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COAL CHARACTERISTICS OF MAJOR COAL-BEARING SEQUENCES, GALLUP FIELD, NORTHWESTERN NEW MEXICO

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Abstract—The New Mexico Bureau of Mines and Mineral Resources (NMBM&MR) has collected coal resource and coal quality data for the National Coal Resource Data System (NCRDS) and recently was the lead agency for a state-funded drilling project designed specifically to obtain coal samples for analysis. The stratigraphic and quality data collected from these projects provide a sufficient data base to begin examination of the coal characteristics of the two major coal-bearing sequences in the Gallup coal field.

The Gallup field is of economic importance because of the coal resources in the Dilco Coal Member of the Crevasse Canyon Formation, and the undifferentiated Gibson Coal Member of the Crevasse Canyon and Cleary Coal Member of the Menefee Formation. Both coal-bearing sequences developed just shoreward of two major reversals in shoreline movement, when nearly stationary conditions existed. Consequently, the transitional deposits of the Dilco and Gibson-Cleary coal-bearing sequences contain multiple, stacked and often thick coal seams. This contrasts with coal deposition during active shoreline migration when coals are thinner and scattered throughout the section. The characteristics of the Gallup-field coals appear to be indicative of their position relative to the shoreline at the time of deposition.

INTRODUCTION

This study is an assimilation of the quality and lithologic data from two long-term projects at the New Mexico Bureau of Mines and Mineral Resources. For the past five years, several investigators at the NMBM&MR in addition to the writer have been involved in the collection of cores for quality analyses in strippable coal areas of New Mexico. Through this program funded by New Mexico Research and Development Institute (NMRDI) and several companies, a standard set of lithologic and quality data was obtained for most of the coal-bearing formations and areas in the San Juan Basin of northwestern New Mexico. The NMBM&MR in cooperation with the U.S. Geological Survey (USGS) has been collecting stratigraphic and quality data in the coal-bearing areas in New Mexico for entry into the USGS National Coal Resource Data System (NCRDS) for the past nine years.

Inspection of the NMRDI and NCRDS data sets indicates that enough stratigraphic data exists in the Gallup field to provide a sufficient base for the examination of the two major coal-bearing sequences. These are the Dilco Coal Member of the Crevasse Canyon Formation, and the Gibson Coal Member of the Crevasse Canyon and Cleary Coal Member of the Menefee Formation, undifferentiated. The quality data available for the Dilco Coal Member are inadequate (39 samples) to contour, therefore, only a general quality analysis of these coals is presented. The Gibson-Cleary has a more extensive quality data base (119 samples) and can be looked at by contouring and on a township basis to determine if any trends exist.

BACKGROUND

Mining

Coal mining began in the Gallup field in the early 1880's when the Atlantic and Pacific Railroad (now the Atchison, Topeka and Santa Fe Railroad) put the railroad through the area and created the town of Gallup as a coal-supply point. It was fortunate that the railroad took this route because of the close proximity of major coal reserves. From the early 1880's to 1920, production was over 825,000 tons. Underground mining continued in the Gallup area until 1951 with production from 1920–1952 amounting to 9.2 million tons (Reports of the United States Mine Inspector, 1893–1912, and New Mexico Mine Inspector, 1920–1952). During this 70-year period of underground mining in the Gallup area, almost 100 mines and prospects are reported to have been in operation, mining Gibson-Cleary, Dilco and Gallup Sandstone coals (Nickelson, 1988). The present-day surface mining operations began in the early 1960's with Pittsburg and Midway's McKinley mine (first production in 1961) on the western side of the Gallup field. The McKinley mine and the Carbon Coal's Mentmore mine (opened 1978, closed 1985) both produce from the Gibson-Cleary. The Sundance mine (Amcoal, Inc.) and the Carbon No. 2 mine (Carbon Coal Company) southeast and south of Gallup, mined Dilco coals by surface methods. The McKinley mine is the only surface mine in the Gallup field in operation today.

Previous work

The Gallup coal field has been of geologic interest since the early 1900's when Shaler (1907) investigated the Durango-Gallup field. Gardner continued the study of coals in this area in his 1909 report on the Gallup-San Mateo area. Sears (1925) did one of the most significant works specifically on the coal resources of the Gallup area. The U.S. Bureau of Mines (1936) published a report on the quality of coals in New Mexico with analyses from mines, including many from this area. In 1956, Beaumont, Dane and Sears revised the nomenclature for the Mesaverde Group and subsequently used this nomenclature in mapping the Gallup area (O'Sullivan and Beaumont, 1957). Lease and Shomaker (1971) summarized the coal resources of the Gallup field from previous investigations as well as their own work. Recently, many of the quadrangles in the Gallup area have been mapped by USGS investigators (Millgate, in press; Stricker and Mapel, unpublished) and NMBM&MR workers (Tabet, 1981). The NMRDI project is the most recent investigation of the coals involving drilling and quality analysis.

GEOLOGIC SETTING

Structure

The Gallup field is in the southwestern part of the San Juan Basin, northwestern corner of New Mexico and southwestern Colorado (Fig. 1). The Gallup field is defined (Shomaker et al., 1971) on the eastern side of the steeply dipping beds along the Nutria monocline, the western edge by the Zuni uplift, and on the western side by the steeply dipping outcrops of the north-trending Defiance uplift (Fig. 2). The area between these two features is referred to as the Gallup sag or the Gallup-Zuni embayment. Within the Gallup sag, the attitude of the rocks is influenced locally by the Gallup and Torrivio anticlines and associated synclines. The southern boundary of the Gallup field is arbitrarily placed at the bottom of T12N, and the northern boundary is defined by barren outcrops of the Menefee Formation.

Stratigraphy

The Upper Cretaceous sediments in the Gallup area represent deposition during three of the five major transgressive-regressive cycles

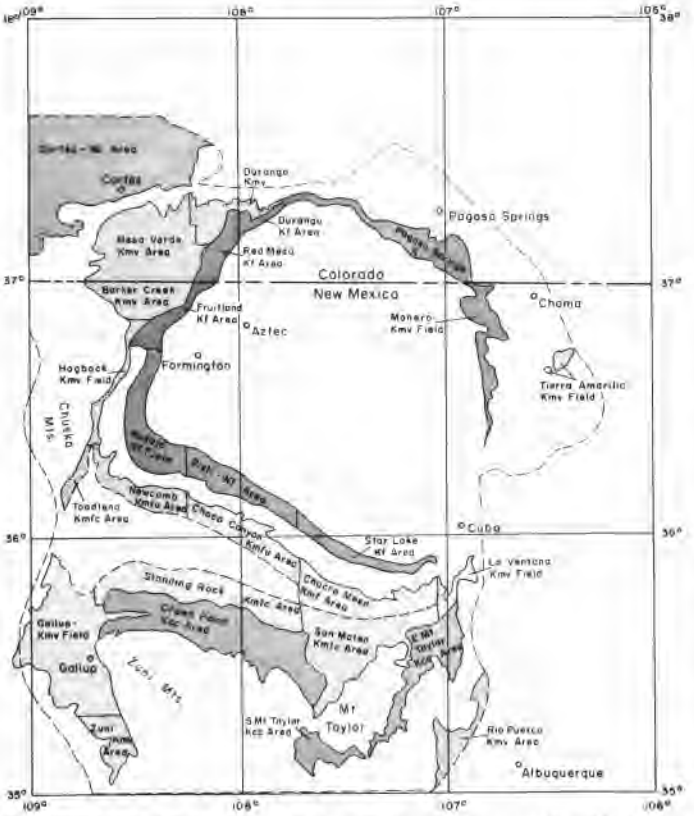

FIGURE 1. Coal fields in the San Juan Basin, northwestern New Mexico and southwestern Colorado. From Shomaker et al. (1971, p. 32).

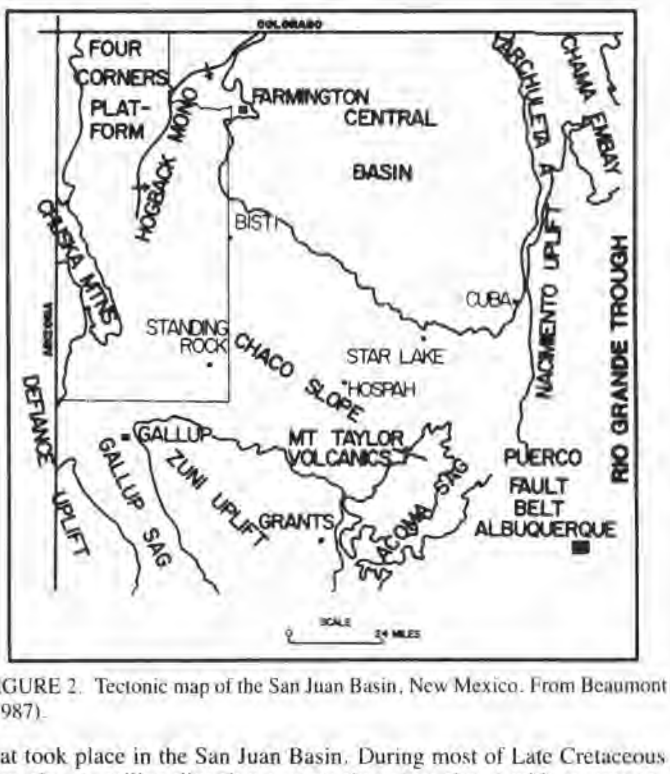

FIGURE 2. Tectonic map of the San Juan Basin, New Mexico. From Beaumont (1987).

that took place in the San Juan Basin. During most of Late Cretaceous time the strandline direction was northwest-southeast with an approximate trend of N50°W. The maximum landward position of the shoreline progressively shifted to the northeast with each transgressive-regressive cycle until the final withdrawal of the sea in late Pierre time. This created a jagged wedge of nonmarine rocks in the southern part of the basin interfingering with an irregular wedge of marine strata to the north. This sediment pattern left an almost unbroken record of transgressive and regressive deposits (Beaumont, 1987).

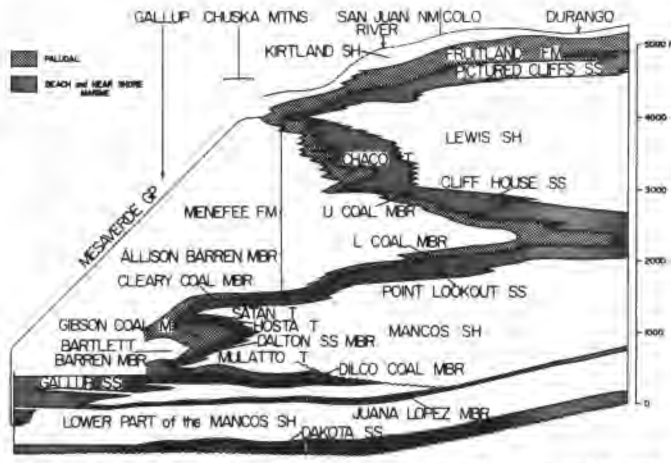

FIGURE 3. Stratigraphic diagram showing sequence, thickness and nomenclature of Cretaceous rocks in the San Juan Basin, New Mexico and Colorado. After Shomaker et al. (1971, fig. 6).

The Gallup field includes the coal-bearing units of the Gallup Sandstone, the Crevasse Canyon Formation and the Menefee Formation of the Mesaverde Group (Fig. 3). The Gallup Sandstone is a major regressive clastic unit consisting of a nearshore and barrier–beach marine sequence of sandstone interbedded with shale and contains one or more coals in the upper shale-dominated sequences. The Gallup Sandstone grades upward and landward into fluvial sandstones, mudstone and coal. Beaumont (1987) believes that the coal beds in the upper part of the Gallup Sandstone in the Gallup area are genetically related to and probably occur within a tongue of the overlying Dilco Coal Member of the Crevasse Canyon Formation. Although the Gallup Sandstone coal beds are reported by Sears (1925, p. 25) to have been mined, and were sampled at the Myers mine by the USBM (one analysis, 1936), these coals were not encountered in the NMRDI-supported drilling in sufficient thicknesses to warrant sampling and analyses.

Overlying the Gallup Sandstone is the regressive and partly transgressive sequence of the Dilco Coal Member of the Crevasse Canyon Formation (Fig. 3). The Dilco is a nonmarine sequence of sandstone, siltstone, mudstone, carbonaceous shale and coal. This unit is approximately 250–300 ft thick (Sears, 1925; NMRDI drilling, 1986, 1988) in the Gallup field and contains severals coals of economic thickness.

Figure 3 illustrates that the Dilco Coal Member in the Gallup area is not overlain by the Dalton Sandstone Member of the Crevasse Canyon as it is farther to the north and east. This occurs because the maximum landward position of the Dalton shoreline is northeast of the Gallup field. The Dilco Coal Member sequence was deposited during a time of major reversal in the shoreline from a predominantly transgressive to predominantly regressive sequence. Beaumont et al. (1971, p. 185) believe the rate of shoreline movement during these times of major reversal is much slower than in the middle of a transgressive or regressive phase. These transitional periods consist of standstills and minor shifts in the shoreline which allow for multiple intervals of back–barrier–swamp development, and result in the deposition of a thick coal-bearing sequence. The transitional sequence of the Dilco Coal Member represents deposits shoreward of the reversal of the Dalton shoreline and part of the next regressive cycle (Beaumont, 1971).

Overlying the Dilco Coal Member is the Bartlett Barren Member of the Crevasse Canyon Formation. The Bartlett is a 300–400 ft thick (Sears, 1925; NMRDI drilling, 1988) section of fluvial sandstone, siltstone, mudstone and very thin coal. The lower Bartlett Barren Member represents deposition during a regression of the shoreline to the northeast, and the upper part represents the floodplain deposits landward of the subsequent transgression of the shoreline.

As the shoreline continued to move to the southwest, the paludal sequence of the Gibson Coal Member was deposited on top of the Bartlett Barren Member. This sequence is similar to the Dilco Coal Member, containing sandstone, siltstone, carbonaceous shale and coal. The Gallup area was once again southwest of the maximum transgression of the shoreline, and the marine Point Lookout Sandstone was not deposited in this area. In most of the southern part of the San Juan Basin, the coastal barrier sandstones of the Point Lookout are used to separate the Gibson Coal Member of the Crevasse Canyon Formation and the Cleary Coal Member of the Menefee Formation. The Gibson Coal Member of the Crevasse Canyon and the Cleary Coal Member of the Menefee Formation are both of paludal origin, and without the presence of the Point Lookout Sandstone they cannot be differentiated. In the Gallup coal field the two coal-bearing sequences are referred to as the Gibson-Cleary undifferentiated. The Gibson-Cleary represents a thick coal-bearing sequence (150–200 ft) deposited during a major reversal in the Cretaceous shoreline, shoreward of the maximum position of the Point Lookout shoreline northeast of the Gallup area. The relative position of the Gallup area with respect to the shoreline during this transition from a transgressive to a regressive phase allowed for thick peat deposits to develop shoreward of the major buildup of barrier sandstones. Nearly stationary conditions of the shoreline during this time resulted in deposition of the thick coals seen in the Gibson-Cleary today.

COMPARISON AND ANALYSES OF DATA

The data presented for comparison of thickness and number of seams and quality of coal in the Gallup field are from the NMRDI coal quality study and data collected for entry into NCRDS. The quality data presented is a compilation of: (1) the analyses from the NMRDI project done by Frank Campbell at the NMBM&MR coal lab, (2) data collected for NCRDS from coal companies who had commercial labs or in-house labs run their analyses and (3) the U.S. Bureau of Mines analyses, also in the NCRDS. The lithologic data (coal thickness, number of seams) is from the NMRDI-supported drilling and from other public and private drilling programs.

The depositional environment of these coals is such that individual beds are lenticular and have limited lateral continuity either parallel or normal to the shoreline. Correlation of individual seams with the spacing of the available data would be suspect; therefore, no comparison of the coals on a seam-by-seam basis was made. Composite analyses using the weighted averages for the individual seams at each location were calculated and used for contouring and obtaining an average value for each township.

The diagrams (Figs. 4–11) show the boundaries of the Gallup field and major structural features, as well as the contours and averages for each township for the different parameters being considered.

NUMBER OF SEAMS AND SEAM THICKNESS

Dilco Coal Member

The Dilco Coal Member of the Crevasse Canyon Formation contains multiple coal seams, five of which are considered economic in the Gallup area (Lease and Shomaker, 1971). The NMRDI drilling encountered 7 to 9 seams within the Dilco coal-bearing sequence, ranging in thickness from 1 to 6 ft with an average thickness of 2.3 ft. The coal thicknesses considered here are greater than 1.2 ft. Figure 4 is a contour map of the average coal thickness at each drill site in the Dilco Coal Member, and the averages for each township are indicated. The average township thickness of the Dilco coals ranges from 1.3 to 3.4 ft, but the average seam thickness tends to be greater in the northeastern part of the Gallup field. Figure 5 is a contour map of the number of seams at each location greater than 1.2 ft thick with the averages for each township. The average number of seams varies from 2 to 5. The values for T12 and 13N, R17W are suspect because of the small number of points in these townships. An increase to the northeast in the number of beds within the Dilco coal-bearing sequence is apparent from the contouring. Sears (1925) indicates an increase in the total Dilco Coal Member thickness from west to east, and Tabet (1981) states that the

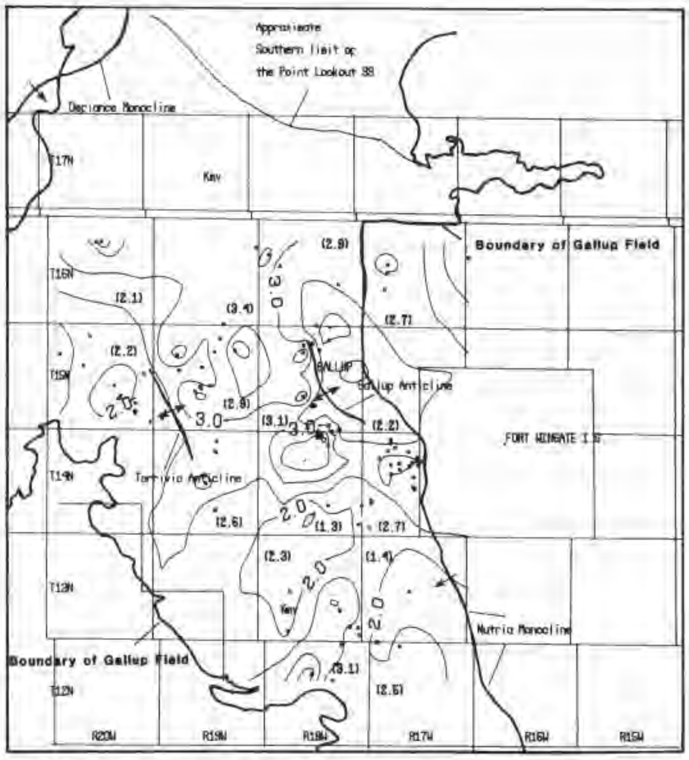

FIGURE 4. Contour map of average seam thickness, Dilco Coal Member in the Gallup field, CI = 0.5 ft. Numbers in ( ) represent averages for each township. Base map adapted from Shomaker et al. (1971, pl. 1).

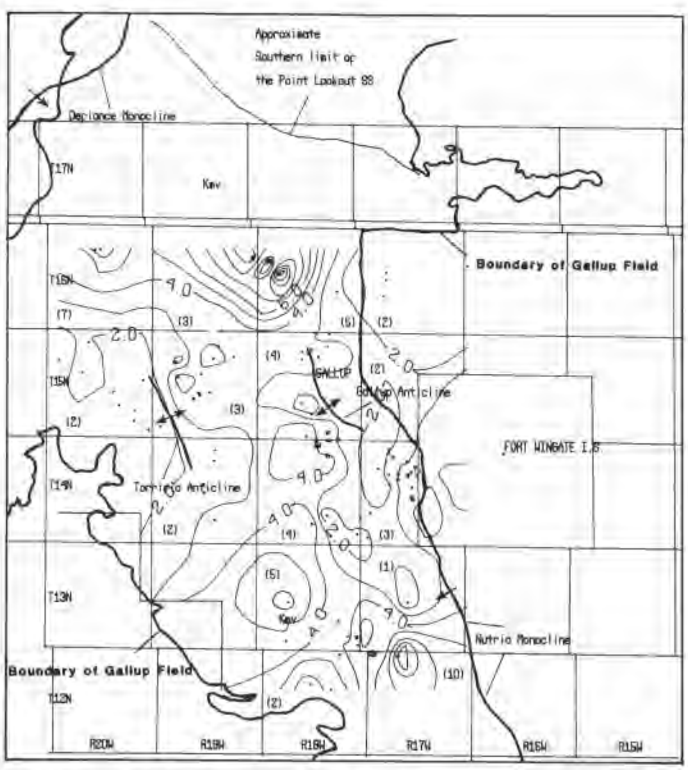

FIGURE 5. Contour map of number of seams, Dilco Coal Member in the Gallup field, CI = 1. Numbers in ( ) represent averages for each township. Base map adapted from Shomaker et al. (1971, pl. 1).

number of seams within the Dilco in the Pinehaven area in the southeastern part of the Gallup field also shows an increase from west to east. These observations support the idea that the number of coals is greatest shoreward of the maximum extent of the shoreline. Several minor stillstands or reversals probably occurred during the major reversal in the progression of the shoreline, creating numerous conditions, laterally and vertically, conducive to coal development.

Gibson Coal Member and Cleary Coal Member of the Crevasse Canyon and Menefee formations, undifferentiated

The Gibson-Cleary contains several coal seams of economic thickness. Lease and Shomaker (1971) state that there are 5 seams of economic thickness. The NMRDI drilling in the northern part of the Gallup field encountered 3 to 16 coal beds, but 8 is the average number present in the Gibson-Cleary coal-bearing sequence. The thickness of these coals ranged from 1 to 6.6 ft with an average thickness of 2.3 ft. Although drilling was restricted to T15 and 16N, a substantial decrease in the number of coals, 3 to 4 coals compared to 6 to 9 coals per location, was apparent in the southern township. Drill-hole data from the Pinehaven quadrangle (Tabet, 1981) indicate that the Gibson-Cleary coals in the southern part of the Gallup field are thinner (average 1.5 ft) and fewer (3–5 seams) than those in the northern part of the field. Sears (1925, plate 1) shows a thickening of the Gibson-Cleary coal-bearing sequence from the eastern side of the Gallup sag to the west in the vicinity of the town of Gallup, but no noticeable increase in the number of coal seams.

The Gibson-Cleary average coal seam thickness contours increase to the northwest, and the averages per township (Fig. 6) show a general thickening to the north-northwest. The average seam thickness in the southern part of the field is about half that seen in the north. The contour map (Fig. 7) of the number of Gibson-Cleary coals and the average per township indicates there are more seams present on the northeastern side of the Gallup sag. The locations with more seams do not necessarily contain the thickest coals, which is evident by comparing Figures 6 and 7. The higher frequency of coal beds in T16N, R18 and 19W may be due to several fluctuations of the shoreline to the northeast of this area, creating multiple but short-lived swamp environments inland. The area (T17N, R20W) with the thickest coals does not necessarily have the greatest number of seams, which may indicate the shoreline northeast of this area had fewer fluctuations, allowing for thicker but fewer coals to develop inland.

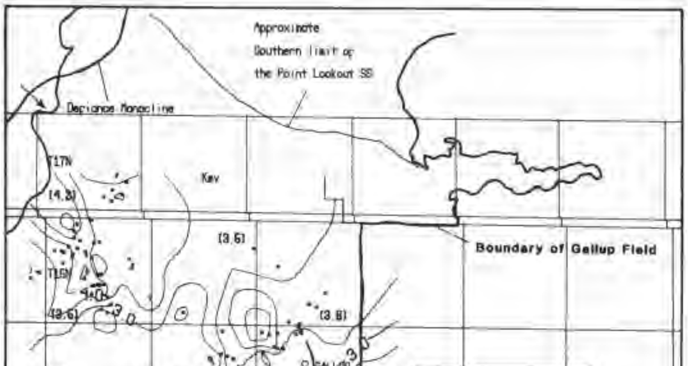

FIGURE 6. Contour map of average seam thickness, Gibson-Cleary coals in the Gallup field, CI = 0.5 ft. Numbers in ( ) represent averages for each township. Base map adapted from Shomaker et al. (1971, pl. 1).

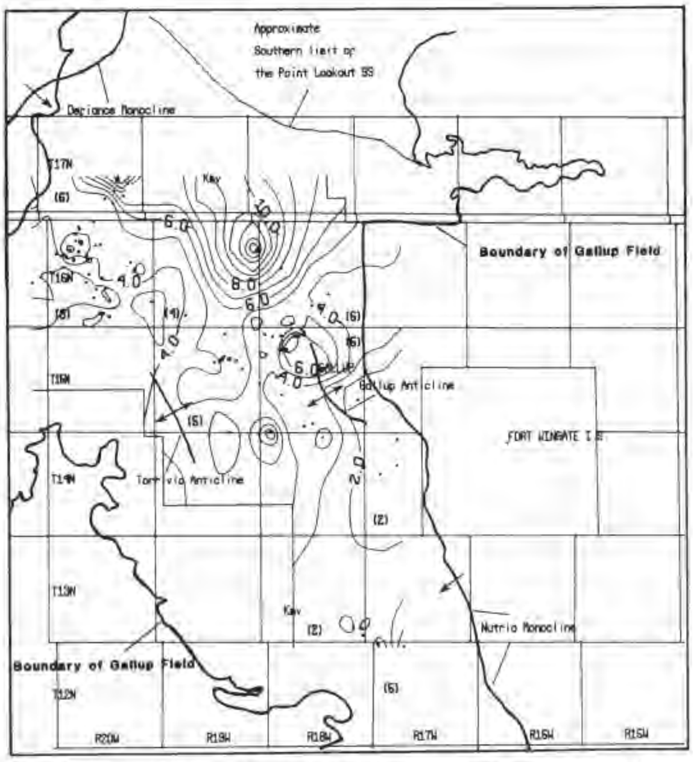

FIGURE 7. Contour map of number of seams, Gibson-Cleary coals in the Gallup field, CI = 1. Numbers in ( ) represent averages for each township. Base map adapted from Shomaker et al. (1971, pl. 1).

COAL QUALITY

Dilco coals

The coal quality analyses for the Dilco Coal Member of the Crevasse Canyon are limited; therefore, these coals will be examined only by township. The NMRDI drilling program obtained 11 samples from Dilco coal beds. Lithologically, these coals are bright, hard and had good cleat. The majority of the Dilco coals had shale partings, contained some pyrite but had little or no resin. The two townships with adequate data are T15N, R18 and 19W, which have some of the thicker coals (average 2.9–3.1 ft) in the Dilco Coal Member (Figs. 4, 5). The quality parameters are on a moist, ash-free (MAF) basis, except for ash, and are averages of the composite weighted averages for each location:

	T15N, R19W	T15N, R18W
% ash	11.24%	8.89%
% sulfur	0.8 %	0.9 %
% moisture	12.3 %	12.2 %
Btu/lb	12,223	12,289
No. of samples	15	23

The major differences in the average coal quality of these two townships is in the ash and sulfur contents. The average sulfur content is higher in the easternmost township, presumably closer to the shoreline. The ash content is higher in the westernmost township which is farther inland. The NMRDI samples show an increase in the percentage of partings (3.6–17.5%) in the coals from east to west, and the overall sandstone-shale ratio in the Dilco coal-bearing sequence at the NMRDI locations increase landward from 0.12 to 0.61. The Dilco coals average MAF Btu value increases slightly to the east, the inverse of the moisture content, but these changes are probably not significant. Very little can be said about the quality of Dilco coals with the amount of data available, except that they have a moderate sulfur content (0.8% sulfur, average for New Mexico coals) and they are high-volatile C bituminous in rank.

Gibson-Cleary coals

The Gibson-Cleary coals cored in the NMRDI drilling are bright to moderately bright, moderately hard and had well-developed cleat. These coals usually contained some resin and pyrite, and very few were shaly. Only 20% of the coals sampled in the NMRDI drilling had partings less than 0.8 ft, or less than 20% of the total coal thickness that averaged approximately 4% of the entire coal sample.

The Gibson-Cleary coals have a larger quality data base and therefore can be examined through contouring of composite analyses of weighted averages and averages of these composites by township. Figures 8 and 9 deal with the ash and sulfur (MAF) percentages of these coals. The ash content increases from northeast to southwest, which might be expected going from coal deposits closer to the shoreline to coals deposited in a floodplain environment. Most of the coal beds sampled in the NMRDI project which are considered to have been farthest from the shoreline did have more partings than the coals sampled that are considered to have been closer to the shoreline. The sulfur content generally decreases from northeast to southwest, although there are areas (T15 and 16N, R19W) that have a low sulfur content. The coals deposited closer to the shoreline could have been influenced by minor invasions of seawater, resulting in higher sulfur content. The areas which have lower sulfur content, but are close to the shore, may have been better protected from seawater invasion (larger barrier–beach buildups) or have been influenced by a major fluvial drainage system. The contour map of the average moisture content (Fig. 10) indicates a higher percentage moisture in the northeastern corner of T16N, R18W. The township averages vary from 14.5% to 16.7% moisture (MAF) in the Gallup area. The MAF Btu value averages (Fig. 11) range from 11,864 Btu/lb in the southeast to 11,447 Btu/lb in the northwestern

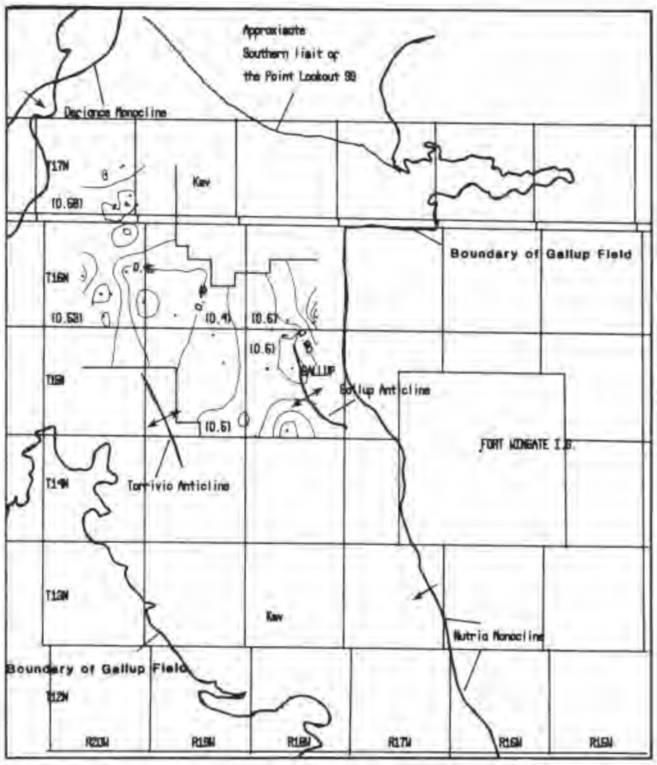

FIGURE 9. Contour map of weighted averages, percent sulfur (MAF), Gibson-Cleary coals in the Gallup field, CI = 0.075%. Numbers in ( ) represent averages for each township. Base map adapted from Shomaker et al. (1971, pl. 1).

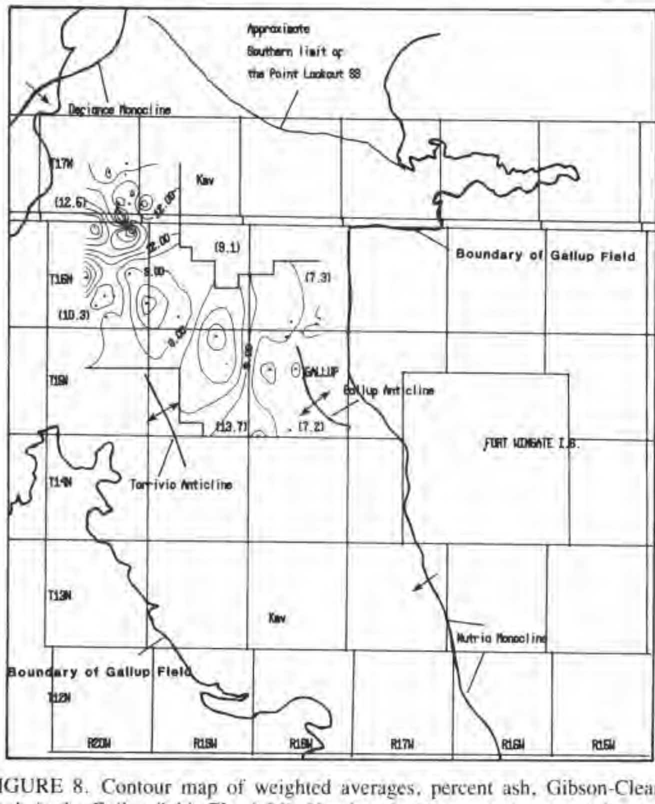

FIGURE 8. Contour map of weighted averages, percent ash, Gibson-Cleary coals in the Gallup field, CI = 1.0%. Numbers in ( ) represent averages for each township. Base map adapted from Shomaker et al. (1971, pl. 1).

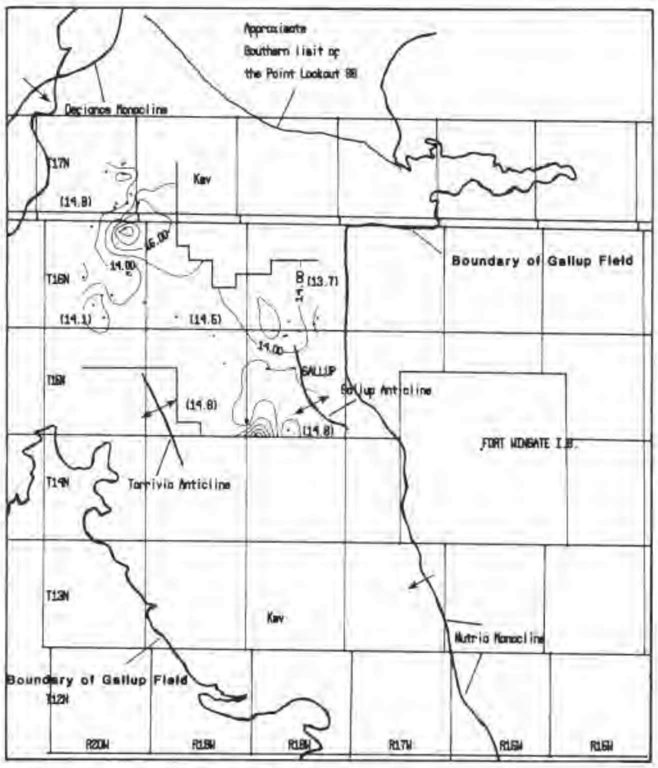

FIGURE 10. Contour map of weighted averages, percent moisture (MAF), Gibson-Cleary coals in the Gallup field, CI = 1.0%. Numbers in ( ) represent averages for each township. Base map adapted from Shomaker et al. (1971, pl. 1).

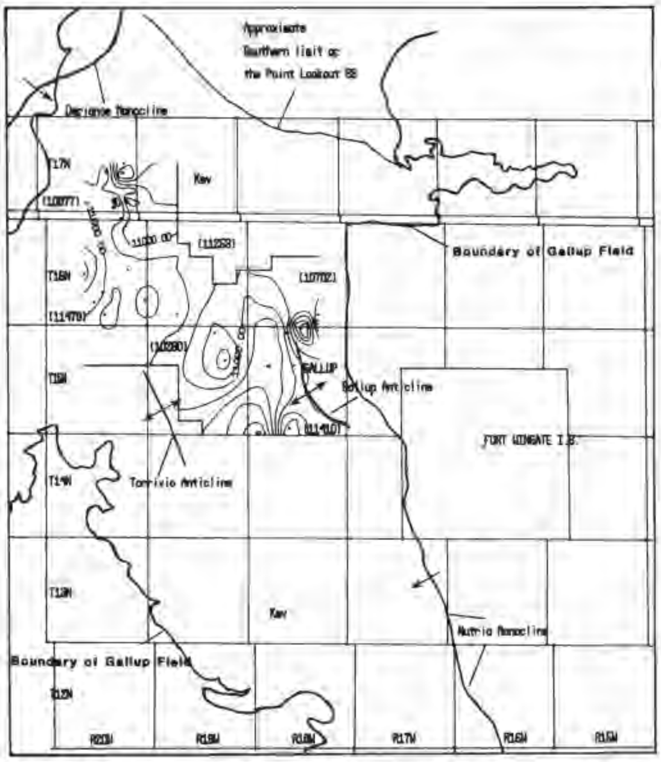

FIGURE 11. Contour map of weighted averages, percent Btu/lb (MAF), Gibson-Cleary coals in the Gallup field, CI = 250 Btu/lb. Numbers in ( ) represent averages for each township. Base map adapted from Shomaker et al. (1971, pl. 1).

part of the Gallup field. The average rank of the Gibson-Cleary coals is high-volatile C bituminous.

Comparisons

Comparison of the two major coal intervals in the Gallup field on a township basis shows both Dilco and Gibson-Cleary coals have an increased ash content to the west. The ash percentages do not differ greatly between the Dilco and Gibson-Cleary coals (8.89–11.24% and 7.2–13.7%), although the Gibson-Cleary coals have a wider range of ash content. The NMRDI samples of the Dilco and Gibson-Cleary coals show a greater percentage of partings (less than 0.8 ft or less than 20% of the total coal) in the Dilco coals, which would indicate that the ash content in the Gibson-Cleary coals represents finely disseminated ash throughout the coal. The sulfur content (MAF) is lower in the Gibson-Cleary coals (0.4–0.6%) than in the Dilco coals (0.8–0.9%), which may indicate that the Dilco coals, where analyses were available, were closer to the shoreline than those in the Gibson-Cleary. This would be expected since the maximum extent of the Dalton Sandstone shoreline was farther to the southwest than the subsequent maximum extent of the Point Lookout Sandstone. Both sets of coal analyses show the sulfur content decreasing from east-northeast to west-southwest.

The moisture content (MAF) of the Gibson-Cleary coals (14.5–16.7%) is higher than the moisture content in the Dilco coal samples (12.2–12.3%). The (MAF) Btu values of the Dilco coals are higher (12,223–12,289 Btu/lb) than the Gibson-Cleary coals (11,447–11,864 Btu/lb). The decreased moisture and higher Btu values are probably a consequence of the greater time and depth of burial for the Dilco coals.

CONCLUSIONS

The Gallup field has long been an area of coal mining activity with large amounts of coal produced from the two major coal-bearing sequences, the Dilco Coal Member of the Crevasse Canyon Formation and the Gibson-Cleary of the Crevasse Canyon and Menefee formations, undifferentiated. Although many geological studies and exploration programs have been carried out in the area, the quality and thickness trends of these coals have not been looked at in great detail. This study has been an attempt to look at the data available, and to determine if any trends are evident which can be related to the depositional environments of the coal-bearing sequences. Although the writer feels more data are needed to obtain a better understanding of these coals, a few inferences can be made from the available information.

The contours and averages per township of the seam thickness and number of seams in both the Dilco Coal Member and Gibson-Cleary indicate that the greatest number and generally the thickest seams were developed close to the shoreline, inland from the major buildups of barrier sandstones. Both the Dilco and Gibson-Cleary sequences were deposited during times of major reversals when the rate of shoreline movement was reduced almost to a standstill. This resulted in the numerous and the sometimes thick coal seams present in both the Dilco and Gibson-Cleary sequences in the northern Gallup field. Farther inland, to the southwest, the potential for coal development was less constant because of the influx of sediment and minor shoreline shifts which limited the swamp environments in any one place. Therefore, the coals present in these areas are thinner and less frequent in the overall sequence.

The quality analyses of the Dilco and Gibson-Cleary coals is interpreted to mean that the coal swamps that developed nearer the shoreline were subject to invasions of sulfate-bearing seawater which resulted in their having higher sulfur contents than those farther inland. These nearshore coals have a lower ash content than those deposited in a more fluvial environment where there would tend to be more influx of sediment into the swamps. Moisture and Btu values show greater differences between the Dilco and Gibson-Cleary coals than within the individual sequences. The Dilco coals have a lower moisture and a higher Btu value than the Gibson-Cleary coals, probably because of the older age and greater depth of burial.

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Pyramid Mountain looking W. Note recent sand dune in lower left foreground. Jurassic section exposed here is Wanakah Formation (lower slopes on right), Cow Springs Member of Entrada Sandstone (parallel-bedded cliffs in foreground), Westwater Canyon Sandstone of Morrison Formation (far cliff) and Brushy Basin Member of Morrison Formation (top of "pyramid"). Photograph taken 24 February 1989 by Paul L. Sealey.