Stratigraphic cross sections, with the top of the Wellington Formation as the datum, show: (1) changes in thicknesses due to basement faulting; (2) top of the "granite wash"; (3) one particular fault block in the east which strongly influenced Permian sedimentation; (4) thin wedge of sediments on the most positive fault blocks, as opposed to the intermediate thicknesses on less positive fault blocks; and (5) greatly expanded Pennsylvanian sections in the basin (Plates II-IV).

CHAPTER IV

STRATIGRAPHIC FRAMEWORK

"Granite wash" north of the Wichita Mountains is Permian and Pennsylvanian in age. Because facies and thickness changes are abrupt and limestones are too thin and impersistent for correlation, only gross subdivisions can be made in the study area. Reliable electric-log tops are of the Wellington Formation and the Virgilian Series. Type electric-logs are shown in Fig. 2. The top of "granite wash" represents a contact between facies rather than a chronostratigraphic surface. Conglomeratic "granite wash" characteristically has a high but variable resistivity and is commonly more porous than arkosic sandstone, as evidenced by greater self-potential deflection. Older rocks, fragments of which are included in the "granite wash," are Cambrian granites, rhyolites, gabbros, and basalts-spillites, and Ordovician to Devonian carbonates and siliceous shales.

Pennsylvanian System

Pennsylvanian strata overlap Mississippian and older strata in the Wichita Mountain area (Frezon and Dixon, 1975). Desmoinesian strata overstep older Pennsylvanian rocks in some areas near the mountain front. Some areas of the uplift have no Pennsylvanian strata. Total thickness of Pennsylvanian strata in the study area ranges from 5000 to 15,000 feet. The Pennsylvanian interval examined in this study is

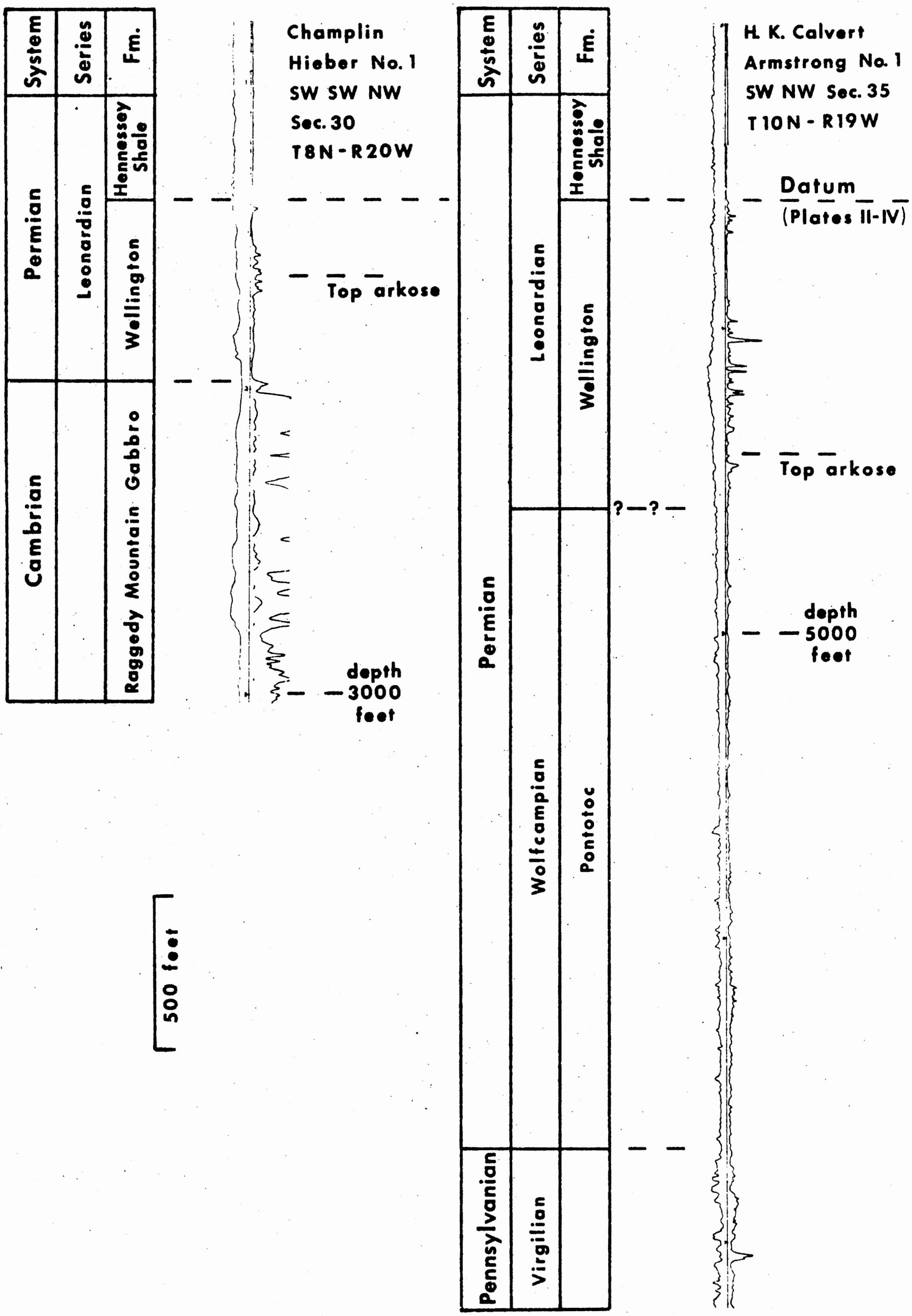

Fig. 2.-Type electric-logs for uplift and basin.

Virgilian in age. Virgilian strata have a maximum thickness of approximately 3500 feet east of Cordell. Minimum thickness in the basin is 1500 feet in the western part of the study area. The Pennsylvanian System is distinguished by fusilinid zones. In parts of the Anadarko basin, differentiation corresponding to the Douglas, Shawnee, and Wabunsee Groups of Kansas is possible. However, in the study area divisions of the Virgilian Series are not recognized.

Dominant lithologies of the Virgilian Series are conglomerates and sandstones near the uplift; they interfinger with gray mudstones and siltstones in the basin. In general, the western, central, and eastern regions of the study area are dominated by granitic, rhyolitic, and carbonate clasts, respectively. In each case the dominant clast type corresponds to the most common rock type of the adjacent source area (Edwards, 1959).

Permian System

Permian strata in the study area include rocks of the Wolfcampian and Leonardian Series. Wolfcampian Series strata in the Anadarko basin are more than 2000 feet thick in three areas (MacLachlan, 1967). In northern Oklahoma, Wolfcampian Series is divided into the Admire, Council Grove, and Chase Groups. However, in the study area impersistent limestones and complex facies relationships prevent delineation of the groups within the series or of the series itself. Boulder conglomerates suggest occasional strong orogenic pulses in the Wichita uplift. Other Lower Permian lithologies include pebble conglomerate, sandstone, mudstone, and limestone. Lobes of arkose which extend to southern Ellis County and northern Kingfisher County (MacLachlan, 1967) are deeper than 5000 feet and are not included in the study.

Thicknesses of Leonard Series strata are more than 3700 feet in the western and eastern part of the Anadarko basin (MacLachlan, 1967). The lowermost Leonardian unit is the Wellington Formation, which locally is more than 1000 feet thick (MacLachlan, 1967). Arkosic clastics extend upward at least into the Wellington, and in some areas the entire section is arkosic. The lower part of the Post Oak Conglomerate on outcrop interfingers with and is equivalent to the Wellington Formation. The upper part of the Post Oak Conglomerate interfingers with and is equivalent to the lower part of Hennessey Shale. Wellington lithologies include conglomerate, sandstone, and mudstone.

Sandstone-Conglomerate Percentage and Thickness

Sandstone-conglomerate percentages in the "granite wash" section down to a depth of 5000 feet range from zero to more than 70 percent (Plate V). Sandstone-conglomerate percentages generally decrease basinward in each fault block and northward in the basin. An exception is the block in T7-8N, R15-18W where percentages increase northward. Sandstone-conglomerate is not present in a group of trapezoidal fault blocks in T8N, R21-24W. A marked northward bulge in percentages north of Hobart reflects the northward convexity of contours on the top of the "granite wash."

Sandstone-conglomerate thicknesses range from zero to more than 1000 feet (Plates II-IV). Within each fault block thickness changes are similar to the changes in sand percentage. A northward bulge in thickness in the area of Cordell corresponds to higher percentages and the convexity of contours on the top of "granite wash."

CHAPTER V

SEDIMENTOLOGIC FEATURES OF UPPER VIRGILIAN IN WEST SENTINEL FIELD

Virgilian strata in West Sentinel field were used for detailed sedimentologic study because of availability of core, relatively dense well spacing, and a gamma-ray anomaly in sandstone-conglomerate. Applicability of this study to other areas or stratigraphic intervals depends upon three elements: (1) paleotopographic relief, (2) basin subsidence, and (3) distance from source. The interval studied is representative of high relief, rapid subsidence, and short transport. These elements characterize Missourian, Virgilian, and to a lesser extent, Wolfcampian and Leonardian conditions in a narrow, but geographically shifting, belt adjoining the topographically positive Wichita uplift.

The West Sentinel field is a 1.3-million-bbl oil and 3.6-billion cu ft gas field producing from Virgilian "granite wash."

No Virgilian strata crop out in the study area. Subsurface data include core samples and electric logs. Four dominant lithologies or facies are represented by distinctive electric-log characteristics, which were used to infer gross geometry. Internal features and diagenetic features were determined from core samples.

Within a genetically related sequence, the main facies, in ascending order, are siltstone-shale, moderately sorted sandstone, conglomerate, and interbedded sandstone and siltstone-shale. Normal stratigraphic sequence and electric-log characteristics are illustrated on the type log (Fig. 3).

Geometry

Correlation even within the West Sentinel area is complicated by facies changes and faulting. In West Sentinel field correlation sections were prepared using the base of the uppermost siltstone-shale unit examined as the datum (Plate VI). Siltstone-shale units are 60 to 150 feet thick. Variation in thickness of a particular unit along depositional strike is minimal (less than ten percent). Although thickness increases basinward, this facies in the area of some eight miles by four miles is tabular in shape, rather than distinctively wedge-shaped. Correlations beyond the field boundary are uncertain due to faulting rather than to facies change. Generally, the upper contact is abrupt, whereas the basal contact is gradational.

Moderately sorted sandstone sections are 10 to 25 feet thick. Thickness varies considerably both along depositional strike and basinward. The upper contact may be gradational to siltstone-shale or erosional to conglomerate. Basal contacts are sharp but uncommonly erosional. Genetic units are thin, sheetlike, and continuous laterally. Lateral changes, as inferred from electric-log features, are gradational.

Conglomerate units range from 90 to 230 feet in thickness, which varies along depositional strike and increases basinward. Although conglomerate within one unit is laterally continuous, the presence of shale, siltstone, and sandstone interbeds suggests multistoried and

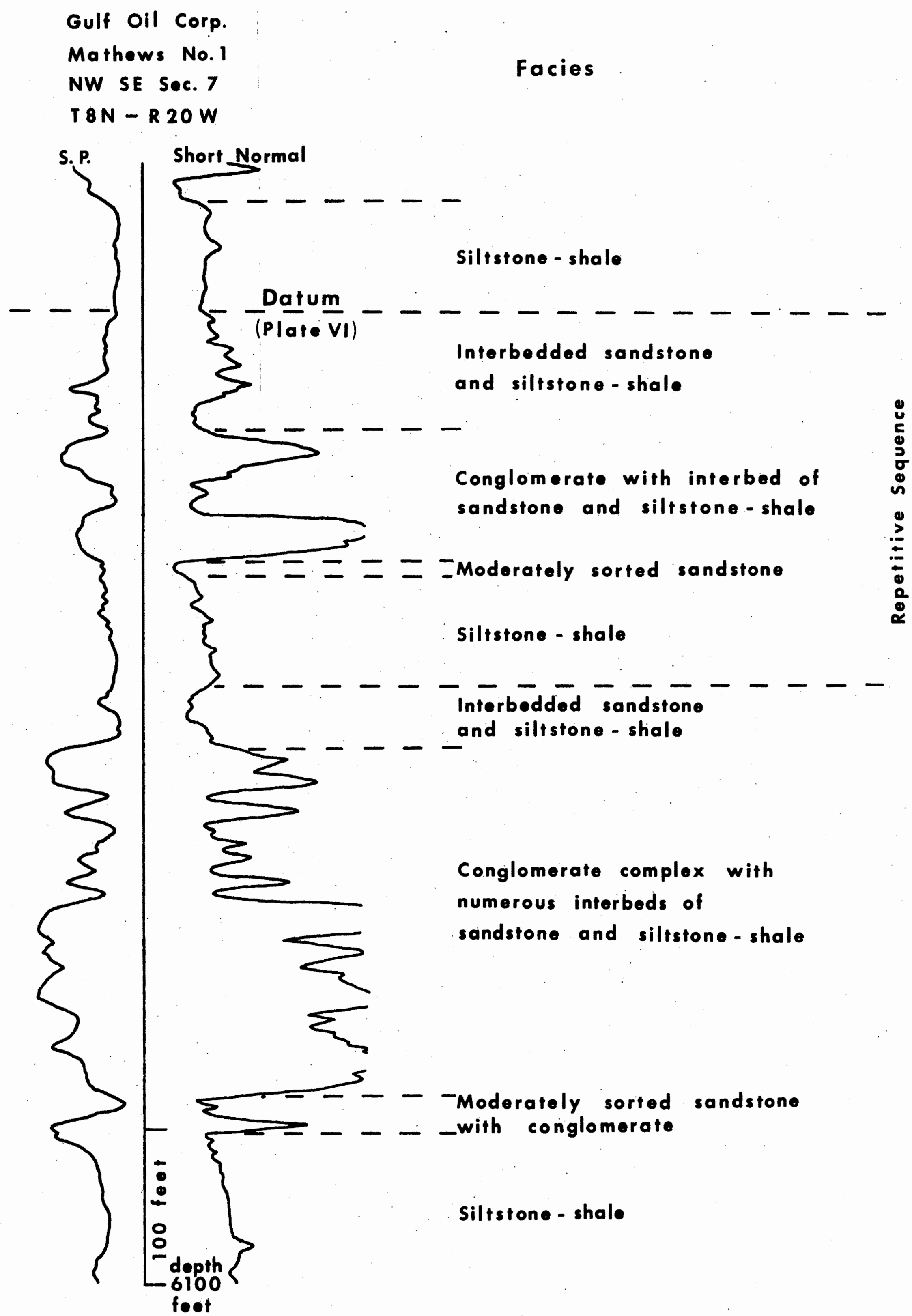

Fig. 3.-Comparison of electric-log characteristics and facies.

coalescing units. The upper contact is marked by abrupt absence of cobble size material, and the upward change from granule and very coarse sand size material into very fine sand and silt occurs within three to twelve inches. The basal contact is erosional, with conglomerate overlying sandstone or siltstone-shale. Although lateral contacts were not observed, lenticular shape is inferred from lack of electric-log correlation of genetic units recognizable in core samples. A genetic unit is 20 to 75 feet thick, and multistoried units are 90 to 230 feet thick.

Sandstone and siltstone-shale units are 30 to 75 feet thick, and they vary considerably in thickness along depositional-paleostructural strike. Also, thickness generally decreases basinward. Sandstone sections, 1 to 5 feet thick, cannot be reliably correlated between the closest wells (with ¼ mile spacing). Lenticular shape is inferred. Grain-size change at the base is abrupt; the basal contacts of some units are erosional. Most sandstones grade sharply upward into siltstone-shale. Some sandstone sections are modestly multistoried and are inferred to be multilateral. The ratio of sandstone to siltstone-shale increases with depth in each well, with a correlative increase in multistoried sandstone sections. While genetic units have sharp or erosional basal contacts, the entire facies, reflected by electric-log characteristics, is gradational between the overlying siltstone-shale and underlying conglomerate.

Internal Features

Siltstone-shale units typically contain the following sedimentary structures: flaser bedding, burrows, massive bioturbation, siltstone dikes, soft-sediment fractures and folds, and interlamination (Plate VII). The average grain size is silt, but sizes range from medium sand to clay. Most siltstone laminae and beds are one-half to three inches thick. Thicker beds are of very fine sand, with little clay. The sandstone beds are light tan, and the shale laminae are black. Overall color is black to dark gray. Significant constituents are fossil fragments and carbonaceous material (Fig. 4). Most fossils are brachiopod fragments, with some complete brachiopods up to 38 mm in size. A few poorly preserved fusilinids are also present. One crinoid stem was observed in a bed composed primarily of small shell fragments. Distribution of fossil fragments is irregular; some layers have numerous, large, well preserved brachiopods, but others are unfossiliferous. Carbonaceous material and carbonized wood are present throughout. Sizes are from 1 mm to over 70 mm in length. Wood fragments, up to 6 mm thick, show vitreous coaly fractures, with occasional secondary calcite. Finely disseminated plant fragments are less than 1 mm thick and 1 to 10 mm in length. One pressed flat frond is 13 mm across. Fine "coffee grounds," which are present throughout, are most abundant in the sandy beds. Compositionally, the siltstones are arkoses (Fig. 5). The predominant clay is chlorite, and the predominant cement is dolomite. Matrix composes approximately 35 percent of the rock. Grains are angular to very angular and sorting is poor to moderate (Figs. 6 and 7). The siltstones, therefore, are compositionally and texturally immature.

Moderately sorted sandstones have the following sedimentary structures: small-scale trough crossbeds, deformed beds, massive bedding, and interlamination (Plate VII). Most sandstones are well

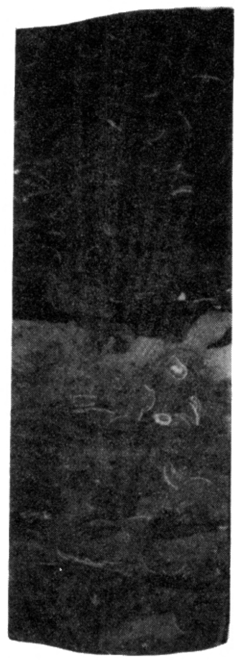

Fig. 4.-Siltstone-shale showing fossil fragments, deformed siltstone bed with siltstone dike, carbonaceous material, and massive bioturbation (2.5 X 8 inches; depth 5660 feet; sample location on Plate VII).

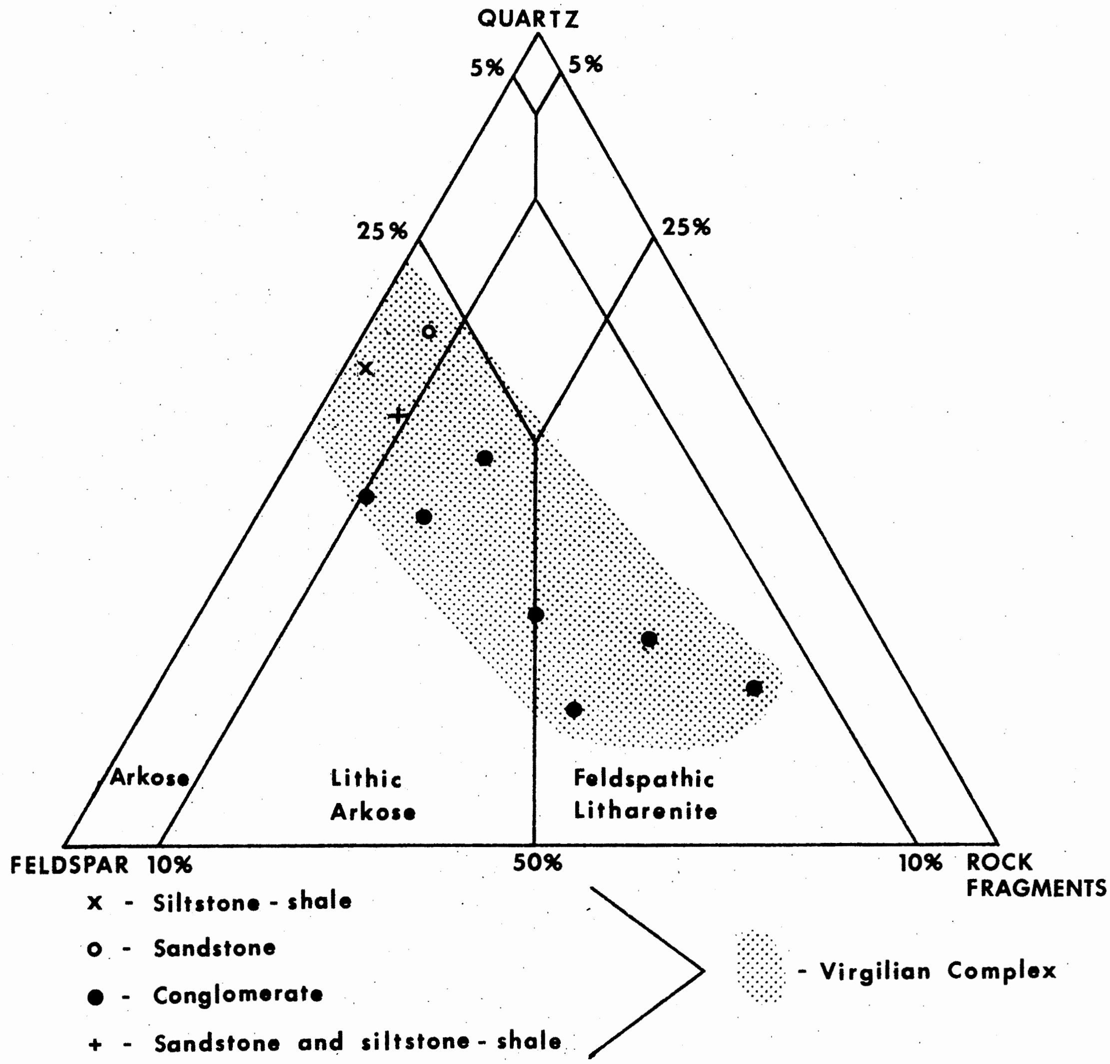

Fig. 5.-Compositional classification of facies, based on classification of McBride (1963).

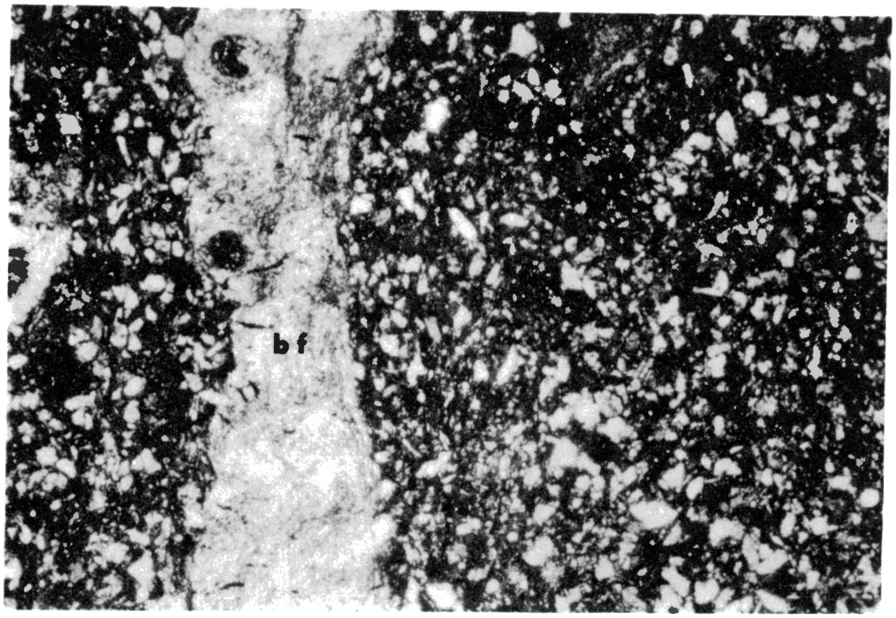

Fig. 6.-Brachiopod fragment (bf) with angular, silt-size quartz and feldspar in chlorite matrix (2.5 X 1.7 mm; crossed nicols).

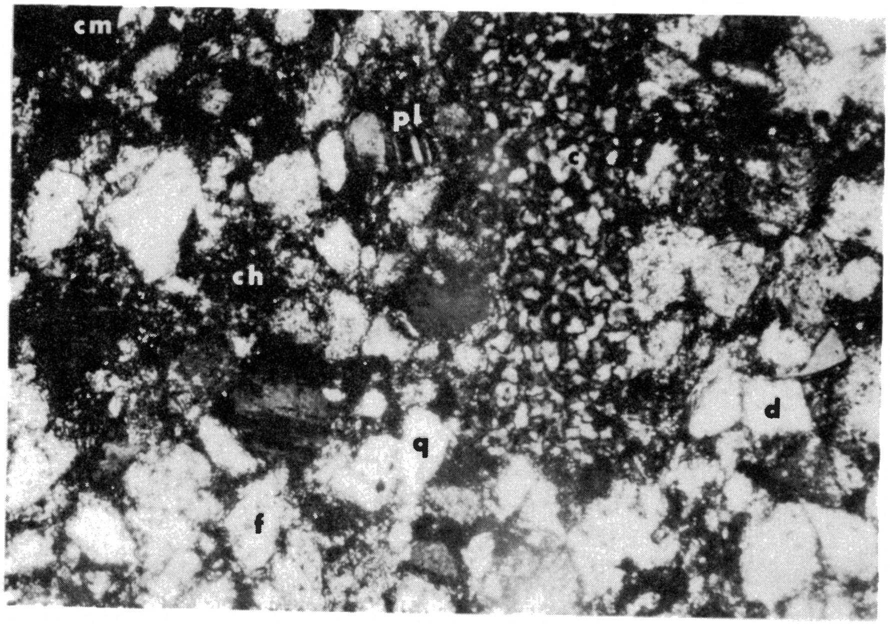

Fig. 7.-Chert (c), plagioclase (pl), quartz (q), feldspar (f), and carbonaceous material (cm) in dolomite (d) and chlorite (ch) matrix (0.7 X 0.5 mm; crossed nicols).

consolidated, carbonate-cemented, massively bedded, light green due to clay, and moderately sorted (Fig. 8). The sandstones are arkoses (Fig. 5); quartz is predominant, and other constituents include potassium feldspar, plagioclase, calcite grains, biotite, and rock fragments (Figs. 9 and 10). Chlorite clay is very common as matrix and composes approximately 30 percent of the rock. Sandstones are texturally and compositionally submature.

Conglomeratic units, which are massively bedded, contain sandstone interbeds. Sandstone interbeds contain deformed bedding, small-scale crossbedding, interlamination with shale, and clay clasts (Plate VII). One interbed, 3 feet thick, is silty coal. Grain size in conglomerate ranges up to more than 450 mm. The matrix is poorly cemented very coarse sand to granules. Pebble and sand-sized material is angular. The lower limit of moderately rounded rock fragments ranges from 10 to 30 mm. Cobbles and boulders are well rounded. Carbonate pebbles are more rounded than granitic pebbles of the same size (Fig. 11). Where both types are present, the maximum size of granitic boulders is greater than the maximum size of carbonate boulders. Sorting is very poor (Fig. 12). Sandstone interbeds within the conglomerates contain carbonaceous material, feldspar, and quartz in addition to granophyre, microperthite, and carbonate rock fragments. Sorting is poor to very poor (Fig. 13). The dominant clay in the matrix is chlorite. Petrographically, the conglomerates and sandstone interbeds are lithic arkoses and feldspathic litharenites (Fig. 5). Compositionally and texturally, the conglomerates and associated sandstone interbeds are immature.

Interbedded sandstone and siltstone-shale units typically contain the following structures: parallel bedding or lamination, erosional

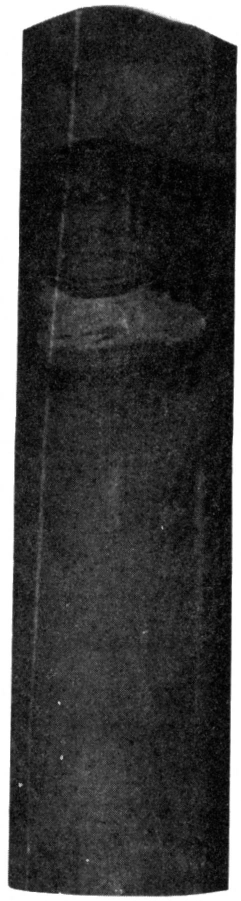

Fig. 8.-Moderately sorted sandstone showing massive bedding, deformed bed, and carbonaceous material (2.5 X 10 inches; depth 5650 feet; sample location on Plate VII).

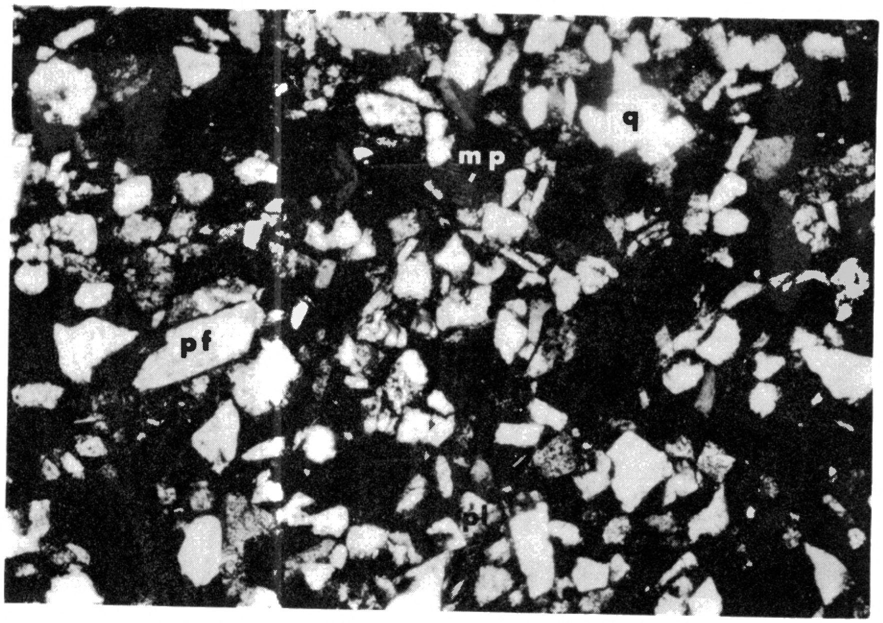

Fig. 9-Angular, medium sand-size quartz (q), potassium feldspar (pf), plagioclase (pl), and microperthite (mp) in dolomite and chlorite matrix (2.5 X 1.7 mm; crossed nicols).

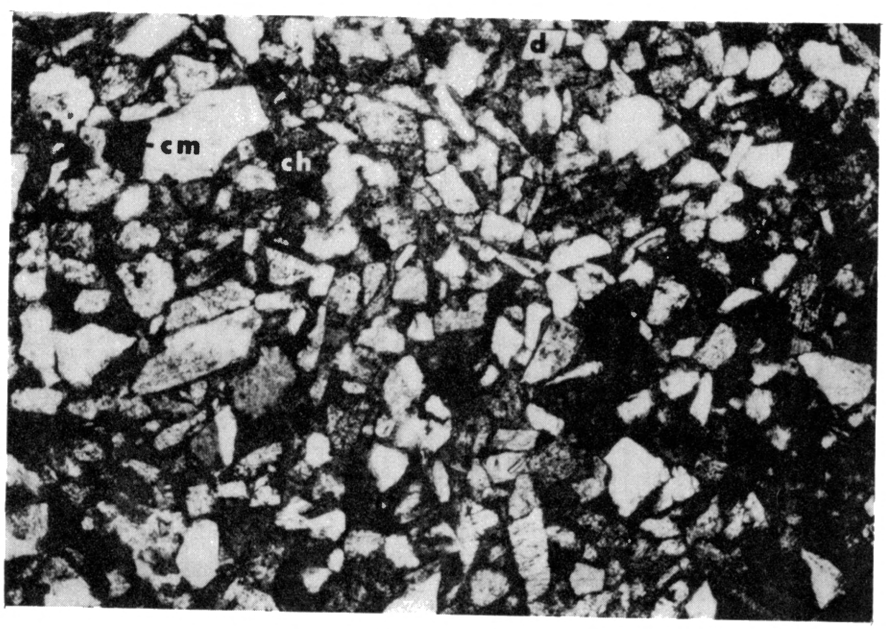

Fig. 10.-Same as above, showing carbonaceous material (cm), rhombic dolomite (d), and chlorite (ch) matrix (2.5 X 1.7 mm; plane-polarized light).

Fig. 11.-Conglomerate showing 6 inch granitic cobble on left, rounded carbonate pebbles, angular granules, very poor sorting, and sand and granule size matrix (2.5 X 6 inches; depth 5635 feet; location on Plate VII).

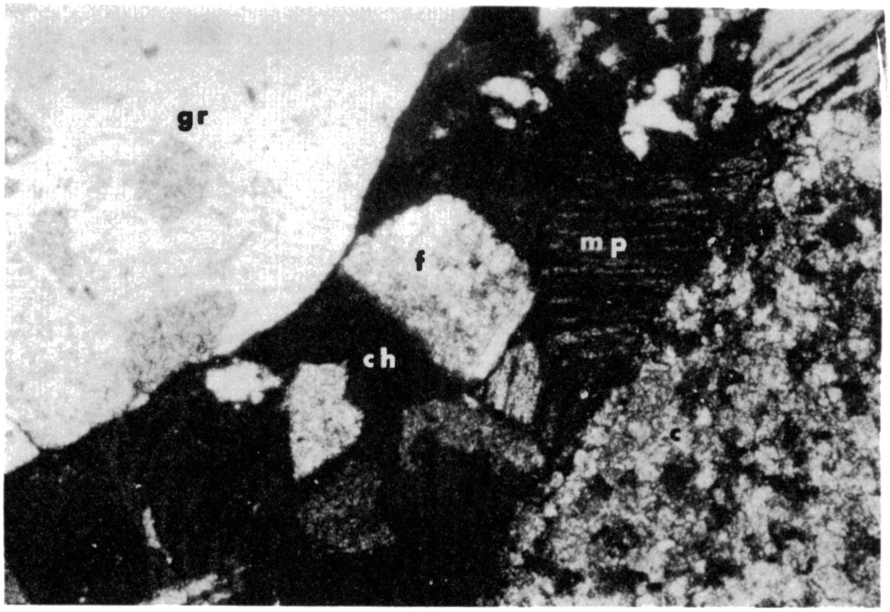

Fig. 12.-Granitic (gr) and carbonate (c) pebbles with coarse sand-size microperthite (mp) and feldspar (f) grains in chlorite (ch) matrix (2.5 X 1.7 mm; crossed nicols).

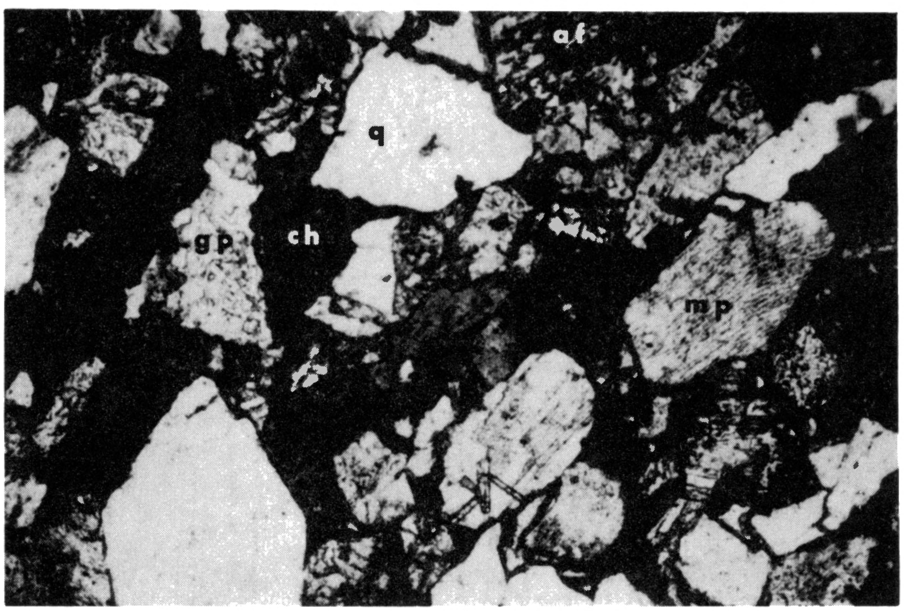

Fig. 13.-Granophyre (gp), quartz (q), altered feldspar (af), and microperthite (mp) in chlorite (ch) matrix (2.5 X 1.7 mm; plane-polarized light).

scours, inclined bedding, flaser bedding, soft-sediment faults and folds, and sandstone dikes (Plate VII). Other features are concretions, clay clasts, and burrows. The average grain size is medium sand; the range in size is from clay to cobble. Sand grains are angular with very poor to moderate sorting. Most sandstones are carbonate-cemented, with a high percentage of clay. Color is variable. Sections with a high percentage of clay are light to dark gray. Sand sections are brown, tan, or gray (Fig. 14). The lower part of a unit has less clay and silt than the upper part. Some sandstone units have erosional bases and clay clasts in lowermost parts overlying shale and siltstone. The lower part of a unit is massively bedded sandstone or conglomerate with an occasional shale interbed. Genetic units are 6 inches to 48 inches thick. No shell fragments are present in the sandstone and siltstone-shale units. The upper part contains carbonaceous material, 1 mm to 70 mm in length. Carbonaceous material is present predominantly in clay-rich sections. The sandstones are arkoses (Fig. 5), composed of quartz, plagioclase, potassium feldspar, biotite, rock fragments, and clay. The dominant clay is chlorite. Sorting is poor to moderate. Grains are angular to subangular (Figs. 15 and 16). Sandstones are texturally and compositionally immature.

Depositional Environments

The determination of depositional environments in West Sentinel field is based on sequence, geometry, sedimentary features, and lithology. The discussion of environments is divided into four general parts: (1) the four dominant lithologies are discussed separately and an environment is postulated for each, (2) the section in the West

Fig. 14.-Sandstone and siltstone-shale showing soft-sediment faults, compaction, and disturbed lamination (2.5 X 10 inches; depth 5732 feet; location on Plate VII).

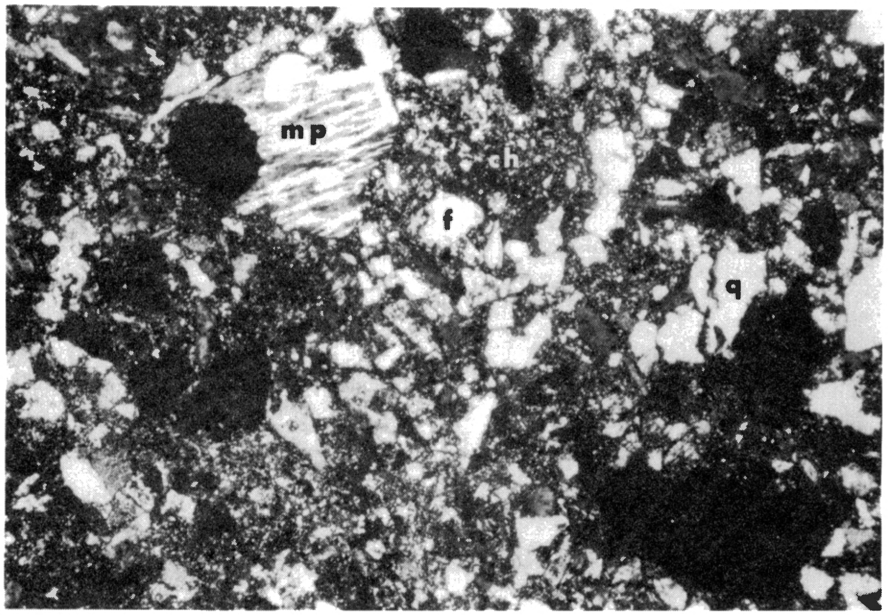

Fig. 15.-Microperthite (mp), quartz (q) and potassium feldspar (f) in matrix of chlorite (ch) and carbonate cement (2.5 X 1.7 mm; crossed nicols).

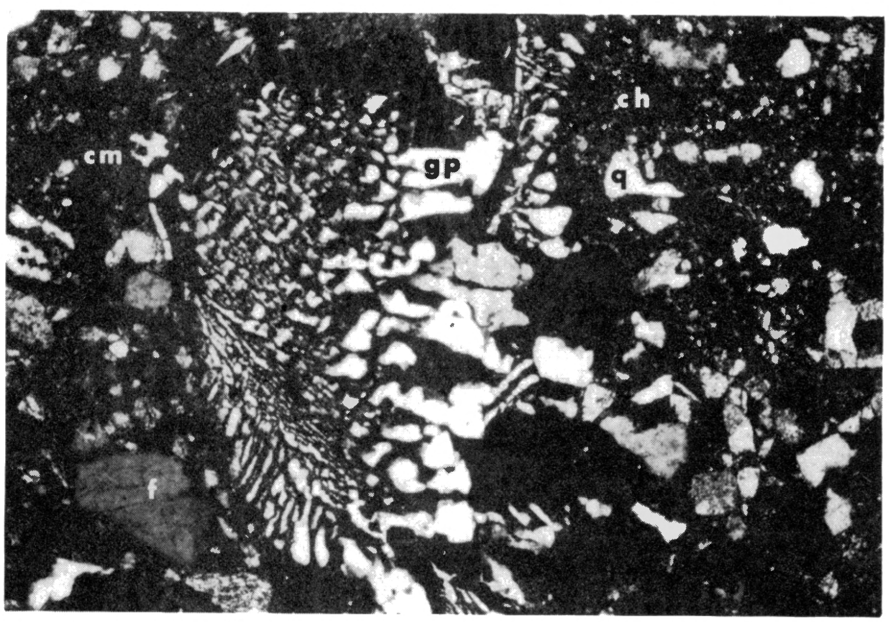

Fig. 16.-Granophyre (gp), feldspar (f), quartz (q), and carbonaceous material (cm) in matrix of chlorite (ch) and fine-grained carbonate cement (2.5 X 1.7 mm; crossed nicols).

Sentinel field environments are compared with modern and ancient examples.

Siltstone-Shale

Fossiliferous siltstone-shale was deposited in a nearshore, shallow-marine environment. Evidence for a marine environment is: (1) abundance of marine fossils, many of which are complete; (2) massive bioturbation; (3) high percentage of carbonate cement; (4) presence of dark gray to black shale; (5) tabular, laterally extensive geometry; and (6) distinctive basal contact. Deposition in shallow, nearshore conditions is evidenced by the preservation of much finely disseminated plant material with shallow-marine fossils and proximity vertically to very coarse-grained regressive facies. Soft-sediment folds in the siltstone beds suggests that deposition was rapid and localized and/or on an unstable slope.

Sandstone

Moderately sorted sandstones were deposited in coastal, possibly strandline, environments. Winnowing by wave action and currents is thought to be responsible for the moderate sorting. These sandstones are characteristically light green with little trace of the dark clay and carbonaceous material. Most stratification was destroyed by burrowing organisms which produced essentially massive units. The range in environments represented probably includes shallow marine, delta-fringe, and barrier-bar. The upper contact is locally erosional, with the overlying conglomerate, which may produce variation in thickness. One variation from the ideal sequence is a bed of silty sandstone or siltstone-shale above the moderately sorted sandstone. This unit may represent a minor transgression to shallow-marine conditions. Another variation, a bed of conglomerate within moderately sorted sandstone, may represent introduction of coarse clastics during a flood or reworking of previously deposited alluvial fan units. The angular shape of sand grains suggests that the source was nearby; redistribution and transport by coastal currents and waves is inferred to be minimal.

Conglomerate

Conglomerate units containing granitic, rhyolitic, and carbonate boulders in massive beds above erosional bases were deposited as alluvial fans. This environment is supported also by the structural setting. Virgilian strata in the West Sentinel field area were deposited on a fault block intermediate between the deep Anadarko basin and the most active Wichita uplift fault blocks. The nearest area where rocks were exposed is 3 miles to the southwest (Ham et al., 1963). This is assumed to be approximately the shortest transport distance of granitic boulders. Comparison of the conglomeratic units of the interval studied with the alluvial fans studied by Wilson (1970) is subject to the following assumptions: (1) the conglomeratic units studied are alluvial-fan deposits; (2) the apex is at the present position of the fault separating the Wichita uplift from the West Sentinel "basin;" (3) the distance of the conglomerate from the apex is the distance from the fault line to the Gulf Oil Corporation, Mathews No. 1; (4) differences in climate, vegetation, clast types, and clay content were either minimal or not significant enough to produce major variation in transport mode; (5) minor faults (one of which is thought to be less than ¼ mile south of the West Sentinel field area) did not produce fault scarps which acted as the fall line for fans of reworked sediments; and (6) the maximum clast size observed in vertical borehole sequences is approximately equal to true maximum clast size. Notwithstanding the imprecision necessitated by the assumptions, the plot of maximum clast size versus distance from the assumed apex corresponds to plots for several modern alluvial fans (Fig. 17). Approximation of paleotopographic relief of the Wichita Mountains during deposition of these Virgilian conglomerates can possibly be made by comparing the present-day relief in the areas of those alluvial fans which show similar size-distance plots. Two such fans are in the White Mountains of California and Nevada. Local relief is 6000 to 8000 feet in horizontal distances of 4 to 8 miles (Beaty, 1963). The White Mountains have a granitic core covered by sedimentary, metamorphic, and volcanic rocks. An alluvial fan in Nevada with similar size-distance plots is in an area with local topographic relief of more than 1300 feet in a horizontal distance of less than 1 mile (Bluck, 1964). If the slope of the upper surface of conglomeratic units at the time of deposition is estimated by comparison with an alluvial fan of the Santa Catalina Mountains, Arizona (Blissenbach, 1952), it was one degree or less (Fig. 18). However, abundant plant fragments and silty coal in the West Sentinel core suggest a humid environment, and the slope of an alluvial fan decreases with increase in precipitation (Bull, 1964; Reineck and Singh, 1975).

The source area of the coarse clastics was the Wichita uplift. The composition of conglomerates and sandstones is similar to the

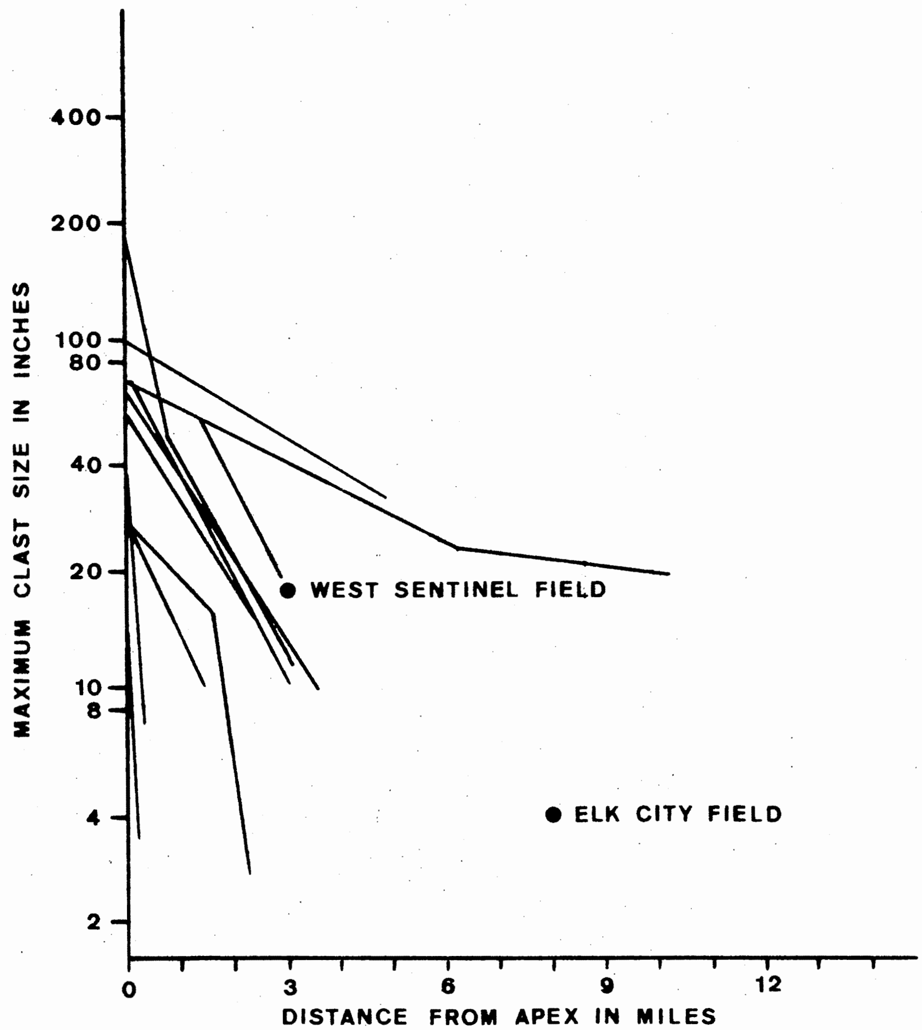

Fig. 17.-Size-distance plots of alluvial fans, modified from Wilson (1970).

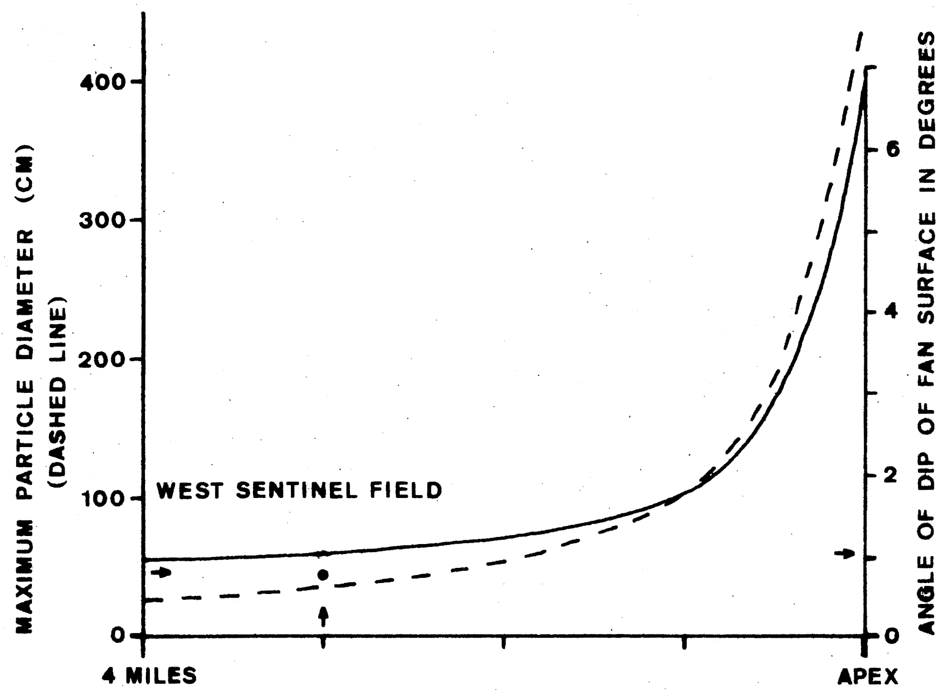

Fig. 18.-Alluvial fan slope and size-distance plot, modified from Blissenbach (1952).

igneous rocks of the source area. Because shallow-marine, delta-fringe, and strandline deposits may receive contributions from distant source areas through marine and coastal currents, the matrix of the alluvial-fan conglomerates was studied for determination of rock-fragment types in sandstones. Because granophyric textures are predominant, the major source was probably the Wichita Granite group in which granophyric texture is ubiquitous. The less common microperthite may have been derived from the Wichita Granite and/or the Carlton Rhyolite. Although the Raggedy Mountain Gabbro is reported in the subsurface 4 miles south of the West Sentinel field, gabbroic and anorthositic fragments from the layered series were not identified. The apparent absence of these types of fragments is possibly due to rapid weathering; gabbro or anorthosite may be the source for some of the individual plagioclase grains.

Sandstone and Siltstone-Shale

Interbedded sandstone and siltstone-shale units are reworked fan-delta deposits. An initial transgressive phase due to increase in subsidence rate, diminution of source area, and/or shift in major drainage apparently resulted in formation of a repetitive sequence with overall fining upward. Evidence supporting reworked, or destructive, deposits in interdeltaic coastal environments is as follows: (1) position in sequence between marine units and coarse-grained alluvial fans, (2) repetitive sequence of sandstone with conglomerate and siltstone-shale, overall fining upward, (3) upward decrease in thickness of sandstone beds, (4) soft-sediment fractures and folds suggestive of a relatively steep depositional slope, and (5) presence of abundant large plant fragments but absence of shell fragments suggestive of rapid deposition. The basal contacts of coarse layers are sharp or erosional. Overall relationships support a transgressive shoreline with a nearby source of coarse clastics.

Virgilian Complex

The Virgilian strata studied in West Sentinel field is interpreted to be a fan-delta complex. The term, fan-delta, was originated by Holmes (1965) in describing deltas forming in a lake (Buttermere and Crummock Water in English Lake District) and in the ocean (Bristol Channel at Lynmouth, North Devon, England). Fan-deltas were defined by McGowen (1970) as ". . . basically alluvial fans that prograde into a body of water from an adjacent highland." An alternate term is "tectonic delta complex" used by Friedman and Johnson (1966) to describe "a deltaic complex built into a marine basin contiguous to an active mountain front and dominated by orogenic sandstones." Authors who have described complexes containing both alluvial fan and deltaic facies are Laming (1966), Burke (1967), Meckel (1967), Allen and Friend (1968), Klein (1968), Thompson (1968), Nilsen (1969), Wilson (1970), McGowen and Groat (1971), Erxleben (1975), and Wescott and Ethridge (1978).

West Sentinel field alluvial fans prograded over marine units. The repetition of several such sequences permits division of the strata into separate units or couples, each of which includes deposition of a fan-delta. The term "tectonic delta complex" as used by Friedman and Johnson (1966) is applicable to the entire interval studied. The necessary elements -- an active mountain front, a marine basin, orogenic sandstones, and deltaic influx -- were all satisfied during deposition of the strata studied.

Coalescing alluvial fans and associated units probably filled the structurally controlled area represented by the fault block on which West Sentinel field is located.

The interval studied is characterized by repetitive sequences of transgressive-regressive couplets. In ascending order, a couplet typically consists of fossiliferous siltstone-shale, moderately sorted sandstone, conglomerate, and interbedded sandstone and siltstone-shale. Fossiliferous siltstone-shale marks the culmination of the transgressive phase. The shift from dominantly transgressive conditions to regressive conditions is marked by deposition of a moderately sorted sandstone. Conglomerate represents culmination of the regression. As a regression waned due to eustatic change in sea level or shift of depocenter, the interbedded sandstones and siltstone-shale was deposited. Two of these sequences are present in the cored interval studied. Electric-log interpretation suggests the presence of at least four such couplets in the Virgilian of West Sentinel field. More couplets are probably present, but the distinctive features of the ideal sequence are absent.

Modern and Ancient Analogies

Modern fan-deltas or alluvial fan and delta environments provide a basis for interpretation and comparison of sequence, internal features, and gross geometry. The Gum Hollow fan-delta, Nueces Bay, Texas (McGowen, 1970) is a small-scale example of a single fan-delta. The adjacent relief (35 to 45 feet), average grain size (fine sand), and limited extent place it in a different category than the interval at

West Sentinel field. Observation of the Gum Hollow fan-delta through time has shown that progradation occurs almost exclusively in discrete and sporadic stages corresponding to heavy rainfalls or hurricanes. During heavy rainfalls sediment is distributed by sheetfloods covering the entire surface of the fan. Moderate rainfall produces braided streams. Channeling occurs mainly in the axial fan part during waning floods. The maximum depth of the bay is 3 feet. Wind, wave, and tide action significantly reworks sediments and overprints sedimentary structures formed by fluvial processes.

The Yallahs fan-delta, Jamaica (Burke, 1967; Wescott and Ethridge, 1978), is a modern example of an alluvial fan prograding into the ocean. The maximum grain size is boulder, a feature which makes it comparable to the West Sentinel field interval. Adjacent relief is 6600 feet at 15 miles from shore. The position of the fan is structurally controlled. The fan is smaller than the West Sentinel field complex, but it should be noted that it completely fills the available space in the fault-controlled trough. The alluvial-fan part of the Yallahs fan-delta is covered with braided streams and abandoned channels with normal sedimentary structures. Some freshwater ponds are present.

The Colorado River delta, Baja California (Thompson, 1968) is associated with alluvial fans. In contrast to other fan-deltas, it has extensive coastal mudflats. Notwithstanding adjacent mountains with relief averaging 4500 feet, alluvial fans do not prograde directly into the sea. The extensive mudflat deposits were not observed in the West Sentinel cored interval.

The subsurface Henrietta fan-delta of North-central Texas

(Erxleben, 1975) has a vertical sequence and electric-log characteristics similar to the Virgilian section in West Sentinel field. Massive, coarse-grained, arkosic sandstone facies represent prograding alluvial fans deposited by braided-stream systems. Individual units display sharp upper and lower contacts. This facies corresponds to the conglomerate units in the Virgilian cored interval in West Sentinel field. Thin coal units associated with the major lobe of the Henrietta fan-delta are analogous to the silty coal present as an interbed of West Sentinel alluvial conglomerates. The Henrietta fan-delta has been recognized over a wide area, with major and minor lobes differentiated by interfingering limestones. The overall geometry suggests that the entire fan-delta system prograded from one area. A fault-bounded trough is speculated to have controlled the trend of the main lobe (Erxleben, 1975). The extent of structural control on West Sentinel sedimentation, beyond the uplift of the Wichita province, is not known.

The Catskill "tectonic delta complex" (Friedman and Johnson, 1966) of New York is an example of an ancient (Devonian) alluvial fan and deltaic environment. Three dominant lithofacies are recognized: (1) continental Catskill, (2) nearshore Chemung, and (3) marine Portage. The complex is useful as a guide due to its large size and abundant outcrops. Facies relationships and time lines established by faunal control show that time lines cut facies. The broad alluvial fans extended over 100 miles into the basin. Interfingering of the Catskill lithofacies with nearshore Chemung lithofacies corresponds to orogenic episodes. Green units are thought to have been deposited more rapidly than the red beds, which apparently formed during periods of prolonged exposure. The absence of red beds in the West Sentinel field area may be due to limited exposure. Abrupt vertical changes in facies suggest that local orogenic activity was of greater influence in the West Sentinel field than in the formation of the Catskill section. A similarity between the West Sentinel field strata and the Catskill facies is that only the large material is rounded (Mencher, 1939).

Comparison with "Granite Wash" in Elk City Field

The Elk City field, 11 to 14 miles northwest of West Sentinel field, is a 60-million-bbl oil and 4.4-billion cu ft gas field producing from eight zones in Missourian rocks. Sneider et al. (1977) determined the depositional environments and reservoir geometry and continuity of two reservoir zones, consisting of conglomerates and sandstones and associated nonreservoir siltstones, shales, and limestones in a 500-foot producing interval at depths of 8800 to 11,000 feet. Depositional environments of the reservoirs were: (1) barrier-bar, (2) alluvial channel, (3) distributary channel, and (4) delta-fringe. The field is a structural trap, with an anticlinal axis approximately parallel to the Wichita uplift. The trend of the barrier bar is east-west. Both the alluvial channel and distributary channel are oriented north-south. Delta-fringe deposits have no discernible trend within the field limits.

Although the reservoirs at Elk City field are deeper and not stratigraphically equivalent to the strata described herein, comparison is useful because of its location relative to the West Sentinel field and the Wichita uplift. The field is 6 to 9 miles north of the Wichita uplift. It is located 4 miles north of the thickest sedimentary section of the Anadarko basin (Ham et al., 1964). Elk City strata were deposited as parts of fan-delta complexes. The greater distance from the source area (of the Wichita uplift) to Elk City field than to the West Sentinel field is reflected primarily by finer textures. The barrier-bar deposits are characterized by bioturbation below horizontal bedding and by coarsening-upward texture. The equivalent in the West Sentinel field is the moderately sorted sandstone.

In comparison to sandstones at West Sentinel, delta-fringe deposits in the Elk City field are better sorted, and they contain less carbonaceous material, and fewer soft-sediment deformed beds. Repetitious textural sequences, with overall coarsening upward, and parallel bedding are diagnostic features. The fining upward sequences of interbedded sandstone and siltstone-shale at West Sentinel contrast sharply to sequences of the delta-fringe deposits at Elk City; also the grain size of the former is finer grained than the latter. The moderately sorted sandstone at West Sentinel is similar in position (in the vertical sequence) and in nature of contact to the Elk City delta-fringe units.

Alluvial-channel conglomerates and sandstones in the Elk City field, formed by high-gradient, braided streams (Sneider et al., 1977), show sharp changes in grain size. The corresponding facies in the West Sentinel field, interpreted as alluvial-fan deposits, is coarser grained and more massively bedded than the Elk City alluvial deposits. The Elk City alluvial-channel sandstones are narrow, linear, and erosive with respect to contiguous units. The West Sentinel alluvial fans are thicker and more extensive laterally. Distributary sandstones at Elk City are narrower, thinner, and finer grained than the alluvial deposits.

The different facies at Elk City may best be explained as elements of a fan-delta complex. Proximity to a source area with significant relief, units with cobbles in association with marine deposits, moderate to poor sorting in reservoir-type rocks are indicative of fan-delta conditions. Assuming that age differences are not a significant factor in sedimentologic comparisons, the differences between the Elk City and West Sentinel deposits probably are due primarily to the differences in distances to the source area; these were reflected by gentler slopes and less competent stream flow to the north. Transgression is represented at Elk City by limestone and at West Sentinel by siltstone-shale. Regression in the former area is represented by finer conglomerates than those in the upslope area. Because of the steeper slope near the uplift, initial phases of a transgression were represented there by destructive features of a fan-delta rather than the complete cessation of regressive conditions typical of areas with gentler slopes.

The Wichita-Anadarko fans did not prograde extensively into basinal areas even though the large average grain size of alluvial-fan deposits suggests sufficient relief for laterally extensive deposition. The limited lateral extent is probably due to marked basin subsidence and limited width of the source area.

Diagenetic Features

The diagenetic sequence was early cementation by calcite, alteration to and cementation by chlorite and dolomite, and later pore filling with kaolinite. The first stage, cementation by calcite, is evidenced by minor amounts of calcite found in X-ray examination. Surface exposures of Post Oak Conglomerate have calcite, illite, and kaolinite, but no dolomite. It is thought that these were probably present in the first stage of diagenesis of the West Sentinel sediments, but all of the illite and kaolinite and most of the calcite was later altered.

The second stage was alteration to chlorite and dolomite. Dolomite rhombs within chlorite suggest that dolomite cementation persisted longer than chlorite alteration (Figs. 19-21). The source of magnesium during alteration may have been from weathering of ferrmagnesium minerals in gabbroic rocks to the south.

Minor pore filling with kaolinite was the last stage of diagenesis (Figs. 22 and 23). Later hydrocarbons entered some of the pores not filled during the three stages of diagenesis (Figs. 24 and 25).

Diagenetic features apparently are related to gross facies. Facies associated with marine- or coastal-dominated environments have higher amounts of dolomite and lower amounts of kaolinite than facies associated with continental environments. This may reflect differences in composition, pore water, and porosity. The coarser continental deposits tend to contain fewer carbonate fragments than their marine-coastal counterparts, and the latter are more closely associated with fossils.

Uranium Concentration

A suggestion that the West Sentinel field fan-delta complex may have some potential for enriched uranium is the presence of two thick, high-intensity gamma-ray anomalies in the alluvial fan facies of the

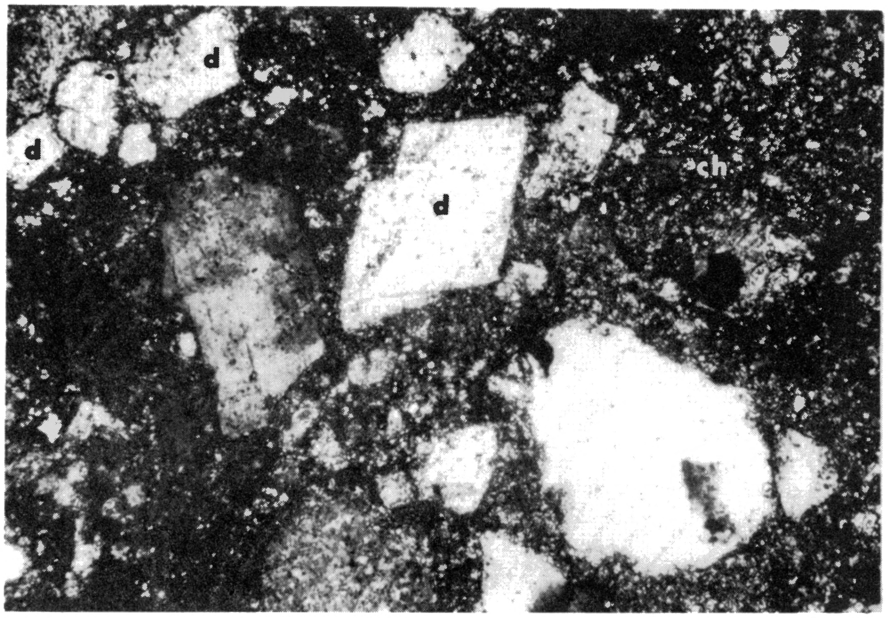

Fig. 19.-Dolomite rhombs (d) in matrix of chlorite (ch) and fine-grained carbonate cement (0.7 X 0.5 mm; crossed nicols).

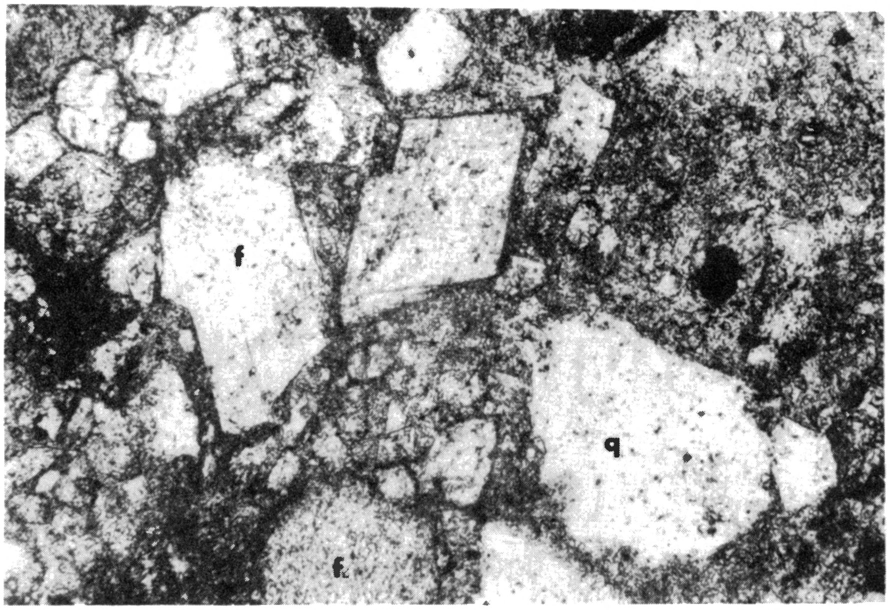

Fig. 20.-Same as above, showing corroded edges of quartz (q) and altered feldspars (f) (0.7 X 0.5 mm; plane-polarized light).

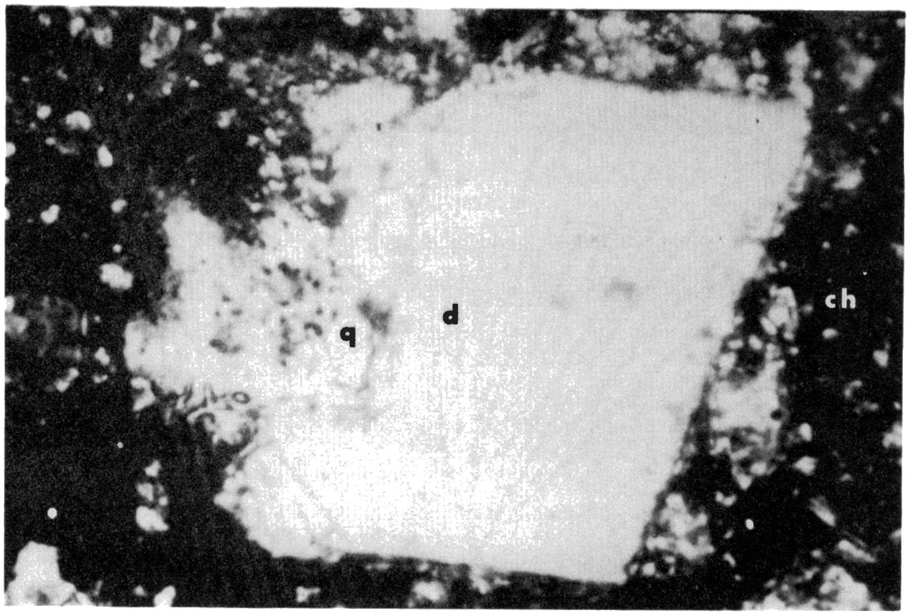

Fig. 21.-Dolomite rhomb (d) replacing quartz (q) in matrix of chlorite (ch) and fine-grained carbonate cement (0.19 X 0.13 mm; crossed nicols).

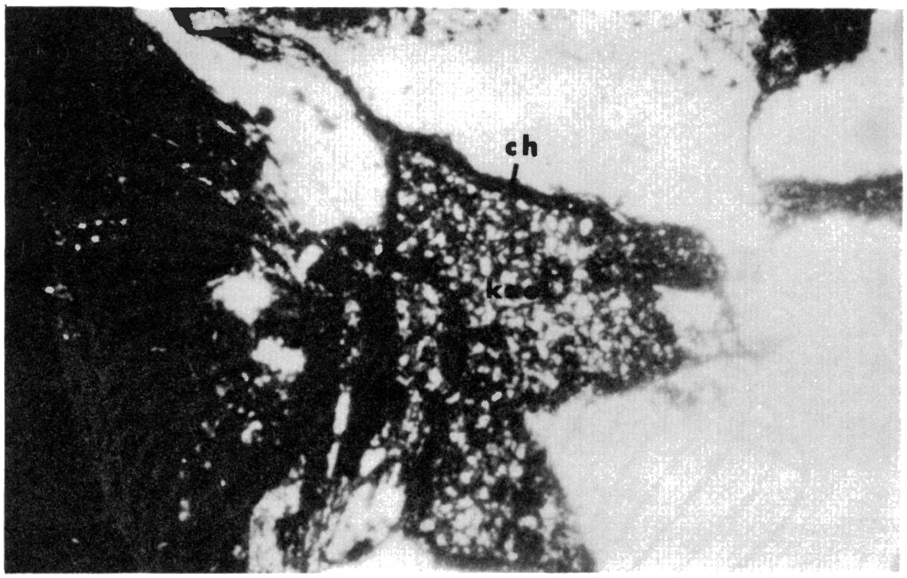

Fig. 22.-Pore with chlorite rim (ch) surrounding kaolinite (kaol) (0.7 X 0.5 mm; crossed nicols).

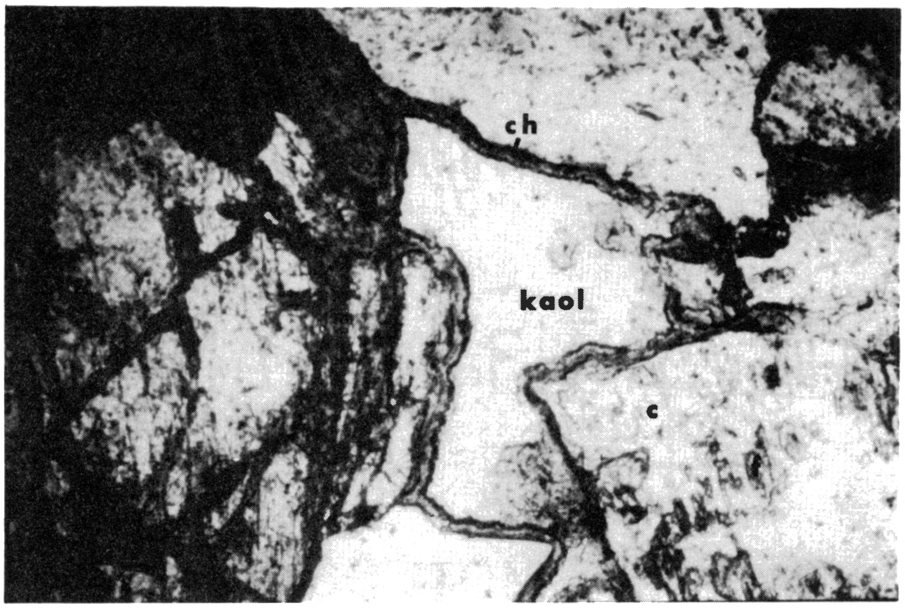

Fig. 23.-Same as above, showing chlorite rim (ch), kaolinite (kaol), and feldspar grain (f) almost completely replaced by carbonate (c) (0.7 X 0.5 mm; plane-polarized light).

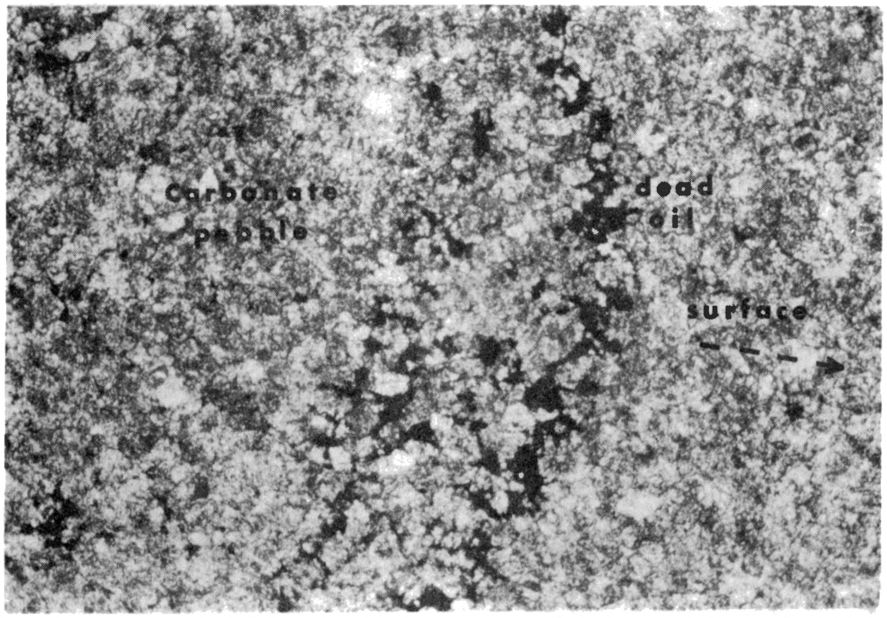

Fig. 24.-Carbonate pebble showing layer of dead oil filling intercrystalline porosity. Layers are at uniform distance from pebble surface producing "banded" cross-sections (2.5 X 1.7 mm; plane-polarized light).

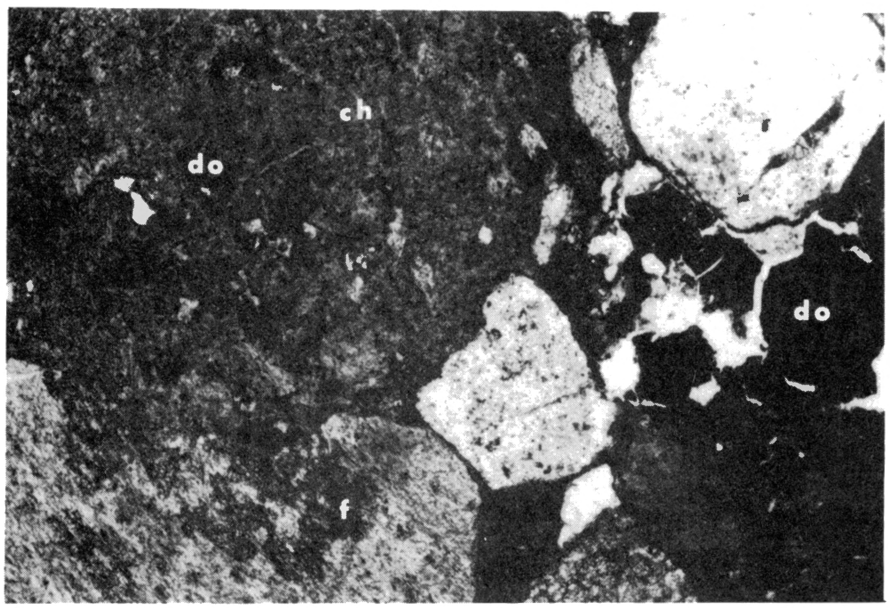

Fig. 25.-Dense chlorite (ch) pore filling with dead oil (do) in pore space, and altered feldspar (f) (2.5 X 1.7 mm; plane-polarized light).

Gulf Oil Corporation, Durland No. 1 well (Appendix B, Well No. 9; also Appendix C, Well No. 21). Several features which are related to uranium values in Permian-Pennsylvanian strata (Al-Shaieb et al., 1977b), characterize West Sentinel field rocks. They are high feldspar content, abundant carbonaceous material, associated faults, and presence of hydrocarbons.

Uranium values in core samples from an alluvial fan deposit in the Gulf Oil Corporation, Mathews No. 1 well range from 2 to 4 ppm. The alluvial fan sampled is stratigraphically equivalent to the alluvial fan showing the high-intensity gamma-ray anomaly in the Gulf Oil Corporation, Durland No. 1 well. These wells are 6 miles apart.

CHAPTER VI

GAMMA-RAY ANOMALIES

A survey of gamma-ray logs in the study area was made in order to determine anomalously high gamma-ray intensities in shallow (less than 5000 feet) "granite wash." True lithology of the anomalous zones cannot be verified in every case. Therefore, the following guides were used in designating anomalies as significant: (1) the anomalous zone must be below the shallowest occurence (top) of arkose, (2) the anomalous zone must be in conglomerate, sandstone, or siltstone (as determined by self-potential deflection on electric-log, where available), and (3) the gamma-ray intensity must be significantly higher than background. The last criteria is subjective because units of intensity measurement (API or meq Ra/ton) and intensity scales are not standardized. The scales were determined by the logging operator. Significant intensities are designated as off-scale values.

Three types of gamma-ray anomalies exist in arkosic sandstones: (1) thin (less than 20 feet), high-intensity (over 300 API) zones (Appendix C, Well numbers 3, 4, 9-11, and 13), (2) moderately thick (20 to 60 feet), moderate-intensity (over 200 API) zones (Appendix C, Well numbers 5, 15, and 17), and (3) thick (over 60 feet), low-intensity (over 150 API) zones (Appendix C, Well numbers 1, 2, 6-9, 12, 14, 16, and 18-20). The first two types are associated with nearby faults and/or hydrocarbon production. The third type is associated with shallow gas production (Plate I).

One anomalous zone of a possible fourth type (high intensity and thick interval) is in a well in the West Sentinel field at a depth greater than 5000 feet (Appendix C, Well No. 21, also, Appendix B, Well No. 9). This zone is associated with a major fault and oil production.

CHAPTER VII

SUMMARY

Principal conclusions of this study are as follows:

1. Arkosic facies of the study area were deposited as fan-delta complexes.

2. Regressive phases were culminated by coarse-grained alluvial fan deposits near the Wichita uplift which show decreases in grain size basinward.

3. Transgressive phases were culminated by fine-grained shallow marine deposits near the Wichita uplift and limestones basinward.

4. Repetitive facies sequences deposited near the Wichita uplift were, in ascending order, siltstone-shale, sandstone, conglomerate, and interbedded sandstone and siltstone-shale.

5. Fan-delta complexes near the Wichita uplift contain, in ascending order, nearshore shallow-marine deposits, coastal delta-fringe or strandline deposits, alluvial fan deposits, and reworked fan-delta deposits.

6. Diagenetic overprints indicate multiple phases of mineralogic replacement and formation.

7. The large grain size, northward decrease in grain size, and types of igneous clasts within the alluvial fan facies indicate that the source area is the Wichita uplift.

8. Indications that conditions may be favorable for uranium

concentration are high feldspar content, associated faulting, production of hydrocarbons, abundant carbonaceous material, and alluvial deposits with high porosity. Anomalously high gamma-ray intensities were noted in some zones which generally represent some combination of these factors.

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APPENDIXES

APPENDIX A

LOCATIONS OF LOGS USED IN PREPARATION OF STRATIGRAPHIC CROSS SECTIONS

No.	Operator and Well Number	Location
	West-East Stratigraphic Cross Section A-A'	
1.	Pure Oil Co., Taute #1	NW SE Sec. 34-10N-25W
2.	Northern Ordnance Inc., Crawford #1	NW SE Sec. 25- 9N-22W
3.	Gulf Oil Co., Mathews #1	NW SE Sec. 7- 8N-20W
4.	The Carter Oil Co., Galloway #2	NE NW NW Sec. 22- 8N-18W
5.	Rowan Oil Co., Smith #1	SE NW Sec. 34- 8N-16W
6.	Sinclair Prairie Oil Co., Hall #1	NW NW SE Sec. 36- 7N-13W
	West-East Stratigraphic Cross Section B-B'	
7.	Ryan Oil Co., Gordon #1	NW SW Sec. 20-10N-26W
8.	Wilcox Oil Co., Dugger #1	NW SE Sec. 12-10N-23W
9.	Shell Oil Co., Adams #1	SE SE Sec. 6- 9N-19W
10.	H. K. Clavert., Armstrong #1	SW NW Sec. 35-10N-19W
11.	Champlin Refining Co., R. T. Morris #1	SE SE NW Sec. 9- 9N-16W
	South-North Stratigraphic Cross Section C-C'	
12.	Pure Oil Co., Hudgins #A-1	NE NW NW Sec. 26- 9N-26W
7.	Ryan Oil Co., Gordon #1	NW SW Sec. 20-10N-26W
	South-North Stratigraphic Cross Section D-D'	
13.	Gulf Oil Co., Sam Day #1	SE NE SE Sec. 12- 8N-22W
2.	Northern Ordnance Inc., Crawford #1	NW SE Sec. 25- 9N-22W
14.	Pure Oil Co., Bohannon #1	SE SW NE Sec. 10- 9N-23W
8.	Wilcox Oil Co., Dugger #1	NW SE Sec. 12-10N-23W
	South-North Stratigraphic Cross Section E-E'	
15.	Champlin Refining Co., Hieber #1	SW SW NW Sec. 30- 8N-20W
3.	Gulf Oil Co., Mathews #1	NW SE Sec. 7- 8N-20W
16.	Shell Oil Co., L. J. Counts #1	NW NE Sec. 29- 9N-20W
9.	Shell Oil Co., Adams #1	SE SE Sec. 6- 9N-19W
	South-North Stratigraphic Cross Section F-F'	
17.	Radar Oil Explor. Co., Inc., Gerber #29-1	SE Sec. 29- 6N-17W
18	Schafer Oil Corp. & H. B. Alspaugh, Linstead #1	NE NW SE NW Sec. 21- 7N-17W
5.	Rowan Oil Co., Smith #1	SE NW Sec. 34- 8N-16W
19.	California Co., Reeder #1	NE NW Sec. 1- 8N-17W
11.	Champlin Refining Co., R. T. Morris #1	SE SE NW Sec. 9- 9N-16W
20.	Gulf Oil Co., Goeringer #1	NE SE Sec. 28-11N-16W

APPENDIX B

LOCATIONS OF LOGS USED IN PREPARATION OF CORRELATION SECTIONS

No.	Operator and Well Number	Location
	West-East Correlation Section G-G'	
1.	Gulf Oil Corp., Mathews #1	NW SE Sec. 7- 8N-20W
2.	Gulf Oil Corp., Hare #1	NE SW Sec. 8- 8N-20W
3.	Gulf Oil Corp., Dessie Hopkins #1	NW SE Sec. 8- 8N-20W
4.	Gulf Oil Corp., A. D. Walker #1	NE SW Sec. 9- 8N-20W
5.	Gulf Oil Corp., Miller #1	S½ NW SW Sec. 10- 8N-20W
6.	Carter Oil Company, Baumgart #1	NW SE Sec. 10- 8N-20W
	West-East Correlation Section H-H'	
7.	Amoco Production, H. D. Aldrich #1	NW NW Sec. 11- 8N-21W
8.	Gulf Oil Corp., Gaines #1	SE SW NW Sec. 8- 8N-20W
9.	Gulf Oil Corp., Durland #1	SE SE NW Sec. 8- 8N-20W
10.	Gulf Oil Corp., Crawford #1	SE SW NE Sec. 8- 8N-20W
11.	Trice Prod. Co. & Calvert Drlg. Inc., Miller #2	SE SW NW Sec. 9- 8N-20W
12.	Trice Production Co., Miller #1	SE SE NW Sec. 9- 8N-20W
13.	Gulf Oil Corp., Tyner #2	SE SW NE Sec. 9- 8N-20W
14.	Gulf Oil Corp., Tyner #1	SE NE Sec. 9- 8N-20W
	South-North Correlation Section J-J'	
2.	Gulf Oil Corp., Hare #1	NE SW Sec. 8- 8N-20W
9.	Gulf Oil Corp., Durland #1	SE SE NW Sec. 8- 8N-20W
15.	Gulf Oil Corp., Sudik #1	SE SE Sec. 5- 8N-20W
16.	Phillips Petroleum Co., Celsor #1	NW SE Sec. 28- 9N-20W

APPENDIX C

WELLS WITH GAMMA-RAY ANOMALIES

IN ARKOSIC FACIES

No.	Operator and Well Number	Location
1.	Russell V. Johnson, Jr., Reed #1	S½ SE SW Sec. 3- 9N-25W
2.	Getty Oil Company, Murray #1	NE SE Sec. 10- 9N-25W
3.	T. K. Hendrick, Duran #1	NE¼ Sec. 15- 9N-25W
4.	Occidental Petroleum Corp. & Glover, Hefner, Kennedy Oil Co., JoAnn Felton #1	SW¼ Sec. 3- 9N-22W
5.	Shell Oil Co., Whetledge #1-8	NE SE Sec. 8- 9N-22W
6.	Phillips Petroleum Co., Smith "Y" #1	SW¼ Sec. 25- 8N-26W
7.	Ardmore Drlg. Co., Holmberg #1	SW NE Sec. 1- 8N-25W
8.	Arthur B. Ramsey, Garrett #1	SE SE Sec. 34- 8N-21W
9.	Coquina Oil Corp., Hill #1	NW¼ Sec. 25- 8N-18W
10.	Skelly Oil Co., R. H. Robinson #1	NE SE Sec. 26- 8N-18W
11.	Phillips Petroleum Co., Wesner "A" #1	SW NE SW Sec. 35- 9N-17W
12.	Garrett Petroleum Co., Blaine #1	NE NE NE Sec. 16- 7N-26W
13.	H. A. Chapman Expl., Inc., Kane #1	NW SW Sec. 36- 7N-26W
14.	Thermo-Dyne, Inc., Kriska-Harris #1-14	NW NE Sec. 14- 7N-24W
15.	Omega Petroleum Co., Kourie #1	NE NW Sec. 12- 7N-23W
16.	Thermo-Dyne, Inc., State #2-13	NW¼ Sec. 13- 7N-23W
17.	Thermo-Dyne, Inc., Roberts #1-30	C¼ NE½ SE¼ Sec. 30- 7N-22W
18.	Thermo-Dyne, Inc., State #1-28	SE SE Sec. 28- 7N-21W
19.	Wyatt & Choate, Scott #2	NE NW NW Sec. 34- 6N-17W
20.	E. S. Villines et al, Funkhouser #1	NW NW SE Sec. 5- 5N-18W
21.	Gulf Oil Corp., E. G. Durland #1	SE SE NW Sec. 8- 8N-20W

VITA 2

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