Text to Accompany

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FEDERAL COAL RESOURCE OCCURRENCE AND FEDERAL COAL DEVELOPMENT POTENTIAL MAPS OF THE NORTHWEST QUARTER OF THE RED OAK 15-MINUTE QUADRANGLE, LATIMER COUNTY, OKLAHOMA

[Report includes 19 plates]

Prepared for

UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

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This report was prepared under contract to the U.S. Geological Survey, and has not been edited for conformity with Geological Survey editorial standards or stratigraphic nomenclature. Opinions expressed herein do not necessarily represent those of the Geological Survey.

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INTRODUCTION

Purpose

This text is to be used in conjunction with the Federal Coal Resource Occurrence (FCRO) and Federal Coal Development Potential (FCDP) Maps of the northwest quarter of the Red Oak 15-minute quadrangle, Latimer County, Oklahoma.

This report was compiled to support the land-planning work of the Bureau of Land Management (BLM). The work was undertaken by Geological Services of Tulsa, Tulsa, Oklahoma, at the request of the United States Geological Survey under contract number 14-08-0001-17989. The resource information gathered for this report is in response to the Federal Coal Leasing Amendments Act of 1976 (Public Law 94-377). Published and unpublished publicly available information was used as the data base for this study. No new drilling or field mapping was done to supplement this study, nor was any confidential or proprietary data used.

The coal data used in this map report were originally compiled on an enlarged version of the Red Oak 15-minute quadrangle base. Subsequently, the Panola 7.5-minute topographic quadrangle map base was completed by the U.S. Geological Survey. The more recent base map was used in compositing plates 1, 4, 5, 6, 7, 8, 11, 12, 13, 14, and 15 in the accompanying map set.

Minor discrepancies may exist in the locations of the traces of the coal bed outcrops and other surface data points; however, the enclosed maps are internally consistent. The decision to use a more modern and accurate base should not significantly affect the reserve base or reserve tonnage.

Location

The northwest quarter of the Red Oak 15-minute quadrangle is located on the west-central portion of the Howe-Wilburton coal mining district in the southern part of the southeastern Oklahoma coal field. All of the northwest quarter of the quadrangle lies in Latimer County. The city of McAlester is 36 miles (58 km) west of the quadrangle, and the city of Tulsa is approximately 100 miles (160 km) northwest of the quadrangle. The town of Red Oak lies 2 miles (3 km) to the east of the study area in the northeast quarter of the Red Oak 15-minute quadrangle.

Accessibility

The town of Panola is the only settlement of any size in the northwest quarter of the Red Oak 15-minute quadrangle. U.S. Route 270 runs east from Panola about 32 miles (52 km) to Poteau where it joins U.S. Route 59, and west to McAlester, where it joins U.S. Route 69.

There are many improved and unimproved roads in the valleys of the central part of the study area, but the mountainous areas to the north and south are largly inaccessible to surface transportation.

The Chicago, Rock Island, and Pacific Railroad maintains a railroad line which parallels U.S. Route 270 through the study area.

Physiography

The northwest quarter of the Red Oak 15-minute quadrangle is in the Arkoma Basin on the northern edge of the Ouachita Mountains in the Arkansas

Valley physiographic province (Hendricks, 1939). The Choctaw fault, which essentially marks the southern edge of the Basin, cuts across the southern portion of the area.

The topography in the northern half of the study area is dominated by the Sans Bois Mountains, which reach a height of 1,738 feet (530 m), and rise fairly abruptly out of the surrounding land. The southern part of the area is dominated by east-west trending ridges and valleys. The ridges range from 800 to 900 feet (244 to 274 meters) in altitude, while the valley floors are about 500 to 650 feet (183 to 198 meters) above sea level. A fairly broad valley cuts across the southern third of the quadrangle, ranging in width from about 1.5 miles (2.4 km) in the west to more than 2 miles (3.2 km) in the east.

The coal beds of the area crop out to the south of the San Bois Mountains in the valleys of the area. Virtually all of the outcrops are 550 to 700 feet (168-213 m) in elevation.

The area is drained in the south by the Fourche Maline and several of its tributaries.

Climate and Vegetation

The climate in southeastern Oklahoma is for the most part fairly moderate. Winters are short, and extremely cold weather is rare. Summers, however, are generally long and hot. The mean annual temperature is about 62° F (17° C), and ranges from a daily average of about 41° F (5° C in January to to about 82° F (28° C) in July, through it is not unusual to have occasional periods of very hot days (Hendricks, 1939). Annual precipitation in the area averages approximately 41 inches (104 cm), with rains generally abundant in the spring, early summer, fall and winter (Hendricks, 1939).

The area supports a wide variety of vegetation, with oaks, blackjacks, hickories, elms and hackberries being most common. On the higher mountains and ridges pines can also be found. In parts of the valleys that have not been cleared for farming, thick stands of water and willow oaks, hickories, cottonwoods, willows and wild plums may be present (Hendricks, 1939).

Land Status

There are no designated Known Recoverable Coal Resource Areas (KRCRA) within the northwest quarter of the Red Oak 15-minute quadrangle. The Federal Government holds title to the coal mineral rights for approximately 11,490 acres (29 %) of the quadrangle. As of October 19, 1979 none of this land was leased.

GENERAL GEOLOGY

Previous Work

Much work has been done on the southeastern Oklahoma coal field. The first geologic study of the Howe-Wilburton district, of which the northwest quarter of the Red Oak 15-minute quadrangle is a part, was published by Chance (1890) and included a map showing the outcrops of the most important coal beds in the area. In 1897, Drake published the results of his study on the coal fields of the Indian Territory, which consisted of a map and text of the principal coal beds, general stratigraphy, and structural features.

From 1899 to 1910, Taff and his associates published several reports on the Oklahoma coal lands. These included a number of investigations carried out for the United States Geological Survey on the extent and general character of local stratigraphy, including coal beds. Much of his work was a part of Senate Document 390 (1910), which represented a compilation of material collected for the purpose of determining the value and extent of coal deposits in and under the segregated coal lands of the Choctaw and Chickasaw Nations in Oklahoma.

The Oklahoma Geological Survey published a bulletin by Snider in 1914 on the geology of east-central Oklahoma, emphasizing the geologic structure and oil and gas possibilities of the area. Further studies on the southern Oklahoma coal lands were carried out by Shannon et al (1926), Moose and Searle (1929), and Hendricks (1939). These, along with later works by Knechtel and Oakes in the 1940's added greatly to the body of knowledge on Oklahoma coals, particularly in terms of their quality, chemical composition and extent.

A number of estimates as to original and remaining coal reserves have been published; among them are the figures published in papers by Trumbull (1957) and Friedman (1974). Non-proprietary information of coal test holes drilled in various years in the northwest quarter of the Red Oak 15-minute quadrangle was available from USGS files and incorporated into this report.

Stratigraphy

The Arkoma Basin, once part of the larger Ouachita geosyncline, formed as a result of subsidence beginning in Mississippian time and continuing through Early and Middle Pennsylvanian. Strata in the basin are thought to have been deposited in a deltaic environment with sediment coming primarily from eroding highlands to the northeast, north, and northwest (Brannan, 1968). Evidence that the basin was becoming full is provided by coal seams in the upper Atoka and lower Desmoinesian section. Sedimentation continued until Late Pennsylvanian time, when the Arbuckle Orogeny of southern Oklahoma took place (Brannan, 1968). In Early Permian time, Ouachita mountain building to the south of the basin compressed Arkoma Basin strata into a series of long, narrow, east-west anticlinal and synclinal folds (see section on "Structure").

Most of the rock units cropping out in the northwest quarter of the Red Oak 15-minute quadrangle are of Pennsylvanian age, and include the Atoka Formation, as well as the Hartshorne, McAlester and Savanna and Boggy Formations of the lower Desmoinesian Krebs Group. The Hartshorne, McAlester and Boggy Formations are coal bearing in this quadrangle. South of the Choctaw fault are non-coal bearing older rocks associated with the Ouachita Province. They lie south of the Oklahoma coal field and will not be discussed in detail here.

The Atoka Formation was named by Taff and Adams in 1900. It is the oldest exposed formation in the quadrangle, and crops out across the central section of the study area (Hendricks, 1939). The formation consists mostly of black to gray sandy shale interbedded with ridge-forming brown or light gray sandstone units. The sandstone is highly variable in character, both from bed to bed and within a single bed. In most exposures, it is fine-grained, silty, and irregularly bedded; however, locally it may be coarse-grained, clean, and massive to thick-bedded. The Atoka Formation thickens somewhat across the quadrangle, from about 5,500 feet (1,678 m) in the northwest to almost 7,200 feet (2,196 m) at the Choctaw fault in the southeast (Hendricks, 1939).

The Hartshorne Formation, which forms the basal unit of the Desmoinesian Series, crops out in a single band trending east-west across the center of the quadrangle (Hendricks, 1939). It is most probably conformable with the underlying Atoka Formation (McDaniel, 1961, Oakes and Knechtel, 1948), although the sharp and irregular contact between the Hartshorne and Atoka

Formations has led some observers to conclude that a minor unconformity separates them, at least locally (Hendricks, 1939, and Branson, 1962). The contact between the Hartshorne Formation and the overlying McAlester Formation is conformable (Hendricks, 1939).

The boundaries of the Hartshorne Formation have been modified several times since the unit was first mapped by H. M. Chance in 1890. Then called the "Tobucksy" Sandstone, the formation was renamed the Hartshorne Sandstone by Taff in 1899. Early workers defined the formation such that the Upper Hartshorne coal was considered to be part of the overlying McAlester Formation. However, Oakes and Knechtel (1948) recognized a convergence of the Upper and Lower Hartshorne coals in northern LeFlore and eastern Haskell counties, and redefined the Hartshorne Formation to include both coals. The Hartshorne coal, undivided to the north, splits into Upper and Lower Hartshorne coals along a northeast-southwest trending line. This split line lies north of the northwest quarter of the Red Oak 15-minute quadrangle, so only the upper and lower splits of the Hartshorne coal are found here (Plate 13). The presently-used definition of the Hartshorne Formation is one proposed by McDaniel (1961), which supports the boundaries suggested by Oakes and Knechtel (1948), but formally divides the formation into upper and lower members where applicable (based on the above mentioned coal "split line").

The Hartshorne Formation is highly variable in character and thickness throughout the Howe-Wilburton district. In general it contains interbedded sandstones and shales which tend to become discontinuous as the upper and lower coals merge. The sands are for the most part fine-grained, white to brown, silty and micaceous, and the shales are gray and sandy. Plant fossils are abundant in the shales. The formation is roughly 500 feet (152 m) thick in this area.

The McAlester Formation averages about 2,000 to 2,250 feet (610 to 686 m) thick in the northwest quarter of the Red Oak 15-minute quadrangle. It crops out in a band running east-west across the area, and lies conformably on the Hartshorne Formation. The McAlester Formation consists primarily of various unnamed shale members, but includes several sandstone members as well. In ascending order, the McAlester Formation includes the McCurtain Shale Member, and the Warner, Lequire, Cameron, Tamaha and Keota Sandstone Members. The thickness given below of each individual member has been estimated from well logs in the area.

The lowermost unit of the McAlester Formation is the McCurtain Shale Member. This is a dark gray, clayey shale with numerous siderite concretions and plant material. The McCurtain Shale Member contains a few thin sandstone units, including the McCurtain Sandstone and an associated unnamed local coal, which are found approximately 350 feet (107 m) above the base of the shale.

The most persistent sandstone of the McAlester Formation is the Warner Sandstone Member, a fine-grained, argillaceous unit which forms the first prominent escarpment stratigraphically above the Hartshorne Formation. This member forms the upper boundary of the McCurtain Shale. It is highly variable in thickness (Oakes & Knechtel, 1948), and has a locally persistent coals associated with it. Above the Warner Sandstone is an unnamed shale unit which is dark gray, silty and fissile, and in the northeast Red Oak area has an average thickness of 100 feet (30 m). Siderite concretions are common, and few thin sandstones can be found within it.

The Lequire Sandstone Member of the McAlester Formation is found above this unnamed shale. This unit includes variable sandstone lenses interbedded with siltstones and shales, and can include a thin local coal. Units between the Lequire and Keota Sandstone Members are highly variable in thickness and lateral extent. They include two unnamed shale units and the Cameron and Tamaha Sandstone Members.

The Cameron Sandstone in the northwest Red Oak area is a fairly thick ($\pm$ 80 ft., 24 m), massive-to-thin bedded fine-grained sandstone. The overlying shale includes the economically important upper and lower McAlester coals. This unit varies from a green to brown, silty, blocky shale to a green clayey shale which may contain plant remains. The Tamaha Sandstone Member includes a complex of sandstone lenses as opposed to being a single bed (Oakes & Knechtel, 1948) and averages about 20 feet (6 m) thick. The Keota Sandstone Member, separated from the Tamaha by a fairly thick (150 feet, 46 m) unnamed dark gray shale unit, is the uppermost sand unit of the McAlester Formation. It is generally a silty, buff, fine-grained sandstone, ranging from 30 to 70 feet (9 to 21 m) thick. Both the Tamaha and Keota Sandstones tend to be erratic and discontinuous (Russell, 1960). A dark, fissile to blocky shale with siderite concretions marks the top of the McAlester Formation.

The Savanna Formation is the youngest unit exposed in the northwest quarter of the Red Oak 15-minute quadrangle, and is found on the mountains in the northern part of the area. In some places the boundary between it and the McAlester Formation appears to be gradational, while in others it is highly irregular. The sandstones of the Savanna Formation form prominent slopes and ridges which tend to rise sharply out of the surrounding terrain.

These sandstones are generally brown, dense, fine-grained and micaceous, and the interbedded shales are brown to grayish green.

The Boggy Formation is the upper unit of the Krebs Group in the Desmoinesian Series. It lies conformably on the Savanna Formation, and is the youngest unit exposed in the area. It crops out in the northwest corner of the study area on Yancey Mountain, where it is about 850 feet (259 m) thick (Russell, 1960). The formation consists of alternating shale and sandstone units, and its lower boundary is defined as the base of the Bluejacket Sandstone (Russell, 1960).

The Secor coal, part of the Boggy Formation crops out in the extreme northwest corner of the Red Oak quadrangle on Yancey Mountain (Russell, 1960). However, no information on its thickness or quality was available, so it was not evaluated in this quadrangle.

Quaternary deposits of alluvium cover some stream valleys and flood plains in the area.

Structure

The Howe-Wilburton mining district lies within a zone of folded Pennsylvanian rocks characterized by broad, shallow synclines and narrow anticlines (Russell, 1960). The axes of these structures are commonly en echelon, and in general run parallel to the frontal margin of the adjacent Ouachita salient, marked by the Choctaw fault. The principal surface structures in the northwest quarter of the Red Oak 15-minute quadrangle are shown on Plate 1. One of the dominant features in the area is the Sans Bois syncline, the axis of which passes through only the extreme northwest corner of the quadrangle. Strata exposed on the south flank of the syncline in T. 6 N. R. 20 E. are contorted where the structure converges with the axes of the nearby Brazil anticline and Cavanal syncline (Russell, 1960).

The Brazil anticline begins in section 13 of T. 6 N. R. 20 E. in the northeast corner of the northwest quarter of the Red Oak quadrangle, and extends beyound its eastern boundary. Its axis here rises at an angle of 15° from the south flank of the Sans Bois syncline (Russell, 1960). The surface expression of the Brazil anticline is that of a wide valley in which rocks of the McAlester Formation are exposed.

South of the Brazil anticline is the Cavanal syncline, the exis of which just barely reaches inside the eastern edge of the northwest quarter of the Red Oak 15-minute quadrangel. Its topographic expression defines the eastern most tip of Second Mountain, where rocks of Savanna-age are exposed (Russell, 1960). This is a shallow syncline, with beds dipping from 2° to 8°.

The only major fault in the quadrangle is the Choctaw fault, which as previously mentioned, marks the northern edge of the Ouachita thrust zone.

COAL GEOLOGY

Several major coal beds have been identified and mapped in the northwest quarter of the Red Oak 15-minute quadrangle. They include in ascending order the Lower Hartshorne coal, the Upper Hartshorne coal, the lower McAlester (Stigler) coal bed, and the upper McAlester (Stigler Rider) coal bed. In addition to these are several other minor local coals, and the Secor coal, which has been mapped in the northwest corner of the quadrangle but for which no data was available.

In this study area there are measurements of three local coals that exceed the Reserve Base thickness of 1 foot (0.3 m) and are treated as isolated data points (see below). They iclude two local coals measured in data point 12, and one measured in data point 15 (see Plate 1 for location and Plate 3 for correlation).

Upper and Lower Hartshorne Coal Beds

The Hartshorne coals occur at or near the top of the Hartshorne Sandstone Formation. The split line for the Hartshorne coal is located north of the Red Oak 15-minute quadrangle, so only the upper and lower Hartshorne coals are found here. They both crop out in a band trending east-west across the central portion of the quadrangle, and dip generally to the north at 18° to 34° (Hendricks, 1939). The structure on these two coals is shown on Plate 13,

The upper Hartshorne coal is very thin, and possibly absent, through much of the quadrangle (Plate 11). Data on the coal is quite sparse, but seems to indicate that for the most part the bed is less than the Reserve Base thickness of 1 foot (0.3 m). Two gas well logs (one each i Sections 21 and 23 of T. 6 N. R. 20 E.) indicate that the Upper Hartshorne is not present in that vicinity.

The lower Hartshorne coal, in contrast, is is fairly thick in the area, with estimates of 6 feet (1.8 m) in the two above mentioned well logs. It thins somewhat toward the cropline, though measurements of up to 5.5 feet (1.7 m) have been made near the outcrop to the west (Plate 12).

Some mining of the lower Hartshorne coal has been done, but none, apparently, of the upper Hartshorne (Plate 1). Approximately 45 to 60 feet (14 to 18 m) of interburden separates the two seams, as shown on Plate 14.

Upper and Lower McAlester Coal Beds

The upper and lower McAlester coal beds crop out north of the upper and lower Hartshorne coals, up to a half mile south of the front edge of the Sans Bois Mountains, and dip to the north at 17° to 24°. The structure of these two coals is shown on Plate 6. Anywhere from about 50 feet to just over 60 feet (15 to 18 m) of interburden separates the upper and lower McAlester coals (Plate 7).

Isopach measurements for both the upper and lower McAlester coals have come almost exclusively from well logs, with a few more exact measurements from bore holes near the lower McAlester crop line. The upper McAlester coal varies from about 1 to 2 feet (0.3 to 0.6 m) thick, and the lower McAlester from 1 to 3 feet (0.3 to 0.9 m) thick. No mining of either seam has taken place to date.

Chemical Analyses of Coal

No information was available on the chemical analyses of any of the coals in the northwest quarter of the Red Oak 15-minute quadrangle.

Isolated Data Points

In instances where single or isolated measurements of coal beds thicker than 1.0 foot (0.3 m) are encountered, the standard criteria for construction of isopach, structure contour, mining ratio, and overburden isopach maps are not available. The lack of data concerning these beds limits the extent to which they can be reasonably projectd in any direction, and usually precludes their correlation with other, better known beds. For this reason, isolated data points have been mapped on separate figures for non-isopached coal beds. These figures are not included in this report, but are kept on file at the BLM Office in Tulsa. However, coal reserves from these isolated data points are included in Tables 2 and 3, and in the Reserve Base tonnages shown on Plate 2.

All isolated data points in the northwest quarter of the Red Oak 15-minute quadrangle are measurements of unnamed local coals.

COAL RESOURCES

Data from drill holes, mine measured sections, outcrops, well logs and mine maps were used to construct outcrop, isopach, and structure contour maps of the various coal beds in the northwest quarter of the Red Oak 15-minute quadrangle (see below). The source of each indexed data point shown on Plate 1 is listed in Appendix I at the end of this report.

A system for classifying coal resources has been published by the U.S. Bureau of Mines and the U.S. Geological Survey, and published by U.S. Geological Survey Bulletin 1450-B (1976). Under this system resources are classified as either Identified or Undiscovered. Identified Resources are specific bodies of coal whose location, rank, quality and quantity are known from geologic evidence supported by specific measurements, while Undiscovered Resources are bodies of coal which are thought to exist, based on broad geologic knowledge and theory.

Identified Resources may be subdivided into three categories of reliabililty of occurrence, according to their distance from a known point of coal-bed measurement. In order of decreasing reliability, these categories are: measured, indicated and inferred. Measured coal is that which is located within 0.25 mile (0.4 km) from a measurement point, indicated coal extends 0.5 mile (0.8 km) beyound measured coal to a distance of 0.75 mile (1.2 km) from the measurement point, and inferred coal extends 2.25 miles (3.6 km) beyond indicated coal, or a maximum distance of 3 miles (4.8 km) from the measurement point.

Undiscovered Resources may be either hypothetical or speculative. Hypothetical resources are those undiscovered coal resources that may reasonably be expected to exist in known coal fields under known geologic conditions. They are located beyond the outer boundary of inferred resources (see above) in areas where the coal-bed continuity is assumed, based on geologic evidence Hypothetical resources are those more than 3 miles (4.8 km) from the nearest measurement point. There are no hypothetical resources in this quadrangle.

Speculative resources are undiscovered Resources that may occur in favorable areas where no discoveries have yet been made. Speculative resources have not been estimated in this report.

Coal resources for the upper and lower McAlester coals, and the upper and lower Hartshorn coals were calculated using data obtained from their coal isopach maps (Plates 4, 5, 11 and 12 respectively). The coal-bed acreage (measured by planimeter and calculated using the trapezoidal method [modified from Hollo and Fifadara, 1980]) multiplied by the average thickness of the coal bed, and by a conversion factor of 1,800 short tons of coal per acre-foot (13,238 metric tons per hectare-meter) for bituminous coal yields the coal resources in short tons. Coal resource tonnages were calculated for measured, indicated, inferred and hypothetical categories (as defined below) for unleased Federal coal lands. Coal beds thicker than 1 foot (0.3 m) that lie less than 3,000 feet (914 m) below the ground surface are included. These criteria differ from those stated in U.S. Geological

Survey Bulletin 1450-B, which calls for a minimum thickness of 28 inches (71 cm) and a maximum depth of 1,000 feet (305 m) for bituminous coal. Narrow strips between mines where undisturbed coal is less than 246 feet (75 m) from the nearest mine are considered to have no reserves and are included within mined-out areas. Mine boundaries are only approximately located (as stated in the legend on Plate 1) and therefore these narrow areas may in reality not even exist. For this reason they are considered to have no reserves, and have not been planimetered.

Reserve Base and Reserve tonnages for the above-mentioned coal beds are shown on Plates 9, 10, 16, and 17, and have been rounded to the nearest 10,000 short tons (9,072 metric tons). In this report, Reserve Base coal is the gross amount of Identified Resources that occurs in beds 1 foot (0.3 m) or more thick and under less than 3,000 feet (914 m) of overburden. Reserves are the recoverable part of the Reserve Base coal. In the southeastern Oklahoma coal field, a recovery factor of 80 percent is applied toward surface-minable Reserve Base coal, and a recovery factor of 50 percent is applied toward subsurface-minable Reserve Base coal. No recovery factor is applicable for in-situ coal gasification methods.

The total tonnage per section for Reserve Base coal, including both surface and subsurface-minable coal, are shown in the northwest corner of each section in Federal coal land on Plate 2. All values shown on Plate 2 are rounded to the nearest 10,000 short tons (9,072 metric tons), and total approximately 118.81 million short tons (107.78 million metric tons) for the entire quadrangle, including tonnages in the isolated data points. Reserve Base and tonnages from the various development potential categories for surface and subsurface mining and in-situ coal gasification methods are shown in tables 1 and 2.

Geological Services of Tulsa has not made any determination of economic recoverability for any of the coal beds described in this report.

COAL DEVELOPMENT POTENTIAL

Coal development potential areas are drawn to coincide with the boundaries of the smallest legal land subdivisions shown on Plate 2. In sections or parts of sections where no land subdivisions have been surveyed by the BLM, approximate 40-acre (16-hectare) parcels have been used to show to limits of the high, moderate, or low development potentials. A constraint imposed by the BLM specifies that the highest development potential affecting any part of a 40-acre (16-hectare) lot, tract, or parcel be applied to that entire lot, tract, or parcel. For example, if 5 acres (2 hectares) within a parcel meet criteria for a high development potential; 25 acres (10 hectares), a moderate development potential; and 10 acres (4 hectares), a low development potential; then the entire 40 acres (16 hectares) are assigned a high development potential. For purposes of this report, any lot or tract assigned a coal development potential contains coal in beds with a nominal minimum areal extent of 1 acre (0.4 hectare).

Development Potential for Surface Mining Methods

Areas where the coal beds of Reserve Base thickness are overlain by 150 feet (46 m) or less of overburden are considered to have potential for surface mining and are assigned a high, moderate, or low development potential based on their mining ratios (cubic yards of overburden per ton of recoverable coal). The formula used to calculate mining ratios for surface mining of coal is as follows:

t_c (rf) where MR = mining ratio

t_o = thickness of overburden in feet

t_c = thickness of coal in feet

rf = recovery factor (80 percent for this quadrangle)

cf = conversion factor for yield MR value in terms of cubic yards of overburden per short tons of recoverable coal:

0.896 for bituminous coal

Note: To convert mining ratio to cubic meters of overburden per metric ton of recoverable coal, multiply MR by 0.8428.

Areas of high, moderate, and low development potential for surface mining methods are defined as areas underlain by coal beds having respective mining ratio values of 0 to 10, 10 to 15, and greater than 15. These mining ratio values for each development potential category are based on economic and technological criteria and were provided by the U.S.Geological Survey.

Areas where the coal data is absent or extremely limited between the 150-foot (46 m) overburden line and the coal outcrop are assigned unknown development potential for surface mining methods. This applies to areas where coal beds 1.0 foot (0.3 m) or more thick are not known but may occur, and to those areas influenced by isolated data points. Limited knowledge pertaining to the areal distribution, thickness, depth and attitude of the coals in these areas prevents accurate evaluation of development potential in the high, moderate, or low categories. The areas influenced by isolated data points in this quadrangle contain no coal available for surface mining.

The coal development potential for surface mining methods is shown on Plate 18. A summary of all tonnage values is presented in Table 1. Of the

Federal coal land not subject to currently outstanding coal lease, permit, license or preference right lease having a known development potential for surface mining, 19 percent is rated high, 2 percent is rated moderate, and 10 percent is rated low. The remaining Federal land (69 percent) is classified as having no development potential for surface mining methods.

Development Potential for Subsurface and In-Situ Coal Gasification Methods

Areas considered to have a development potential for conventional subsurface mining methods are those areas where the coal beds of Reserve Base thickness are between 150 and 3,000 feet (46 and 914 m) below the ground surface and have dips of 15° or less. Coal beds lying between 150 and 3,000 feet (46 and 914 m) below the ground surface, dipping greater than 15°, are considered to have a development potential for in-situ coal gasification methods.

Areas of high, moderate, and low development potential for conventional subsurface mining methods are defined as areas underlain by coal beds at depths ranging from 150 to 1,000 feet (46 to 305 m), 1,000 to 2,000 feet (305 to 610 m), and 2,000 to 3,000 feet (610 to 914 m), respectively.

Areas where the coal data is absent or extremely limited between 150 and 3,000 feet (46 to 914 m) below the ground surface are assigned unknown development potential. This applies to areas where coal beds of Reserve Base thickness are not known, but may occur, and to those areas influenced by isolated data points. The areas influenced by isolated data points in this quadrangle contain approximately 0.62 million short tons (0.56 million metric tons) of coal available for conventional subsurface mining.

The coal development potential for conventional subsurface mining and in-situ gasification methods is shown on Plate 19. A summary of all tonnage values is presented in Table 3. Of the Federal land areas having a known development potential for conventional subsurface mining methods, 55 percent is rated high, 15 percent is rated moderate, and none is rated low. Thirteen percent of the remaining Federal land in the quadrangle is classified as having unknown (7%) or no (6%) development potential for either conventional subsurface mining or in-situ gasification methods.

Table 1. Coal Reserve Base data for surface mining methods for Federal coal land (in short tons) in the northwest quarter of the Red Oak 15-minute quadrangle, Latimer County, Oklahoma.

Coal Bed or Coal Zone	High Development Potential	Moderate Development Potential	Low Development Potential	Unknown Development Potential	TOTAL
Upper McAlester	370,000	190,000	1,920,000	--------	2,480,000
Lower McAlester	410,000	410,000	1,450,000	--------	2,270,000
Upper Hartshorne	30,000	30,000	510,000	--------	570,000
Lower Hartshorne	250,000	130,000	2,740,000	--------	3,120,000
Isolated Data Point	--------	--------	--------	--------	--------
TOTALS	1,060,000	760,000	6,620,000	--------	8,440,000

Table 2. Coal Reserve Base data for subsurface mining and in-situ gasification methods for Federal coal land (in short tons) in the northwest quarter of the Red Oak 15-minute quadrangle, Latimer County, Oklahoma.

Coal Bed or Coal Zone	High Subsurface Development Potential	Moderate Subsurface Development Potential	Low Subsurface Development Potential	Low In-Situ Development Potential	Unknown Development Potential	TOTAL
Upper McAlester	8,540,000	6,200,000	----------	400,000	-------	15,140,000
Lower McAlester	12,550,000	9,560,000	10,000	530,000	-------	22,650,000
Upper Hartshorne	290,000	850,000	260,000	6,220,000	-------	7,620,000
Lower Hartshorne	1,600,000	15,710,000	21,300,000	25,730,000	-------	64,340,000
Isolated Data Points	----------	-----------	-----------	---------	620,000	620,000
TOTAL	22,980,000	32,320,000	21,570,000	32,880,000	620,000	110,370,000

Table 3. Coal reserve Base and hypothetical data for subsurface mining and in-situ gasification methods for Federal coal lands (in short tons) in the northeast quarter of the Red Oak 15-minute quadrangle, Latimer County, Oklahoma.

Coal Bed	High Subsurface Development Potential	Moderate Subsurface Development Potential	Low Subsurface Development Potential	Low In-Situ Development Potential	Unknown Development Potential	Hypothetical Coal Tonnage	TOTAL
Upper McAlester	780,000	390,000	5,600,000	-	-	-	6,770,000
Lower McAlester	36,230,000	11,280,000	-	-	-	-	47,510,000
Upper Hartshorne	1,760,000	13,880,000	16,710,000	16,460,000	-	8,810,000	57,620,000
Lower Hartshorne	2,690,000	20,520,000	23,800,000	16,530,000	-	11,270,000	74,810,000
Isolated Data Points	-	-	-	-	220,000	-	220,000
TOTAL	41,460,000	46,070,000	46,110,000	32,990,000	220,000	20,080,000	186,930,000

Based on criteria provided by the U.S. Geological Survey coal beds of Reserve Base thickness dipping between 15° and 35°, regardless of tonnage, have a low development potential for in-situ coal gasification methods. Beds dipping from 35° to 90°, with a minimum of 50 million tons of coal in a single unfaulted bed or multiple, closely spaced, approximately parallel beds have a moderate development potential for in-situ gasification methods. Coal lying between the 150-foot (46 m) overburden isopach and the outcrop is not included in total coal tonnages available because it is needed for cover and containment in the in-situ process.

In the northeast quarter of the Red Oak 15-minute quadrangle 24 percent of Federal coal land is classified as having low development potential for in-situ coal gasification. However, 31 percent of this land also has a moderate to high development potential for conventional subsurface mining (Plate 19). No land in the quadrangle has a moderate development potential for in-situ gasification.

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APPENDIX I. SOURCE AND RELIABILITY OF DATA USED ON PLATE 1.

Listed below is a point by point accounting as to the source and reliability of all information shown on Plate 1. Also presented are any notes or comments pertaining to individual data points.

DATA POINT #	LOCATION	INCREASING RELIABILITY →	1	2	3	4	5	REFERENCE	NOTES/COMMENTS
	SE NW	Location		X				Russell, 1960, p. 53	
	Section 18	Overburden			X			Measured Section #15	
1	T 6 N | R 21 E	Coal Thickness			X				
	NE SE	Location					X	Midwest Oil Corp.,	Reference datum 20'
	Section 13	Overburden				X		Gardner #1, 1962	above GL. 1" and 2.5"
2	T 6 N | R 20 E	Coal Thickness		X					Ind. log.
	NW SE	Location					X	Midwest Oil Corp.,	Reference datum 20' above
	Section 14	Overburden				X		Garrett #1, 1964	GL. 2.5" E-log and gamma
3	T 6 N | R 20 E	Coal Thickness		X					
	SW NE	Location					X	Shell Oil Co.	Reference datum 18' above
	Section 15	Overburden				X		Foster 1-15, 1965	GL. 1" IEL/G, Dens. logs.
4	T 6 N | R 20 E	Coal Thickness		X					
	S/2 N/2	Location					X	Shell Oil Co.	Reference datum 19' above
	Section 16	Overburden				X		Parsons 1-16, 1966	GL. 2.5" IEL/G.
5	T 6 N | R 20 E	Coal Thickness		X					
	NW SE	Location					X	Leben Drilling, Inc.	Reference datum 18'
	Section 17	Overburden				X		Parsons 1-17	above GL.
6	T 6 N | R 20 E	Coal Thickness		X				1969	1" Gamma Log.
	SW NE	Location					X	Shell Oil Co.	Ref. datum 21' above GL.
	Section 21	Overburden				X		Jankowsky 1-21	2.5" Gamma, Acoustic log.
7	T 6 N | R 20 E	Coal Thickness		X				1964	UH-CNI
	W/2 E/2 NW	Location					X	Dyco Petroleum Corp.	Ref. datum 14' above GL
	Section 23	Overburden				X		Music #1	5" Dens. log.
8	T 6 N | R 20 E	Coal Thickness		X				1974	UH-CNI
	SE NE	Location					X	Midwest Oil Corp.	Ref. datum 22' above GL.
	Section 24	Overburden				X		Sorrells #1	Gamma, IEL.
9	T 6 N | R 20 E	Coal Thickness		X				1962	
	NW SE	Location					X	Leed Oil & Gas	Ref. datum 25' above
	Section 31	Overburden			X			Wilburton Mountain #1	GL. Locat. 2200 FEL,
10	T 6 N | R 20 E	Coal Thickness		X				1979	2500 FSL.
	SW SW	Location					X	Mobil Oil Corp.	KB 20.4' above GL.
	Section 33	Overburden				X		Parks #1	2.5" E log/Gamma.
11	T 6 N | R 20 E	Coal Thickness		X				1963	

DATE POINT #	LOCATION	INCREASING RELIABILITY →	1	2	3	4	5	REFERENCE	NOTES/COMMENTS
	NW SE	Location					X	Pan Am Pet. Corp.	Ref. datum 20' above
	Section 31	Overburden				X		Melone #1	GL
12	T 6 N | R 21 E	Coal Thickness		X				1964	
	SW SE	Location		X				USGS files, 1959,	
	Section 1	Overburden			X			Bore Hole #16	
13	T 5 N | R 20 E	Coal Thickness			X				
	SE SW	Location					X	USGS files, 1959	Hartshorne Sandstone
	Section 1	Overburden					X	Bore Hole #28	at 616'.
14	T 5 N | R 20 E	Coal Thickness				X			
	NE NW	Location					X	Sen. Document 390 (1910)	
	Section 4	Overburden					X	p. 63, Bore Hole #16	
15	T 5 N | R 20 E	Coal Thickness					X		
	C N/2 SE	Location		X				Hendricks, 1939, Plate 35,	Slope mine.
	Section 5	Overburden	-	-	-	-	-	Measured section #67	
16	T 5 N | R 20 E	Coal Thickness			X				
	SE NE	Location					X	Cooper, C.L., 1928,	Located with USGS
	Section 12	Overburden	-	-	-	-	-	p. 32, 33, Measured	mine map.
17	T 5 N | R 19 E	Coal Thickness					X	Section B	
	SE NE	Location					X	Cooper, C.L., 1928, p. 32,	Located with USGS
	Section 12	Overburden	-	-	-	-	-	33, Measured section A	mine map.
18	T 5 N | R 19 E	Coal Thickness					X		
	SW NE	Location					X	Moose & Searle, 1929, p. 50,	Located with USGS
	Section 7	Overburden	-	-	-	-	-	Measured section A	mine map.
19	T 5 N | R 20 E	Coal Thickness					X		
	SW NE	Location					X	Moose & Searle, 1929, p. 50,	Located with USGS
	Section 7	Overburden	-	-	-	-	-	Measured section B	mine map.
20	T 5 N | R 20 E	Coal Thickness					X		
	SW NW	Location				X		USGS files, 1944	1855'W, 80'N of center
	Section 8	Overburden	-	-	-	-	-	Gore - Hoover Mine	Est. between 3.0' and 5.5'
21	T 5 N | R 20 E	Coal Thickness		X					coal
	SE NW	Location				X		USGS files, 1925	955'W 10'N center
	Section 8	Overburden	-	-	-	-	-	Dodd Bros.' Mine	Composite of 2 sections
22	T 5 N | R 20 E	Coal Thickness		X					(3.0' and 5.1')
	SW NE	Location			X			Hendricks, 1939, p. 266	Upper part of composite
	Section 8	Overburden	-	-	-	-	-		section
23	T 5 N | R 20 E	Coal Thickness			X				
	NW SE	Location			X			Hendricks, 1939, p. 266	Lower part of composite
	Section 8	Overburden	-	-	-	-	-		section
24	T 5 N | R 20 E	Coal Thickness			X				
	SW NE	Location				X		USGS files, 1915,	600' E, 130'N of
25	section 8	Overburden	-	-	-	-	-	Katigan & Clark Mine	center of section.

APPENDIX II TABLES OF OIL AND GAS TEST HOLES

Note: "Top Log Int." refers to the measured depth to the top of the interval logged by the particular sonde. Driller log total depth, referenced to K.B. or D.F., has been abbreviated to T.D. (Note: This may vary from T.D. referenced to G.L.). The measured depth at which coal is reported on the scout card appears in the column titled "Scout Card Coal". The column titled "Harts./Drill./Scout" contains the measured depths drilled to the top of the Hartshorne Sandstone, as reported by the driller logs and the scout cards.

* Logged interval stratigraphically below Hartshorne Coals.

Sec-Tn-Rg	Operator/Farm Location	Driller Logs Coal Reported Thickness & Depth	Scout Card Coal	Harts. Drill. Scout	Top Log Int. Gamma Elec.	Top Log Int. Dens. Sonic	T.D. Year
1-5-20							
2-5-20	Mustang/Booth 1-2			1485			14343
	NW NW SE NW, 1108 FSL 1532 FWL ofNW/4	NR	NR	1485			1978
3-5-20	Mustang/#1-3 Cathey			NR		7700	12865
	1170 FSL 1190 FWL of NE/4	NR	NR	NR	1901		1978
4-5-20	Dyco/#1 Gentry			NR			7671
	1445 FSL 1170 FWL	NR	NR	NR			1977
9-5-20	Dyco/#1 Golightly			NR			12388
	CNE	NR	NR	NR			1976
17-5-20	Cox/#1 Shay			NR	100B	6000B	7250
	C S/2 NW	NR	NR	NR			1978
17-5-20	Humble/#1 Shay			NR		14300	14503
	SW NE SW	NR	NR	NR		10350	1966
17-5-20	Pitco/Poteet #1-17			NR			
	CSW	NR	NR	NR			
19-5-21	Ambassador/# G. W. Muncey			NR			12187
	CSW NE	NR	NR	NR	4030*		1962
22-5-21	Ambassador/#1 Muse			NR			11489
	2015 FSL 695 FWL of NE/4	NR	NR	NR	2014*	2014	1964
13-6-20	Midwest/#1 Gardner			2208		7600	13941
	2052 FSL 4060 FWL	NR	NR	2208	198		1963
14-6-20	Midwest/#1 Garrett			NR	9600	8300	9970
	1440 FSL 1200 FWL of SE	NR	NR	3300	212		1964
15-6-20	Shell/#1-15 Foster			NR	301	7650	9150
	170 FSL 682 FWL of NE	NR	NR	3840	301	7650	1965
16-6-20	Shell/#1-16 Parsons			NR	300		10340
	C S/2 N/2	NR	NR	NR	300		1966
16-6-20	Dyco/#A-1 Parson			NR			10325
	C E/2 NE	NR	NR	NR			1976

Sec-Tn-Rg	Operator/Farm Location	Driller Logs Coal Reported Thickness & Depth	Scout Card Coal	Harts. Drill. Scout	Top Log Int. Gamma Elec.	Dens. Sonic	T.D. Year
17-6-20	Leben/#1-17 Parsons			NR	150	7600	10300
	2640 FSL 1000 FWL of SE/4	NR	NR	4416	4576		1969
18-6-20	Leben/#1-18 Jankowski			NR			11000
	SW NE SE	NR	NR	4576			1970
21-6-20	Prospective/#1-21 Joel			3680			9695
	C E/2 NW NW	NR	NR	NR			1979
21-6-20	Shell/#1-21 Jankowsky			NR	441		14460
	S/2 S/2 N/2	NR	NR	NR	4403	441	1965
23-6-20	Dyco/#1 Music			3339	3100	3250	9500
	1320 FSL 1570 FWL of NW/4	NR	NR	3339	988		1975
24-6-20	Pitco/#1-24 Young & Collier			NR			9500
	1980 FSL 1440 FWL of NE/4	NR	NR	NR			1978
24-6-20	Midwest/#1 Sorrells			NR	0	6050	13811
	3550 FSL 3959 FWL	NR	NR	2880	333		1963
31-6-20	Pan Am/Mallone #1			NR			10067
	NW NW SE	NR	NR	NR	6450		1964
31-6-20	Leede/ Wilb. Mt. #1			NR	436		
	2200 FEL 2500 FSL	NR	NR	NR	436		
33-6-20	Socony Mobil/#1 P. Parks			2317	302		13243
	NE SE SW SW	276' interval @ 2317	NR	2319	302		1964
34-6-20	Sunset/#1 Fisherman			NR		8550	13200
	SW NE SW NE	NR	NR	NR	3210		1969
19-6-21	Humble/#1 Foster Jr.			NR			12800
	CSE NW NE	NR	NR	2005	2655		1975
31-6-21	Pan. Amer./#1 Melone			NR	20	20	13362
	NW NW SE	NR	NR		20	20	1965