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COAL RESOURCE OCCURRENCE AND COAL DEVELOPMENT POTENTIAL MAPS OF THE MONUMENT BUTTE QUADRANGLE MOFFAT COUNTY, COLORADO

[Report includes 8 plates]

Prepared for

UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

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This report has not been edited for conformity with U.S. Geological Survey editorial standards or stratigraphic nomenclature.

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Purpose

This text is to be used in conjunction with Coal Resource Occurrence and Coal Development Potential Maps of the Monument Butte quadrangle, Moffat County, Colorado. This report was compiled to support the land planning work of the Bureau of Land Management (BLM) and to provide a systematic coal resource inventory of Federal coal lands in Known Recoverable Coal Resource Areas (KRCRA's) in the western United States. This investigation was undertaken by Dames & Moore, Denver, Colorado, at the request of the U.S. Geological Survey under contract Number 14-08-001-15789. The resource information gathered for this report is in response to the Federal Coal Leasing Amendments Act of 1975 (P.L. 94-377). Published and unpublished public information was used as the data base for this study. No new drilling or field mapping was performed as part of this study, nor was any confidential data used.

Location

The Monument Butte quadrangle is located in southeastern Moffat County in northwestern Colorado, approximately 16 miles (26 km) south-southwest of Craig and 25 miles (40 km) north-northeast of Meeker, Colorado via Colorado Highway 13. With the exception of a few ranches, the area within the quadrangle is unpopulated.

Accessibility

Colorado Highway 13 (also Colorado highway 789) crosses the northern portion of the quadrangle from west to east and turns north toward Craig near the eastern edge of the quadrangle. Several light-duty roads extending from Colorado Highway 13 provide access to most of the Monument Butte quadrangle. Unimproved dirt roads and jeep trails provide access to the remainder of the quadrangle.

Railway service for the Monument Butte quadrangle area is provided by the Denver & Rio Grande Western Railroad from Denver to the railhead which terminates at Craig, approximately 10 airline-miles (16 km) north of the quadrangle, and serves as the major transportation route for coal shipped east from northwestern Colorado.

Physiography

The Monument Butte quadrangle lies in the southern part of the Wyoming Basin physiographic province, just off the northeastern edge of the Colorado Plateau physiographic province, as defined in Howard and Williams (1972), and is approximately 4 miles (6 km) west-southwest of the Williams Fork Mountains and 52 miles (84 km) west of the Continental Divide.

Approximately 1,650 feet (503 m) of relief is present in the Monument Butte quadrangle. Altitudes range from 7,845 feet (2,391 m) on Thornburg Mountain in the southwest to below 6,200 feet (1,890 m) in Stinking Gulch in the northwestern part of the quadrangle.

The landscape of the central part of the quadrangle is characterized by moderate to gentle slopes cut by minor stream valleys. Landscapes in the northern, eastern, and northwestern portions of the quadrangle are more rugged and are dominated by steeper slopes dissected by narrow gulches. Iles Mountain in the northern portion of the quadrangle rises along a prominent east-west trending ridge that is approximately 1,000 feet (305 m) above Stinking Gulch and Morapos Creek.

Axial Basin enters the quadrangle from the northwest and southeast and occupies the central part of the Monument Butte quadrangle.

Three prominent topographic highs occur in this quadrangle: Thornburg Mountain in the southwest, Monument Butte in the east, and Iles Mountain which lies in the northern portion of the quadrangle.

The Monument Butte quadrangle is drained by Morapos Creek, Deer Creek, and by a branch of Milk Creek. Morapos and Deer Creek flow northeastward, join in the northeastern portion of the quadrangle, and drain into the Williams Fork, which flows into the Yampa River. A branch of Milk Creek flows from the southeastern corner of the quadrangle northwestwardly through Stinking Gulch, merging with Milk Creek just west of the quadrangle. Milk Creek, in turn, flows north into the Yampa River. Several intermittent streams flow northward from Iles Mountain into the Yampa River.

Climate and Vegetation

The climate of northwestern Colorado is semi-arid with an abundance of clear, sunny days and large daily temperature variations. Annual precipitation in the Monument Butte quadrangle averages approximately 20 inches (51 cm), most of which occurs as snowfall during the winter months. Average daily temperatures in the Monument Butte area range from 4° to 32° F (-15.5° to 0°C) in January to 42° to 85°F (6° to 29° C) in July.

Winds are generally from the west; however, wind direction is modified by local topography.

The typical types of vegetation in the Monument Butte quadrangle are sagebrush and mountain shrubs. Crops are cultivated upon the relatively gentle slopes of Axial Basin while land in the northern portion of the quadrangle supports some pinyon and juniper trees. An area barren of major vegetation occurs along the northwestern edge of the quadrangle in Stinking Gulch.

Land Status

The Monument Butte quadrangle lies on the southwestern edge of the Yampa Known Recoverable Coal Resource Area (KRCRA) and on the northeastern edge of the Danforth Hills KRCRA. Approximately 20 percent of the quadrangle lies within the KRCRA boundaries, with the Federal government owning the coal rights to approximately 90 percent of that area (as shown on plate 2). No outstanding Federal coal leases, prospecting permits, or licenses are present within the quadrangle.

GENERAL GEOLOGY

Previous Work

The first geologic description of the general area of the Monument Butte quadrangle was published by Emmons (1877) as part of a survey of the fortieth parallel. C. A. White compiled topographic and geologic maps of northwestern Colorado (1878 and 1889) and was the first geologist to note the extensive coal deposits in the Yampa and Danforth Hills area.

Several regional investigations of coal and geology resulted in papers by Hills (1893), Hewett (1889), Storrs (1902), Fenneman and Gale (1906), Gale (1910) and Sears (1924). A detailed investigation of the coal beds and geology of the Monument Butte quadrangle was undertaken by Hancock, and was published in 1925. A portion of the quadrangle was mapped by Dyni (1966), who wrote a short paper on the geology of the area to accompany his map. The most recent geological map of the area was compiled by Tweto (1976).

Stratigraphy

Rocks which crop out in the Monument Butte quadrangle range from Upper Cretaceous to Tertiary in age. These include the Cretaceous-age, coal-bearing Iles and Williams Fork Formations of the Mesaverde Group; the underlying Cretaceous-age Mancos Shale, and a Tertiary-age basalt flow.

The non-coal-bearing Mancos Shale is exposed in the central portion of the quadrangle as well as along three major positive structural features: the Axial Basin Anticline, the White River Uplift, and an extension of the Hamilton Dome. It is composed of dark-gray, marine shale with interbedded slatey shale and calcareous sandstones. The upper 800 feet (244 m) are characterized by zones of thin-bedded sandstones (Hancock, 1925).

The Mesaverde Group conformably overlies the Mancos Shale and consists of two formations, the Iles and the Williams Fork. The Iles

Formation is exposed in the southwestern, east-central, and northern portions of the Monument Butte quadrangle, where it is approximately 1,300 feet (396 m) thick and consists of ledge-forming, fine-grained massive sandstone beds with interbedded dark-gray, sandy shales, and thin coal beds. The major sandstone bed which is recognized in the formation is the Trout Creek Sandstone Member. The top of the Trout Creek Sandstone Member is the contact between the Iles Formation and the overlying Williams Fork Formation. The Trout Creek Sandstone Member is approximately 80 feet (24 m) thick in the Monument Butte quadrangle, and consists of massive, fine-grained white- to buff-colored sandstone. Coal beds of the Iles Formation comprise the Lower Coal Group of the Mesaverde Group (Fenneman and Gale, 1906).

The Williams Fork Formation conformably overlies the Iles Formation and is approximately 1,500 feet (457 m) thick in the Monument Butte area, but only the lower half of the formation which contains the Middle Coal Group of the Mesaverde Group (Fenneman and Gale, 1906) is exposed in the quadrangle. The formation consists of massive, lenticular, white- to buff-colored fine-grained sandstone with interbedded dark-gray sandy shale, carbonaceous shale and coal.

The Williams Fork Formation is generally divided into three subdivisions: a lower coal-bearing sandstone and shale sequence, the Twentymile Sandstone Member, and an upper coal-bearing sandstone and shale sequence. Of these three units, only the lower coal-bearing sandstone and shale sequence which contains the Middle Coal Group of the Mesaverde Group occurs in the Monument Butte quadrangle.

A vesicular basalt flow caps a low hill in sections 5 and 6, T. 3 N., R. 91 W. The basalt unconformably overlies the Mancos Shale and, according to Hancock (1925), similar flows nearby are contemporaneous with the Tertiary-age Browns Park Formation.

The Cretaceous-age rocks accumulated close to the western edge of a Late Cretaceous epeirogenic seaway which covered part of the western interior of North America (Ryer, 1977). Several transgressive-regressive cycles resulted in the deposition of a series of marine, near-shore marine, and non-marine sediments in the Monument Butte area. The Mancos Shale was deposited in an offshore marine environment which existed east of the shifting strand line. Deposition of the Mancos Shale in the quadrangle area ended with the eastward movement of the shoreline, and the subsequent deposition of the Iles Formation. The interbedded sandstones, shales, and coals of the Iles and Williams Fork Formations were deposited as a result of minor changes in the position of the shoreline. During the deposition of the Iles and Williams Fork Formations, near-shore marine, littoral, brackish, fresh water, and fluvial environments existed in the Monument Butte area.

Numerous coal beds of limited areal extent were deposited in the Monument Butte quadrangle in environments associated with fluvial systems such as back-levee and coastal plain swamps, interchannel basin areas, and abandoned channels. The major sandstones of the Iles and Williams Fork Formations were deposited in shallow marine and near-shore environments.

Structure

An area which is part of the Danforth Hills KRCRA occurs in the southwestern corner of the quadrangle and borders on the northeastern flank of the Piceance Creek Basin, the western flank of the northernmost extension of the White River uplift, and the southern flank of the Axial Basin Anticline. Two areas that are part of the Yampa KRCRA are within the Monument Butte quadrangle. One is located north of the Axial Basin Anticline in the northern third of the quadrangle and the other is east of the White River Uplift along the east-central edge of the quadrangle (U.S. Geological Survey, 1977).

The Axial Basin Anticline, the northernmost extension of the White River Uplift, and an extension of the Hamilton Dome, meet in the the north central portion of the Monument Butte quadrangle along with three corresponding negative structural features: the Hart, Elkhorn, and Round Bottom synclines.

The positive structural features bring the relatively incompetent Mancos Shale to the surface and form topographic lows as a result of erosion while the synclines retain the relatively resistant Iles and Williams Fork Formations which are the caps that top the Iles and Thornburg Mountains and Monument Butte.

Two east-west trending high-angle faults have been mapped by Hancock and cross the central portion of the Monument Butte quadrangle. These two faults define a minor graben.

Bed dips are generally less than 15° except on the eastern flank of the Elkhorn Syncline where 50° to 60° dips to the west are common and near the Hamilton Dome in the northeast corner of the quadrangle where dips of about 30° to the west occur. Structure contour maps of the MG[3] and MG[6] coal beds were constructed using, as a base, the structure contour maps of Hancock (1925) and Dyni (1966) which are drawn on the top of the Trout Creek Sandstone Member.

COAL GEOLOGY

Coal beds of the Middle and Lower Coal Groups of the Mesaverde Group, have been identified in the Monument Butte quadrangle (plate 1). In this quadrangle, the Lower Coal Group includes all coal beds beginning approximately 400 feet (122 m) above the base of the Iles Formation and extending to the Trout Creek Sandstone Member. However, several thin coal beds of the Lower Coal Group are found lower in the stratigraphic section in the Hamilton quadrangle to the east. The Middle Coal Group includes the coal beds in the lower coal-bearing zone of the Williams Fork Formation (Gale and Fenneman, 1906). In the Monument Butte quadrangle, as well as in adjacent quadrangles, coal beds of the Middle and Lower Coal Groups are characteristically lenticular and of limited areal extent.

Coal beds are not formally named in this quadrangle, but have been numbered with bracketed numbers for identification purposes in this report.

Lower Group Coal Beds

The zone in which the coal beds of the Lower Coal Group are found begins approximately 400 feet (122 m) above the base of the Iles Formation and extends upward to the base of the Trout Creek Sandstone Member. Several thin lenticular Lower Coal Group coal beds have been identified in this zone in the Monument Butte quadrangle, but only two of these beds are greater than the Reserve Base thickness of 5 feet (1.5 m). These coal beds are numbered LG[1] and LG[2]. Because each of these beds has been measured at only one location and cannot be correlated with other measured outcrops, they have been treated as isolated data points (see Isolated Data Points section of this report).

Chemical analyses are not available for the Lower Group coal beds in the Monument Butte quadrangle. However, an analysis (Lord, 1913), shown in table 1, from a Lower Coal Group coal bed in the Hamilton quadrangle to the east is high-volatile C bituminous in rank when calculated on a moist, mineral-matter-free basis (ASTM, 1977). It is believed that Lower Group coals found in the Monument Butte quadrangle are of similar rank.

Middle Group Coal Beds

The Middle Coal Group, which is the lower coal-bearing sequence of the Williams Fork Formation, begins at the top of the Trout Creek Sandstone Member and extends upward approximately 1,200 feet (366 m) to the bottom of the Twentymile Sandstone Member of the Williams Fork Formation. Only the lower half of the lower coal-bearing sequence is exposed in the Monument Butte quadrangle. Four coal beds of Reserve Base thickness and belonging to the Middle Coal Group have been identified in this quadrangle. Two of these beds, the MG[5] and the MG[7], were measured at only one location and have been treated as isolated data points.

No chemical analyses of Middle Group coal beds from the Monument Butte quadrangle are available, but it is believed that the quality of the coal is similar to that reported by Hancock (1925) for Middle Group coal beds found in the Hamilton quadrangle. Based on the analysis reported by Hancock (table 1), the coal beds of the Middle Coal Group in this quadrangle have been ranked as high-volatile C bituminous.

MG[3] Coal Bed

The MG[3] coal bed has been identified at two locations in secs. 29 and 32, T. 4 N., R. 92 W., where respective measurements were 7.5+ and 12.6 feet (2.3+ and 3.8 m). The dotted line on plate 4 represents a limit of confidence beyond which isopach and structural contours are not drawn because of insufficient data. It is believed, however, that the bed continues to be of Reserve Base thickness in the area beyond this line. According to Hancock (1925) and Dyni (1966), the MG[3] coal bed lies approximately 25 to 35 feet (7.6 to 10.7 m) stratigraphically above the top of the Trout Creek Sandstone Member of the Iles Formation. As calculated from plate 4, the dip of the coal bed is approximately 25° toward the west-southwest.

MG[6] Coal Bed

The MG[6] coal bed has been identified in sec. 4, T. 3 N., R. 92 W., and in sec. 33, T. 4 N., R. 92 W., where thickness measurements are, respectively, 13.6 and 14.5 feet (4.1 and 4.4 m) excluding the shale partings which measure 4.7 and 5.2 feet (1.4 to 1.6 m) thick. The dotted line on plate 4 represents a limit of confidence beyond which isopach and structure contours are not drawn because of insufficient geologic data, although it is believed that the bed is of Reserve Base thickness in the area beyond this line. The MG[6] coal bed lies approximately 170 feet (52 m) above the top of the Trout Creek Sandstone Member (Dyni, 1966). The dip of the MG[6] coal bed, as derived from plate 4, is approximately 25° toward the west-southwest.

Isolated Data Points

In instances where isolated measurements of coal beds thicker than 5 feet (1.5 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 projected in any direction and usually precludes correlations with other, better known beds. For purposes of Reserve Base calculation isolated data points have been projected in a radius of 1,000 feet (305 m) down dip from their points of measurement on projected outcrops. Isolated data point maps appear on plate 7.

COAL RESOURCES

Information from the outcrop measurements and the geologic maps of Hancock (1925) and Dyni (1966) was used to construct outcrop, isopach, and structure contour maps of the MG[3] and MG[6] coal beds, as well as maps of isolated data points for the LG[1], LG[2], MG[5], and MG[7] coal beds.

Coal resources of the Lower and Middle Group coal beds were calculated using data obtained from the coal isopach maps (plate 4) and the isolated data point maps (plate 7). The coal-bed acreage (measured by planimeter) multiplied by the average thickness of the coal bed times 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 of coal for each isopached coal bed. Reserve Base and Reserve tonnages for the MG[3] and MG[6] coal beds are shown on plate 6 and are rounded to the nearest 10,000 short tons (9,072 metric tons). Coal beds thicker than 5 feet (1.5 m) that lie less than 3,000 feet (914 m) below the ground surface are included. These criteria differ somewhat from those used in calculating Reserve Base and Reserve tonnages as stated in U.S. Geological Survey Bulletin 1450-B which calls for a minimum thickness of 28 inches (70 cm) and a maximum depth of 1,000 feet (305 m) for bituminous coal. Only Reserve Base tonnages (designated as inferred resources) are calculated for areas influenced by isolated data points in this quadrangle. Total coal Reserve Base tonnages per Federal section are shown on plate 2 and total approximately 5,800,000 short tons (5,262,000 metric tons) for the entire quadrangle.

Reserve Base tonnages in the various development potential categories for surface and subsurface mining methods are shown in table 2.

Dames & Moore has not made any determination of economic recovery 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-ha) parcels have been used to show the limits of the high, moderate, or low development potentials. A constraint imposed by the BLM specifies that the highest development potential affecting any portion of a 40-acre (16-ha) lot, tract, or parcel be applied to that entire lot, tract, or parcel. For example, if 5 acres (2 ha) within a parcel meet criteria for a high development potential, 25 acres (10 ha) a moderate development potential, and 10 acres (4 ha) a low development potential, then the entire 40 acres (16 ha) are assigned a high development potential.

Development Potential for Surface Mining Methods

Areas where the coal beds of Reserve Base thickness are overlain by 200 feet (61 m) or less of overburden are considered to have potential for surface mining and were assigned a high, moderate, or low development potential based on the mining ratio (cubic yards of overburden per ton of recoverable coal). The formula used to calculate mining ratios for surface mining of coal is presented below:

$$MR = \frac{t_o\ (cf)}{t_c\ (rf)}$$

where MR = mining ratio

t_o = thickness of overburden in feet

t_c = thickness of coal in feet

rf = recovery factor (85 percent for this quadrangle)

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

0.911 for subbituminous 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 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 that were provided by the U.S. Geological Survey.

Unknown development potentials have been assigned to those areas where coal data is absent or extremely limited, including areas influenced by isolated data points. Even though these areas may contain coal thicker than 5 feet (1.5 m), limited knowledge pertaining to the areal distribution, thickness, depth, and attitude of the coal beds prevents accurate evaluation of development potential in the high, moderate, or low categories. Tonnages for the isolated data points in the unknown potential category for surface mining methods total 1.40 million short tons (1.27 million metric tons).

The coal development potential for surface mining methods (less than 200 feet or 61 meters of overburden) is shown on plate 8.

Of those Federal coal land areas having a known development potential for surface mining methods within the Yampa and Danforth Hills KRCRA's in this quadrangle, 70 percent are rated high, 15 percent are rated moderate, and 15 percent are rated low. The remaining Federal lands within the KRCRA's are classified as having unknown development potential for surface mining methods, implying that no known coal beds 5 feet (1.5 m) or more thick, excluding isolated data points, occur within 200 feet (61 m) of the ground surface but that coal-bearing units are present.

Development Potential for Subsurface and In-Situ Mining Methods

Areas of high, moderate, and low development potential for conventional subsurface mining are defined as areas underlain by coal beds of Reserve Base thickness which dip at 15° or less that occur at depths ranging from 200 to 1,000 feet (61 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. Coal beds lying between 200 and 3,000 feet (61 and 914 m) below the ground surface, dipping greater than 15°, are considered to have a development potential for in-situ mining methods.

Because the coal beds in this quadrangle, including the isolated points, have dips greater than 15°, the development potential for conventional subsurface mining methods on Federal coal lands is rated as unknown. Tonnages for the unknown (subsurface) development potential for isolated data points total 1.58 million short tons (1.43 million metric tons).

The development potential for in-situ mining methods for all Federal lands within the KRCRA's in this quadrangle have been rated low because of the probability that in-situ mining would not be compatible with the development of coal resources by surface mining methods and because the Reserve Base tonnage for coal beds dipping more than 15° total only 3.24 million short tons (2.94 million metric tons).

Table 1. -- Chemical analyses of coals on an as-received basis, Monument Butte quadrangle, Moffat County, Colorado

LOCATION	COAL GROUP	Source	Proximate				Ultimate					Heating Value	
			Moisture	Volatile matter	Fixed carbon	Ash	Sulfur	Hydrogen	Carbon	Nitrogen	Oxygen	Calories	Btu/lb
SW¼ sec. 24, T. 5 N., R. 91 W., Hamilton (Badger Creek) Mine (From Hamilton quadrangle)	Lower Coal Group	1,2, 3	12.5	29.7	48.0	9.8	0.8	5.6	60.4	1.3	22.1	5,917	10,650
sec. 26, T. 4 N., R. 91 W., Roby Mine (from Hamilton quadrangle)	Middle Coal Group	2	14.2	36.3	45.3	4.2	0.6	5.8	63.5	1.2	24.7	6,100	10,980

1. Campbell, 1912
2. Hancock, 1925
3. Lord, 1913

Note: To convert Btu/pound to kilojoules/kilogram, multiply by 2.326

Table 2. -- Surface and subsurface Reserve Base data for Federal coal lands (in short tons) in the Monument Butte quadrangle, Moffat County, Colorado

	Surface Development Potential					Subsurface Development Potential
Coal Bed Name	High	Moderate	Low	Unknown	Total	Unknown
MG {3}	270,000	150,000	280,000	0	700,000	940,000
MG {6}	340,000	60,000	60,000	0	460,000	720,000
Non-isopached coal beds	0	0	0	1,400,000	1,400,000	1,580,000
Total	610,000	210,000	340,000	1,400,000	2,560,000	3,240,000*

Note: To convert short tons to metric tons, multiply by 0.9072

* Tonnage for coal beds dipping greater than 15°.

Table 3. -- Sources of data used on plate 1

Plate 1 Index Number	Source	Data Base
1	Hancock, 1925, U.S. Geological Survey Bulletin 757, pl. 15	Measured Section H 259
2	Hancock, 1925, U.S. Geological Survey Bulletin 757, pl. 14	Measured Section H 242
3	Hancock, 1925, U.S. Geological Survey Bulletin 757, pl. 14	Measured Section H 239
4	Hancock, 1925, U.S. Geological Survey Bulletin 757, pl. 14	Measured Section H 238
5	Hancock, 1925, U.S. Geological Survey Bulletin 757, pl. 15	Measured Section H 251
6	Hancock, 1925, U.S. Geological Survey Bulletin 757, pl. 15	Measured Section H 252
7	Hancock, 1925, U.S. Geological Survey Bulletin 757, pl. 15	Measured Section H 254
8	Hancock, 1925, U.S. Geological Survey Bulletin 757, pl. 15	Measured Section H 253
9	Hancock, 1925, U.S. Geological Survey Bulletin 757, pl. 11	Measured Section H 320
10	Hancock, 1925, U.S. Geological Survey Bulletin 757, pl. 10	Measured Section H 409
11	Hancock, 1925, U.S. Geological Survey Bulletin 757, pl. 10	Measured Section H 424
12	Hancock, 1925, U.S. Geological Survey Bulletin 757, pl. 10	Measured Section H 423
13	Hancock, 1925, U.S. Geological Survey Bulletin 757, pl. 14	Measured Section H 240
14	Dyni, J. R., 1966, U.S. Geological Survey Oil and Gas Investigation Map OM-216	Section # 2
15	Bass Enterprises	Oil/gas well No. 1 Littlejohn

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