THE STIGLER COAL AND COLLATERAL STRATA IN PARTS OF HASKELL, LE FLORE, MCINTOSH, AND MUSKOGEE COUNTIES, OKLAHOMA

By

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PREFACE

Prior to completion of the Kerr-McClellan Arkansas River Navigation System in 1971, the Stigler coal was being mined at one locality within the study area. With completion of the navigation system, low-cost, high volume transportation has placed coal along the navigation system in a competitive position with other fuels in areas that can be reached by barge transport. A second mining operation has begun extracting the Stigler coal since completion of the navigation system.

The advantages of gas over conventional fuel uses of coal, coupled with an increasing demand and dwindling reserves of natural gas, has intensified interest in coal gasification. The Oklahoma Geological Survey is presently committed to locating 100 million tons of recoverable coal for the purpose of supplying a gasification plant. These developments enhance the attractiveness of coal exploration in areas such as outlined in this study.

The purpose of this study is essentially twofold: (1) determine depositional environments in the interval of the Stigler coal and to attempt to show the relationship of coal occurrence to the overall sedimentologic framework; and (2) determine the distribution and quality of strippable reserves and outline those areas most favorable for surface mining.

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CHAPTER I

ABSTRACT

The study area includes approximately 825 sq mi in all or part of 31 townships in Haskell, Le Flore, McIntosh, and Muskogee Counties.

The Stigler coal is included in the McAlester Formation, Krebs Group, Desmoinesian Series, Pennsylvanian System. The study interval consists of the middle 2/3 of the McAlester Formation. The stratigraphic section is characterized by alternating, predominant shale and subordinate sandstones. The study interval thickens southeastward into the Arkoma Basin from less than 150 ft in the northwest corner of the study area to nearly 500 ft across southern Haskell and northwestern Le Flore Counties.

The shale units are primarily marine clay-shales and secondarily silty prodelta and carbonaceous marsh and swamp units. The sandstones vary from medium- to very fine-grained, moderate to well sorted, feldspar- and lithic-rich quartzarenites. Overall, general paleocurrent trend is east-southeastward. The sandstone facies are characterized by widely spaced lenticular channel sandstones with erosional bases and more widespread, thin bedded, interchannel sandstones with gradational contacts.

In general, that part of the McAlester Formation included in the study interval within the study area can be best described as a distal, mud-dominated, sequence of marine shale and sandstone, prodelta and in-

terdistributary silty shales, and delta fringe and distributary sandstones, representing an eastward prograding lobe of a large deltaic complex to the west and northwest.

The presence of numerous thin coals and underclays, including the Stigler coal, in marine shales indicates periodic, abrupt sea level changes.

Three groups of the bituminous class are represented by the Stigler coal: (1) high volatile A bituminous, (2) medium volatile bituminous, and (3) low volatile bituminous. The Stigler coal is classified as a banded coal composed primarily of vitrain and secondarily of attritus. Thickness varies from 11 to 32 inches within the study area. Sulfur content is important economically and varies from less than 1 percent to over 5 percent. Ash content varies from 2.6 to 11.6 percent and closely parallels the distribution of sulfur.

Estimated recoverable reserves total over 50 million tons. Reserves are differentiated generally according to possible utilization based on sulfur content. Utilization is divided into two groups: (1) suitability for carbonization and (2) suitability for general fuel use.

CHAPTER II

INTRODUCTION

The study area is located in east-central Oklahoma, southeast of Tulsa and west of Fort Smith, Arkansas. It includes approximately 825 sq mi in all or part of 31 townships in Haskell, Le Flore, McIntosh and Muskogee Counties (Fig. 1). Stigler is the largest town within the study area and the county seat of Haskell County. Smaller towns include Keota, McCurtain, Porum, Warner, and Webbers Falls. Communities and smaller settlements are Briartown, Hoyt, Whitefield, Lequire, Tamaha, and Cowlington.

Objectives and Methods

The purpose of this study is to provide a regional appraisal and detailed reconnaissance of favorable areas for extracting the Stigler coal by surface mining methods and to show the distribution of the quality and quantity of remaining strippable reserves and to classify these reserves generally according to suitability of use. A corollary objective is to show the position of the Stigler coal in the overall sedimentologic framework and to attempt to show the relationships of depositional controls on the quality and quantity of coal reserves within the area of investigation. The basic approach to this problem is fourfold: (1) determine depositional environments in the sedimentary interval of the Stigler coal and their relationships to distribution of coal quality and

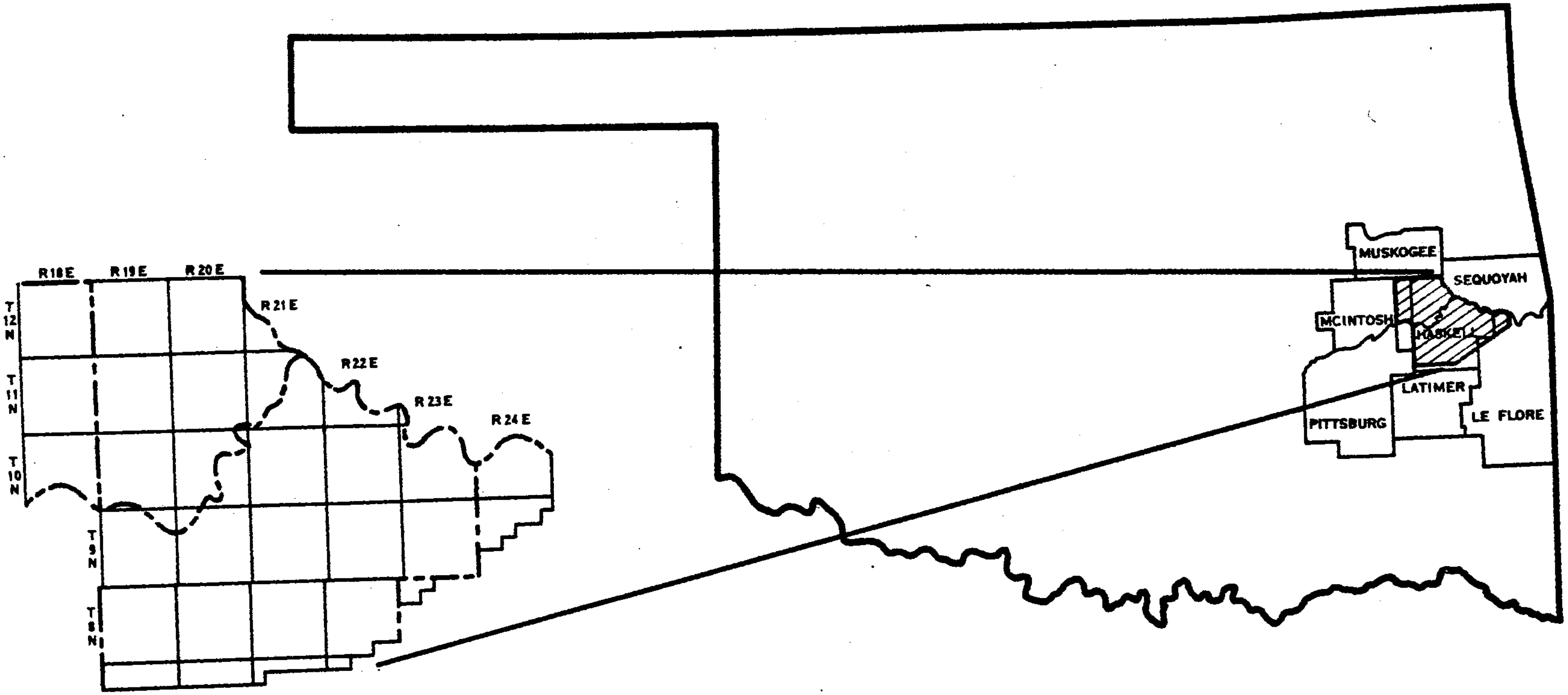


Fig. 1.-Location map of study area

reserves; (2) attempt to project these relationships to areas of limited or no control as an exploration tool; (3) approximate total reserves within the study area according to quality and suitability to use; (4) outline those areas which appear most favorable for surface mining methods of extraction.

This study relies heavily upon pre-existing published and unpublished data. The first step was the compilation of existing geologic mapping into a generalized geologic map of the study area (Fig. 2). The second step was outcrop study supplemented by core descriptions, both of which are recorded graphically on forms designed by Shelton (1963) specifically for sedimentologic study (Appendix A). The third step was collection, compilation, and plotting of data pertaining to coal thickness and quality. The last step is the calculation of strippable reserves by category and the locating of favorable areas for stripping.

Previous Investigations

Published accounts of investigations of coal resources in southeastern Oklahoma date from the late 1800's. Chance (1890), Drake (1897), Taff and Adams (1900), and Taff (1899, 1901, 1902, 1905) were among the first to make reconnaissance studies and describe the geology. Detailed mapping progressed more slowly. Wilson (1935) described and named several units within the present study area and later (Wilson, 1937) mapped parts of Muskogee and McIntosh Counties. Oakes and Knechtel (1948) mapped and described the geology of Haskell County. Knechtel (1949) mapped and described the geology of northern Le Flore County. Master's candidates have more recently remapped in greater detail the original mapping by Wilson (Coleman, 1958; Stine, 1958; Gregware, 1958; Webb, 1957). Investigations concerning characteristics of the Stigler coal are almost non-existent. Published thickness data are the most complete but are confined primarily to northern and western Haskell County. Published coal analyses from several publications are listed and referenced in Appendix B. No previous published material attempts to interpret the relationship between distribution of constituents in Oklahoma coals and possible geological controls except for percentage fixed carbon (Hendricks, 1935). Published data on reserves are even more exiguous. The most recent and realistic estimate of coal resources in Oklahoma is by Trumbull (1957). Trumbull summarized estimated remaining reserves by rank, county, and coal bed. Trumbull makes no attempt to estimate recoverable reserves by surface mining methods which is one of the primary objectives of this study.

CHAPTER III

STRATIGRAPHY AND PETROLOGY

This study is primarily concerned with the Stigler coal; therefore, discussion is arbitrarily limited to a relatively thin stratigraphic interval. The discussion of system, series, groups, and formations is brief and intended only as a framework to define the studied interval.

Pennsylvanian System

The Pennsylvanian System in Oklahoma is very nearly complete. Rocks representative of all major divisions of the Pennsylvanian System crop out in the Arkoma Basin or on the Oklahoma Platform. Rocks that crop out within the study area are Middle Pennsylvanian in age and are included in the Atokan and Desmoinesian Series.

The stratigraphic section thickens southward and eastward into the Arkoma Basin where Atokan and Desmoinesian rocks may total 15,000 ft. The section is predominantly shale with subordinant sandstones and thin coal beds. Limestones are conspicuous only in their absence.

The studied interval is in the Desmoinesian Series; therefore, further discussion is limited to rocks of Desmoinesian Series. The Desmoinesian Series in Oklahoma is generally correlative to upper Pottsvillian and Alleghenian Series of the Appalachian region and to the Strawn Series in Texas. The Desmoinesian is generally the accepted series name in the Mid-Continent and Cordilleran regions.

Desmoinesian Series

The Desmoinesian Series in Oklahoma is divided into the Krebs, Cabaniss, and Marmaton Groups. Only the Krebs and lowermost Cabaniss Groups are present in the eastern Oklahoma part of the Arkoma Basin, and only the Krebs Group and underlying Atoka Series crop out within the study area. Table I is a correlation chart of the Desmoinesian Series in Oklahoma showing the groups and formations in the Arkoma Basin and on the Oklahoma Platform.

Krebs Group

The rocks of the Krebs Group are predominantly shale. Sandstones are lenticular and individual sandstone beds are seldom continuous laterally, although intervals containing sandstone appear to maintain continuity over considerable areas. Reasons for this are discussed in Chapter IV. The Krebs Group attains a maximum thickness of 8000 ft (Oakes, 1953) near Poteau, Oklahoma, and thins northward to about 500 ft in the northwestern part of the study area.

In the Arkoma Basin and the Oklahoma Platform (Table I) the Krebs Group is divided into the Hartshorne, McAlester, Savanna and Boggy Formations, in ascending order.

McAlester Formation

The McAlester Formation was named by Taff (1899), presumably from outcrops near McAlester. Taff described the interval as consisting of a three part series: the lowest 800 ft is almost entirely shale; the middle division consists of 500 ft of section with three to four sandstone beds separated by shales 100 to 200 ft thick; the upper division consists

TABLE I

GROUPS AND FORMATIONS OF THE DESMOINESIAN SERIES, ARKOMA BASIN AND OKLAHOMA PLATFORM

Group	Oklahoma Platform	Arkoma Basin
Marmaton	Holdenville Lenapah Nowata Altamont Bandera Pawnee Labette Fort Scott	Holdenville Wewoka Wetumka Calvin
Cabaniss	Senora	Senora Stuart Thurman
Krebs	Boggy Savanna McAlester Hartshorne	Boggy Savanna McAlester Hartshorne

of 700 ft of shale with the McAlester coal approximately 50 ft above its base. Although the McAlester Formation varies considerably in thickness from the type locality in Pittsburg County to and within the study area, Taff's description easily fits the general lithologic sequence of the McAlester Formation in the latter area. In present usage the base of the McAlester Formation is the top of the Upper Hartshorne coal (Branson, 1956) and the upper contact is the top of the first shale unit above the Keota Sandstone (Oakes and Knechtel, 1948). As described previously for the major divisions of the Pennsylvanian System in the Arkoma Basin, the McAlester Formation thins northward from approximately 2800 ft near Red Oak, Latimer County (Hendricks, 1939), to about 280 ft in the northern part of the study area (Stine, 1958).

Wilson (1935) and Newell (1937) first published names of the various members of the McAlester Formation. These names are listed in Figure 3, a diagrammatic section of the McAlester Formation. Only those members indicated in the study interval, are discussed further.

Overall, the study interval (Fig. 3) is a relatively uniform southeastward thickening wedge of sandstone and shale; however, the sandstones are lenticular and usually increase in thickness at the expense of the intervening shales. In general, the studied interval increases in thickness from less than 150 ft in the northwestern corner of the study area to nearly 500 ft in southern Haskell and northwestern Le Flore Counties.

The diversity of opinions of what are correlative mappable units and the discontinuity of several members obscure stratigraphic relationships (Newell, 1937; Knechtel, 1949; Oakes and Knechtel, 1948; Stine, 1958). No characterization of a member at one locality can be extended over the entire study area. The following member descriptions represent a limited number of observations at localities of the better exposures where the more important sandstone characteristics such as contact relationships, vertical grain size changes, bedding characteristics, and sedimentary structures and their associated directional features can be seen. Each of the remaining unnamed shale members separating the sandstone is treated with the underlying sandstone except the shale interval containing the Stigler coal which is discussed separately in a manner similar to that treatment given for the sandstone members. The reason for this procedure is that the shale intervals weather easily and are either poorly exposed or not exposed at all, whereas recent stripping operations for the Stigler coal have created exposures in the overlying shale that afford opportunity for study.

Warner Sandstone and Overlying Shale. The Warner Sandstone normally

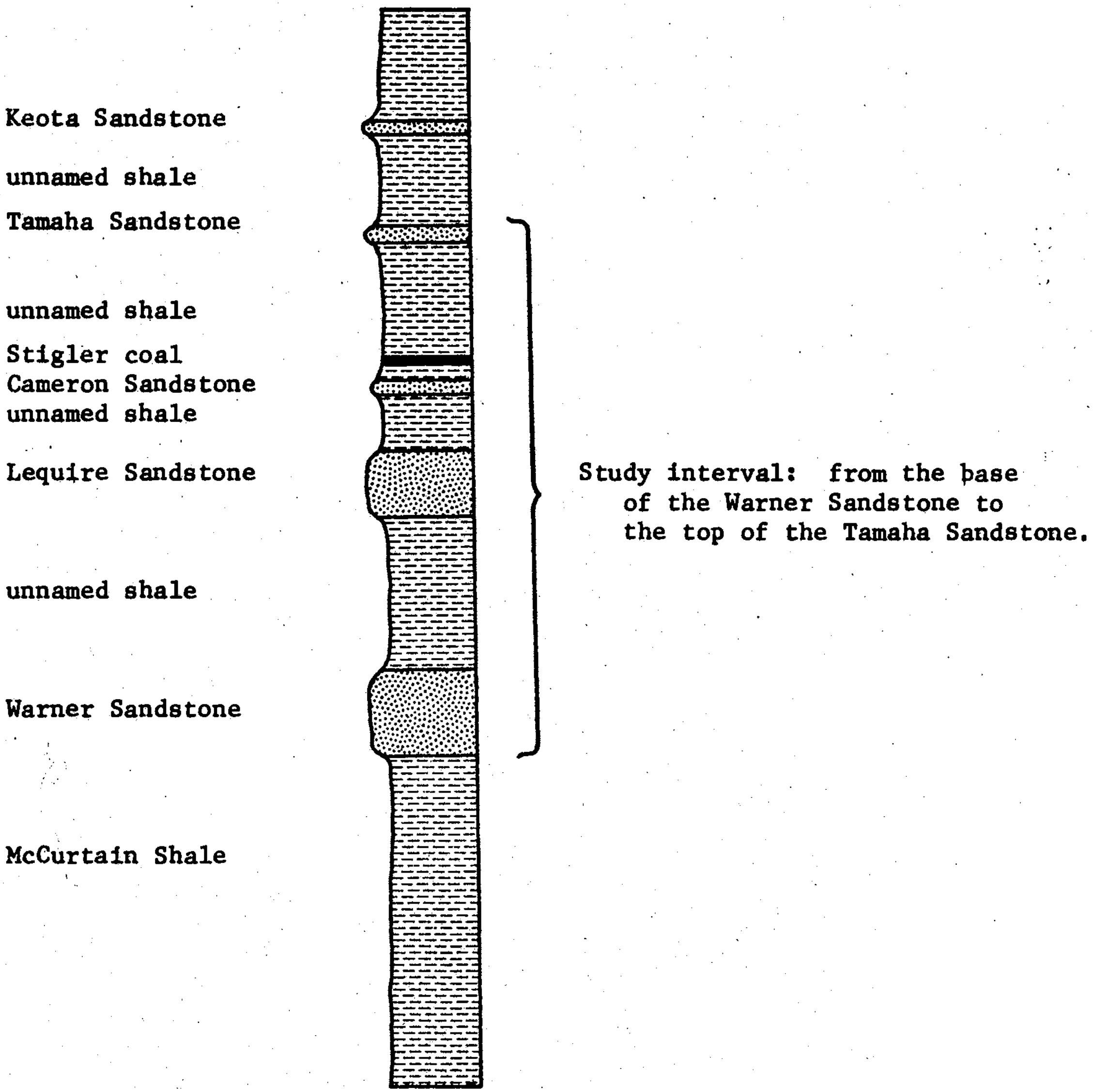


Fig. 3.-Generalized diagrammatic section of the McAlester Formation

forms prominent escarpments where it crops out, but locally topographic expression is much subdued. The Warner Sandstone varies considerably in both thickness and character across the area. The Warner can best be described as a complex interval containing two notably different genetic sequences. These are shown graphically in Section 2. The lower sequence is made up of a system of widely spaced channels with maximum thicknesses of 63 ft in Muskogee County, 50 ft in Haskell County (Sections 8, 9, and 10), and 150 ft in Le Flore County just southeast of the study area (Knechtel, 1949). Most of this lower sequence seems to maintain a thickness which laterally varies only from about 10 to 20 ft. The base is commonly gradational, although minor channeling contributes to local sharp lower contacts. Interbedding of fine- to upper fine-grained sandstone and friable siltstone is also common in this lower sequence between channels. Primarily from topographic expression, the major channels do not appear to exceed 1/2 mile in width whereas the thin interchannel sandstone seems to be present over most of the area.

Medium-scale cross-bedding and accretionary bank-slope structures (initial dip) predominate in the major channels with subordinate small-scale cross-bedding, rib-and-furrow, and parting lineation, near the top where the sandstone is finer grained. The interchannel sandstone exhibits small-scale cross-bedding and less commonly, medium-scale cross-bedding corresponding to increase in grain sizes. A few localities show parallel ripples and distorted bedding.

The channels show an overall upward decrease in grain size from upper fine- to very fine-grained sandstone with an occasional thin zone of lower medium-grained sandstone. Figure 4 provides a visual record of texture and constituents. Chert fragments are very common, usually

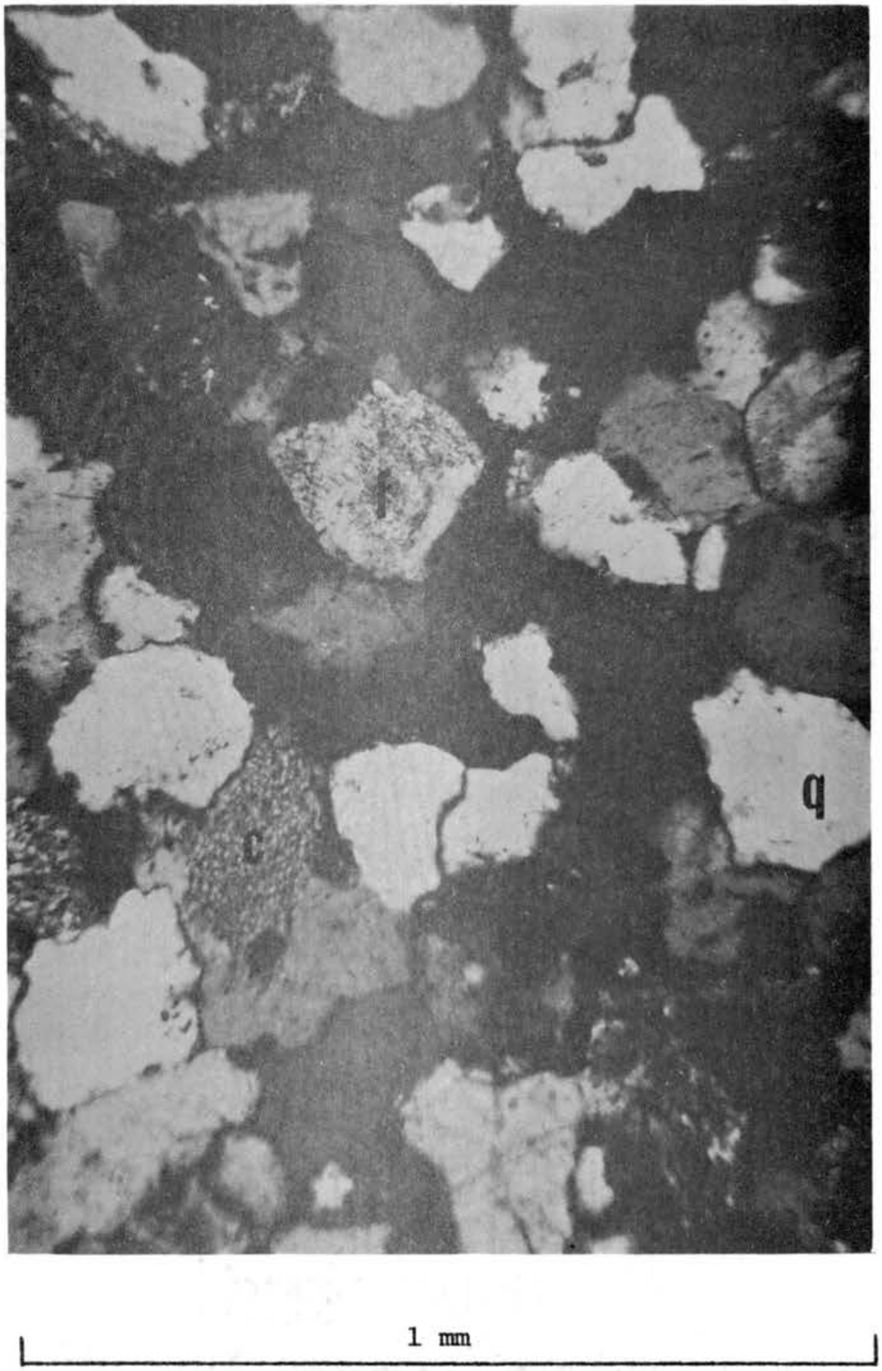


Fig. 4.-Photomicrograph of the Warner Sandstone from the lower channel sequence. The feldspar-rich quartzarenite is composed of subangular, fine-grained, well-sorted quartz (q), chert (c), and feldspar (f). Crossed nicols.

greater than 5 percent, and feldspar and other rock fragments make up about 5 percent of the sandstone. By McBride's (1963) classification of common sandstones, this sandstone would be classified as a feldspar-rich quartzarenite. Sideritic clay-drapes are abundant along with local scattered sideritic concretions (clay-ironstone). Thin intraformational clay-pebble conglomerate zones are present along with abundant wood fragments and carbonaceous zones. Calcareous cement is present locally within the Warner Sandstone in addition to finely crystalline siderite that is almost universally present in sandstones of the McAlester Formation.

A sufficient quantity of paleocurrent data was not collected to justify statistical treatment, but observed sediment transport directions generally are eastward or southeastward. Figure 5 is a reconstruction of possible channel distributions in the lower Warner sequence and is not intended to show the exact distribution but is given for comparison with the distribution of other sandstones in the McAlester Formation.

The upper sequence of the Warner complex differs considerably from the lower sequence. Its approximate limits are better defined, at least north of the Canadian River, and its characteristics are less variable. Lateral contacts were not observed nor was the upper contact clearly observable, but the lower contact is erosional and locally contains a clay-pebble conglomerate. The sandstone crops out in a southeast trending band at least 26 miles long. Width varies from 7 to 10 miles although continuity is not demonstrable everywhere within this band (Fig. 6). Maximum thickness is approximately 35 ft near Warner and its northern boundary. The interval appears to thin southward, although this may be due to weathering characteristics and subsequent erosion rather than

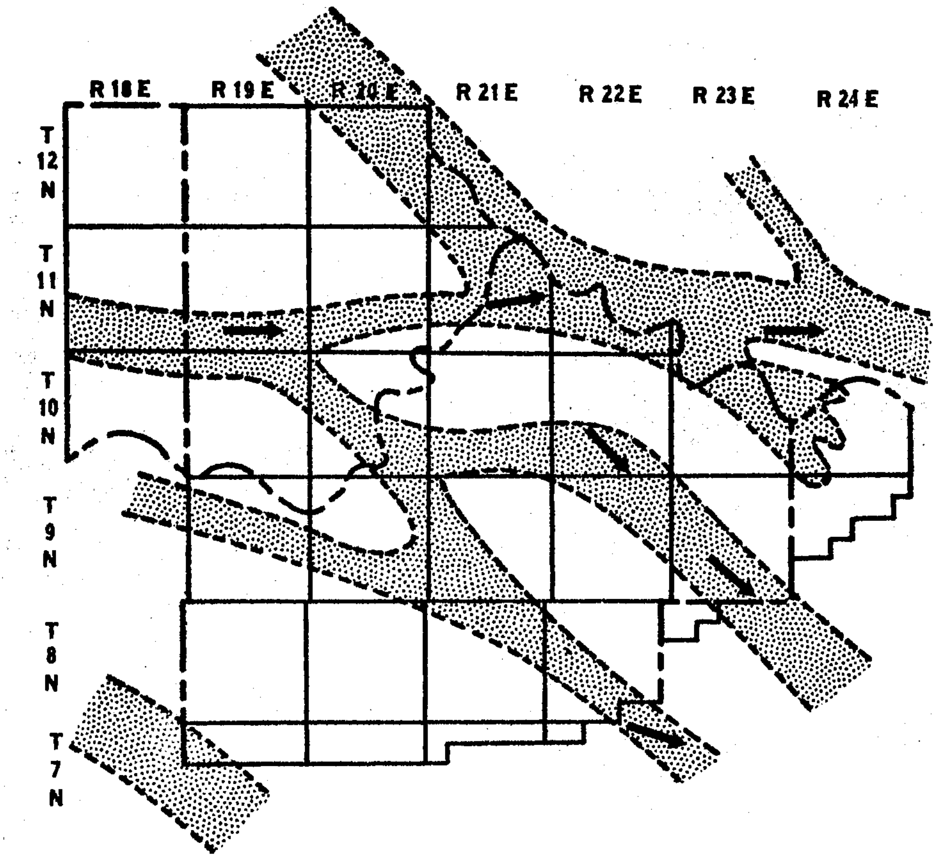


Fig. 5.-Reconstructed, inferred channel distribution and trends in the lower Warner Sandstone sequence. Paleocurrent directions are shown by arrows.

change in thickness. Near its southern boundary in T 10 N, R 20 E it appears to be only 5 to 7 ft thick. Characteristics are remarkably uniform throughout the area of development. The lower 1/2 to 2/3 of the section is characterized by medium-scale tabular cross-bed sets up to 30 inches thick which in local vertical sections show low variability in foreset dip direction, commonly less than 20° (Fig. 7). The upper 1/3 to 1/2 is characterized by penecontemporaneously deformed beds, including recumbent foresets (Fig. 8), convolute bedding, and diapiric structures. Paleocurrent directions are southeastward and are shown on Figure 6. Texturally, medium-grained quartz sand predominates. Feld-

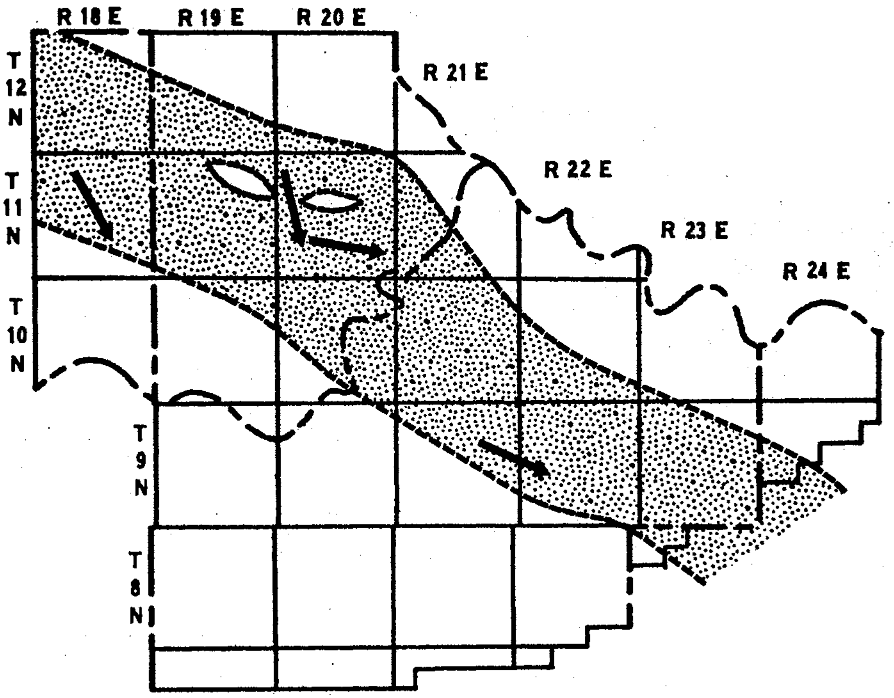


Fig. 6.-Reconstructed, inferred channel trend of the upper Warner Sandstone sequence. Paleocurrent directions are shown by arrows.

spar, rock fragments, and chert are present, as they are in all the sandstones within the McAlester Formation, in subordinate amounts of 5 to 10 percent. Vertical changes in grain size are not obvious but locally show a slight upward fining. Figure 9, although not representative of typical intergrain relationships because the thin-section was made from a well-cemented concretionary zone, show grain size, shape, and constituents. Normally, this sandstone is soft, friable, and moderately sorted.

The overlying shale which is covered for the most part, contains in southern Muskogee County several thin, lenticular sandstones which are included in a later discussion of the Cameron-Lequire interval. In Haskell County the interval is covered, but Sections 8, 9, and 10 show

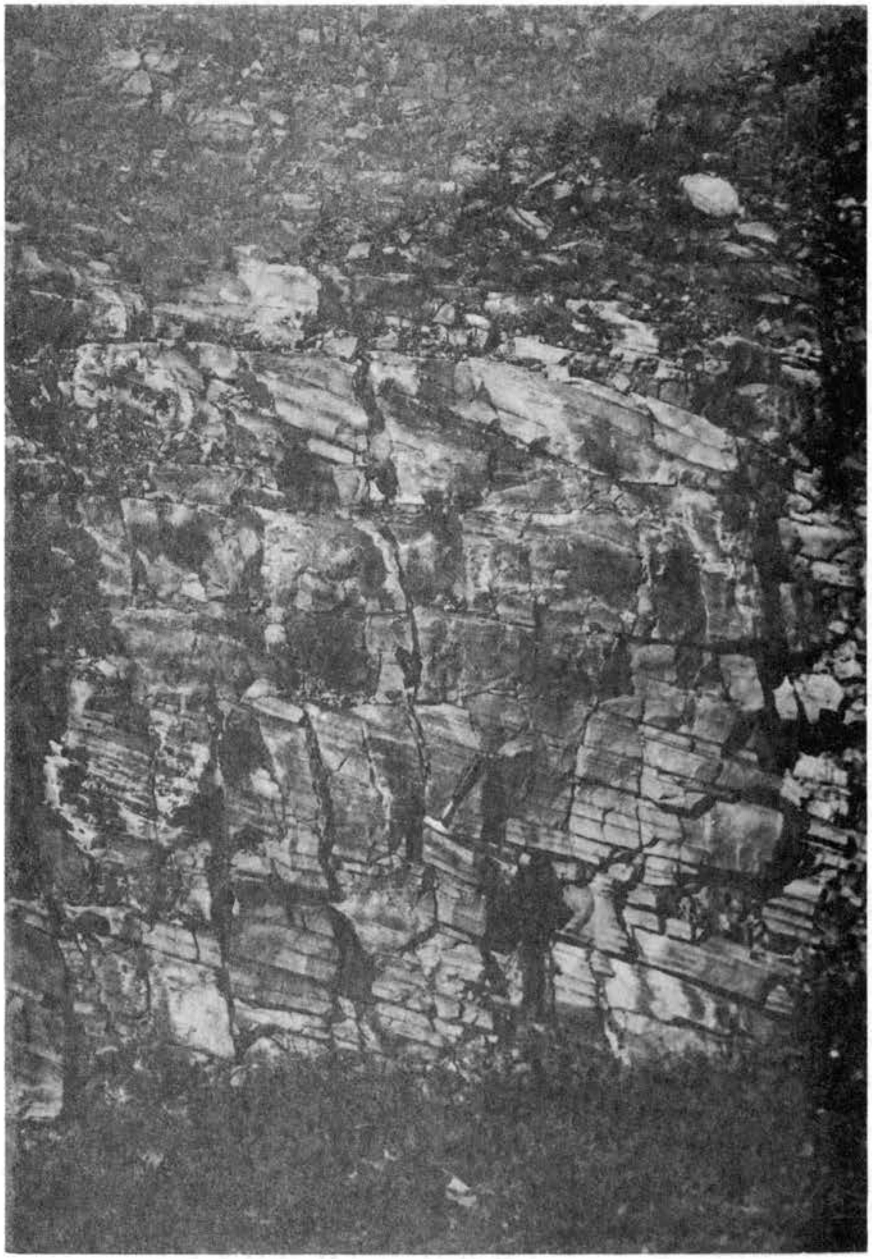


Fig. 7.-Medium scale, tabular cross-bedding in the upper channel sequence of the Warner Sandstone. View northward.

Fig. 8.-Recumbent forests, a type of penecontemporaneous soft-sediment deformation in the upper channel sequence of the Warner Sandstone. View southward.

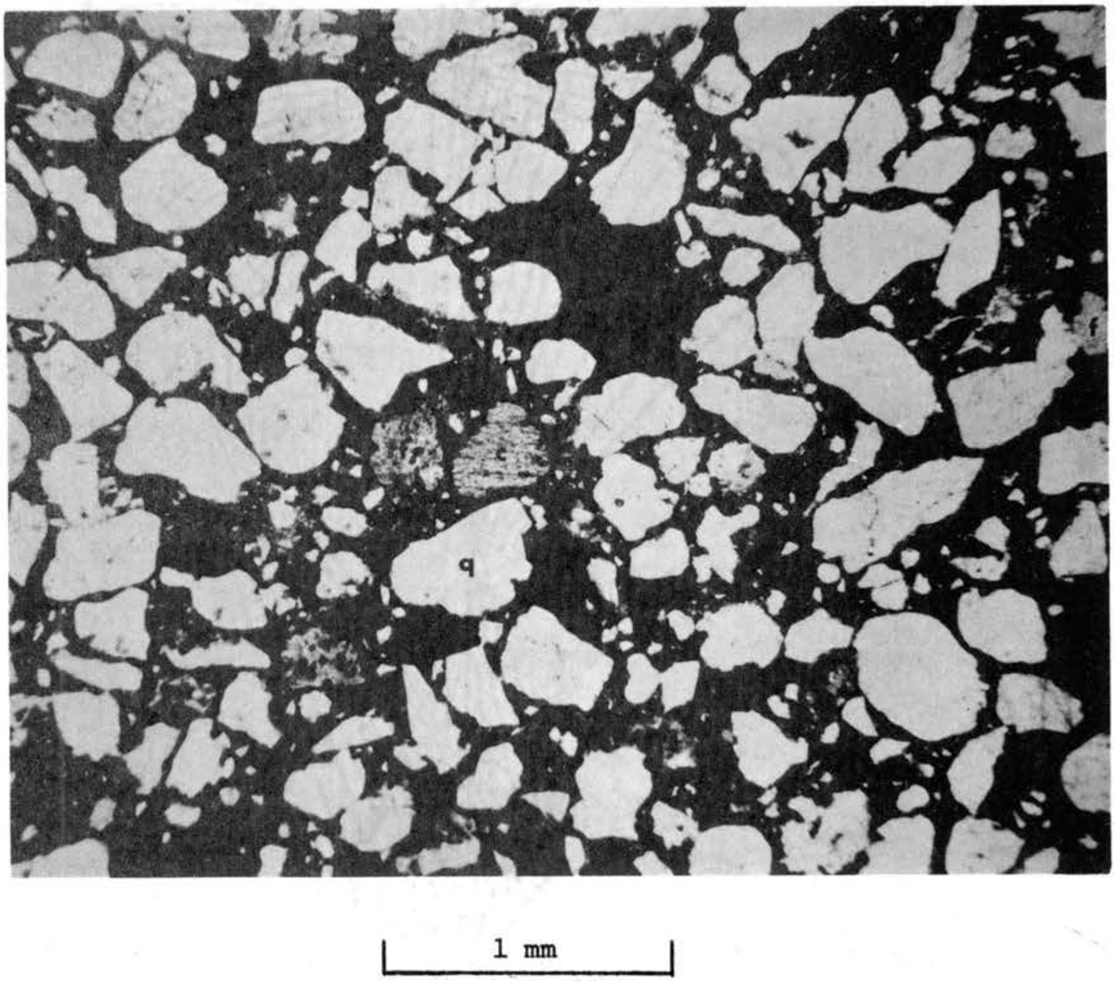


Fig. 9.-Photomicrograph of the Warner Sandstone from the upper channel sequence. The feldspar- and lithic-rich quartzarenite is composed of rounded to angular, moderately sorted, medium-grained quartz (q), feldspar (f), rock fragments (rf), and chert (c). Plane polarized light. Matrix is iron-stained carbonate, probably siderite.

the approximate thickness in that area. In northwestern Le Flore County (Section 11) only shale is present in the interval from the Warner Sandstone to the base of the Stigler coal. That part of the shale interval correlative with the shale section overlying the Warner Sandstone elsewhere is not known. By interpolation the correlative interval is about the same thickness as shown in Sections 8, 9, and 10. The interval consists of gray, fissile, micaceous shale containing marine fauna.

Lequire Sandstone and Overlying Shale. The Lequire Sandstone has many characteristics in common with the lower channel and interchannel sequence of the Warner Sandstone. Like the Warner Sandstone, the Lequire Sandstone at different localities has different characteristics. Two notable areas are NW1/4 NE1/4 Sec. 31, T 8 N, R 20 E (Section 4) and SW1/4 Sec. 28, T 9 N, R 20 E (Section 5). At the former locality the Lequire Sandstone is characterized by interbedded and interlaminated very fine sandstone or siltstone and silty shale, exhibiting flaser bedding (Fig. 10), small-scale cross-bedding, parting lineation (poorly developed and commonly distorted), convolute bedding (Fig. 11), tracks, trails and a few small vertical burrows. Vertical changes in grain size are not obvious. An apparent slight upward and downward fining from the middle is masked by the numerous interbedded shales. The upper contact is obviously gradational. The lower contact seems sharp, but this feature is evidently the result of loading the underlying unconsolidated mud with silt rather than any type of scour or erosion prior to deposition of the silt.

At the locality of Section 5 the Lequire has the same characteristics as the channels in the lower Warner sequence. The base is erosional. Present near the base are clay pebbles and cobbles along with car-

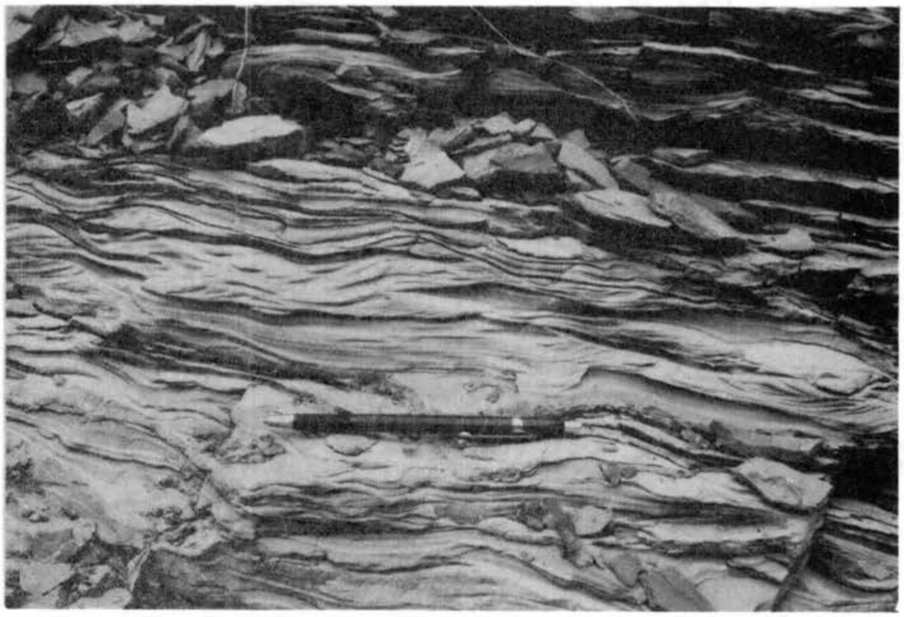


Fig. 10.-Flaser bedding in the Lequire Sandstone. View westward.

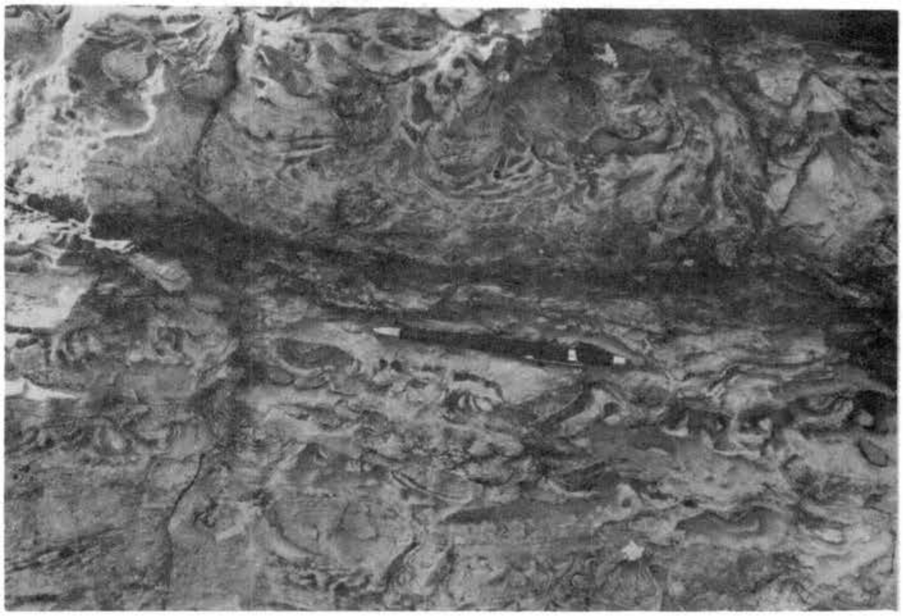


Fig. 11.-Convolute bedding in the Lequire Sandstone. View westward.

bonized impressions of wood fragments. Sand-filled casts of log fragments up to 6 ft long are also present. Texturally and mineralogically this facies of the Lequire Sandstone approximates the comparable Warner facies; namely, an upper fine-grained, well sorted, feldspar-rich quartzarenite. There is an obvious upward decrease in grain size. The lower 3/4 of the section is characterized by initial dip, horizontal bedding and, less commonly, medium-scale cross-bedding. Rib-and-furrow and parting lineation characterize the finer sandstone near the top of the section. Paleocurrent directions and sandstone distributions indicate an eastern sediment transport direction. These are shown in Figure 12.

Sections 8, 9, and 10 indicate a considerable increase in thickness eastward from the locality of Section 5. These sections also indicate lateral extension of the thicker sandstone section across T 8 N, R 21 E. This vertical and horizontal increase in sandstone is indicative of construction of a multilateral and multistoried complex. Southward and eastward from this point the Lequire thins and is represented by 10 to 40 ft of interbedded and interlaminated very fine sandstone and siltstone, rippled, calcareous, burrowed in places, and commonly has gradational upper and lower contacts. Northward from T 8 N, R 21 E, the Lequire thins along with the underlying shale until it is no longer stratigraphically distinct and is then mapped with the Warner Sandstone.

The shale between the Lequire Sandstone and overlying Stigler coal thins northward and westward from about 50 ft in southern Haskell County (Sections 8, 9, and 10) an indeterminant thickness (possibly 75 ft) in western Le Flore County (Section 11), to 20 ft or less in Muskogee and McIntosh Counties (Sections 1, 2, and 3).

This interval contains the Cameron Sandstone which is mapped as a

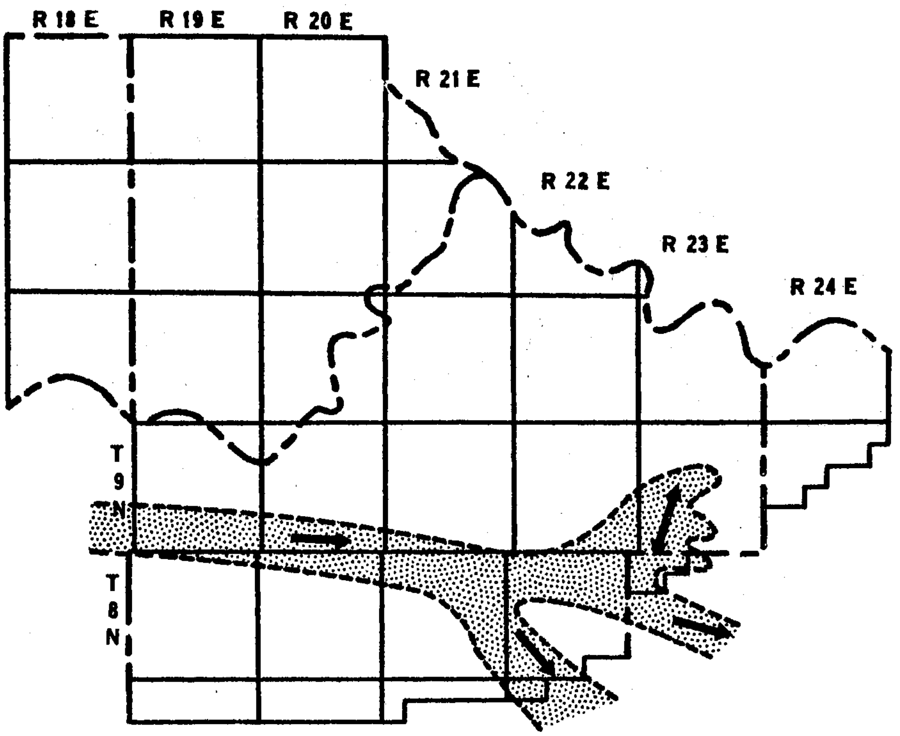


Figure 12.-Reconstructed, inferred channel distribution and trends of the Lequire Sandstone. Paleocurrent directions are shown by arrows.

distinct unit over much of northern Le Flore and Haskell Counties and informally in Muskogee and northeastern McIntosh Counties. The Cameron Sandstone is given member status in previous studies (Wilson, 1935) although most writers concede that it is discontinuous and, therefore, not necessarily a distinct mappable unit (Oakes and Knechtel, 1948; Knechtel, 1949). It is shown as a distinct unit south of the Canadian River but is mapped as Cameron-Lequire undivided north of the Canadian River (Fig. 2). South of the Canadian River the Cameron consists of only a few feet of fine-grained, oscillation ripple-marked, thin-bedded and laminated, small-scale cross-bedded sandstone, with occasional burrows, tracks and trails. The same characteristics are generally exhibited northward in Muskogee County; however, Stine (1958; Section 3) reports a local thickness exceeding 15 ft in SE1/4, T 10 N, R 19 E. In Ts 10 and 11 N, R 20 E additional thin lenticular sandstones are present in the interval (Section 2). These seldom exceed 2 ft in thickness and are very lenticular, fine-grained, and are characterized by linguoid and rhomboid ripples. The intervening shales are silty and variegated. Paleocurrent directions are variable and may be bimodal. Thin section analysis indicates a mineral suite comparable to those previously discussed for other members in the McAlester Formation.

Stigler Coal and Overlying Shale. A discussion of the characteristics and distribution of the Stigler coal is given in Chapter VI. The Stigler coal is entirely within a shale sequence that thins northwestward. The rate of thinning is less in the interval above the coal than that below the coal. Normally the Stigler coal has a well-developed underclay about 1 1/2 to 2 ft thick, but locally it is less than 1 ft thick.

The shale interval from the Stigler coal to the base of the Tamaha Sandstone ranges from about 90 ft in southern Haskell County (Sections 9 and 10) to 40 ft in the extreme northwestern corner of the study area. This same interval in eastern Haskell and northwestern Le Flore Counties (Section 11) is either over 200 ft thick or the Tamaha Sandstone is absent. The latter is probably the case since there is no sandstone in that interval cropping out farther south.

One of the most important determinations in this study is the character of the rock immediately above the coal. Observations were limited by the lack of good exposures above the coal. Although many strip pits and prospects have been made along the outcrop most are weathered or filled with water; therefore, observations are from present mining operations, the more recently abandoned operations and from cores. The Garland Coal and Mining Company is presently operating northeast of Stigler in Sec. 33, T 10 N, R 21 E, and the Sierra Coal Corporation is operating northeast of Porum in Sec. 13, T 11 N, R 19 E. Observations of cores from Robert S. Kerr Lock and Dam (Section 11) supplement and substantiate findings from the active pits. Sections 1, 2, 3, 7 and 11 show graphically in some detail the characteristics of the rock above the Stigler coal. A notable relationship that seems valid is that of sulfur content within the coal to character of the overlying shale. Analyses of coal samples from the locality of Sections 1, 3, 7, and 11 show sulfur contents less than 1 percent. The shale above the coal at these localities lack marine affinities. Analysis of coal at the locale of Section 2 has a high sulfur content (nearly 4 percent). The shale at this locality has definite marine affinities which include marine fauna, a thin limestone, and a much lower content of carbonaceous matter. Locales not showing marine affinities normally contain abundant carbonaceous matter above the coal, numerous carbonized leaf and plant fragments and a lack of fauna.

Northeast of Stigler (Section 7) approximately 22 ft above the Stigler coal is a thin fragmental algal limestone (Fig. 13) 1 to 7 inches thick. This limestone rests immediately upon a thin coal 1 to 4 inches thick commonly referred to as the "rider vein". An underclay and root-disturbed zone underlies the thin coal. Upward from this zone a few scattered pelecypods and some other unidentified type of fossil are found on the upper surface of siderite concretions. Thirty-five ft above the "rider vein" is an abundantly fossiliferous concretionary band containing

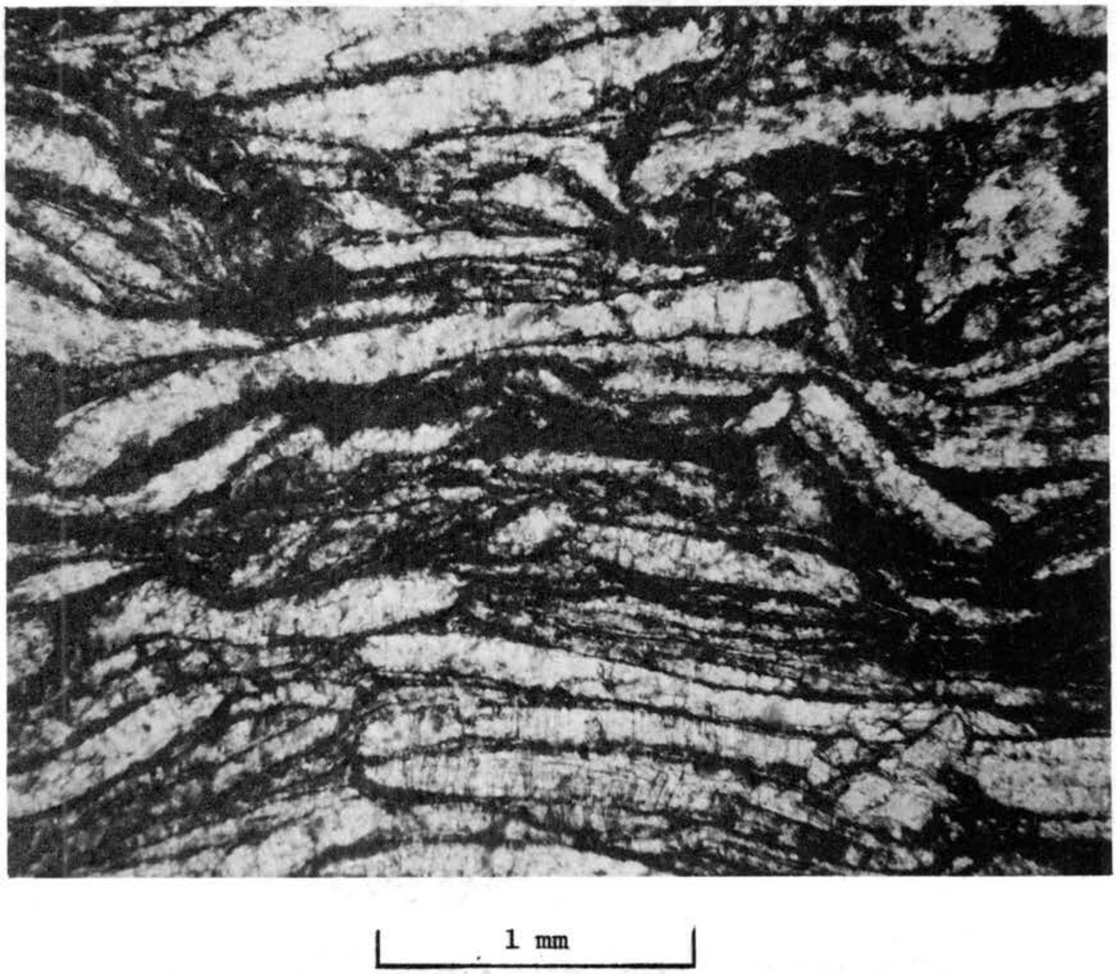


Fig. 13.-Photomicrograph of fragmental algal limestone capping the "rider vein" 22 ft above the Stigler coal. Black material between the algal plates is carbonaceous matter. Plane polarized light.

crinoid fragments, bryozoans, and pelecypods (Fig. 14). The shale a few ft above this zone contains burrows (bioturbated bedding). The bedding is increasingly bioturbated upward as the shale becomes increasingly silty and micaceous. The bioturbated nature of the bedding continues upward into the Tamaha Sandstone.

Tamaha Sandstone. The Tamaha Sandstone has its best development northeast of Stigler in the vicinity of Tamaha. In that locale it is 20 to 25 ft thick (Section 7). Northward from this area mapping is incomplete and the Tamaha has not been described. Eastward, southward, and westward the Tamaha thins until it is no longer mapped. Near Tamaha the sandstone is characterized by gradational upper and lower contacts, small-scale cross-bedding, some horizontal bedding, and a great deal of burrowing which has destroyed most other sedimentary structures. Texturally, the Tamaha is composed of micaceous, weakly calcite cemented, very-fine, well-sorted, predominantly quartz sand with finely divided carbonaceous material throughout. Outward from this area as the Tamaha thins it is more commonly interbedded and interlaminated with shale, is oscillation ripple-marked, and burrows are replaced by tracks and trails. The Tamaha, like the Cameron, is not laterally continuous and commonly is not shown locally on existing geologic maps.

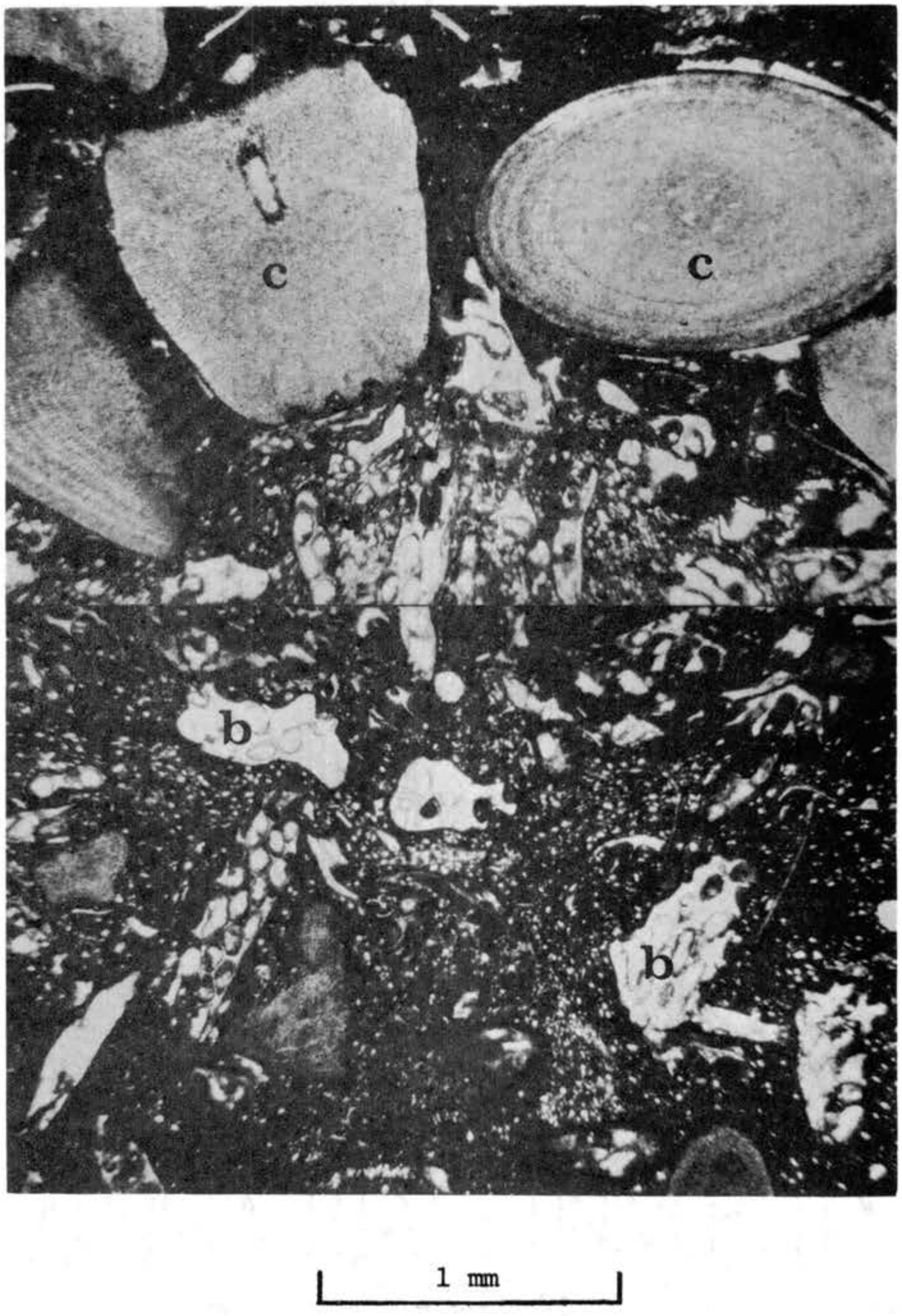


Fig. 14.-Photomicrograph of fossiliferous concretionary band in the shale interval between the "rider vein" and the Tamaha Sandstone. The zone contains detrital fragments of crinoids (c), bryozoans (b), pelecypods, and other fossils. Plane polarized light.

CHAPTER IV

DEPOSITIONAL FRAMEWORK

Rocks of the McAlester Formation within the study area are representative of several depositional environments, all interrelated within the overall sedimentologic framework. Interpretations are based upon the criteria outlined in the preceding chapter and inferences made from the work of others on sedimentary processes of correlative and other Pennsylvanian strata in the Arkoma Basin.

Most of the literature prior to 1960 alluded to a land mass somewhere south and east of the present Ouachita System supplying most, if not all, of the Pennsylvanian sediment to the Arkoma Basin and northward. Common arguments at that time for a southern source included a higher percentage of sand in clastic ratios in the south, a southward increase in thickness, and a greater number of marine limestones in the north.

Busch (1953) recognized from sandstone distribution patterns and geometry the presence of a deltaic distributary system in the subsurface of central Oklahoma at the stratigraphic position of the McAlester Formation. This pattern strongly suggests a northern source (Fig. 15). Briggs (1963) in a paleocurrent study of Mississippian and Pennsylvanian rocks in the Ouachita Mountains and Arkoma Basin noted that paleocurrents indicate a southward sediment transport direction for Pennsylvanian rocks in the Arkoma Basin. McDaniel (1968) interprets deltaic sedimentation

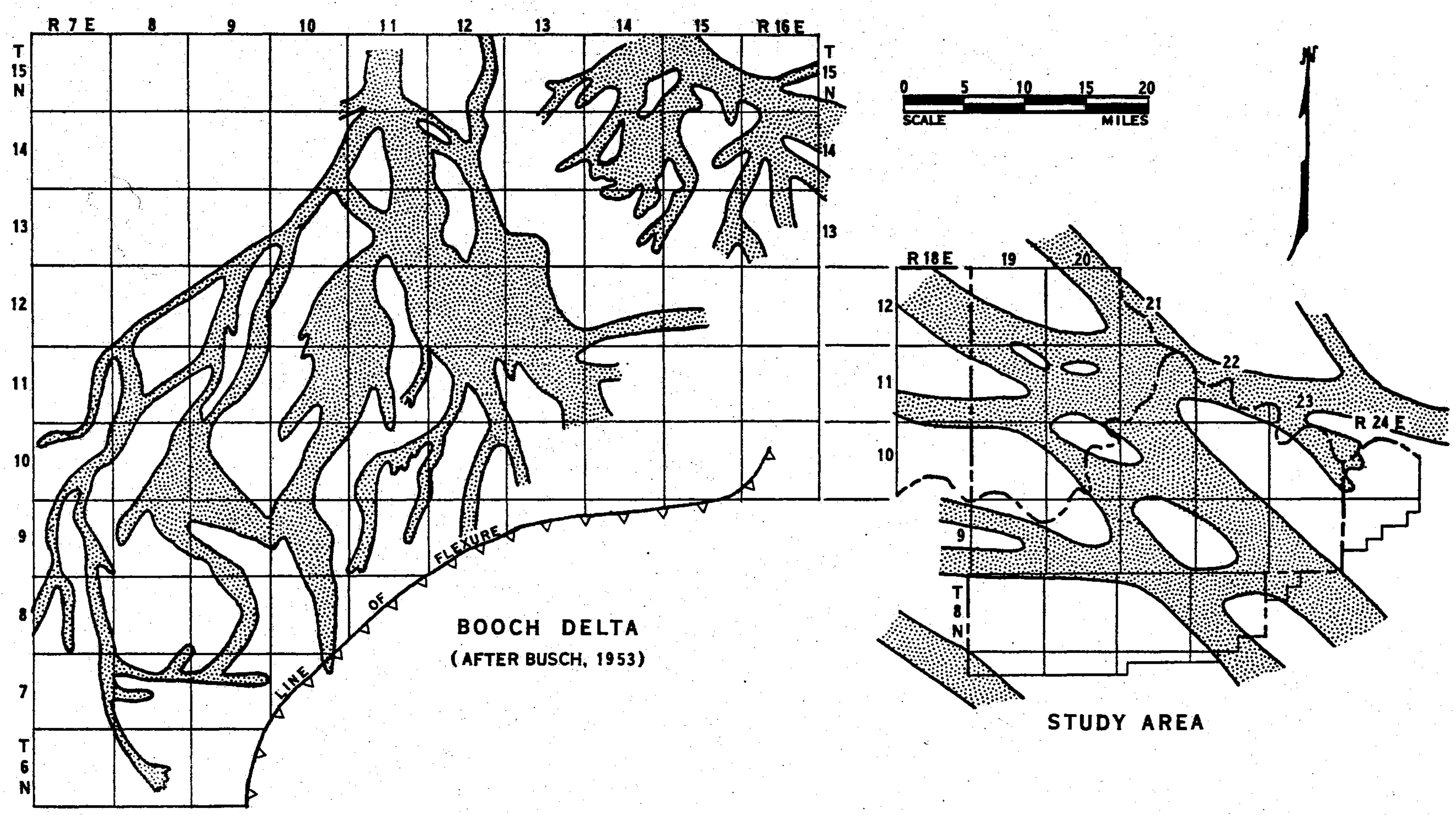


Fig. 15.-Subsurface delta distributary patterns in the subsurface Booch Sandstone and their position relative to channels in the correlative Warner and Lequire Sandstone interval at outcrops in the study area. Stippled area is where sandstone thickness exceeds 20 ft.

in the Hartshorne Formation (immediately beneath the McAlester Formation), with paleocurrents indicative of sediment transport from an eastern or northeastern direction. Limited personal observations of a sandstone in the Savanna Formation (immediately above the McAlester Formation) near McAlester also suggests deltaic sedimentation and a northern source for sediment. Visher (1968) demonstrates the presence of a large southeastward prograding deltaic sequence, represented by the Bluejacket Sandstone of the Boggy Formation.

Observations made in the course of this study substantiate the latter proposition; that the ultimate source of sediment may have been to the north, although within the study area paleocurrent and channel trends indicate the immediate source of sediment was to the west and northwest.

Channels within the lower Warner sequence and the Lequire Sandstone are interpreted as deltaic distributaries. The sandy and silty facies associated with these distributaries are considered to be delta front, delta margin, deltaic plain, interdistributary or natural levee environments. The Lower Warner and Lequire Sandstones represent two sequences of distal delta-lobe progradation eastward from the delta-depocenter represented by Busch's "Booch Delta" (Fig. 15). The upper sandstone facies of the Warner Sandstone is interpreted as an alluvial sequence which probably was deposited during maximum regression. The thinness precludes development of a multistoried unit which possibly lends evidence that the alluvial conditions existed a relatively short time.

The Tamaha Sandstone is interpreted as having been deposited in a shallow marine environment. Gradational contacts, thin-bedding, extensive burrowing, calcite cement, and very-fine, well-sorted sand is evidence for interpretation of deposition in a shallow marine environment. In the area around Tamaha where the Tamaha Sandstone is 20 to 25 ft thick, the presence of extensive burrowing in sandstone with few shaley interbeds indicates accumulation of sand more slowly than would be expected near a deltaic system where sediment influx is greatest.

The Cameron Sandstone has many of the same characteristics as the Tamaha but is thinner and so poorly exposed in the study area that environmental interpretations cannot be made with confidence.

Fauna observed in the McAlester Formation were from shale intervals and include genera Aviculopecten, Bellerophon, Cymatospira, Euphemites, Goniasma, Nuculana, Nuculopsis, and Worthenia, all of which are marine forms tolerant of salinity changes and turbid conditions. Gastropods and pelecypods are the most common. From fauna content and lithologic characteristics the shale of the McAlester Formation within the study area is interpreted as being deposited primarily in a shallow marine environment and secondarily in prodelta, interdistributary, marsh, and swamp environments.

Numerous thin coal beds attest to swampy conditions over much of the area at various times. The Stigler coal appears to have accumulated on a marine or prodelta mud surface indicative of a rapid regression that could have been caused by regional tectonic activity or eustatic change in sea level. The Stigler coal is either immediately overlain by marine shale or by marsh or swamp carbonaceous shales which grade upward into marine units. The great number of underclay developments within a short stratigraphic interval beneath the Stigler coal shown in Section 11, in marine shales suggest abrupt relative sea level changes.

Overall, that part of the McAlester Formation included in the study interval within the study area can be best described as two distal, mud-dominated, deltaic sequences which prograded eastward from a large deltaic complex to the west and northwest.

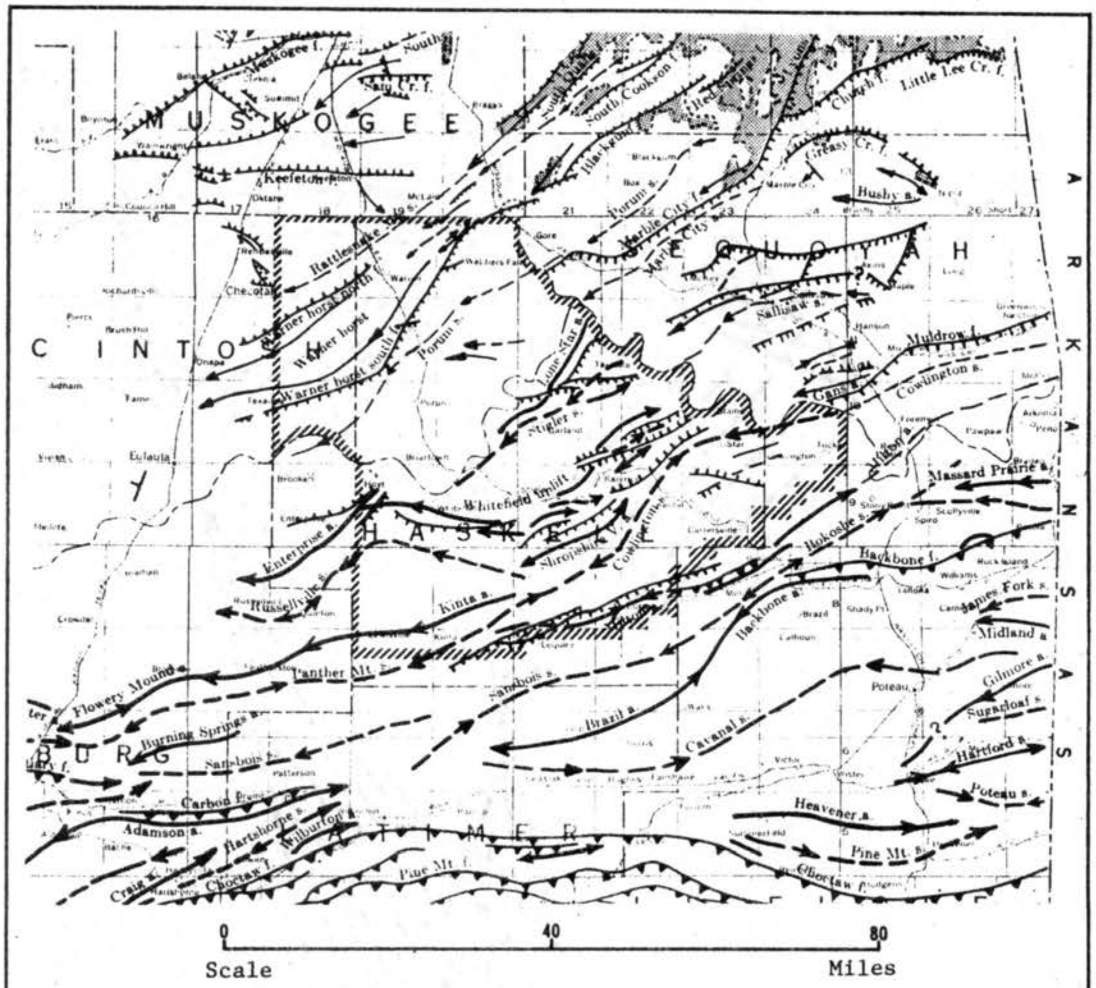
The two delta lobes represent cyclic sequences which were probably generated by a combination of eustatic changes in sea level and "channel-shifts" and "delta-switching" farther west and upstream in the main distributary system. The terms "internally" and "externally generated cycles" are proposed by Coleman and Gagliano (1964) to express the nature of control for cyclic deposition. Internally generated cycles are produced by depositional processes such as "channel-shifts" and "delta-switching". Externally generated cycles are produced by regional tectonic activity or eustatic sea level changes. Externally generated cycles seem evident in the McAlester Formation from the presence of coal and underclay zones developed on marine mud surfaces. A possible sequence of events for deposition of the Stigler coal include a relatively rapid lowering of sea level with subsequent peat accumulation in a laterally continuous sheet geometry, followed by transgression and deposition of swamp, marsh, and marine muds. Whether the peat-forming material accumulated during the transgressive phase, regressive phase or both during this abrupt cycle is not known. Eustatic sea level changes could be responsible for these cycles. Wanless (1969) cites the Lexington coal in Missouri, and the Mystic coal in Iowa as examples of coals accumulating in areas of abrupt marine regression which is suggested for the Stigler coal.

CHAPTER V

STRUCTURE

Structure and topography, by virtue of their control on overburden depth, govern areal limit that can be economically surface mined. Because the Stigler coal crops out within a shale sequence and the overlying Tamaha Sandstone only locally creates much topographic expression, structure is the more influential consideration of the two in limiting stripping operations.

Regionally, the study area is influenced by the Ozark tectonic province and the Ouachita system (Arbenz, 1956; Fig. 16). North of the Canadian River the prevailing structural feature is a regional dip of about 2° west-southwest that is locally modified by a series of southwest trending normal(?) faults and gentle folds (Wilson, 1937). According to Wilson, joints in sandstones north of the Canadian River "seem usually to be referable to two main systems, one striking about N 37° W and the other about N 85° E". Melton (1931) made joint studies from Missouri to central Texas in Pennsylvanian and Permian rocks. Strike directions were of two sets: N 15° W to N 55° W and N 35° E to N 75° E. Strike sets measured by Wilson striking northwest fit within Melton's first set, but Wilson's northeast striking set is oriented more east-west than Melton's second set. Melton interprets the joints along with other factors as indicating a late Permian or post-Permian regional uplift of the combined area of "Llanoria" and the Ozark region. South of



EXPLANATION

▨ Boundary of Study Area

ABBREVIATIONS	
a.	anticline
s.	syncline
am.	anticlinorium
sm.	synclinorium
f.	fault
gr.	graben
Cr.	creek
V.	valley
Mt.	mountain

SYMBOLS

ꞱꞱꞱꞱꞱꞱ High angle normal or reverse fault. Hachures on downthrown side.

▲▲▲▲▲ High angle or low angle reverse fault. Teeth on upper plate.

⟶ Anticline

– – – → Syncline

After Arbenz, 1956

Fig. 16.-Local and regional structural features

the Canadian River the area is characterized by doubly-plunging synclinal and anticlinal flexures. The folds are commonly asymmetric, roughly parallel, and trend primarily northeast-southwest and secondarily east-west. Fold intensity decreases northwestward away from the Ouachita system. Oakes and Knechtel (1948) believe that many of the numerous faults in Haskell County are associated with the folds.

At least three tectonic styles seem evident. First, basin subsidence was probably characterized by growth faulting although no growth faults are specifically recognized within the study area. Second, the folds are a result of compressional stress that produced thrust faults farther south. The structural grain of the folds, however, does not conform to that of the thrust zone directly south. If only one episode of thrusting and folding with the maximum principle stress oriented in one direction was the case, then the structural grain within the thrust belt should conform more closely to that of the folded belt. Possible explanations include multiple episodes of compression with different orientations for the maximum principle stress, or the orientation of the present folded structures could be controlled by pre-existing basin configuration and structural features which developed during basin subsidence (Harris and Zietz, 1962). A third structural style is indicated by normal faults, particularly those downthrown to the south, superimposed on the folds. These faults developed after folding and may be a result of basin readjustment following Ouachita tectonic activity and/or regional uplift.

The outcrop of the Stigler coal in the study area is influenced primarily by eight structural features. From southeast to northwest these include the Milton anticline, Cowlington syncline, Kinta anticline, Russellville syncline, Stigler syncline, and the Warner horst bounded on the southeast by the Porum syncline and on the northwest by the Rattlesnake Mountain syncline. Numerous unnamed faults are present. Absolute displacement is not known for most of the faults but relative displacement is shown in Figures 2 and 16. From outcrop patterns all the faults appear to have vertical displacements less than a few hundred feet. These faults limit areas that could be surface mined. For example, in T 9 N, R 23 E the outcrop of the Stigler coal is offset more than 2 miles; in the southwestern corner of T 11 N, R 22 E the structural dips vary considerably on either side of the fault; and in the Warner horst the Stigler outcrop is displaced westward at least 6 miles.

Of primary concern to this study is structural dip. As mentioned previously, intensity of folding decreases northward and northwestward and dips become more gentle. In effect, the areal limit that can be surface mined generally increases in that direction. Quantitatively, in terms of reserves, the Stigler syncline and the Porum syncline are the most important structural features. Both are asymmetrical with steeper flanks to the northwest. The southeastern flanks have structural dips locally less than 1°. These two areas alone contain the bulk of strippable reserves. This fact demonstrates the importance of structure in delimiting areas where sufficient reserves warrant surface mining.

CHAPTER VI

CHARACTERISTICS AND CONSTITUENTS OF THE STIGLER COAL

Coal is formed from accumulations of plant remains modified by chemical, biological, and physical processes during and after burial (Williamson, 1967). The characteristics and constitution of coal are controlled by these modifying processes. The properties of the Stigler coal are likewise influenced by these processes, but due to the limited scope of this study no effort is made to correlate these processes to the properties of the Stigler coal. Those readers interested in the origin of coal are referred to White et. al. (1913).

The primary purpose of this study relative to the properties of the Stigler coal is to discuss the characteristics and constituents that directly influence mining economics. These are grouped under four major headings: classification, thickness, sulfur content, and ash content. That part under classification concerning lithologic class and physical components is primarily of academic interest but should be included in any disucssion of coal classification.

Classification

There are many methods of coal classification. Practically every chemical and physical characteristic as well as commercial description has been proposed for the classification of coal. The most common classifications are by type, rank, grade, and components. These, in turn, are based upon chemical analyses and physical characteristics. Classification by type may be according to botanical evidence, age of the coal, and general appearance (commonly banding). Classification by rank is based upon the percent fixed carbon, volatile matter, and Btu, determined from proximate analyses. Classification by grade is based upon calorific value, ash content, ash-softening temperature, sulfur content, and breaking characteristics. Classification by composition is based upon megascopic or microscopic recognition of the various components. This kind of classification is sometimes included with classification by type. Classification of the Stigler coal in this study is limited to megascopic components and to rank, which is most commonly used.

Rank

The classification by rank used in this study is according to the American Society for Testing Materials (1971). This classification is reproduced in Table II. The basis for rank classification is the percentage of fixed carbon or volatile matter, and the calorific value expressed in British thermal units (Btu) per pound.

Values used in the classification of the Stigler coal are calculated from proximate analyses (Appendix B) to the mineral-matter-free basis using approximation formulas (ASTM, 1971).

Analyses indicate the Stigler coal over the entire area is of the Bituminous class. Three groups are represented: low volatile bituminous, medium volatile bituminous, and high volatile A bituminous. The distribution of these groups is shown in Figure 17. The boundary between low and medium volatile bituminous coal corresponds to the 78 percent

TABLE II

CLASSIFICATION OF COALS BY RANK

Class	Group	Fixed Carbon Limits, percent (Dry, Mineral-Matter-Free Basis)		Volatile Matter Limits, percent (Dry, Mineral-Matter-Free Basis)		Calorific Value Limits Btu per pound (Moist,[2] Mineral-Matter-Free Basis)		Agglomerating Character
		Equal or Greater Than	Less Than	Greater Than	Equal or Less Than	Equal or Greater Than	Less Than	
I. Anthracitic	1. Meta-anthracite	98	...	...	2	...	...	non-agglomerating
	2. Anthracite	92	98	2	8	...	...	
	3. Semianthracite[3]	86	92	8	14	...	...	
II. Bituminous	1. Low volatile bituminous coal	78	86	14	22	...	...	Commonly agglomerating[5]
	2. Medium volatile bituminous coal	69	78	22	31	...	...	
	3. High volatile A bituminous coal	....	69	31	...	14 000[4]	...	
	4. High volatile B bituminous coal	....	...	...	...	13 000[4]	14 000	
	5. High volatile C bituminous coal	....	...	...	...	11 500	13 000	
						10 500	11 500	agglomerating
III. Subbituminous	1. Subbituminous A coal	....	...	...	...	10 500	11 500	non-agglomerating
	2. Subbituminous B coal	....	...	...	...	9 500	10 500	
	3. Subbituminous C coal	....	...	...	...	8 300	9 500	
IV. Lignitic	1. Lignite A	....	...	...	...	6 300	8 300	
	2. Lignite B	....	...	...	...	...	6 300	

[1] This classification does not include a few coals, principally nonbanded varieties, which have unusual physical and chemical properties and which come within the limits of fixed carbon or calorific value of the high-volatile bituminous and subbituminous ranks. All of these coals either contain less than 48 percent dry, mineral-matter-free fixed carbon or have more than 15,500 moist, mineral-matter-free British thermal units per pound.

[2] Moist refers to coal containing its natural inherent moisture but not including visible water on the surface of the coal.

[3] If agglomerating, classify in low-volatile group of the bituminous class.

[4] Coals having 69 percent or more fixed carbon on the dry, mineral-matter-free basis shall be classified according to fixed carbon, regardless of calorific value.

[5] It is recognized that there may be nonagglomerating varieties in these groups of the bituminous class, and there are notable exceptions in high volatile C bituminous group.

isocarb contour. The boundary between medium and high volatile A bituminous coal corresponds to the 69 percent isocarb contour.

Analyses of samples from T 12 N, R 18 E and T 10 N, R 19 E are from weathered outcrops and are not used for rank classification in this study.

Lithologic Class and Physical Components

Terminology used in this discussion is according to ASTM Standard Definitions, Designation: D 2796-69 (1971). All coal may be classified into two major classes, banded and nonbanded coal. Banded coal is defined as coal that is conspicuously heterogeneous in composition and includes (1) bands of vitrain of brilliant luster, (2) attrital bands of lesser luster and of striated, granulose, or rough texture, and commonly (3) splinters, chips, and layers of fusain. The banded class of coal is the most common of coal classes and is prevalent in all ranks, although the contrasts in banding are less obvious in lignite and meta-anthracite.

Nonbanded coal is defined as a coal having a consistent fine-grained texture, gray to greasy luster, toughness, and tendency to break in broad conchoidal fracture with wide spacing of joints. Nonbanded coal never has a brilliant luster. It is formed by sedimentary aggregation and diagenetic compaction of pulverized plant detritus. Its properties depend on (1) the nature of the various organic particles present, (2) the amount of codeposited detrital minerals, and (3) its geologic history. Nonbanded coal may be subdivided into cannel coal and boghead coal.

Banded coal may be further subdivided by the thickness of the individual bands (Table III; Rose, 1945).

The Stigler coal is obviously a banded coal. The Stigler coal in

TABLE III

CLASSIFICATION OF COAL ACCORDING TO BANDED STRUCTURE

Designation	Thickness of Bands Millimeters	Remarks
Coarsely banded	> 2	. . .
Finely banded or stripped	2-0.5	. . .
Microbanded or striated	< 0.5	Bands not visible to naked eye
Mixed banded	. . .	Both coarse and fine bands
Nonbanded (little or no lamination)	. . .	Cannel and boghead coals which break with conchoidal fracture

T 11 N, R 19 E (Fig. 18) is classified as a microbanded to coarsely-banded coal, whereas in T 10 N, R 21 E (Fig. 19), it is classifed as finely- to coarsely-banded coal.

During the course of field work a classification based on banding was used differing from that shown in Table III. Three divisions were used: banding greater than 1 cm was classed as coarse; banding from 2 mm to 1 cm was classed as medium; banding less than 2 mm was classed as fine. This system of classification is reflected in the graphic measured sections.

The physical components of the coal classes are also according to ASTM definitions. The three primary components are vitrain, fusain, and attritus or attrital coal. Vitrain is defined as the material in coal composing the shiny black bands that have brilliant luster, vitreous appearance and conchoidal fracture. Vitrain is usually more closely

Fig. 18.-Polished section of Stigler coal from Sec. 13, T 11 N, R 19 E, finely-banded to microbanded. Darker banding is vitrain, lighter bands are finely disseminated pyrite bands within bands of attritus and vitrain.

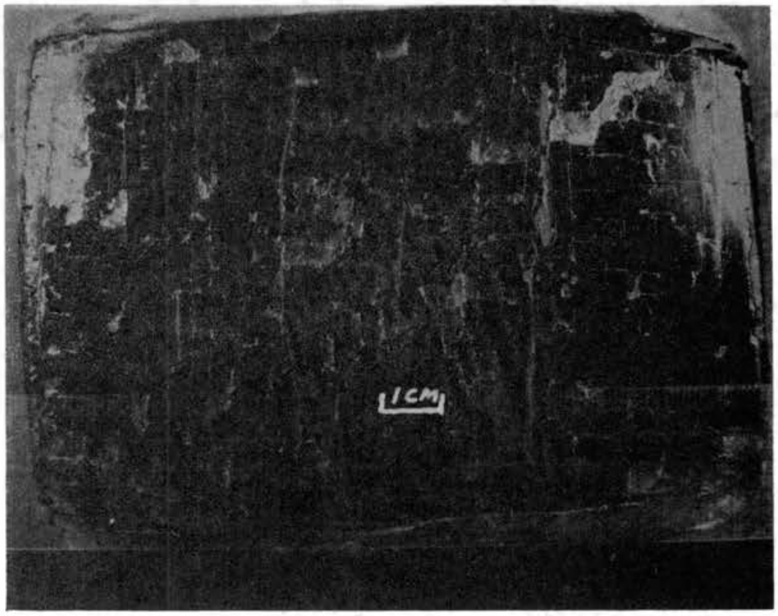


Fig. 19.-Polished section of Stigler coal from Sec. 33, T 10 N, R 21 E. The thick black bands are vitrain, the lighter bands are attritus. No pyrite is visible.

jointed than the other lithologic components in the same bed. Fusain is defined as the material in coal that resembles charcoal, occurring as dull black chips, lenses or layers. Fusain is very friable except where mineralized and typically has a minute fibrous and porous structure. Attrital coal is the material composed of plant microfragments that occupy interstices between other lithologic coal components. Two components commonly referred to but only generally considered here are clarain and durain. Dapples (1942) considers both to be attrital coals but that clarain is actually microstriated vitrain in an attrital groundmass.

The lithologic composition of the Stigler coal does not vary greatly over the study area although the appearance may differ markedly. For example, coal from T 11 N, R 19 E differs in physical appearance from coal in T 10 N, R 21 E and T 10 N, R 24 E. There are two reasons for the apparent difference: (1) the coal in T 11 N, R 19 E is somewhat finer-banded and (2) higher sulfur content makes the dissimilarity in banded components much more perceptible. The relative abundance of lithologic components remains about equal.

Vitrain is the most abundant component and the most easily recognized (Fig. 19). Vitrain usually accounted for over 80 percent of the components recognized. The remainder is primarily attritus. A few chips and wedges are tentatively identified as fusain.

Observations were from polished sections made from "grab" samples and from cleavage faces of the coal in place in the active pits. The percentage listed above generally shows relative abundance only, since a statistical analysis was not made.

Thickness

The thickness and areal limit that can be stripped determine the reserves of the Stigler coal. All thickness data on the Stigler coal are contained in Appendix C. These data are plotted on Figure 20, a thickness map of the Stigler coal within the study area. All data points were used in constructing the map but in the interest of clarity, not all of the data points are shown.

The area of greatest thickness is northeast of Stigler where the maximum recorded thickness is 32 inches. The overall thickest trend (corresponding to the 25 inch contour in Figure 20) extends from east of Porum east-southeast and trifurcates northeast of Stigler. Smaller areas with more than 25 inches thickness are in T 8 N, R 19 E and T 8 N, R 22 E. The thinnest measurement made of definitely the Stigler coal, was 11 inches in the extreme northwestern corner of the study area. Overall, the coal is thinnest in the northwestern corner and across the southern part of the study area. The reason for the thickness distribution is indeterminable with the limited data available. This type of evidence is probably contained in the coal and is not resolvable from indirect evidence such as chemical analyses or megascopic examination used in this study.

Sulfur Content

Sulfur is an undesirable but economically important constituent of all coals. It apparently does not occur as free elemental sulfur but is present as a chemically bound organic combination of the carbonaceous matter or in inorganic combination as pyrite or marcasite and as calcium and/or ferrous sulfate (Powell, 1921). These are referred to as organic, pyritic, and sulfate sulfur, respectively.

Little is known about organic sulfur in coal. Krevelen (1961) concludes that organic sulfur compounds are distributed uniformly throughout coal as part of its fundamental constitution. Gluskoter and Hopkins (1970) report that organic sulfur varies very little in Illinois coals whereas the changes in total sulfur content reflect changes in the pyritic content. Thiessen (1945) and Wandless (1959) make the same general conclusion, as the total sulfur content changes the organic sulfur content does also, but the rate of change is much less than that of pyritic sulfur. Sulfate sulfur usually is quantitatively unimportant. Gluskoter and Hopkins (1970) report a mean sulfate sulfur content of Illinois coals of 0.08 percent and that values over 0.20 percent are rare. Thiessen (1945) believes that sulfate sulfur occurs in coal only as a weathering product of pyrite.

In this study only the total sulfur content is considered. No effort is made to differentiate the various sulfur forms present in the Stigler coal although pyritic sulfur is readily visible in the high sulfur samples (Fig. 21). When considering production of high sulfur coals, there are two facts concerning the forms of sulfur that must be taken into account: (1) organic and pyritic sulfur are quantitatively the most important and (2) only pyritic sulfur can be removed mechanically by coal-cleaning processes and only when the pyrite particles are concentrated. Ordinary coal-washing processes will not remove finely disseminated pyrite.

The origin of sulfur in coal is debatable. Confusion arises from the fact that there are several forms of sulfur in coal and there may be several origins for each form. Stutzer (1940) believes most of the sulfur had its origin in the sulfur contained in the plant substances making up the plants. White et. al. (1913) attributed high sulfur content in

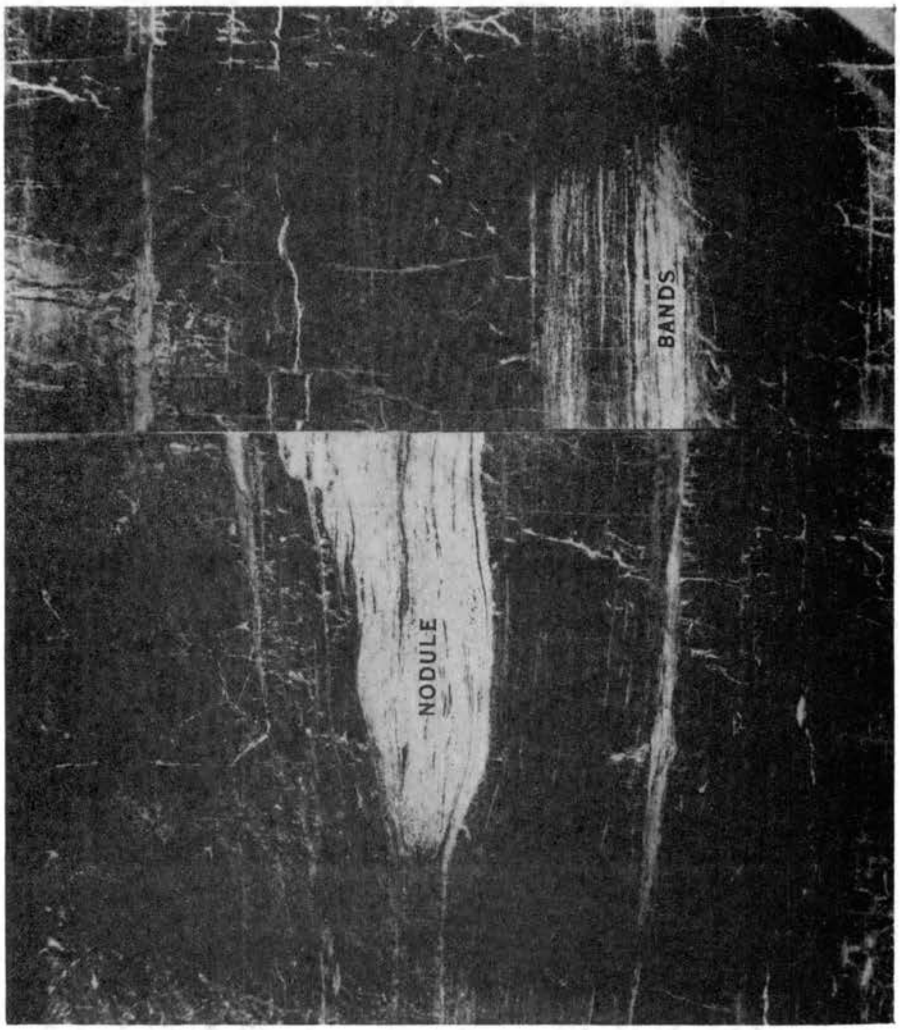


Fig. 21.-Polished section of Stigler coal from Sec. 13, T 11 N, R 19 E, showing nodules, bands and disseminated pyrite

the Interior Basin coals to submergence of peat-forming deposits under sea water and the subsequent action of bacteria contained in the sea water. The relationship of sulfur content and character of the overlying rock is recognized in many parts of the world. In general, when rocks overlying coal have marine affinities sulfur content of the coal is higher than when the overlying rock does not have marine affinities. This relationship is recognized in coals of England and Pakistan (Francis, 1954), South Wales (Wandless, 1959), Russia, Germany, Australia, Indiana, and Illinois (Gluskoter and Hopkins, 1970).

This same relationship can be demonstrated with the Stigler coal. As mentioned previously (Chapter IV), where the Stigler coal has high sulfur content and can be observed in fresh cuts (T 11 N, R 19 E), the coal is immediately overlain by a thin limestone or calcareous shale containing marine fauna. In localities where analyses of coal samples show low sulfur content the overlying shale is characterized by abundant carbonaceous matter including carbonized plant impressions and thin (less than 1 mm) coal zones, a lack of calcareous material in the shale, and an absence of fauna.

The distribution of sulfur in the Stigler coal is shown by a sulfur isograd map (Fig. 22). This map was used primarily as control for differentiating reserves by quality. Control points are widely spaced due to the limited number of analyses made on the Stigler coal. More dense control would probably indicate greater local variation but might not alter the overall, visualized, general distribution of sulfur. Obviously, this map should be used strictly as a guide and not as an indication of absolute sulfur values.

One of the objectives of this study was to develop relationships of coal quality to geologic attributes and attempt to project these relationships into areas where control is limited or nonexistent. If the relationship of sulfur content to marine or non-marine rocks is valid, sulfur content can be projected into areas where no analyses are available if outcrops are diagnostic. This is attempted with difficulty in the study area because of poor outcrops.

In Section 17, T 12 N, R 19 E, Wilson (1937) noted the presence of a calcareous shale containing numerous marine fossils immediately overlying the Stigler coal. By using the criteria noted above, the Stigler coal should be higher in sulfur at this locality. Figure 22 is constructed to reflect this interpretation. These pits are now abandoned and flooded; therefore, a sample for analysis could not be obtained. If surface mining is resumed at this locality at a future date, analyses should lend evidence to substantiate or discredit the nature of superjacent rocks as a guide to sulfur content in coal. Analyses are not available for the southern part of the study area and likewise, descriptions of the rock immediately above the coal are scarce and/or not sufficiently detailed to be diagnostic. Coal in this area is arbitrarily considered to be low in sulfur and is included in reserves (Chapter VII) with less than 1 percent sulfur.

Sulfur content of the Stigler coal within the study area varies from less than 1/2 of 1 percent to slightly over 5 percent. Values expressed in Figure 22 and Appendix B are for total sulfur content. In fresh samples from Sec. 13, T 11 N, R 19 E where sulfur content is high, pyrite is clearly observable. The sulfur occurs in nodules and lenses and as finely disseminated microbands (Fig. 21). In fresh samples from Sec. 33, T 10 N, R 21 E where sulfur content is less than 1 percent pyrite is neither visible megascopically nor microscopically (Fig. 19).

Ash Content

Ash is the solid residue remaining after complete combustion of coal. The ash content does not necessarily reflect the solid residue in coal. It is derived from material in the coal that is changed by heat and oxidation to form ash. Ash forming material may have been brought into the coal-forming peat as detrital matter, or may have been part of the original organically combined matter, or may have been emplaced by biologic activity soon after coal-forming processes began, or may have been precipitated mineral matter carried in solution in percolating water.

Stutzer (1940) indicates that the main constituents of ashes of living plants, the alkalies, are found in only very small quantities in coal ashes. He postulates that the alkalies are either leached out or used repeatedly by succeeding generations of plants. Aluminum silicates are a source for the alkalies which are found in coal ash and they come from foreign mineral substances and not from the plants. Frazier and Osanik (1969) indicate ash contents of recent peat deposits of the Louisiana coastal plain are extremely high. These values vary from 29.8 percent, moisture-free basis, to a high of 69.2 percent. This fact could be interpreted as meaning present-day peat accumulations along the Gulf coastal plain are not analogous to ancient peat accumulations such as occurred during the Pennsylvanian Period.

Like sulfur, the presence of ash in coal decreases the value. Ash is a diluent as well as sometimes being detrimental. The efficiency of furnace operation is lowered from 0.2 to 0.25 percent for each percent of ash present in the coal (Stutzer, 1940). Other problems caused or contributed to by ash content include "clinkering", adhesion of slag to refractory walls, adhesion of slag to grate bars, or destruction of metal parts by solution in slag components (Barrett, 1945).

The ash content of the Stigler coal varies from 2.6 to 11.6 percent (Appendix B). These points are plotted in Figure 23, an ash isograd map. Similarity exists between the sulfur isograd map and the ash isograd map. Since some sulfur is left in incombustible form when coal is incinerated, the initial sulfur content of coal influences the total noncombustible material. By this reasoning, the ash isograds should reflect the sulfur content to some extent.

Analyses are not available for the southern part of the study area, and like the sulfur, ash content is unknown.

CHAPTER VII

RESERVES AND UTILIZATION SUITABILITY

Reserves calculations are based upon a reasonable estimate of near-future economic strippability. Total reserves are based upon a stripping ratio of 50 ft of overburden to 1 ft of coal without regard to coal value or marketability. This stripping ratio can nearly be met, presently, where coking quality coal is produced. Reserves are differentiated generally according to possible utilization based upon sulfur content. Possible uses are arbitrarily assigned to only two groups: (1) suitability for carbonization (coke and coke by-products manufacturing) and (2) suitability for general fuel use, such as steam generation and gasification.

Sulfur: The Discriminative Criterion

The use in this study of sulfur content as a single criterion for determining utilization suitability is a matter of simple elimination. Rank is not a useful criterion for differentiation because all three ranks exhibited by the Stigler coal are commonly coaked (Rose, 1927). By ASTM Standards (1949), the maximum amount of ash in dry coal used for coking purposes is 9 percent. Since the ash content closely parallels that of sulfur in the study area, duplication would result from using ash as a differentiating criterion. Calorific value is also nondiagnostic because of the uniformity throughout the study area. Petrographic analysis in previous studies has been useful in determining coking characteristics. Anthraxylon, or vitrain, is the best coking constituent; on the other hand, fusain will not coke by itself, although it may contribute to the strength of the coke (Wilson and Wells, 1950). Again, this characteristic is not distinctive because the Stigler coal is primarily vitrain throughout the study area. Sulfur content, on the other hand, changes considerably over the study area and low sulfur content is one of the special requirements for coal used in making coke (ASTM, 1949). Therefore, by elimination, sulfur content is the only remaining, easily determinable characteristic to use in differentiating reserves by utilization suitability.

There are other characteristics affecting coking behavior of coal. These characteristics are generally physical characteristics that cannot be determined with confidence unless tested under actual coking conditions and are therefore not considered here. They include plasticity, swelling characteristics, agglutinating and agglomerating characteristics, and bulk density.

Many of the undesirable physical characteristics as well as some compositional characteristics can be compensated for by blending different coals (Davis _et_. _al_., 1944). Sulfur is not so easily handled. ASTM specifications prescribe limits of 1.5 percent sulfur in dry coke from gas coals (high volatile coals), 1.3 percent in dry coke for blast furnace use, and 1.0 percent in dry coke for foundry use. These values are generally low for most coals; therefore, blending is not usually employed to reduce sulfur content. Consequently, high sulfur content alone commonly eliminates coal for coking utilization.

Coal suited to steam generation or gasification does not have universally accepted restrictions placed on composition such as coking coal does. Composition and characteristics are normally considered by purchaser and seller in contract agreements.

Reserves and Estimation Procedure

In this study, reserves are divided into three groups: (1) less than 1 percent sulfur, probably suitable for manufacturing coke and coke by-products; (2) between 1 and 2 percent sulfur, possibly suited to coke and coke by-product manufacture as individual analyses may dictate or for blending with high sulfur coals used for steam generation in areas where local laws prohibit use of high sulfur coals; (3) more than 2 percent sulfur, suited to general fuel use. These are tabulated by township (Table IV).

The method employed in estimating reserves takes into account thickness of the coal, weight of the coal, sulfur content, and overburden thickness. As mentioned previously, a stripping ratio of 50 ft of overburden to 1 ft of coal limits the down-dip extent of strippable reserves (Fig. 24). The coal was assumed to have a specific gravity of 1.32, or a weight of 1,800 tons per acre-ft (Trumbull, 1957). Figure 20 (coal thickness map), Figure 22 (sulfur isograd map), and Figure 24 (prospect map) were integrated to determine the limits of parameters used in making reserves calculations.

The total strippable reserves within the study area and the totals by sulfur content are shown in Table V. The 80 percent recoverability factor is arbitrarily assigned. Friedman (1971) indicates 80 percent recoverability has been the norm in surface mined coal operations in Oklahoma.

TABLE IV

RECOVERABLE RESERVES BY TOWNSHIP BASED ON SULFUR CONTENT

Township	Sulfur Content (Percent)	Total Tonnage	Recoverable Reserves (80% Recovery Factor)
T 7 N, R 19 E	< 1	171,500	137,200
T 8 N, R 19 E	< 1	814,600	651,600
T 8 N, R 20 E	< 1	1,357,700	1,086,160
T 8 N, R 21 E	< 1	2,098,500	1,678,800
T 8 N, R 22 E	< 1	3,087,000	2,469,600
T 9 N, R 19 E	< 1	1,200,500	960,400
T 9 N, R 20 E	< 1	571,600	457,280
	1-2	1,505,400	1,204,320
	> 2	1,362,500	1,090,000
T 9 N, R 22 E	< 1	5,502,400	4,401,920
T 9 N, R 23 E	< 1	387,300	309,840
T 9 N, R 24 E	< 1	1,357,700	1,086,160
T 10 N, R 19 E	> 2	5,597,700	4,478,160
T 10 N, R 20 E	> 2	952,800	762,240
T 10 N, R 21 E	< 1	1,857,900	1,486,900
	1-2	4,373,300	3,498,640
T 10 N, R 22 E	< 1	856,500	685,200
	1-2	2,667,800	2,134,240
	> 2	4,764,000	3,811,200
T 10 N, R 23 E	> 2	190,600	152,480
T 10 N, R 24 E	< 1	476,400	381,120
T 11 N, R 19 E	> 2	10,049,600	8,039,680
T 11 N, R 20 E	> 2	2,024,700	1,619,760
T 11 N, R 21 E	> 2	495,500	396,400
T 11 N, R 22 E	> 2	1,572,100	1,257,680

TABLE IV (Continued)

Township	Sulfur Content (Percent)	Total Tonnage	Recoverable Reserves (80% Recovery Factor)
T 12 N, R 18 E	< 1	595,500	476,400
	> 2	452,600	362,080
T 12 N, R 19 E	1-2	333,500	266,800
	> 2	1,762,700	1,410,160
T 9 N, R 21 E	< 1	4,459,100	3,567,280
	1-2	833,700	666,960

TABLE V

TOTAL RESERVES BY SULFUR CONTENT

Sulfur Content (Percent)	Total Reserves (in Place)	Recoverable Reserves (80% Recovery Factor)
< 1	24,794,200	19,835,360
1-2	10,166,300	8,133,040
> 2	28,772,200	23,017,760
Total Tonnage	67,732,700	50,986,160

CHAPTER VIII

DEVELOPMENT CONSIDERATIONS

The study area has considerable potential for both large and small-scale mining ventures. The development of individual mining operations is, of course, dependent upon economic return. In evaluating return on investments, the recoverable reserves within each individual prospect, the choice of mining method and machinery, and transportation are chief considerations. Marketability is a fourth consideration and is not considered separately with the limited scope of this study, but is assumed to be established.

Prospective Areas

Figure 24 shows the areal distribution of strippable reserves. The most lucrative areas are in the Porum and Stigler synclines. Roughly 50 percent of the total strippable reserves are located along the southern or eastern flank of these structural features. Other smaller areas contain sufficient reserves to warrant further consideration. The areas east of Kanima and northwest of Warner as well as the continuous band along the south flank of the Cowlington syncline appear worthy of additional exploration. Reserves in the southwest corner of the study area around Kinta are farther removed from the navigation system and appear only marginally acceptable as a prospect.

Mining

Mining operations are presently underway at two locations within the study area: the Garland Coal and Mining Company is operating northeast of Stigler in Sec. 33, T 10 N, R 21 E, and the Sierra Coal Corporation is operating northeast of Porum in Sec. 13, T 11 N, R 19 E. Both operators are using dragline excavators; the Garland operation is using an electric-powered Bucyrus-Erie dragline with a 30 cu yd bucket (Fig. 25); the Sierra operation is excavating with two Bucyrus-Erie diesel-powered draglines with 14 cu yd buckets. Diesel-powered units are most appropriately used where job life is comparatively short, where frequent long distance moves are necessitated, or where power cable handling is impractical (Rumfelt, 1968).

The only serious possible competitor to the dragline in this area would be power shovels. Although power shovels are more efficient, they would be at a disadvantage in the study area for two reasons because of the fact that shovels must operate within the pit: (1) present-day front-end designs limit the stripping depth capability and the ability to construct spoil piles, whereas, equivalent overburden depths can be handled with much smaller capacity draglines, and (2) operation of large shovels either on the coal or immediately above might result in damage to the coal or reduce recoverability where coal is thin and the underclay is soft.

Loading is accomplished by a small shovel (Fig. 26) at the Garland pit and by front-end loader at the Sierra pit. In both cases, the coal is trucked to embarkation points on the Arkansas River Navigation System.

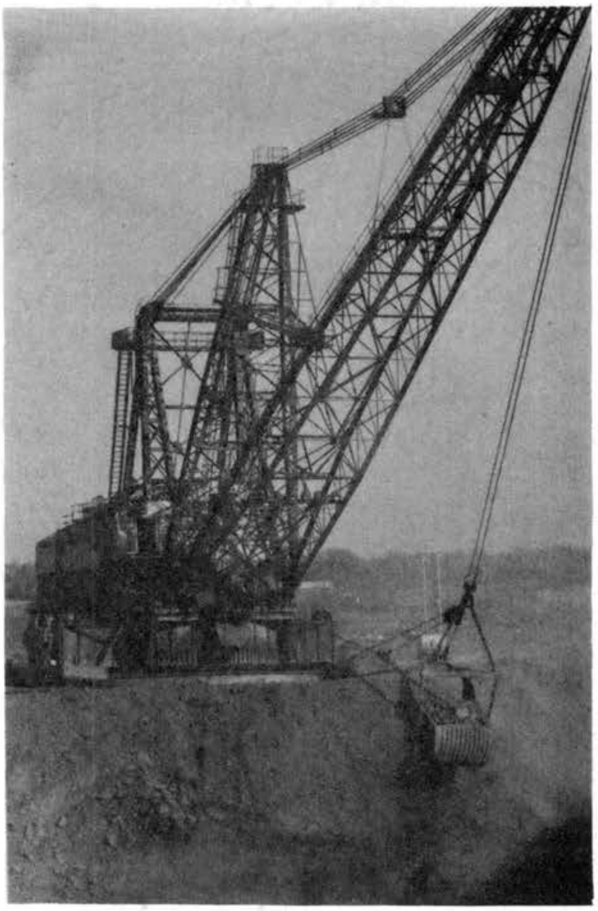


Fig. 25.-Bucyrus-Erie electric powered dragline with 30 cu yd bucket used by the Garland Coal and Mining Company in Haskell County

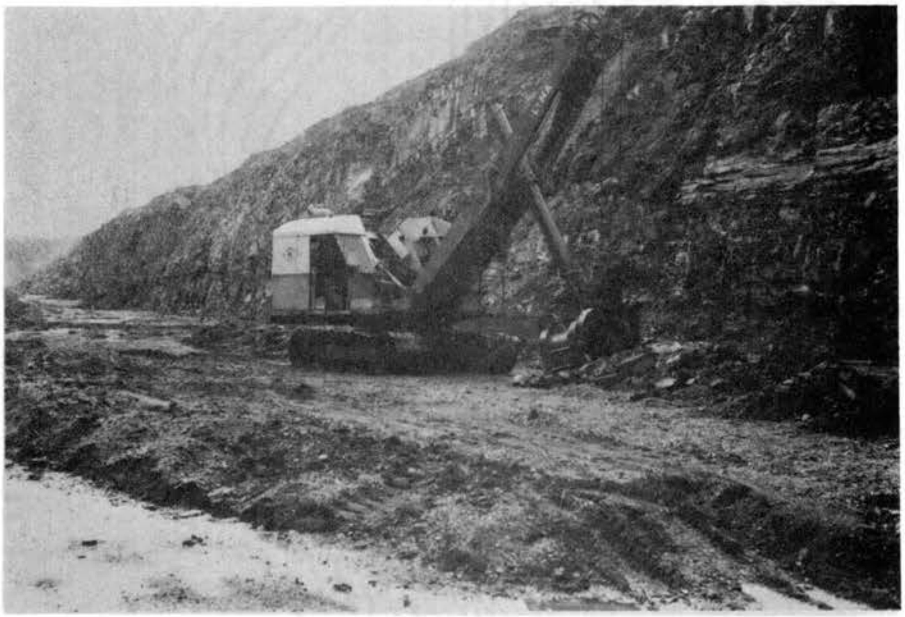


Fig. 26.-Diesel-powered shovel used for loading coal into trucks at the Garland mining operation in Haskell County

Transportation

The study area is served by four state highways, three federal highways, one interstate highway, one railroad, and the Kerr-McClellan Arkansas River Navigation System. These are shown in Figure 24.

The low cost, high volume transportation afforded by the Arkansas River Navigation System is the most important economic consideration in this study and is one of the primary factors in the increasing interest in coal reserves in this area. The actual barge channels are not shown in Figure 24. The main channel runs the length of Robert S. Kerr Reservoir. A second channel extends from the main channel up the Sans Bois arm of Robert S. Kerr Reservoir to just west of Keota. Coal loading facilities are located 2 1/2 mi west of Keota in Sec. 15, T 9 N, R 22 E, and 1/4 mi north of Webbers Falls in Sec. 18, T 18 N, R 21 E. The facilities at these two locations are owned by the Garland Coal and Mining Company and the Sierra Coal Corporation, respectively. Mining prospects located north of the Canadian River can be served by the loading facility at Webbers Falls, while those south of the Canadian River can be served by the facility at Keota.

The Midland Valley Railroad extends southward from Muskogee, through Warner and Porum, then eastward through Stigler and Keota. Until recently, this railroad was used for shipping coal mined near McCurtain from the Hartshorne seam. The lower cost of barge transport places the railroad at a decidedly competitive disadvantage.

The state, federal, and interstate highways are shown in Figure 24. All are hard surfaced, all-weather roads, adequate for trucking coal to loading facilities along the navigation system.

CHAPTER IX

SUMMARY AND CONCLUSIONS

Rocks that crop out within the study area are Desmoinesian and Atokan Series, Pennsylvanian System. The studied interval includes the middle 2/3 of the McAlester Formation of the Krebs Group. The studied portion of the McAlester Formation thickens southward and eastward from less than 150 ft in the extreme northwest part of the study area to about 500 ft in the southern and eastern part of the study area. The stratigraphic section is predominantly shale. Thin sandstones and persistent sandy facies are present in subordinant amounts. Extremely thin, local limestones are present but are stratigraphically unimportant.

The shale sequences within the study interval are not named. They are primarily marine as evidenced by marine fauna. Some are silty or interlaminated with silt and are interpreted as prodelta units. Others contain abundant woody material and root disturbed zones and are interpreted as marsh or swamp deposits.

The sandstones are quite variable in characteristics but all are commonly feldspar- and lithic-rich quartzarenites. Most are well sorted and fine-grained except the upper Warner channel sequence, which is medium-grained and moderate to well sorted. Erosional bases are common to the lenticular channel sandstones and gradational bases are common to the thin bedded sandstones. Sedimentary structures include small-scale and medium-scale cross-bedding, initial dip, current and oscillation ripple marks, occasional streak and parting lineation, and burrows.

The overall general paleocurrent trend is east-southeastward. The Warner and Lequire Sandstones represent two sequences of distal delta-lobe progradation eastward from the subsurface "Booch Delta". The upper Warner sandstone facies is an alluvial sequence deposited during maximum regression. The Tamaha and Cameron Sandstones were deposited in a shallow marine environment.

The development of coals and underclays, including the widespread Stigler coal, on marine shale surfaces suggests periodic, abrupt sea level changes.

Three periods of structural development seem evident: (1) basin subsidence, probably characterized by growth faulting, (2) folding, during periods of compressive stress during the Ouachita orogeny, (3) normal faulting, during regional uplift in Permian or post-Permian time.

The Stigler coal is a remarkably uniform, widespread, banded coal. Analyses indicate the Stigler coal over the entire study area is of the bituminous class. Three groups are represented: low volatile bituminous, medium volatile bituminous, and high volatile A bituminous.

Vitrain is the most abundant and the most easily recognized component. Vitrain usually accounts for over 80 percent of the components. The remainder is primarily attritus. A few chips and wedges are tentatively identified as fusain.

The maximum and minimum recorded thicknesses of the Stigler coal within the study area are 32 and 11 inches, respectively. The reasons for thickness distribution and local variations were indeterminable due to the limited data.

Sulfur content of the Stigler coal varies from less than 1/2 of 1 percent to slightly over 5 percent. Where sulfur content is high, sulfur occurs in nodules, lenses, and finely disseminated microbands of pyrite.

Ash content of the Stigler coal varies from 2.6 to 11.6 percent. The distribution of ash closely parallels that of sulfur.

Estimated strippable reserves of the Stigler coal in place total nearly 64 million tons. Using an 80 percent recoverability factor, over 50 million tons of coal could be produced. Utilization suitability includes gasification, steam generation, and coke and coke by-products manufacturing, based, in order, on decreasing sulfur content.

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APPENDIX A

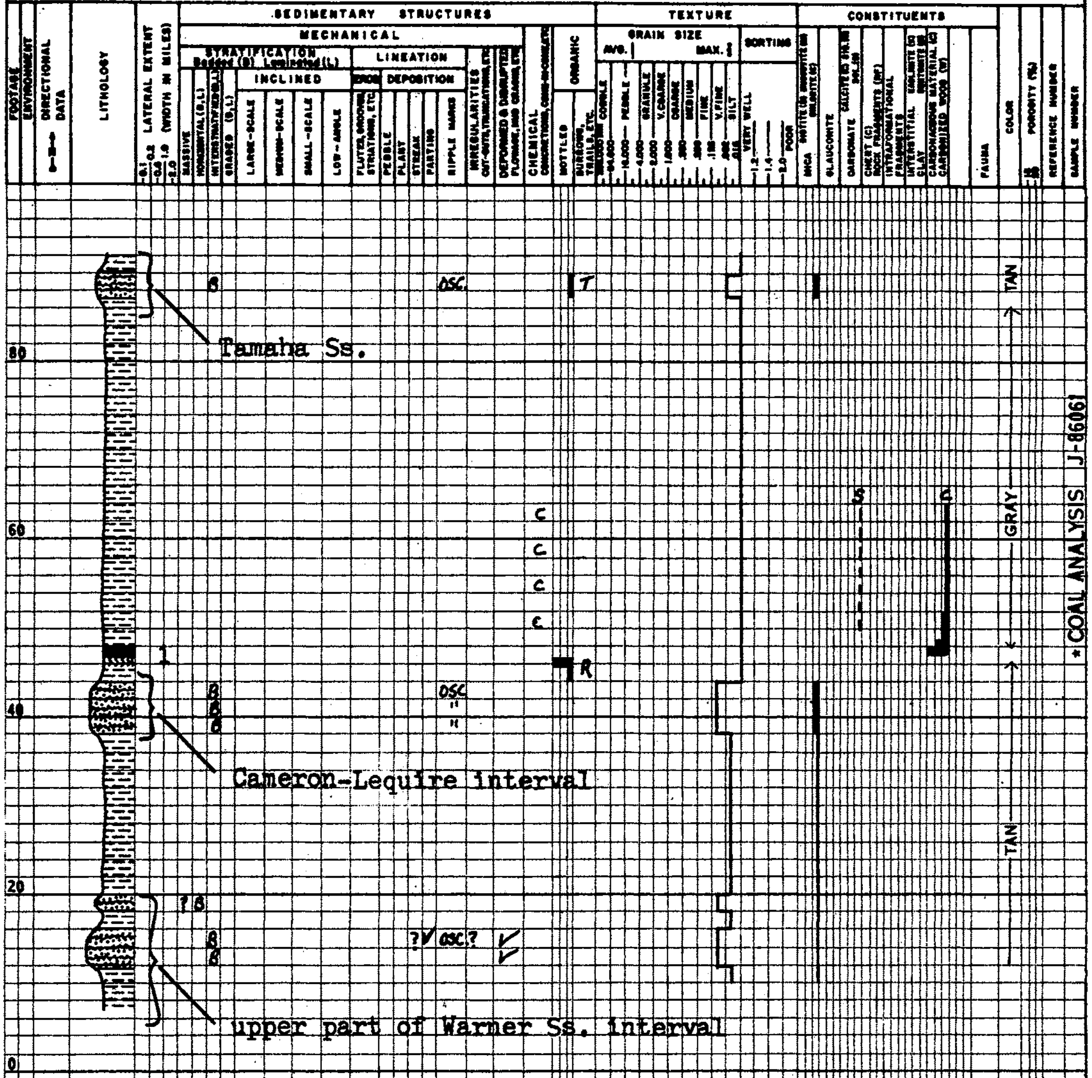
MEASURED STRATIGRAPHIC SECTIONS

SL Sec. 2 T. 12N R. 18E Map Photo

McIntosh Co., Oklahoma Section No. 1

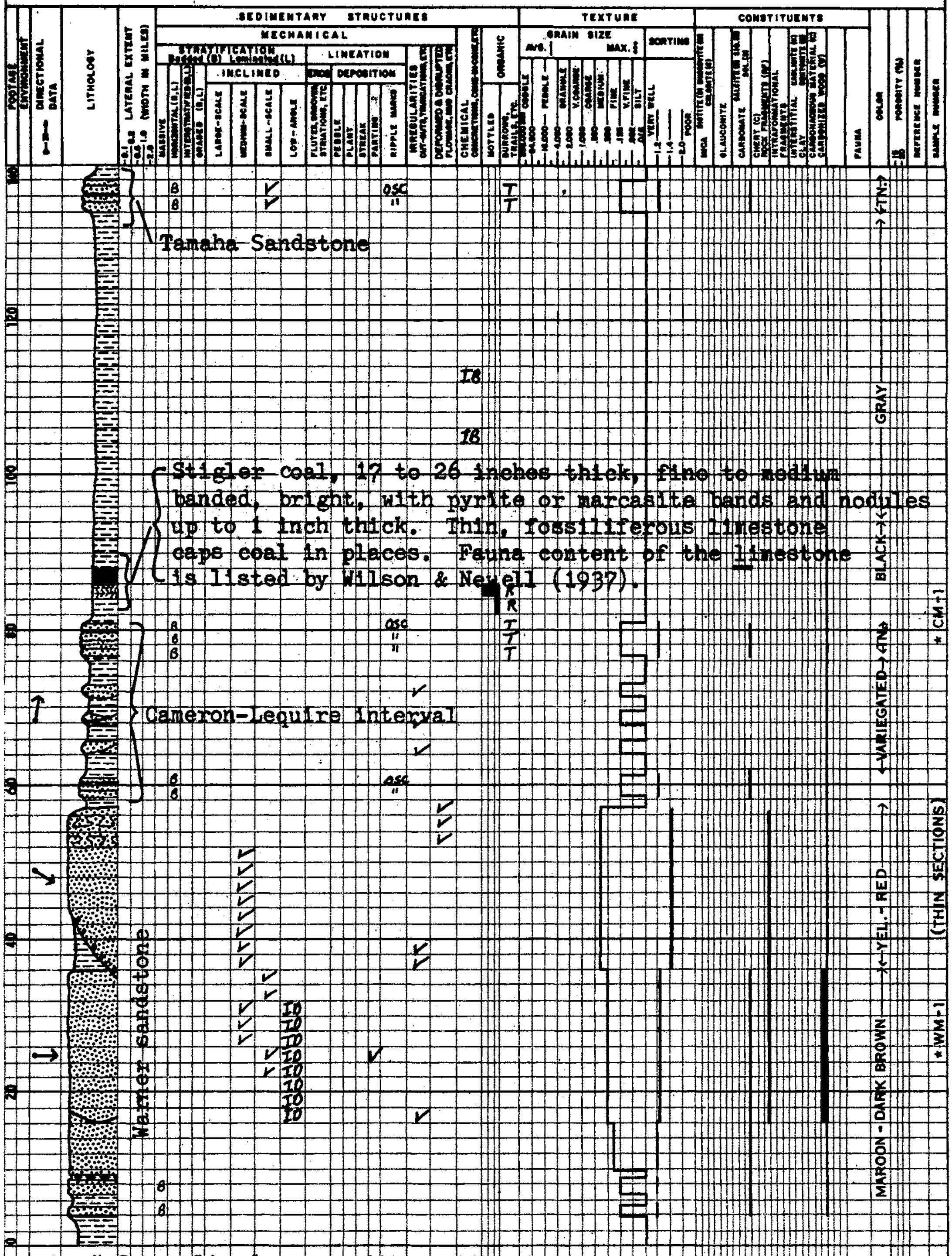
Area Structural Dip 3° WSW By M. D. Karvelot

Outcrop Pattern--Linear belt Formation McAlester



1) Stigler coal, 11 inches thick, fine to medium banded, bright. Numerous small siderite (ironstone) concretions in overlying shale, some containing leaf impressions. One foot of underclay is present.

* Sec. T. 11N.'s 19 & 20 E Map Photo
Muskogee Co. Oklahoma Section No. 2
Area Composite Structural Dip By M. D. Karvelot
Outcrop Pattern--Linear belt Formation McAlester



Stigler coal, 17 to 26 inches thick, fine to medium banded, bright, with pyrite or marcasite bands and nodules up to 1 inch thick. Thin, fossiliferous limestone caps coal in places. Fauna content of the limestone is listed by Wilson & Newell (1937).

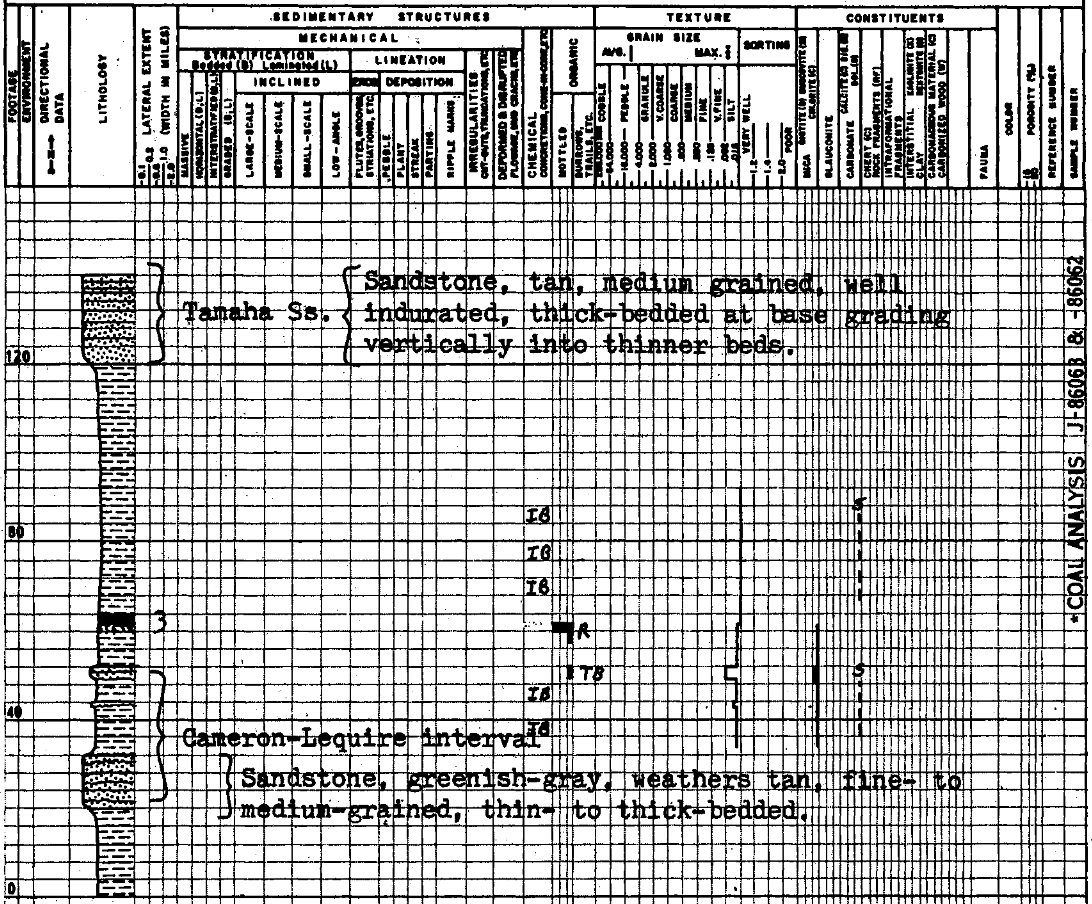
* Generalized, composite section from relationships observed in T 11 N, R's 19 & 20 E.

1) Sec. T. 10N R. 19E Map Photo

Muskogee Co., Oklahoma Section No. 3 (after Stine, 1958)[2]

Area Structural Dip 2-5° W By M. D. Karvelot

Outcrop Pattern - - Linear belt Formation McAlester



Sandstone, tan, medium grained, well indurated, thick-bedded at base grading vertically into thinner beds.

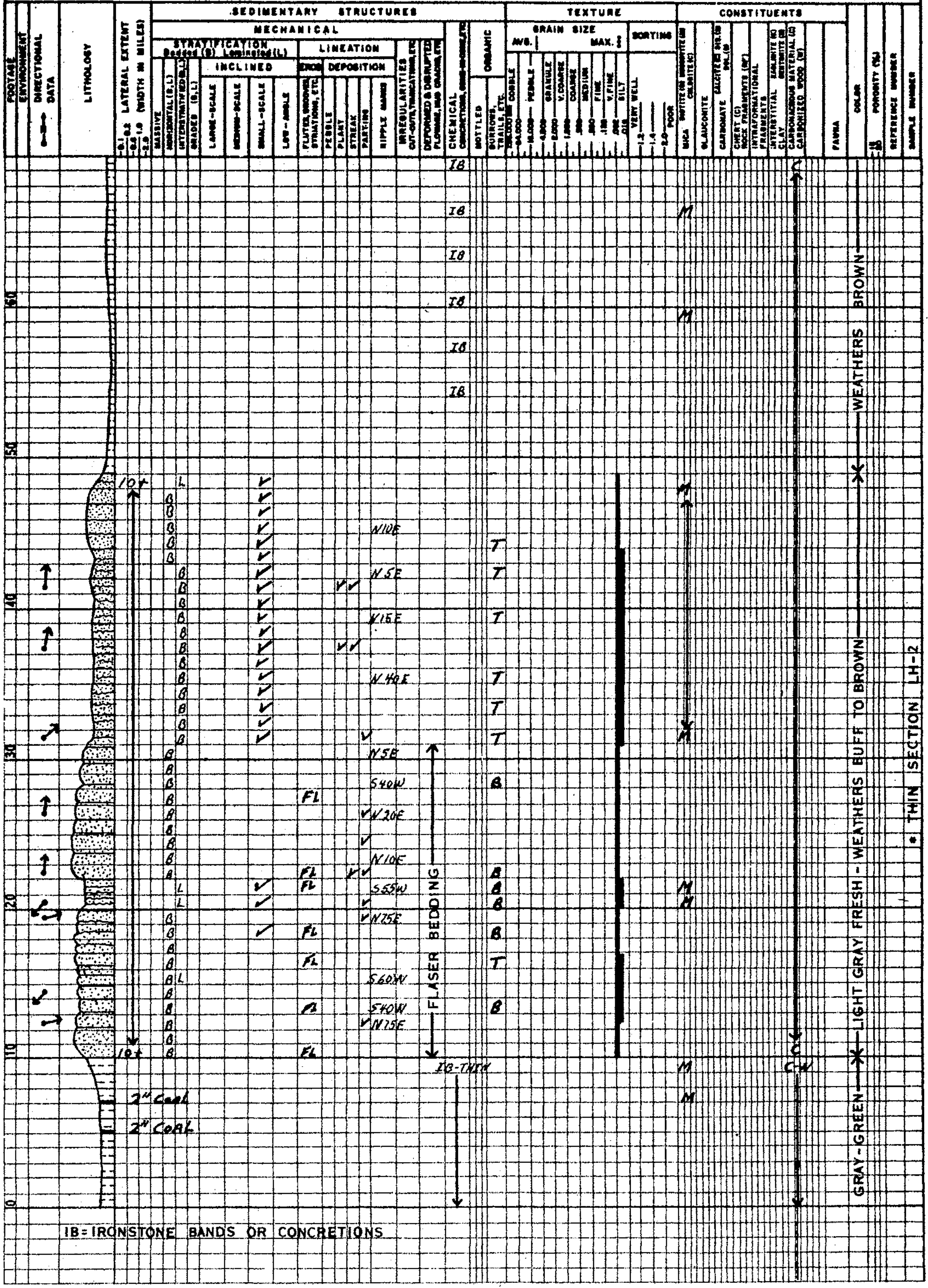
Sandstone, greenish-gray, weathers tan, fine- to medium-grained, thin- to thick-bedded.

1) Composite of strip pit face and along stream bed in NE NW sec. 35 and WL sec. 36, T 10 N, R 19 E.

2) Verbal descriptions and measured interval are by Stine (1958). Graphically shown data are author's.

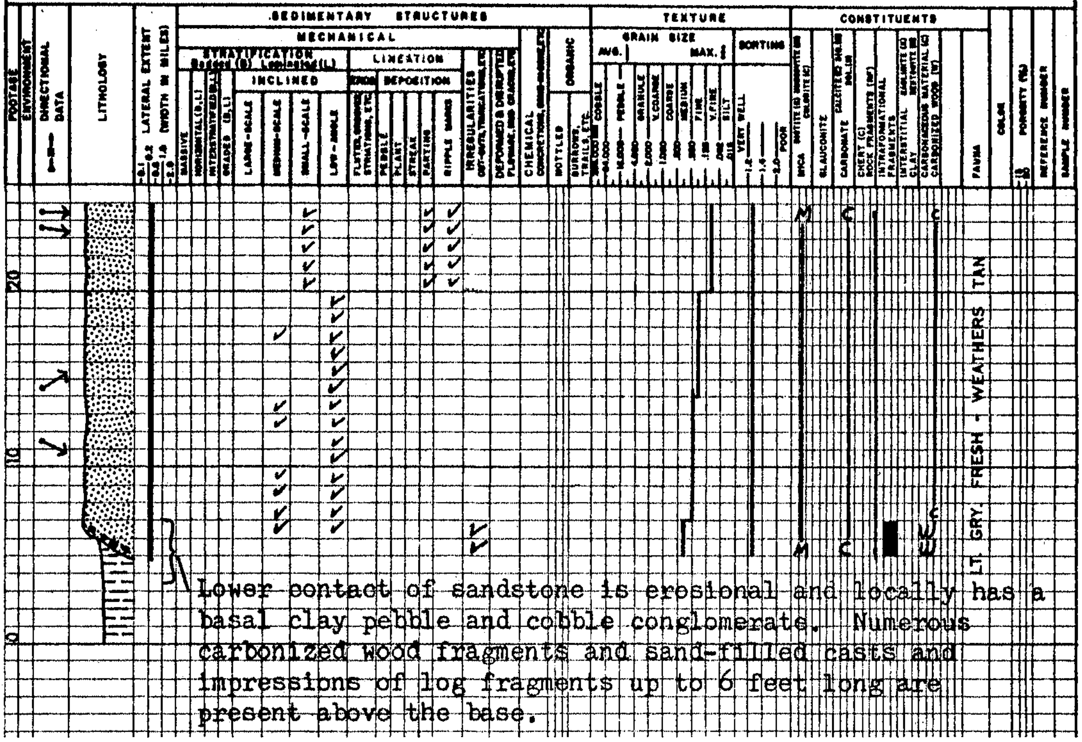
3) Stigler coal, 16 to 19 inches thick, bright, fine to medium banded. Underclay is poorly developed, measuring not more than 1 foot in thickness.

NW NE Sec. 31 T. 8N R. 20E Map Photo
HASKELL Co. OKLAHOMA Section No. 4
Area S.H. 2. NORTH OF KINTA Structural Dip 11° N By M. D. KARVELOT
Outcrop Pattern--Linear ✓ belt Formation McALESTER (LEQUIRE SS. MBR.)



IB = IRONSTONE BANDS OR CONCRETIONS

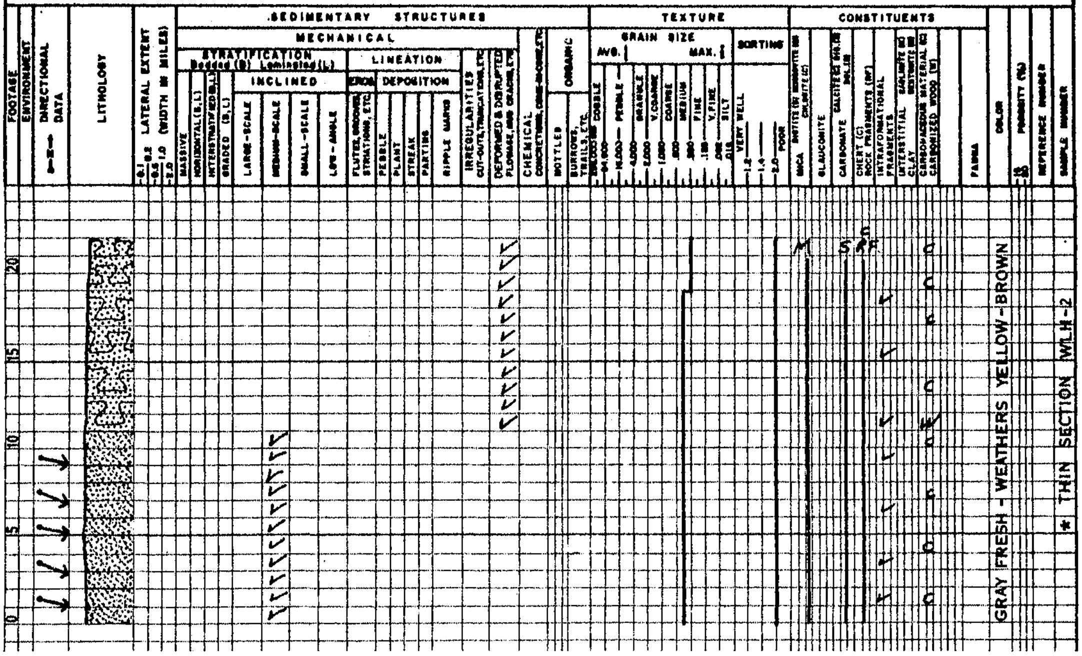
SW 1/4 Sec. 28 T. 9 N R. 20 E Map ____ Photo ____
HASKELL Co., OKLAHOMA Section No. 5
Area QUARRY Structural Dip 5° SSW By M. D. KARVELOT
Outcrop Pattern--Linear ↙ belt ____ Formation McALESTER (LEQUIRE SS. MEMBER)



Lower contact of sandstone is erosional and locally has a basal clay pebble and cobble conglomerate. Numerous carbonized wood fragments and sand-filled casts and impressions of log fragments up to 6 feet long are present above the base.

LT. GRY. FRESH - WEATHERS TAN

CSL Sec. 12 T. 9 N R. 21 E Map ____ Photo ____
HASKELL Co., OKLAHOMA Section No. 6
Area ROADCUT S. H. 9 Structural Dip 4° E By M. D. KARVELOT
Outcrop Pattern--Linear ____ belt ↙ Formation McALESTER (WARNER SS. MEMBER)



GRAY FRESH - WEATHERS YELLOW-BROWN

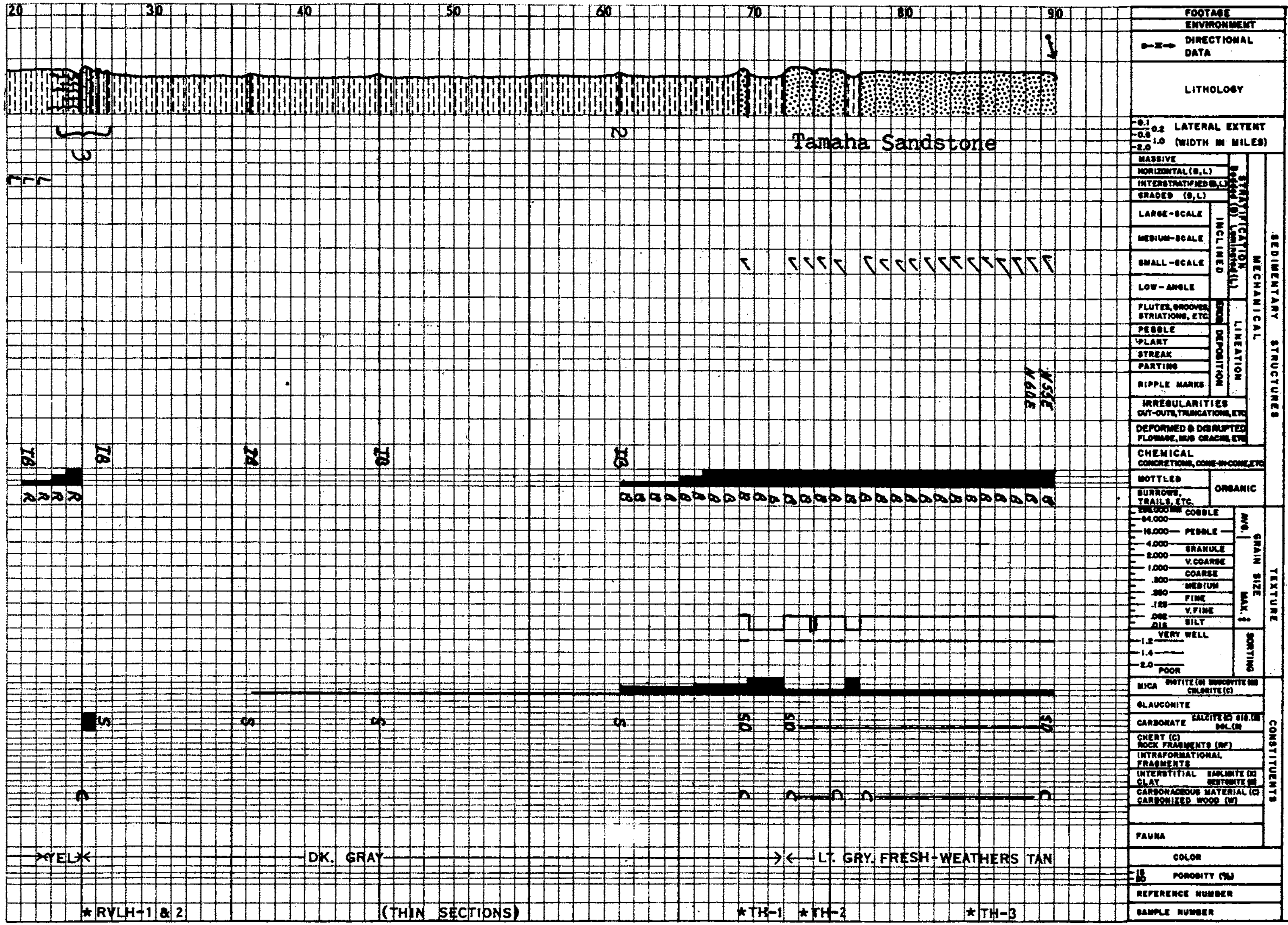
* THIN SECTION WLH-2

1) Sec. T. 10N R. 21E Map

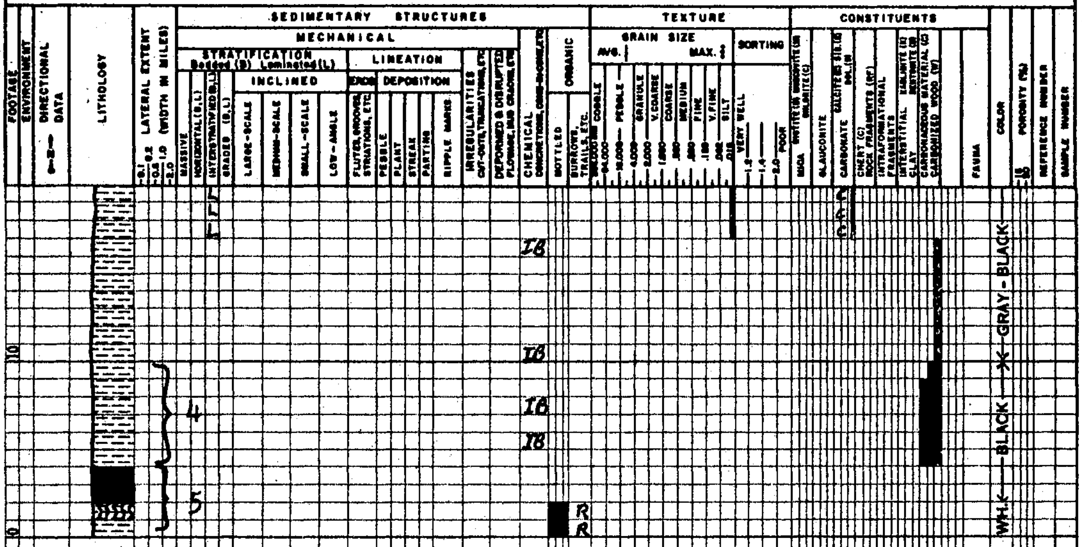
Haskell Co. Oklahoma Section No. 7 Photo

Area Face of strip pit Structural Dip 2° NW By M. D. Karvelot

Outcrop Pattern--Linear belt Formation McAlester



Sec. T. R. Map Photo
Co., Section No. 7-continued
Area Structural Dip By
Outcrop Pattern--Linear belt Formation



1) Composite of strip pit faces in sections 33 and 27, T 10 N, R 21 E.

2) An abundantly fossiliferous, ironstone band containing crinoid fragments, bryozoans, and pelecypods.

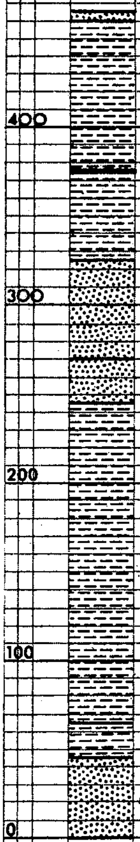
3) In ascending order, a zone consisting of a well-developed underclay, a thin coal $\frac{1}{2}$ to 4 inches thick, capped by a fragmental algal limestone 1 to 7 inches thick, and carbonaceous shale with several ironstone bands.

4) Black shale immediately above the Stigler coal containing extremely abundant carbonized plant fragments and leaf impressions along the bedding planes. Occasional coal laminae up to $\frac{1}{2}$ inch thick, without accompanying underclays or root disturbed zones.

5) The Stigler coal, 20 to 24 inches thick, bright, medium to coarsely banded, underlain by well-developed underclay.

NE NE[1] Sec. 11 T. 8N R. 21E Map ____ Photo ____
Haskell Co., Oklahoma Section No. 8 (Core hole # D-16)[2]
Area ____ Structural Dip ____ By Sneed Core Drill
Outcrop Pattern - - Linear ____ belt ____ Formation McAlester

FOOTAGE | ENVIRONMENT | DIRECTIONAL DATA | LITHOLOGY | LATERAL EXTENT (WIDTH IN MILES) | SEDIMENTARY STRUCTURES: MECHANICAL (STRATIFICATION, LINEATION), IRREGULARITIES, DEFORMED & DISRUPTED, CHEMICAL, ORGANIC | TEXTURE: GRAIN SIZE, SORTING | CONSTITUENTS | FAUNA | COLOR | POROSITY (%) | REFERENCE NUMBER | SAMPLE NUMBER



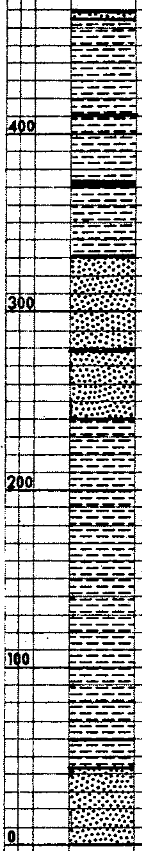
5.7'	Medium hard sandstone	(Tamaha Sandstone)
86.0'	Black sandy shale	
1.4'	Coal (Stigler coal)	
49.6'	Sandy shale with sandstone bands	
55.0'	Medium to hard sandstone	(Lequire Sandstone)
26.0'	Hard gray sandstone	
179.0'	Black sandy shale	
18.0'	Black shale with sandstone bands	(Warner Sandstone)
46.0'	Extra hard sandstone	

[1] 980' W, 375' S of NE corner sec. 11, T 8 N, R 21 E Elev. 604.6'

[2] Core description is by Sneed Core Drilling Co., Inc., for Kerr-McGee Oil Industries, Inc. Notes in parentheses are the author's.

NE NW[1] Sec. 12 T. 8N R. 21E Map Photo
Haskell Co., Oklahoma Section No. 9 (Core hole # D-13)
Area Structural Dip By Sneed Core Drill[2]
Outcrop Pattern--Linear belt Formation McAlester

FOOTAGE | ENVIRONMENT | DIRECTIONAL DATA | LITHOLOGY | LATERAL EXTENT (WIDTH IN MILES) -0.1 -0.2 -0.5 -1.0 -2.0
SEDIMENTARY STRUCTURES — MECHANICAL — STRATIFICATION Bedded (B) Laminated (L): MASSIVE, HORIZONTAL (B,L), INTERSTRATIFIED (B,L), GRADED (B,L); INCLINED: LARGE-SCALE, MEDIUM-SCALE, SMALL-SCALE, LOW-ANGLE; LINEATION: EROSION: FLUTES, GROOVES, STRIATIONS, ETC.; DEPOSITION: PEBBLE, PLANT, STREAK, PARTING, RIPPLE MARKS; IRREGULARITIES CUT-OUTS, TRUNCATIONS, ETC.; DEFORMED & DISRUPTED FLOWAGE, MUD CRACKS, ETC. — CHEMICAL CONCRETIONS, CONE-IN-CONE, ETC. — ORGANIC: MOTTLED, BURROWS, TRAILS, ETC.
TEXTURE — GRAIN SIZE AVG. MAX.: BOULDER COBBLE 64,000 — PEBBLE 16,000 — 4,000 GRANULE 2,000 V.COARSE 1,000 COARSE .500 MEDIUM .250 FINE .125 V.FINE .062 SILT .016; SORTING: VERY WELL 1.2 1.4 2.0 POOR
CONSTITUENTS: MICA BIOTITE (B) MUSCOVITE (M) CHLORITE (C); GLAUCONITE; CARBONATE CALCITE (C) SIDERITE (S) DOL. (D); CHERT (C) ROCK FRAGMENTS (RF); INTRAFORMATIONAL FRAGMENTS; INTERSTITIAL CLAY KAOLINITE (K) MONTMORILLONITE (M) SERICITE (S); CARBONACEOUS MATERIAL (C) CARBONIZED WOOD (W); FAUNA | COLOR | POROSITY (%) 15 20 | REFERENCE NUMBER | SAMPLE NUMBER



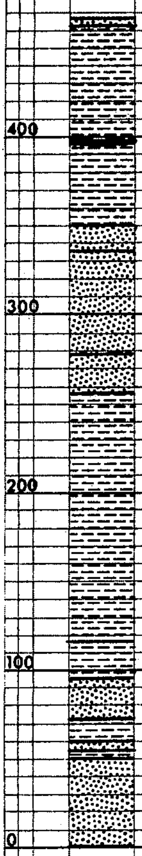
6.3' Hard sandstone (Tamaha Sandstone)
53.5' Black sandy shale
0.3' Coal
35.7' Black sandy shale
1.9' Coal (Stigler coal)
41.1' Sandy shale with sandstone bands
50.0' Medium to hard sandstone
35.0' Hard sandstone
(Lequire Sandstone)
180.0' Black sandy shale
14.0' Black hard sandy shale
48.5' Hard gray sandstone (Warner Sandstone)

[1] 58' S, 1680' E of NW corner sec. 12, T 8 N, R 21 E Elev. 573'

[2] Core description is by Sneed Core Drilling Co., Inc., for Kerr-McGee Oil Industries, Inc. Notes in parentheses are the author's.

NE NE[1] Sec. 23 T. 8N R. 21E Map Photo
Haskell Co., Oklahoma Section No. 10 (Core hole # D-14)
Area Structural Dip By Sneed Core Drill[2]
Outcrop Pattern--Linear belt Formation McAlester

FOOTAGE | ENVIRONMENT | DIRECTIONAL DATA | LITHOLOGY | LATERAL EXTENT (WIDTH IN MILES) 0.1 0.2 0.6 1.0 2.0 | SEDIMENTARY STRUCTURES: MECHANICAL: STRATIFICATION Bedded (B) Laminated (L): MASSIVE, HORIZONTAL (B,L), INTERSTRATIFIED (B,L), GRADED (B,L), INCLINED: LARGE-SCALE, MEDIUM-SCALE, SMALL-SCALE, LOW-ANGLE; LINEATION: EROS.: FLUTES, GROOVES, STRIATIONS, ETC.; DEPOSITION: PEBBLE, PLANT, STREAK, PARTING, RIPPLE MARKS; IRREGULARITIES CUT-OUTS, TRUNCATIONS, ETC.; DEFORMED & DISRUPTED FLOWAGE, MUD CRACKS, ETC.; CHEMICAL CONCRETIONS, CONE-IN-CONE, ETC.; ORGANIC: MOTTLED, BURROWS, TRAILS, ETC. | TEXTURE: GRAIN SIZE AVG. MAX.: COBBLE 256.000 64.000, PEBBLE 16.000 4.000, GRANULE 2.000, V.COARSE 1.000, COARSE .500, MEDIUM .250, FINE .125, V.FINE .062, SILT .016; SORTING: VERY WELL 1.2 1.4 2.0 POOR | CONSTITUENTS: MICA BIOTITE (B) MUSCOVITE (M) CHLORITE (C), GLAUCONITE, CARBONATE CALCITE (C) SID. (S) DOL. (D), CHERT (C) ROCK FRAGMENTS (RF), INTRAFORMATIONAL FRAGMENTS, INTERSTITIAL CLAY KAOLINITE (K) BENTONITE (B), CARBONACEOUS MATERIAL (C) CARBONIZED WOOD (W), FAUNA | COLOR | POROSITY (%) 15 30 | REFERENCE NUMBER | SAMPLE NUMBER

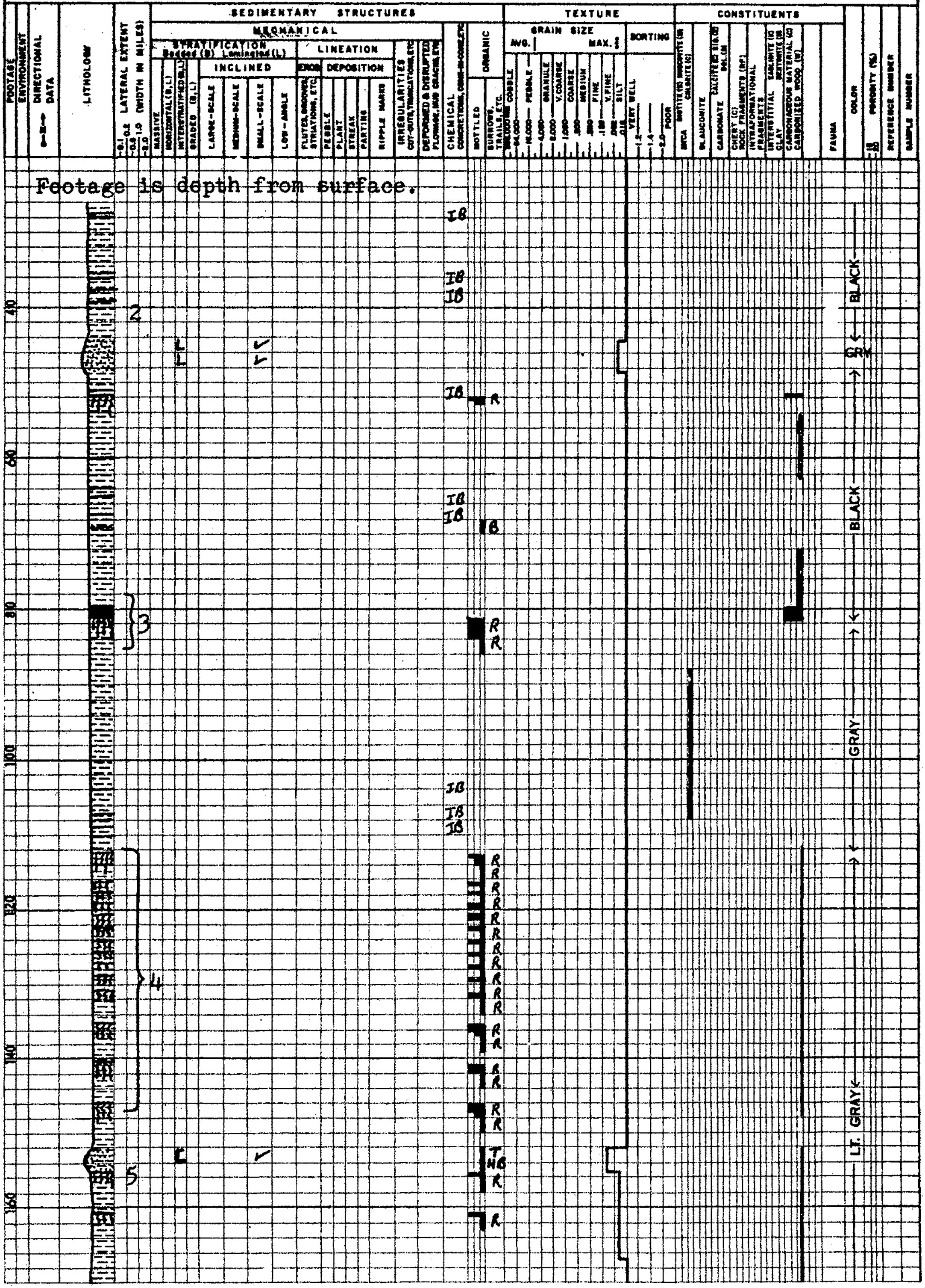


4.5'	Medium hard sandstone	(Tamaha Sandstone)
66.0'	Sandy shale with sandstone bands	
2.0'	Coal	(Stigler coal)
46.0'	Black sandy shale	
17.0'	Medium to hard sandstone	(Lequire Sandstone)
57.0'	hard sandstone	
22.0'	Medium to hard sandstone	
139.0'	Black shale	
21.0'	Shale with sandstone bands	
22.0'	Soft black and gray sandstone	(Warner Sandstone)
6.0'	Shale	
4.0'	Hard sandstone	
5.0'	Shale	
52.0'	Hard gray sandstone	

[1] 409' W, 270' S of NE corner sec. 23, T 8 N, R 21 E Elev. 620'

[2] Core description is by Sneed Core Drilling Co., Inc., for Kerr-McGee Oil Industries, Inc. Notes in parentheses are the author's.

SE^{1} Sec. 8	T. 10N R. 24E	Map	Photo
LeFlore	Co. Oklahoma	Section No. 11 (RSKL&D Core # 32)	
Area	Structural Dip 13° S	By M. D. Karvelot	
Outcrop Pattern- -Linear	belt	Formation McAlester	

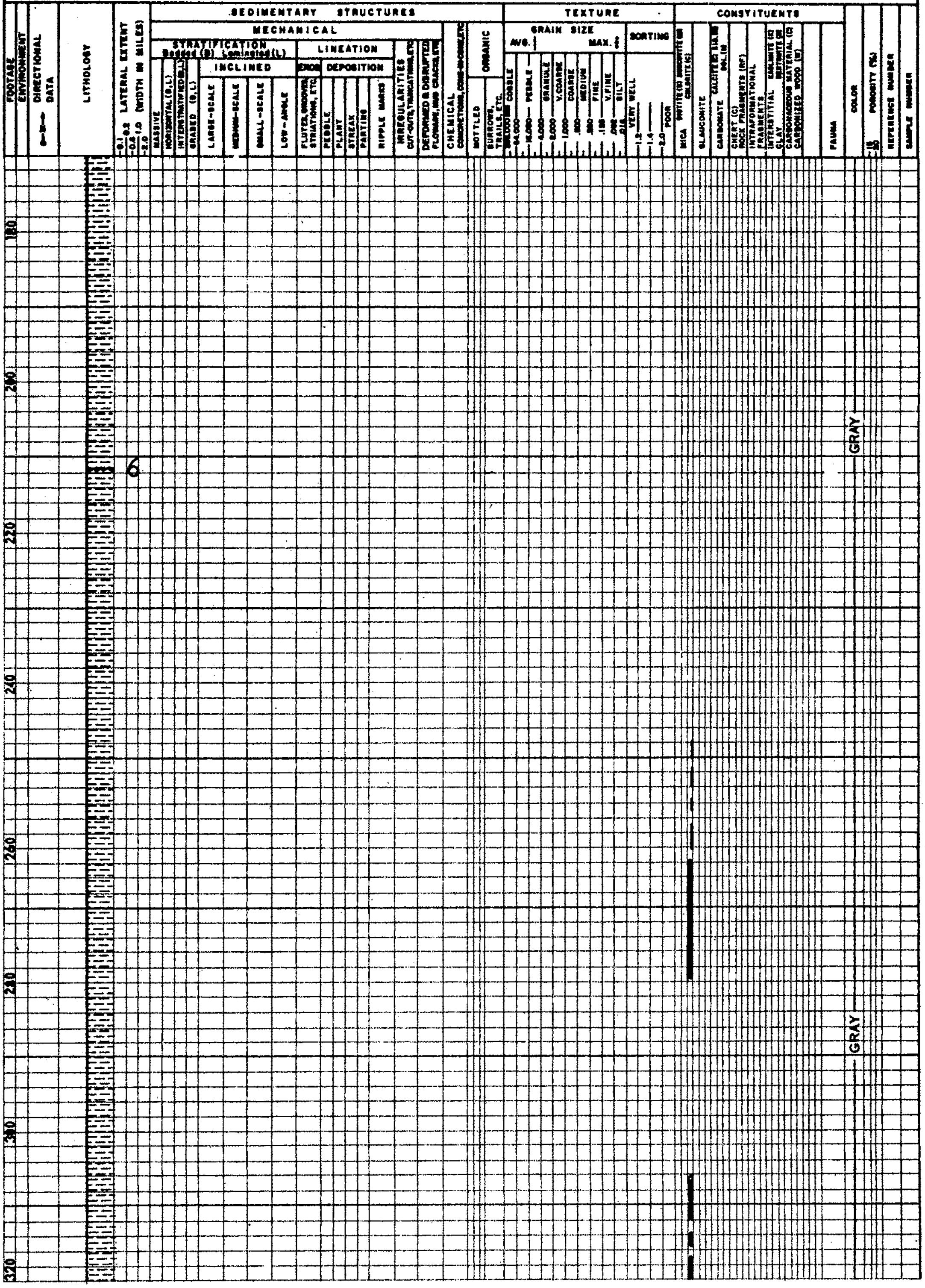


Sec. T. R. Map Photo

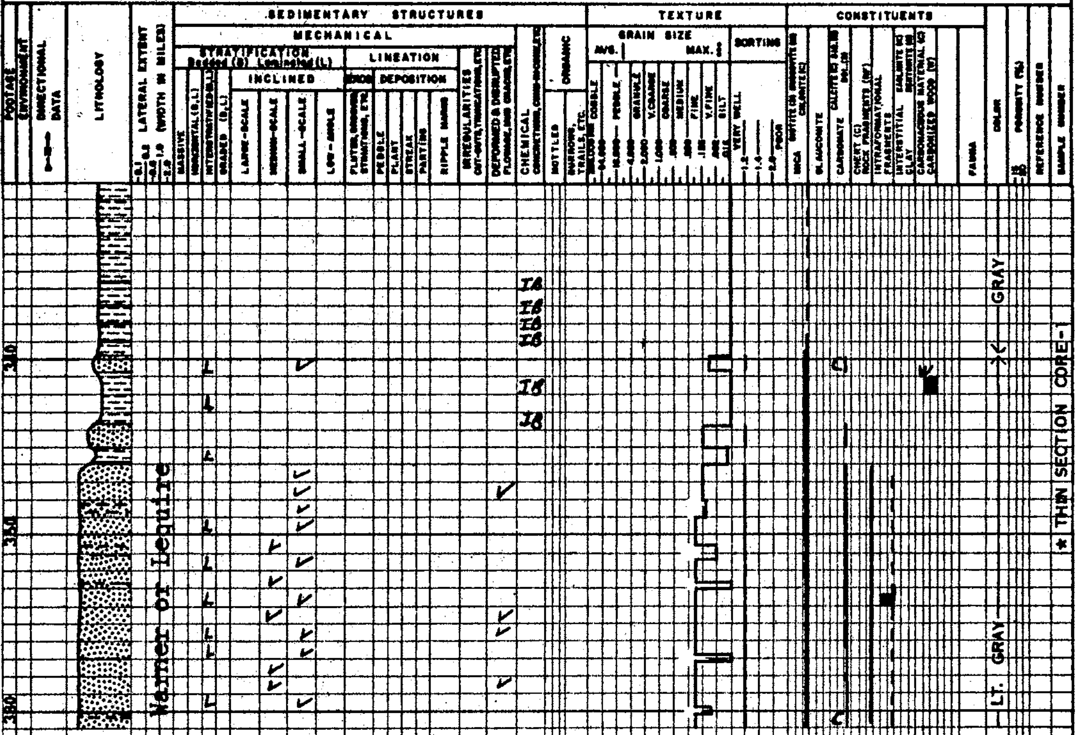
Co., Section No. 11-continued

Area Structural Dip By

Outcrop Pattern -- Linear belt Formation



Sec. T. R. Map Photo
Co, Section No. 11-continued
Area Structural Dip By
Outcrop Pattern--Linear belt Formation



1) Location approximate.

2) Pelecypod

3) Stigler coal. Part of cored interval of coal missing. Shown on Corps of Engineers Geologic Section, Drawing Number 187-DM3-98/2, as being 2 feet in thickness. Bright, medium to fine banded, underclay thin and poorly developed. The coal has a thin siderite cap and the overlying shale contains abundant carbonized wood fragments.

4) Interval 36 feet thick containing 14 separate underclays or root disturbed zones. No coal is preserved over any of the underclays.

5) Zone containing $\frac{1}{2}$ inch coal and 6 inch underclay, overlain by interlaminated silt and shale with tracks and horizontal burrows.

6) Two inch interval containing crinoid fragments and pelecypods.

APPENDIX B

CHEMICAL ANALYSES OF THE STIGLER COAL

LOCALITY, MINE, ETC.	SAMPLE			PROXIMATE				ULTIMATE[4]					AIR-DRYING LOSS	CALORIFIC VALUE		SOFT. TEMP.[5]	REF.[6]
	LAB. NO.[1]	KIND[2]	COND.[3]	MOISTURE	VOLATILE MATTER	FIXED CARBON	ASH	S	H	C	N	O		CAL	BTU		
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
HASKELL COUNTY																	
Stigler, 1 mile northeast of; Turner Bros. strip pit.	17646	A	1	1.5	27.6	67.0	3.9	0.6	---	----	---	---	0.3	8,172	14,710	1,940	123
			2	---	28.0	68.0	4.0	0.6	---	----	---	---	---	8,294	14,930	-----	
2 miles from; H. A. Turner strip pit (north end of pit).	26323	B	1	3.8	27.1	66.6	2.5	0.6	5.2	83.1	1.9	6.7	3.1	8,133	14,640	2,000	193
			2	---	28.2	69.2	2.6	0.7	5.0	86.4	2.0	3.3	---	8,450	15,210	-----	
			3	---	29.0	71.0	---	0.7	5.1	88.7	2.0	3.5	---	8,678	15,620	-----	
3 miles northeast of sec. 5, T 9 N, R 21 E; strip pit (face of workings).	30344	A	1	3.1	26.1	66.2	4.6	0.7	---	----	---	---	2.1	7,972	14,350	2,050	193
			2	---	26.9	68.4	4.7	0.7	---	----	---	---	---	8,228	14,810	-----	
3 miles east of; Acme strip pit (face of coal in pit).	A3085	A	1	3.6	26.9	66.2	3.3	0.7	---	----	---	---	2.8	8,056	14,500	2,010	193
			2	---	27.9	68.9	3.4	0.8	---	----	---	---	---	8,350	15,030	-----	
7 miles northeast of; Garland strip pit (850 feet north, 350 feet east of SW corner of sec. 26, T 10 N, R 21 E).	B88502	A	1	2.4	25.7	67.0	4.9	0.5	---	----	---	---	1.8	-----	14,360	2,140	67
			2	0.6	26.2	68.2	5.0	0.5	---	----	---	---	---	-----	14,620	-----	
			3	---	27.7	72.3	---	0.5	---	----	---	---	---	-----	15,490	-----	
Same (150 feet north, 25 feet west of SE corner of NW ¼, SW ¼ sec. 26, T 10 N, R 21 E).	B88503	A	1	2.5	25.8	68.3	3.4	0.6	---	----	---	---	1.8	-----	14,680	2,150	67
			2	0.7	26.3	69.5	3.5	0.6	---	----	---	---	---	-----	14,950	-----	
			3	---	27.5	72.5	---	0.6	---	----	---	---	---	-----	15,600	-----	
Same (125 feet south, 1,020 feet west of SE corner of NW ¼ sec. 26, T 10 N, R 21 E).	B88504	A	1	2.8	25.6	67.9	3.7	0.7	---	----	---	---	2.2	-----	14,640	-----	67
			2	0.6	26.1	69.5	3.8	0.7	---	----	---	---	---	-----	14,970	-----	
			3	---	27.3	72.7	---	0.8	---	----	---	---	---	-----	15,660	-----	
Same (175 feet north, 390 feet east of SW corner of NW ¼ sec. 26, T 10 N, R 21 E).	B88505	A	1	2.0	24.9	66.9	6.2	0.4	5.0	81.2	1.8	5.4	1.2	-----	14,260	2,100	67
			2	0.8	25.2	67.7	6.3	0.5	4.9	82.2	1.8	4.3	---	-----	14,440	-----	
			3	---	27.1	72.9	---	0.5	5.2	88.4	1.9	4.0	---	-----	15,540	-----	
Same (160 feet north, 1,186 feet west of SE corner of NE ¼ sec. 27, T 10 N, 21 E).	B88506	A	1	2.5	25.1	68.9	3.5	1.0	---	----	---	---	1.8	-----	14,690	2,080	67
			2	0.8	25.6	70.1	3.5	1.1	---	----	---	---	---	-----	14,950	-----	
			3	---	26.7	73.3	---	1.1	---	----	---	---	---	-----	15,630	-----	
Same (Composite of samples B88502 to B88506, inclusive).	B88507	A	1	2.5	25.3	67.9	4.3	0.7	5.2	82.4	1.8	5.6	1.8	-----	14,530	-----	67
			2	0.8	25.8	69.0	4.4	0.7	5.1	83.9	1.9	4.0	---	-----	14,790	-----	
			3	---	27.2	72.8	---	0.7	5.2	88.5	2.0	3.6	---	-----	15,600	-----	

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
HASKELL COUNTY-continued																	
Stigler, 12 miles northeast of; Garland Coal and Mining Co. strip pit, composite of face 300 yards and 450 yards from west end of pit.	169	D	1	2.3	24.2	68.5	5.0	0.8	---	----	---	---	1.5	8,000	14,400	-----	51
Kanima, ½ mile east of; Kanima Consolidated No. 1 mine: Face of main entry, 850 feet from mouth of slope.	170	D	1	2.6	24.9	68.0	4.5	0.6	---	----	---	---	1.9	8,130	14,630	-----	51
Kanima, 2 miles east of; Headly mine (face in strip pit).	A3087	A	1	3.3	21.7	72.1	2.9	0.8	---	----	---	---	2.7	8,144	14,660	2,130	123
			2	---	22.4	74.7	2.9	0.8	---	----	---	---	---	8,422	15,160	-----	
Tamaha, 3 ½ miles from; Floyd Nunnally strip pit. NE ¼ sec. 9, T 10 N, R 22 E (at face of pit).	26324	B	1	3.0	21.3	69.6	6.1	3.8	---	----	---	---	2.7	7,933	14,280	2,250	193
			2	---	22.0	71.7	6.3	4.0	---	----	---	---	---	8,184	14,730	-----	
SW ¼ sec. 19, T 11 N, R 22 E, abandoned Old Slope mine (near mouth of slope).	30706	A	1	5.5	22.7	64.2	7.6	3.4	---	----	---	---	3.6	7,406	13,330	1,920	193
			2	---	24.0	67.9	8.1	3.6	---	----	---	---	---	7,833	14,100	-----	
Whitefield, 1 ½ miles southwest of; sec. 24, T 9 N, R 19 E, Ligon strip pit (face of workings).	26325	B	1	3.9	29.7	63.9	2.5	1.4	---	----	---	---	2.9	8,072	14,530	2,000	193
			2	---	30.9	66.5	2.6	1.4	---	----	---	---	---	8,400	15,120	-----	
LEFLORE COUNTY																	
Robert S. Kerr Lock and Dam, Core 61; SE ¼ sec. 8, T 10 N, R 24 E, upper part of core.	J-86059	C	1	1.0	----	----	---	---	---	----	---	---	---	-----	------	-----	U
			2	---	21.8	72.7	5.5	0.5	---	----	---	---	---	-----	14,450	-----	
Same (Lower part of core).	J-86060	C	1	1.0	----	----	---	---	---	----	---	---	---	-----	------	-----	U
			2	---	21.8	74.2	4.0	0.6	---	----	---	---	---	-----	14,760	-----	
MCINTOSH COUNTY																	
Warner, 5 miles northwest of; outcrop in stream bed, NW SW SW sec. 2, T 12 N, R 18 E.	J-86061	C	1	5.3	----	----	---	---	---	----	---	---	---	-----	------	-----	U
			2	---	33.3	62.3	4.4	0.8	---	----	---	---	---	-----	12,650	-----	

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
MUSKOGEE COUNTY																	
Porum, 3 ½ miles northeast of; T 11 N, R 20 E, Trojan Coal Co. mine (face of stripping).	A23791	B	1	2.3	30.5	60.6	6.6	3.7	5.5	77.8	1.5	4.9	1.0	7,839	14,110	2,340	411
			2	---	31.2	62.0	6.8	3.8	5.4	79.6	1.5	2.9	---	8,022	14,440	-----	
			3	---	33.5	66.5	---	4.1	5.8	85.4	1.6	3.1	---	8,606	15,490	-----	
6 miles northeast of; Trojan Coal Co. strip pit, composite of: Face at middle of pit and face at point 300 yards east of middle of pit.	171	D	1	2.8	29.2	59.6	8.4	3.8	---	----	---	---	2.2	7,650	13,780	-----	51
			2	---	30.0	61.4	8.6	3.9	---	----	---	---	---	7,875	14,170	-----	
3 miles south of; abandoned strip pit, NW NE NW sec. 35, T 10 N, R 19 E, Sample 1.	J-86063	C	1	5.8	----	----	---	---	---	----	---	---	---	-----	------	-----	U
			2	---	29.7	67.5	2.8	0.4	---	----	---	---	---	-----	12,800	-----	
Same, Sample 2.	J-86062	C	1	5.8	----	----	---	---	---	----	---	---	---	-----	------	-----	U
			2	---	29.4	67.9	2.7	0.4	---	----	---	---	---	-----	12,750	-----	
1 mile northeast of; SW ¼ sec. 36, T 11 N, R 19 E, core hole.			1	2.7	30.4	55.6	11.3	4.9	---	----	---	---	---	-----	13,215	-----	C
			2	---	31.2	57.2	11.6	5.1	---	----	---	---	---	-----	13,580	-----	

[1] Laboratory number. Bureau of Mines samples were analyzed at the Pittsburg laboratory. Samples collected by Moose and Rutherford were analyzed in the laboratory of the Department of Chemistry, University of Oklahoma.

[2] Figures in column 3 represent the agency or individual collecting the samples: A, mine sample collected by an engineer of the Bureau of Mines; B, mine sample collected by a geologist of the U. S. Geological Survey; C, sample collected by author for this report; D, sample collected by J. E. Moose and W. R. Rutherford, July 3 to 11, 1928.

[3] Condition of sample; 1, as received; 2, dried at 105° C; 3, moisture and ash free.

[4] Headings of columns for ultimate analysis are standard atomic symbols; sulfur, hydrogen, carbon, nitrogen, and oxygen, respectively.

[5] Softening temperature. Figures in this column represent the temperature at which the cone of coal ash fused to a spherical lump when heated in the furnace in a slightly reducing atmosphere.

[6] References. Figures in column 18 represent the Bureau of Mines Bulletins 123 and 193, Technical Paper 411, Oklahoma Geological Survey Bulletins 51 and 67, in which may be found the description of the section of the bed from which the sample was taken. Figures U and C indicate unpublished analyses by the Bureau of Mines on samples collected by the author for this report, or a confidential source, respectively.

APPENDIX C

COAL THICKNESS DATA

LOCATION		THICKNESS (INCHES)	SOURCE[1]	REF.[2]
HASKELL COUNTY				
T 7 N, R 19 E	NE NE NW 12	12	outcrop	WPA
T 7 N, R 20 E	SE SW NE 1	22	outcrop	WPA
R 8 N, R 19 E	C W L 35	22	borehole	67
	NE SE NW 35	25	do.	67
	SE NW NW 36	18	do.	67
	NE NE NW 36	16	do.	67
T 8 N, R 20 E	SW SE NE 12	18	outcrop	WPA
	SE SW SW 13	16	borehole	67
	NW SE SE 13	18	do.	67
	SW SW SE 21	17	do.	67
	SW NW SW 22	16	do.	67
	NW NE SW 22	12	do.	67
	SW SE NE 22	13	do.	67
	NW SE NW 23	16	do.	67
	SW NW NE 23	18	do.	67
	SW NE NE 23	16	do.	67
	NW NE NW 24	14	do.	67
	NW NW NW 28	17	do.	67
	NE NW NW 28	12	do.	67
	NW SW NE 29	18	do.	67
	NW NW NE 29	17	do.	67
	NE NE NE 29	20	do.	67
	NW SW SW 30	17	do.	67
	NW NW SE 30	14	do.	67
T 8 N, R 21 E	NW NE SE 11	17	Core D-16	K-M
	NW NE NW 12	23	Core D-13	K-M
	SW NW SW 18	18	borehole	67
	SW SE NW 18	18	do.	67
	NW NW NE 18	16	do.	67
	NW SE NW 20	14	outcrop	WPA
	SE SE SW 22	14	Core D-5	K-M
	SE NE NE 28	19	borehole	67
	NW SW NE 28	18	do.	67
	NW NW NW 28	18	do.	67
	SE NW NW 29	20	do.	67
	NW NE NW 29	18	do.	67
	SW NE NE 29	18	do.	67
T 8 N, R 22 E	SE NW NW 2	16.5	borehole	67
	SE SW NW 2	18	do.	67
	NW NW SW 2	18	do.	67
	NW SE SE 3	17	do.	67

LOCATION		THICKNESS (INCHES)	SOURCE[1]	REF.[2]
T 8 N, R 22 E	SW SW SE 3	18	borehole	67
	C S L 8	27	do.	67
	NW SW SW 9	16	do.	67
	NE NE SW 9	20	do.	67
	SE SE NE 9	18	do.	67
	NE NW SW 17	17	do.	67
T 9 N, R 19 E	SE SW SE 10	18	outcrop	WPA
	SW NW SW 24	18	do.	WPA
T 9 N, R 20 E	NE SW NE 17	22	mine	WPA
T 9 N, R 21 E	NE NE NW 4	22	outcrop	67
	SE NW NE 4	18	mine	67
	SE SE NW 4	24	borehole	67
	SE SW NW 4	24	do.	67
	NW NW SW 4	24	do.	67
	SW NW SW 4	23	do.	67
	SW SE SE 5	22	do.	67
	SW SW SE 5	24	do.	67
	NW NE NW 8	24	do.	67
	NW NW NW 8	24	do.	67
	SW NW NW 8	22	do.	67
T 9 N, R 22 E	SE SW NW 3	17	outcrop	67
	SW NE SE 4	25	do.	67
	NW NE NE 7	24	mine	67
	SW NE NW 8	24	do.	67
	SE NW NW 17	20	do.	67
	SE NE NE 24	26	borehole	67
	SW SE SW 24	29	do.	67
	SW SW SW 24	22	do.	67
	NW NW SE 26	28	do.	67
	SW SE SW 26	13	do.	67
	NW NW SE 34	17.5	do.	67
	SE SE SE 34	18	do.	67
	SE NW NW 35	22	do.	67
	NW SW NW 35	12.5	do.	67
	NE NW SW 35	17	outcrop	67
T 9 N, R 23 E	SE NW NW 17	17	outcrop	67
	NE SE NE 18	13	borehole	67
	SW NW SE 18	19.5	do.	67
T 10 N, R 20 E	NW NE SE 13	27	outcrop	67
	NW NW NW 24	26	do.	67
	NE NW SW 26	23	do.	67
T 10 N, R 21 E	SE SE NE 13	31	borehole	67

LOCATION		THICKNESS (INCHES)	SOURCE[1]	REF.[2]
T 10 N, R 21 E	SE SW NE 13	30	borehole	67
	NW NW SE 13	27	do.	67
	NE SE SW 13	31	do.	67
	SE SE SW 13	28	do.	67
	NW SE SW 13	28	do.	67
	NW SW SW 13	28	do.	67
	SW NW NE 23	30	do.	67
	SW NE NE 23	31	do.	67
	NE NE NE 23	31	do.	67
	SE SW NW 26	23	outcrop	67
	NE SW SW 26	23	do.	67
	SE NW NE 27	23	do.	67
	NW SW NE 27	27	borehole	67
	SE SE NW 27	24	do.	67
	SW NW SE 27	28	do.	67
	SE NW SE 27	30	do.	67
	NE NE SE 27	27	outcrop	67
	SE SE SW 33	24	borehole	67
	SE SE NW 34	25	outcrop	67
T 10 N, R 22 E	NW NW NE 5	28	borehole	67
	NW NE NW 5	30	do.	67
	NE SW NW 5	30	do.	67
	SW SW NW 5	30	do.	67
	NE NE SE 6	29	do.	67
	SW NE SE 6	29	do.	67
	NW SW SE 6	28	do.	67
	NE SE NW 7	29	do.	67
	SW SW NE 7	32	do.	67
	SE NW SE 7	28	do.	67
	NW SE SE 7	30	do.	67
	NW SW SE 7	28	do.	67
	SW SW NW 9	25	outcrop	67
	NW NE NE 9	26	do.	67
	NW NE NW 13	19	do.	67
	NE SE NE 14	20	do.	67
	SE SE NW 15	24	do.	67
	NE SE SE 16	19	do.	67
	NE NW NE 17	24	do.	67
	NE NW NE 18	31	borehole	67
	SE NE NW 18	30	do.	67
	NW SE NW 18	31	do.	67
	NW SW NW 18	31	do.	67
T 10 N, R 23 E	NW NW SW 18	20	outcrop	67
T 11 N, R 21 E	SW SW NW 36	26	outcrop	67
T 11 N, R 22 E	SW SE SE 19	25	outcrop	67

LOCATION		THICKNESS (INCHES)	SOURCE[1]	REF.[2]
T 11 N, R 22 E	NE NE SE 30	25	borehole	67
	NW NW NE 31	29	do.	67
	SW SW SE 32	28	do.	67
	SE SW SE 32	27	do.	67
	SW SE SE 32	27	do.	67
	SE SW SW 34	29	outcrop	67
T 11 N, R 21 E	SW SW NW 36	26	outcrop	67
T 11 N, R 22 E	SW SE SE 19	25	outcrop	67
	NE NE SE 30	25	borehole	67
	NW NW NE 31	29	do.	67
	SW SW SE 32	28	do.	67
	SE SW SE 32	27	do.	67
	SW SE SE 32	27	do.	67
	SE SW SW 34	29	outcrop	67
LE FLORE COUNTY				
T 10 N, R 24 E	SE SE SE 8	24	Core 32	CE
	SE SW SE 26	20	outcrop	68
McINTOSH COUNTY				
T 12 N, R 18 E	NW SW SW 2	11	outcrop	U
T 11 N, R 18 E	NE SW NE 3	8	outcrop	U
MUSKOGEE COUNTY				
T 11 N, R 19 E	SW SW NW 27	17	outcrop	57
	SE SE SE 11	21	borehole	SCC
	SE SE NE 11	19	do.	SCC
	SE SE SW 12	21	do.	SCC
	Center 13	22	do.	SCC
	Center 14	19	do.	SCC
	SW SW NW 14	18	do.	SCC
	SE NE SE 15	19	do.	SCC
T 12 N, R 19 E	SW NW NW 17	18	outcrop	57
	SE SE NW 17	14	do.	57
	C N L 18	18	do.	57

LOCATION		THICKNESS (INCHES)	SOURCE[1]	REF.[2]
T 10 N, R 19 E	SE SE SE 1	24	borehole	SCC
	C W L 1	18	do.	SCC
	C E L 12	26	do.	SCC
	Center 12	22	do.	SCC
	NW SE NE 13	22	do.	SCC
	NE SW SW 26	19	outcrop	57
	SE SE SE 27	16	do.	57
	NE NE NW 35	17	do.	U
	SE NW 35	18	mine	57
T 11 N, R 20 E	C S L 18	24	borehole	SCC
	SW SE NE 25	25	do.	SCC
	SE SE SE 25	22	do.	SCC
	SW SE SE 36	22	do.	SCC

[1] Source refers to the type of exposure where the coal was measured. Three types of exposure are listed as outcrop: strip pit face, prospect, and natural outcrop. Mine refers to a drift or slope type of underground mining operation. Core followed by a number indicates a particular core hole designation by the operator.

[2] References: Numbers in this column refer to Oklahoma Geological Survey Bulletins 57, 67, and 68. Letter symbols are as follows: WPA, State Mineral Survey, WPA project 65-65-538, sponsored and directed by the Oklahoma Geological Survey, 1936; K-M, unpublished measurement by Kerr-McGee Corporation; CE, measurement by the U.S. Army Corps of Engineers; SCC, unpublished measurement by Sierra Coal Corporation; U, unpublished measurement by the author.

VITA 2

Michael D. Karvelot

Candidate for the Degree of

Master of Science

Thesis: THE STIGLER COAL AND COLLATERAL STRATA IN PARTS OF HASKELL, LE FLORE, MCINTOSH, AND MUSKOGEE COUNTIES, OKLAHOMA

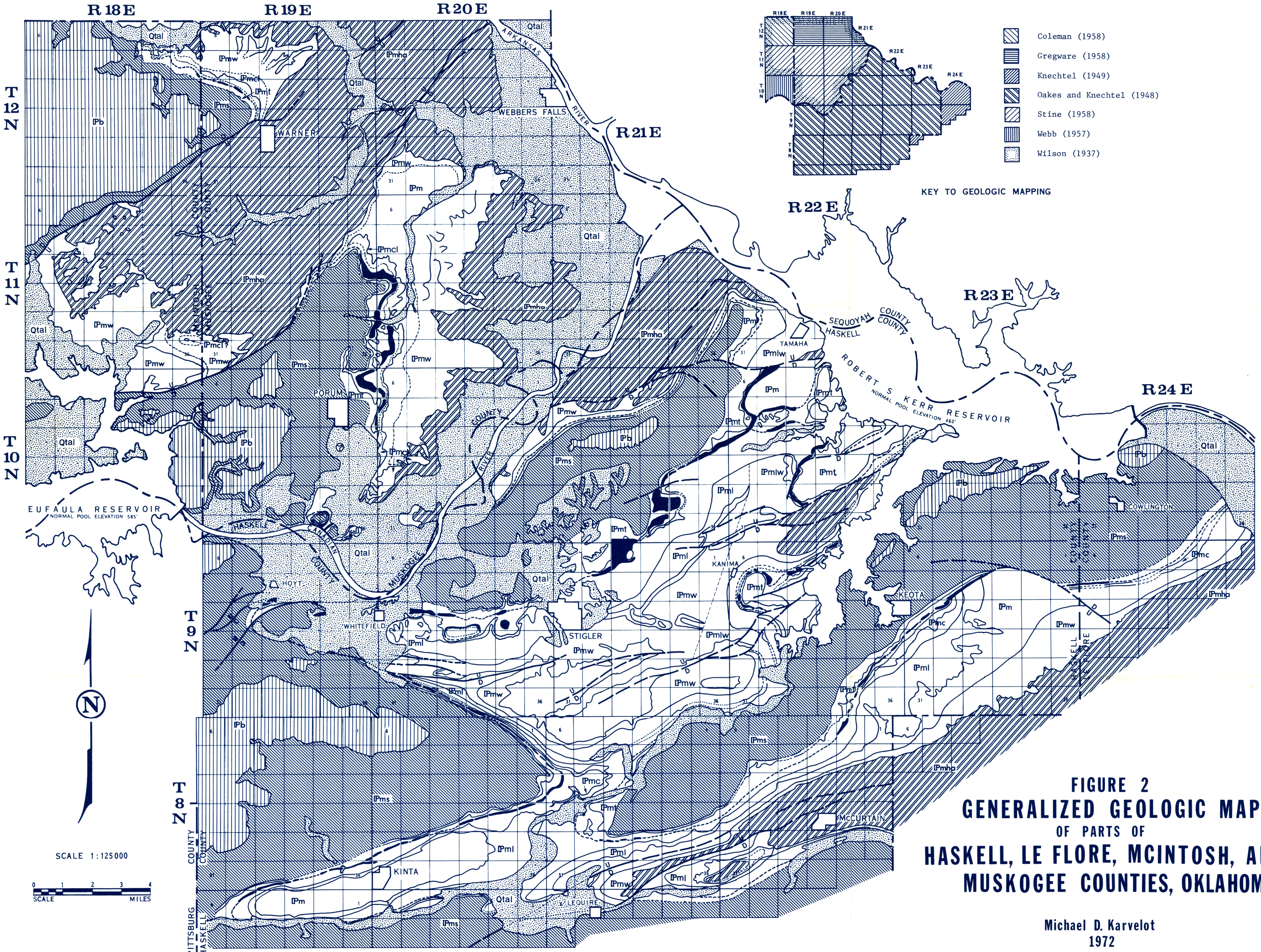
Major Field: Geology

Biographical:

Personal Data: Born in McAlester, Oklahoma, May 9, 1944, the son of Capt. and Mrs. Edward Joseph Karvelot.

Education: Graduated from Talihina High School, Talihina, Oklahoma, in May, 1962; received the Associates of Arts degree from Eastern Oklahoma A & M College, Wilburton, Oklahoma, in May, 1965; received the Bachelor of Science degree from Oklahoma State University, Stillwater, Oklahoma, in May, 1968, with a major in Geology; enrolled in the Master of Science program in Geology at the University of Arizona, Tucson, Arizona, 1967-68; completed requirements for the Master of Science degree at Oklahoma State University in May, 1972.

Professional Experience: Undergraduate teaching assistant, Department of Geology, Oklahoma State University, 1966-67; Junior Geologist, the Sinclair Oil and Gas Company, Midland, Texas, summer, 1967; Graduate Teaching Assistant, Department of Geology, the University of Arizona, Tucson, Arizona, 1967-68; Geologist, the Sinclair Oil and Gas Company, Midland, Texas, 1968-69; Graduate Teaching Assistant, Department of Geology, Oklahoma State University, 1971. Student Member of the American Institute of Mining, Metallurgical, and Petroleum Engineers; Junior member of the American Association of Petroleum Geologists; President, Alpha Omega Chapter of the Society of Sigma Gamma Epsilon.



BASE MAP ADAPTED FROM PUBLISHED U.S.G.S.
TOPOGRAPHIC QUADRANGLE COVERAGE.

EXPLANATION

QUATERNARY

PENNSYLVANIAN SYSTEM

DESMOINESIAN SERIES

ATOKAN

KREBS GROUP

Boggy Fm.

Savanna Fm.

McAlester Fm.

Hartshorne Fm.

Atoka Fm.

Qtal	Quaternary terrace deposits and alluvium, undivided.
ℙb	Boggy Formation, undivided.
ℙms	Savanna Formation and upper part of the McAlester Formation from the Tamaha Sandstone to the base of the overlying Savanna Formation, undivided.
ℙmt	Tamaha Sandstone Member
ℙmc	Cameron Sandstone Member
ℙml	Lequire Sandstone Member
ℙmw	Warner Sandstone Member
ℙmcl	Mapped as Cameron-Lequire, undivided, in Muskogee and McIntosh Counties.
ℙmlw	Mapped as Lequire-Warner, undivided, northeast of Stigler in Haskell County.
ℙm	Undifferentiated, unnamed shale members separating sandstone members of the McAlester Formation.
ℙmha	Atoka Formation, Hartshorne Formation, and lower part of the McAlester Formation from the base of the Warner Sandstone to the top of the underlying Hartshorne Formation, undivided.

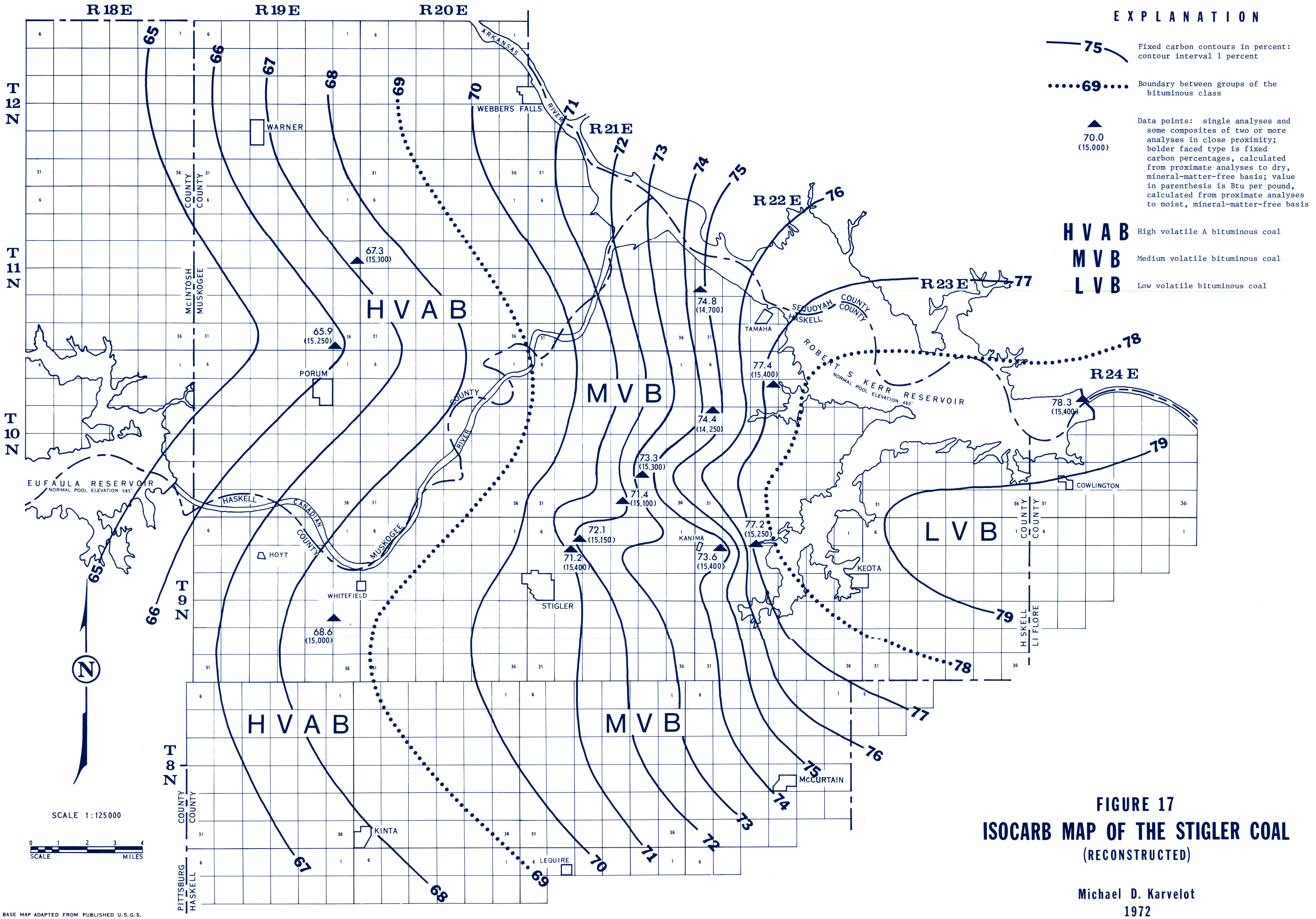
Coal outcrop: dashed where known or inferred, dotted where concealed, queried where unknown

Strip mines and/or abandoned pits

Fault: solid line where known, dashed where inferred, dotted where concealed

FIGURE 2
GENERALIZED GEOLOGIC MAP
OF PARTS OF
HASKELL, LE FLORE, McINTOSH, AND MUSKOGEE COUNTIES, OKLAHOMA

Michael D. Karvelot
1972



BASE MAP ADAPTED FROM PUBLISHED U.S.G.S. TOPOGRAPHIC QUADRANGLE COVERAGE.

FIGURE 17

ISOCARB MAP OF THE STIGLER COAL

(RECONSTRUCTED)

Michael D. Karvelot

1972

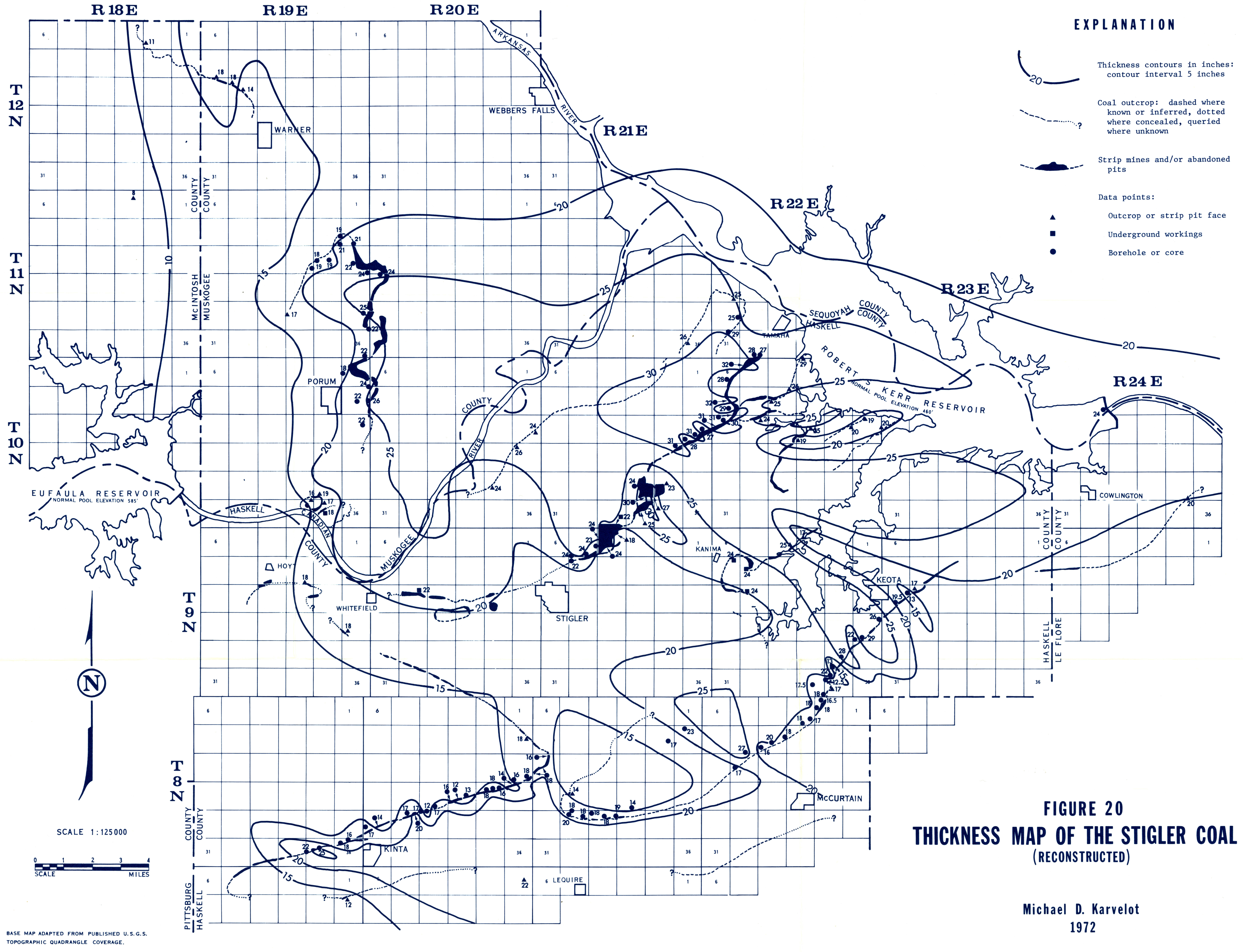
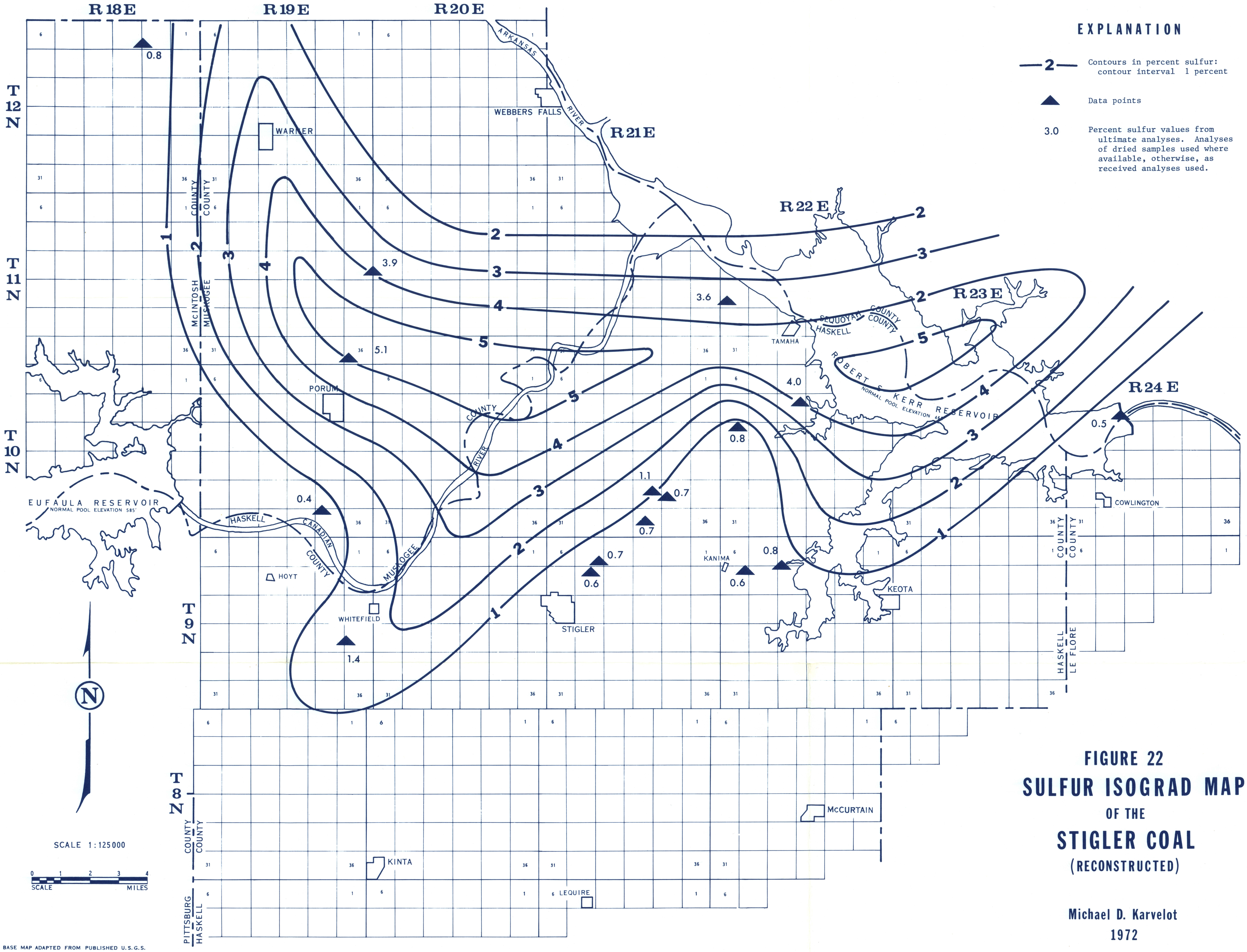


FIGURE 20
THICKNESS MAP OF THE STIGLER COAL
(RECONSTRUCTED)

Michael D. Karvelot
1972



BASE MAP ADAPTED FROM PUBLISHED U.S.G.S. TOPOGRAPHIC QUADRANGLE COVERAGE.

FIGURE 22

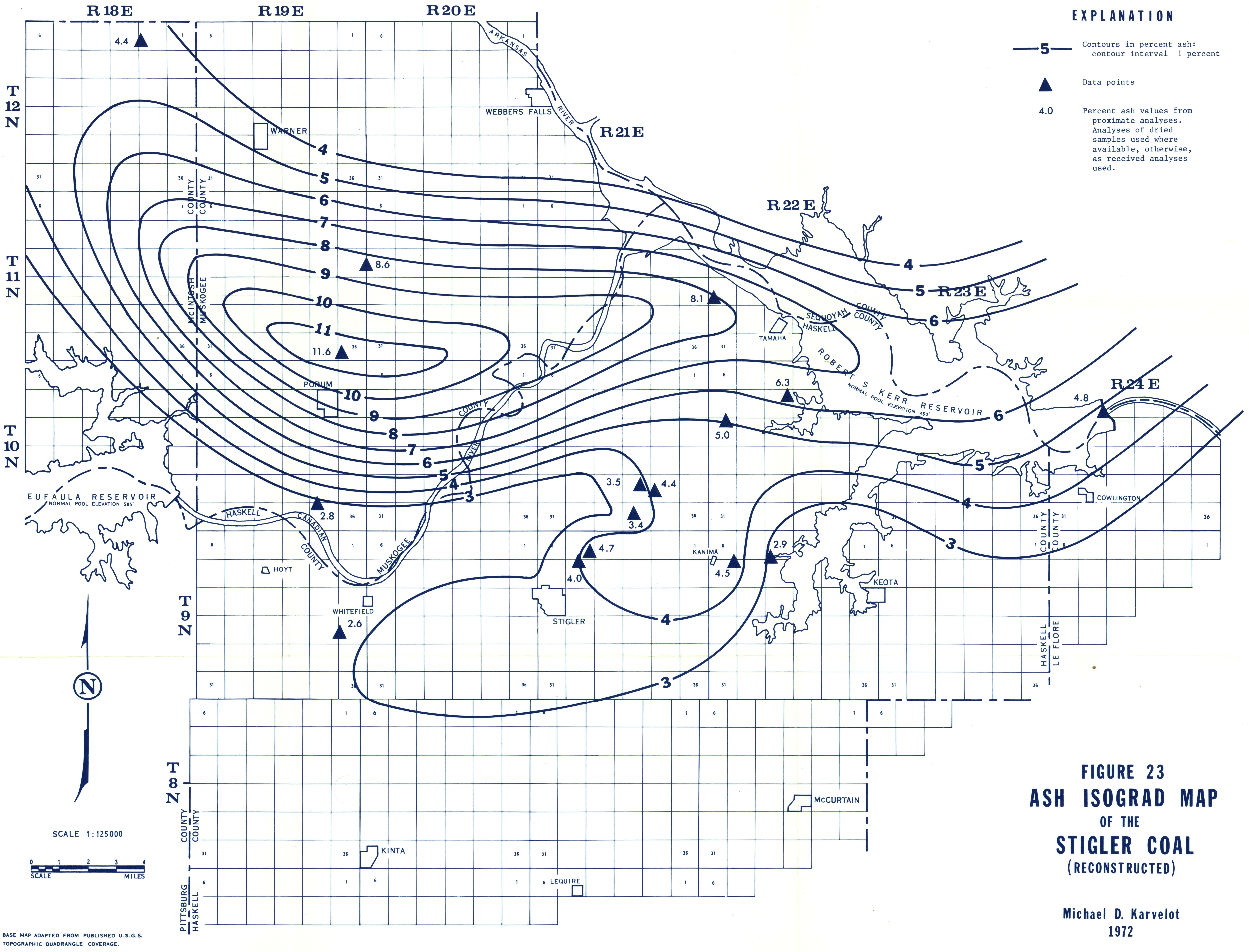
SULFUR ISOGRAD MAP

OF THE

STIGLER COAL

(RECONSTRUCTED)

Michael D. Karvelot
1972

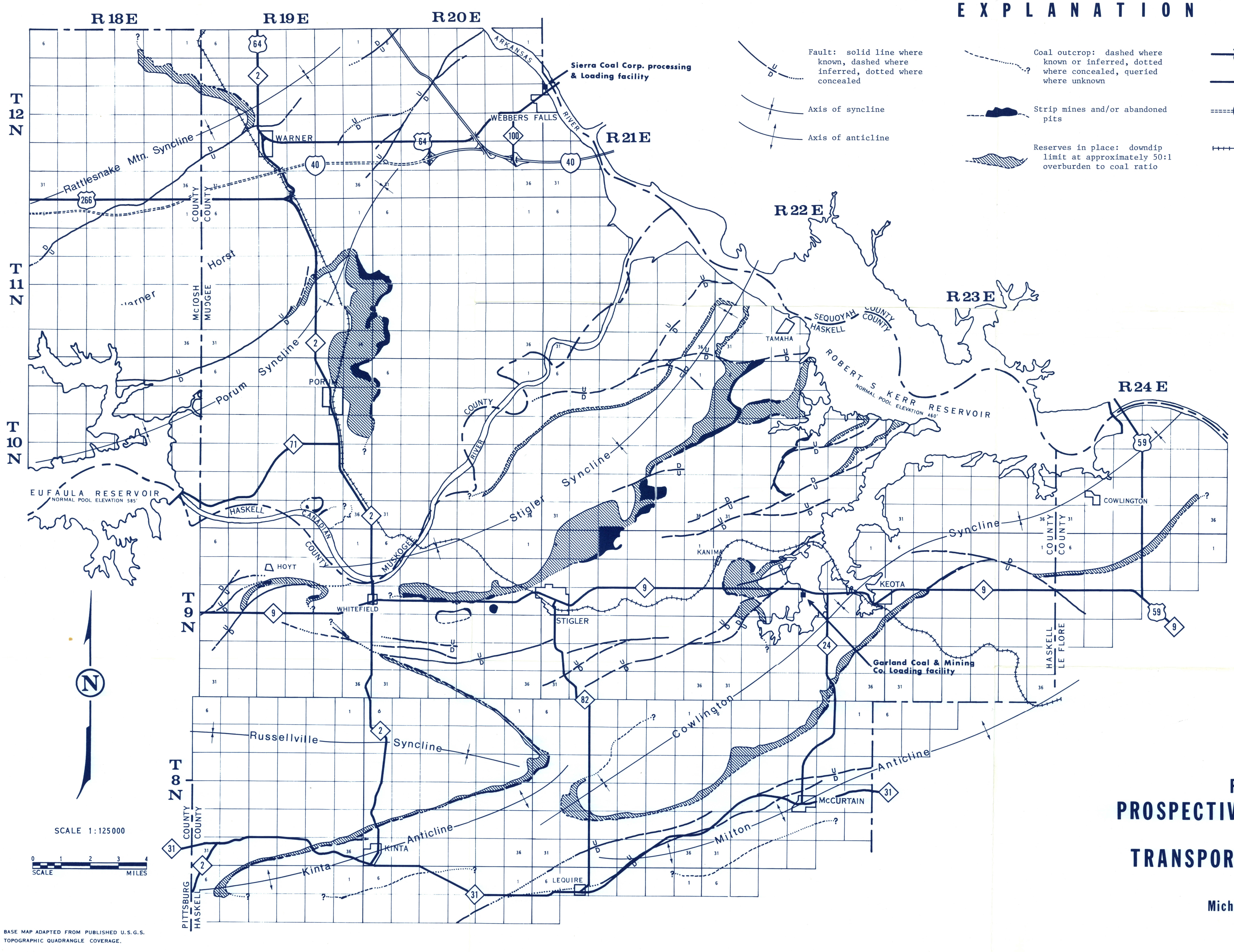


BASE MAP ADAPTED FROM PUBLISHED U.S.G.S. TOPOGRAPHIC QUADRANGLE COVERAGE.

FIGURE 23

ASH ISOGRAD MAP
OF THE
STIGLER COAL
(RECONSTRUCTED)

Michael D. Karvelot
1972



EXPLANATION

Fault: solid line where known, dashed where inferred, dotted where concealed

Axis of syncline

Axis of anticline

Coal outcrop: dashed where known or inferred, dotted where concealed, queried where unknown

Strip mines and/or abandoned pits

Reserves in place: downdip limit at approximately 50:1 overburden to coal ratio

64 U. S. Highway

9 State Highway

40 Interstate Route (dashed where under construction)

Midland Valley Railroad

■ Coal processing and/or loading facilities: Kerr-McClellan Arkansas River Navigation System

Note: Highways and railroad are from General Highway Maps of Haskell, Le Flore, McIntosh, and Muskogee Counties, Oklahoma, prepared by the Oklahoma Department of Highways Planning Division.

FIGURE 24

PROSPECTIVE MINING AREAS AND TRANSPORTATION SYSTEMS

Michael D. Karvelot

1972