Circular 168 1979

Drilling at the Law prospect in 1927

Geology of Jornada del Muerto coal field, Socorro County, New Mexico

by D. E. Tabet

New Mexico Bureau of Mines & Mineral Resources

A DIVISION OF
NEW MEXICO INSTITUTE OF MINING & TECHNOLOGY

Circular 168

New Mexico Bureau of Mines & Mineral Resources

A DIVISION OF
NEW MEXICO INSTITUTE OF MINING & TECHNOLOGY

Geology of Jornada del Muerto coal field, Socorro County, New Mexico

by D. E. Tabet

SOCORRO 1979

First Printing, 1979

Published by Authority of State of New Mexico, NMSA 1953 Sec. 63-1-4
Printed by University of New Mexico Printing Plant, November, 1979

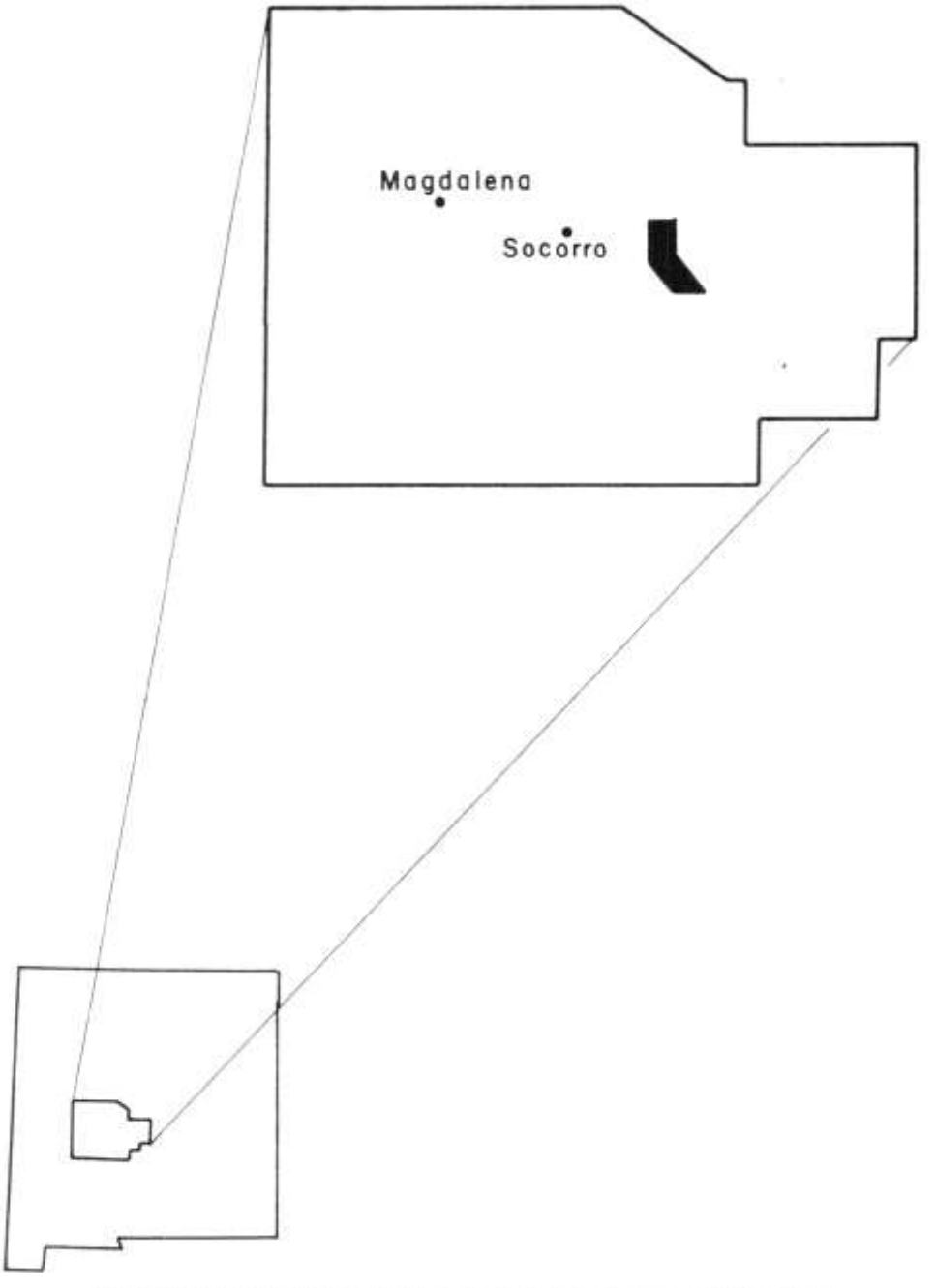
Available from New Mexico Bureau of Mines & Mineral Resources, Socorro, NM 87801 Price $3.50

Contents

Table

Figures

Geologic map



INDEX MAP showing Jornada del Muerto coal field in Socorro County, New Mexico.

Abstract

In the northern part of the Jornada del Muerto Basin, coal-bearing Upper Cretaceous rocks are exposed on the westward-dipping limb of a south-plunging anticline. This faulted exposure measures 0.5 mi east-west and 12 mi north-south. The dip on the west limb ranges from 20° to 40° SW. Lenticular coal beds occur in rocks of the Mesaverde Group that are tentatively correlated with the Dilco Member of the Crevasse Canyon Formation. Maximum thickness of a coal bed in the northern part of the field is 20 inches; however, in the middle of the field, the coal in the Law mine is 28 inches thick. Coal beds in the southern half of the field are covered by Quaternary sediments. Chemical analysis indicates that the coal from the Law mine is a high-volatile C-bituminous coal with a sulfur content of 1.3 percent to 1.4 percent and is similar to the coking coal produced in the Carthage area to the southwest. Coal from the Law mine produces a poor to fair coke and relatively high amounts of light oil and gas. Because little mining and exploration has been done in the Jornada field, production records are not available. Coal beds in the Jornada field may thicken to the southwest toward the Carthage area, but further drilling would be required to prove the thickening. Limited drill-hole data and unpublished gravity data indicate that the coal between the Carthage and Jornada fields is more than 1,000 ft deep.

Introduction

Geography

Five miles northeast of the Carthage coal field in eastern Socorro County, coal-bearing rocks crop out in a northwest-trending strip of land 12 mi long and 0.5 mi wide along the northwest edge of the Jornada del Muerto Basin (geologic map). The area can be reached by traveling north from US-380 on the Del Curto or Williams Ranch roads that lie approximately 10 and 20 mi east of San Antonio.

The northern part of the area consists of north-south ridges of sandstone with valleys underlain by shale. Elevation ranges from 6,200 ft above sea level in the north to 5,100 ft above sea level in the southeastern part of the field. In the north relief is as great as 300 ft, whereas to the south the ridges pass into gently rolling hills and valleys and the maximum relief is about 60 ft.

The area is drained by Cañon Quemado, a large intermittent stream that parallels the north-south sandstone ridges. Numerous small intermittent tributaries join the main drainage along its course.

Vegetation in the area consists primarily of range grasses in the lower, nearly level southern portion and grasses along with piñon, juniper, and scrub oak on the higher slopes and hilltops in the north. Cacti of various types are common.

Population in the area is limited to a few ranching families. Most of the land composing the Jornada coal field is under U.S. Bureau of Land Management administration.

Previous work

The geology of the coal in the Jornada del Muerto coal field has received little study. Storrs' (1902) report on the coal fields of the Rocky Mountains probably included this field in what is referred to as the "Carthage areas," identified as "60 square miles of area situated 8 miles east of the town of San Antonio." Most of Storrs' data concerned the coal field at Carthage proper, located approximately 5 mi southwest of the Jornada field. Gardner (1910), in a more detailed paper on the Carthage field, included a two-paragraph description of an exposure of 2.75 ft of coal in the Jornada field in NE 1/4 SW 1/4 sec. 8, T. 3 S., R. 3 E. He believed the exposure to be in "an isolated, faulted area, detached from a large field to the south that is completely covered by recent unconformable beds." Read and others (1950) describe the Jornada field as underlying parts of Tps. 3, 4, and 5 S., R. 3 E. and possibly an even larger area. They list the reserves for the combined Carthage and Jornada coal fields as over 38 million short tons. The chemistry and coking properties of a sample from the Law mine is given in a report by the U.S. Bureau of Mines (Reynolds and others, 1946). Wilpolt and Wanek (1951) mapped the regional geology for their oil and gas investigation map. Later papers by Kottlowski and Beaumont (1965) and Kottlowski, Beaumont, and Shomaker (1974) summarize the work of previous investigators.

ACKNOWLEDGMENTS—Several people deserve thanks for their help with this project. Howard B. Nickelson, formerly with the Conservation Division of the U.S. Geological Survey, located records for the abandoned federal coal-prospecting permits in the area. William A. Cobban, with the Geologic Division of the USGS, helped with the identification of the marine invertebrate fossils and assigned USGS Mesozoic locality numbers to the significant collections. Finally, special thanks go to Stephen C. Hook, of New Mexico Bureau of Mines and Mineral Resources, for his help in the field, his time identifying the marine invertebrates, and his discussions and review of material concerning the Upper Cretaceous stratigraphy and nomenclature. The cover sketch is based on a photo provided by Howard Nickelson, courtesy of the USGS.

Geology

Cretaceous rocks

Dakota Sandstone

The Dakota Sandstone unconformably overlies the Dockum Formation (Triassic). The Dakota is a well- indurated, orangish-brown, medium-grained quartz sandstone; near the base it is almost white. The sandstone is commonly massive to crossbedded but, as a result of bioturbation, locally displays irregular, highly pitted surfaces with indistinct bedding.

The thickness of the Dakota was measured at one locality in the Jornada field to be 74 ft 7 inches (appendix 1, section 1). Gardner (1910) reported a thickness of 200 ft for the Dakota in the Carthage field to the south.

Mancos Shale

The Mancos Shale conformably overlies the Dakota Sandstone. As in the Carthage area, the Mancos consists of two shale units separated by an intervening sandstone member. In ascending order, these Mancos units probably correspond to a lower tongue, the intervening Tres Hermanos Sandstone Member, and the D-Cross Tongue (Cobban and Hook, 1979).

The valley-forming nature of the Mancos Shale tongues makes accurate measurement of their true thickness difficult. The upper and lower shale units are often covered by a veneer of soil or alluvium. As exposed in arroyos, the shales appear similar; both consist of drab-gray or tan shale or silty shale with a few thin (mostly less than 1-ft) beds of tan quartz sandstone and limestone. Large septarian concretions, occasionally fossiliferous, up to 3 ft long and 1 ft thick, occur at various horizons. The lower shale measured 681 ft 6 inches thick; however, this thickness is slightly exaggerated because the section is faulted. The upper shale measured 363 ft 9 inches.

The Tres Hermanos Sandstone is presently considered a member of the Mancos Shale; work in progress by Hook and Cobban indicates this member may be taken from the Mancos Shale and raised to formational rank (Hook, personal communication, 1979). The Tres Hermanos measures 244 ft 4 inches. The lower 79 ft consist of medium-bedded, fine- to medium-grained, tan quartz sandstone with interbedded calcareous, fossiliferous concretions of darker tan or brown-weathering quartz sandstone. These planar-bedded to shallow crossbedded or bioturbated sands were apparently deposited in a littoral to shallow neritic environment of a regressive sea. A medial 124-ft thick sequence of interbedded drab-gray shale and tan sandstone locally contains petrified wood and oyster shells, which indicate deposition in an area that varied from lagoonal or continental to marine.

As exposed in the northern half of the mapped area, the uppermost 41 ft of the Tres Hermanos Sandstone Member consist of a transgressive deposit of silty, bioturbated sandstone, cream to white near the base and reddish near the top. This sandstone is prominent on aerial photographs of the area. Two thin calcarenite beds occurring immediately above the Tres Hermanos are lithologically equivalent and contain fossils typically found in the Juana Lopez Member of the Mancos Shale in the San Juan Basin.

Mesaverde Group

Overlying the D-Cross Tongue of the Mancos Shale are rocks of the Mesaverde Group. In the northern part of the field area, about 231 ft of the Mesaverde Group are preserved beneath an erosional contact separating this unit from the Baca Formation (Tertiary). To the south, drilling indicates that up to 650 ft are preserved. At the base of the Mesaverde Group is a 20-ft-thick, tan, fine-grained to silty sandstone that occurs 15 ft above the *Lopha sannionis* zone of the D-Cross Tongue of the Mancos Shale and is correlated with the Gallup Sandstone. Brown, calcareous, crossbedded sandstone concretions are common in this basal sandstone unit. Overlying the basal sandstone is a sequence of drab-gray and tan shales, thin tan sandstones, and lenticular coal beds that corresponds to the Dilco Coal Member of the Crevasse Canyon Formation.

Tertiary rocks

Baca Formation

The Baca Formation unconformably overlies the Mesaverde Group (Cretaceous). It is composed of coarse conglomerate, red and white sandstone, and red clay derived from Precambrian quartzite and granite and Paleozoic limestone and sandstone (Wilpolt and Wanek, 1951). The thickness of these varicolored rocks is reported to be 1,023 ft in the Carthage area (Gardner, 1910) and is approximately the same thickness in the Jornada coal field area.

Datil Group

In the southwestern part of the map area, andesitic, rhyolitic and volcaniclastic rocks (probably equivalent to the Spears Formation) cap large hills and lie with angular unconformity on the Baca Formation. Other limited exposures of volcanic rocks, probably remnants of flows of much wider extent, also occur just off the southeast corner of the map. Here the volcanic rocks rest on a surface of folded and beveled Cretaceous rocks. Wilpolt and Wanek (1951) report a thickness of up to 2,000 ft for the Datil Group rocks in the Jornada coal field area.

Quaternary rocks

Evidence of a former pediment surface is preserved on hilltop gravel deposits. These well-rounded, cobble-

sized gravels are at least 50 ft higher than the present valley fill and thus indicate that a substantial amount of dissection and erosion has taken place since their deposition.

Younger alluvium and bolson-fill deposits form a relatively undissected planar surface in the south-central part of the Jornada field and lap up onto the Mesozoic and Tertiary rocks to the north. This surface is preserved by caliche. A veneer of gravel and eolian sand covers much of the surface of the recent basin-fill deposits.

Structural geology

The coal-bearing Cretaceous sedimentary rocks of the Jornada del Muerto coal field lie on the moderately dipping western flank of the southward-plunging Prairie Springs anticline (Wilpolt and Wanek, 1951). The strike of the beds on the west limb swings from nearly north-south in the northern end of the field to a more westerly direction as the nose of the anticline is approached to the south. The dip of the beds ranges from 15° to 40° SW. and averages 27°. Wilpolt and Wanek (1951) show that the Cretaceous beds are faulted downward on the east limb of the anticline and not exposed.

Two sets of faults are apparent in the area. Faults oriented diagonally to the north-south axial plane of the Prairie Springs anticline are probably shear fractures related to the east-west compressional forces that caused the folding. Another set of faults, most oriented north-south but also some oriented east-west, appear to be extensional normal faults. Prominent north-south-trending normal faults run through several sections in the northwestern part of the area. Numerous unmapped faults undoubtedly occur in the areas under cover of Quaternary sediments.

According to preliminary gravity data (Schlue, 1978), the Cretaceous rocks of the Jornada field are the northeastern exposure of a filled basin that is bounded to the southwest by the Carthage coal field (fig. 1). The basin is asymmetrical with a very steep southwestern margin near Carthage and a moderate slope on the northeastern side. Drilling indicates coal-bearing Cretaceous rocks in the center of this basin must be greater than 1,000 ft deep (Wilpolt and Wanek, 1951).

Coal

Surface exposures

The thickest exposures of coal in the northern part of the Jornada del Muerto coal field are found within 100 ft of the top of the Gallup Sandstone of the Mesaverde Group. Thin coal beds are common within this horizon, seldom reaching more than 1 ft thick. The best surface exposure of coal, found in NW 1/4 SW 1/4 sec. 8, T. 3 S., R. 3 E., measures 20 inches thick. This exposure is about 0.25 mi north of the site of an abandoned mine on the Del Curto Ranch.

Determining the position of the coal beds relative to the base of the Mesaverde was impossible because of poor exposures in the southern part of the field. Two coal beds separated by a foot of shale are exposed in the abandoned Law mine in SW 1/4 NW 1/4 sec. 3, T. 4 S., R. 3 E. The lower coal is 28 inches thick and the upper is 8 inches thick. The coal beds are offset by faulting and cannot be traced to the surface. The upper coal has many shale partings while the lower one is a good clean coal. A channel sample of the lower coal bed was sent to the USGS Branch of Coal Resources in Denver, Colorado, for analysis in 1976 (table 1).

Subsurface geology

Limited subsurface information is available from several federal coal-prospecting permits issued in 1927 and in the early 1960's and from one test hole drilled in 1976 by the New Mexico Bureau of Mines and Mineral Resources. Earliest drilling consisted of four holes near the Law mine, while later drilling occurred in various parts of Tps. 3 and 4 S., R. 3 E. The information from these holes is presented in appendix 2.

The four early Law holes ranged from 374 to 987 ft deep, but only two holes penetrated coal up to 3 ft thick, one at roughly 644 ft and the second at 966 ft. Numerous thinner coals are reported from these holes with the thickest being 1 ft 8 inches. The 19 holes drilled during the 1960's are all less than 350 ft deep and only three are deeper than 200 ft. Only two holes, one in the NE 1/4 NE 1/4 sec. 29 and the other in the NW 1/4 NW 1/4 sec. 33, T. 3 S., R. 3 E., intersected coal beds thicker than 3 ft. The hole in sec. 29 hit an estimated 7 ft of coal at 139 ft, while the hole in sec. 33 hit 4 ft of coal at 119 ft. The New Mexico Bureau of Mines and Mineral Resources drilled a hole to approximately 360 ft in the SW 1/4 NW 1/4 sec. 3, T. 4 S., R. 3 E. and penetrated several thin coals. The thickest coal was 2 ft 5 inches occurring at a depth of approximately 67 ft.

Chemical analyses

According to the standard specifications for the classification of coals by rank (American Society for Testing and Materials, 1967), the analytical results listed in table 1 show that the coal from the Law mine in the

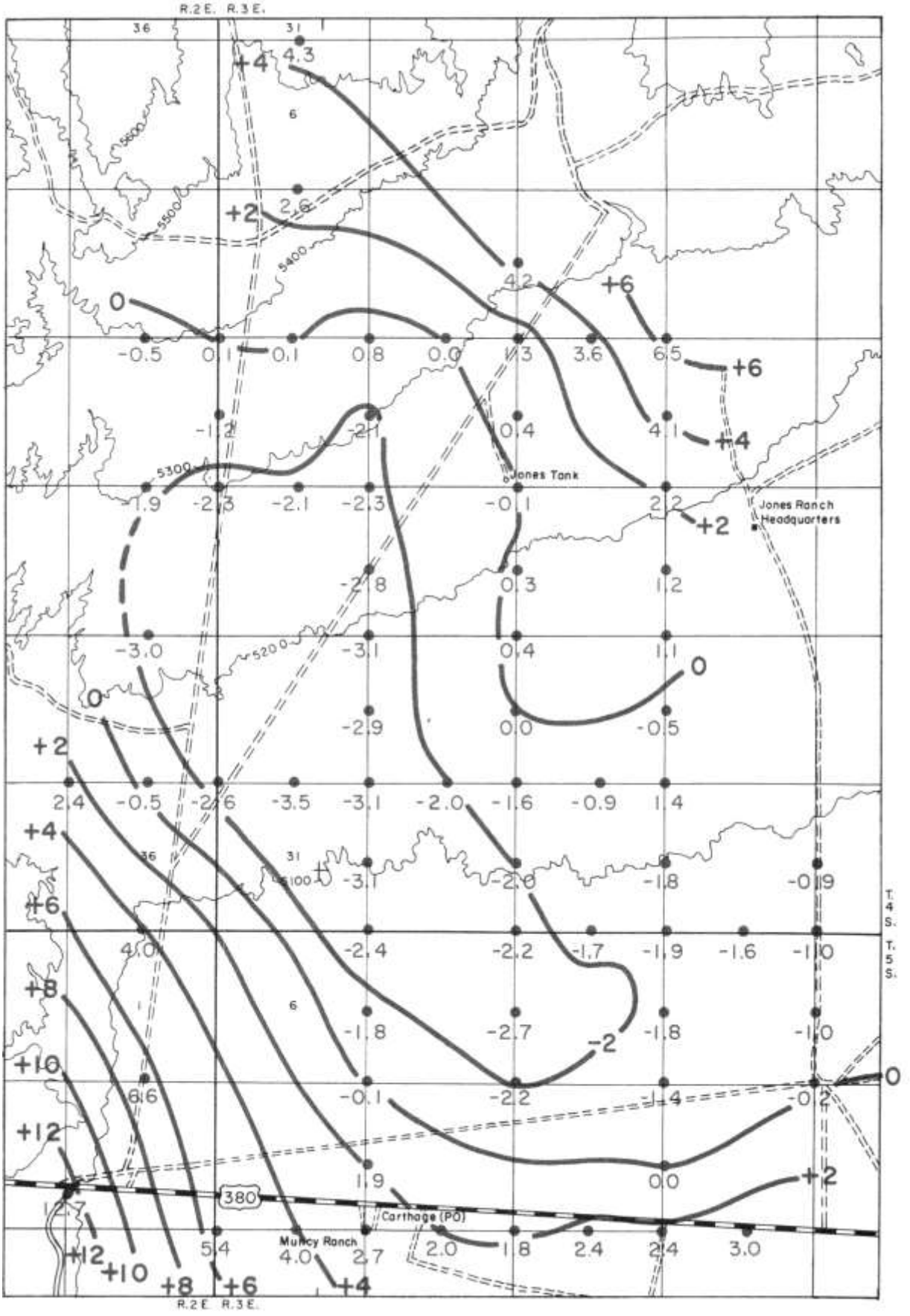


FIGURE 1—GRAVITY MAP WITH REGIONAL TRENDS CORRECTED (modified from Schlue, 1978).

TABLE 1—ANALYSES OF COAL SAMPLES FROM THE JORNADA DEL MUERTO AND CARTHAGE COAL FIELDS. Samples collected by G. S. Austin and D. E. Tabet, New Mexico Bureau of Mines and Mineral Resources, April 10 (Carthage) and May 5 (Jornada), 1975; samples analyzed by the U.S. Geological Survey, Office of Energy Resources, Branch of Coal Resources.

Law mine, Jornada field, SW¼NW¼ sec. 3, T. 4 S., R. 3 E.
Lower bed, 28 inches thick
Face-channel sample, no. D173240

	Proximate analysis				Ultimate analysis					
Sample condition	Moisture	Volatile matter	Fixed carbon	Ash	Hydrogen	Carbon	Nitrogen	Oxygen	Sulfur	Calorific value (Btu)
as received	2.6	41.6	45.2	10.6	5.3	69.4	1.3	12.1	1.3	12,410
ash and moisture free	——	48.0	52.0	——	5.8	79.9	1.5	11.4	1.4	14,300

Hart mine, Carthage field, SE¼SE¼SE¼ sec. 10, T. 5 S., R. 2 E.
Carthage bed (lower seam), 50 inches thick
Composite face-channel sample (two samples analyzed together), nos. D173237 and D173238

	Proximate analysis				Ultimate analysis					
Sample condition	Moisture	Volatile matter	Fixed carbon	Ash	Hydrogen	Carbon	Nitrogen	Oxygen	Sulfur	Calorific value (Btu)
as received	1.6	35.8	46.4	16.2	4.9	66.8	1.3	10.2	0.6	11,950
ash and moisture free	——	43.5	56.5	——	5.8	81.2	1.5	10.8	0.7	14,530

Jornada field is high-volatile C-bituminous coal. This analysis compares closely with the analysis of the coking coal from the Hart mine in the Carthage field. The Jornada coal has a slightly higher Btu value and a lower ash content; on the negative side, it has a higher sulfur content. A paper on the carbonizing properties of western coals (Reynolds and others, 1946) reports that a coal sample from the Law mine produced a poor to fair coke and yielded relatively high amounts of light oil and gas.

Because of environmental considerations, the form and content of sulfur in the coal deserve further consideration. The sulfur content of the Jornada coal places it in the lower end of the medium-sulfur-content category (DeCarlo, Sheridan, and Murphy, 1966). The sulfur content, analyzed as received from the mine, consisted of 0.3 percent as sulfate, 0.70 percent organic sulfur, and 0.25 percent as pyritic sulfide. The form of the sulfur is important because sulfur in the pyritic form can be reduced considerably by conventional coal-cleaning processes, depending upon the size and distribution of the pyritic minerals. The sulfate content of the two samples listed may be somewhat higher than normal because of recent precipitation of gypsum on the exposed face of the abandoned mines.

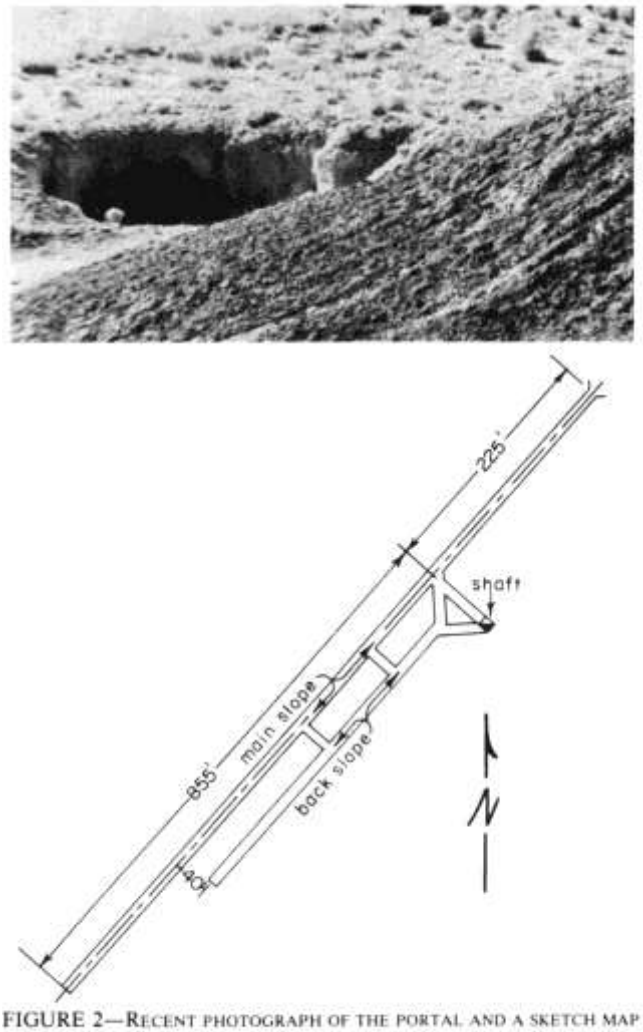


FIGURE 2—RECENT PHOTOGRAPH OF THE PORTAL AND A SKETCH MAP OF LAW MINE (from a 1929 U. S. Geological Survey inspection report.)

Mining

No mining production figures are recorded for the Jornada del Muerto coal field, although at least two small mines or prospects are known. The abandoned mine in SE 1/4 SW 1/4 sec. 8, T. 3 S., R. 3 E. has been completely filled in, but the outline of an opening is still visible at the surface. Some coal cars remain near the opening. No waste dump exists to provide an estimate of the

amount of material mined. The Law mine, in SW 'A NW 'A sec. 3, T. 4 S., R. 3 E., is accessible except near the lower half of the 1,080-ft-long slope, where the timbers have begun to sag and collapse. According to USGS records in Farmington, New Mexico, the mine workings (fig. 2) consisted of a main slope driven S. 50° W. and a parallel-running back slope that branched off the main slope 225 ft from the portal; the slopes were driven on 40-ft centers. The mined interval, 10 ft wide and 7 ft high, worked a 4-ft coal seam including a 1-ft parting. The 8 inches of coal above the shale parting contained numerous thin shale partings. Mining halted during 1927 when the coal seam was lost because of faulting at the back of the slope.

Economic potential

The limited data generated in this study indicates that the field requires further subsurface exploration. The exposed coals in the Jornada field are thin; however, they may thicken in the direction of the Carthage field to the south, where a 5-ft seam of coal was mined. The results of analyses on the samples taken from the Law mine indicate that the Jornada coal is of good quality, although not necessarily suitable for coking purposes. Exploration drilling, especially in the covered southern portion of the field, would have to be undertaken to determine the extent, thickness, and quality of the coal in the whole field before the economic potential of the Jornada del Muerto coal field can be assessed.

Mining in the Jornada field will probably have to be by underground methods because the dip of the coal beds, from 20° to 40°, is too steep for most strip-mining methods. Mineral rights for the majority of the area encompassed by the Jornada field are administered by the U.S. Bureau of Land Management, although some small parcels of land are private. This division of mineral rights and the lack of a federal leasing program pose a problem to exploration and later mining efforts. Faulting, more extensive than that recognized at the surface, may also be a hindrance to mining efforts.

References

American Society for Testing and Materials, 1967, Standard specifications for classification of coals by rank (ASTM Designation D 388-66): Philadelphia, American Society for Testing and Materials, 1967 Book of ASTM Standards, pt. 19, p. 73-78

Cobban, W.A., and Hook, S.C., 1979, *Collignoniceras woollgari woollgari* (Mantell) ammonite fauna From Upper Cretaceous of Western Interior, United States: New Mexico Bureau of Mines and Mineral Resources, Mem. 37, fig. 3. p. 10.

De Carlo, J.A., Sheridan, E.T., and Murphy, Z.E., 1966, Sulfur content of United States coals: U.S. Bureau of Mines, Inf. Circ. 8312, 44 p.

Gardner, J.H., 1910, The Carthage coal field, New Mexico: U.S. Geological Survey, Bull. 381,p. 452-460

Kottlowski, F.E., and Beaumont, E.C., 1965, Coal: New Mexico Bureau of Mines and Mineral Resources, Bull. 87, p. 100-116

Kottlowski, F.E., Beaumont, E.C., and Shomaker, J.W., 1974, Description of seams in New Mexico: Keystone Coal Industry Manual, p. 522-529

Read, C.B., Duffner, R.T., Wood, G.H., and Zapp, A.D., 1950, Coal resources of New Mexico: U.S. Geological Survey, Circ. 89, 24 p.

Reynolds, D.A., Davis, J.D., Brewer, R.E., Ode, W.H., Wolfson, D.E., and Birge, G.W., 1946, Carbonizing properties of western coals: U.S. Bureau of Mines, Tech. Paper 692,79 p.

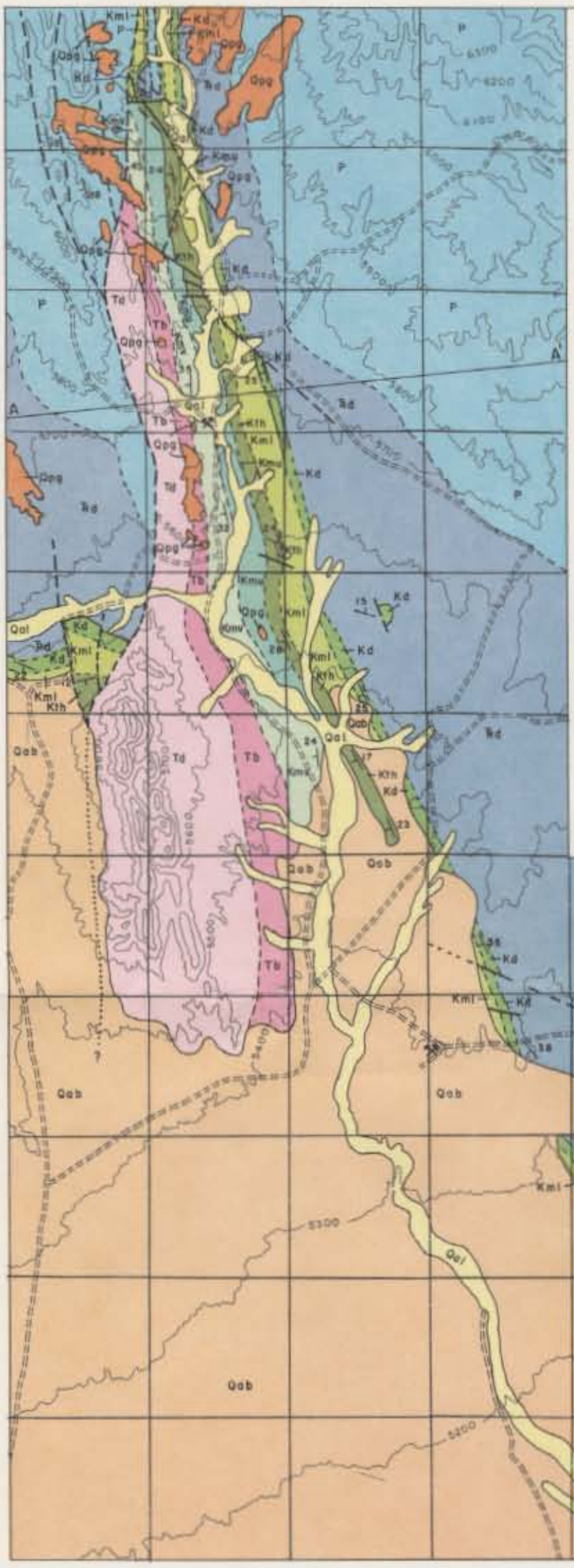
Schlue, J.W., 1978, Report on a gravity survey of the northern Jornada del Muerto, New Mexico: New Mexico Institute of Mining and Technology, Geology Dept. Open-file Rept. 21,19 p.

Storrs, L.S., 1902, The Rocky Mountain coal fields: U.S. Geological Survey, 22nd Ann. Rept., pt. 3, p. 415-471

Wilpolt, R.H., and Wanek, A.A., 1951, Geology of the region from Socorro and San Antonio east of Chupadera Mesa, Socorro County, New Mexico: U.S. Geological Survey, Oil and Gas Inv. Map, OM 121,2 sheets

Appendices start on p. 13.

Geologic map of Jornada del Muerto coal field



QUATERNARY

- Qal — Alluvium
- Qpg — Pediment gravel
- Qab — Older alluvium; bolson fill

TERTIARY

- Td — Datil Formation
- Tb — Baca Formation

CRETACEOUS

- Kmv — Mesaverde Group
- Kmu — Mancos Shale,
  - Kmu — D-Cross Tongue
  - Kth — Tres Hermanos Sandstone Member
  - Kml — lower tongue
- Kd — Dakota Sandstone

TRIASSIC

- Tkd — Dockum Formation

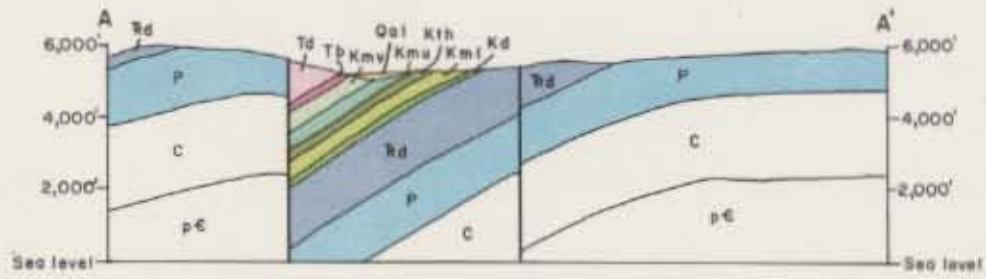
PERMIAN

- P — Permian undifferentiated

- 23 — strike and dip of bedding
- contact, dashed where approximate
- fault, dashed where approximate, dotted where concealed
- mine or prospect

0 1 2 3 mi

contour interval: 100 ft



Geology of Jornada del Muerto coal field, Socorro County, New Mexico

Geology by D. E. Tabet, 1976

10d

Appendices

APPENDIX 1-MEASURED STRATIGRAPHIC SECTIONS

Jornada del Muerto section 1—Bustos Well 7½-minute quadrangle, NE¼ sec. 17, T. 3 S., R. 3 E., Socorro County, New Mexico; measured May 27, 1978, by D. E. Tabet, using a Brunton compass and a Jacob staff. Section covers interval from the base of the Dakota Sandstone up to base of the Tres Hermanos Sandstone Member of the Mancos Shale.

Unit	Lithology	Thickness ft	Thickness inches
	Top of measured section		
	Lower tongue of Mancos Shale (total measured thickness)	680	10
	Lower tongue of Mancos Shale		
28	Shale, silty, medium-light-gray (N6); weathers to grayish orange (10YR 7/4)	14	8
27	Covered interval	194	0
26	Shale, silty, medium-light-gray (N6); and two beds of medium-light-gray (N6) biomicrite 6 inches and 4 inches thick: all weather to grayish orange (10YR 7/4); limestone beds contain Inoceramus sp. fragments and shark teeth	2	0
25	Shale, silty, medium-light-gray (N6); weathers to light gray (N7) or grayish orange (10YR 7/4)	53	8
24	Limestone, micrite, fossiliferous, light-gray (N7); weathers to very pale orange (10YR 8/2): contains *Pycnondonte newberryi* (Stanton), *Sciponoceras gracile* (Shumard), and Hemiaster jacksoni Maury	1	0
23	Shale, silty, light-gray (N7) to medium-light-gray (N6); weathers to light gray (N7) or medium light gray (N6)	42	0
22	Shale, silty, bentonite (?), very light gray (N8) to white (N9)	2	0
21	Shale, silty, medium-light-gray (N6) to light-gray (N7)	60	4
20	Limestone, micrite, medium-light-gray (N6); weathers to light gray (N7)	0	3
19	Shale, silty, light-gray (N7); weathers to light gray (N7) or grayish orange (10YR 7/4)	15	0
18	Shale, sandy, silty, light-gray (N7); weathers to light gray (N7)	12	0
17	Limestone, calcarenite, medium-light-gray (N6); weathers to light gray (N7)	0	5
16	Shale, with silty beds, light-gray (N7); weathers to light gray (N7) or grayish orange (12YR 7/4): fault boundary with unit 15	102	0
15	Sandstone, very fine quartz sand, mainly quartz and calcite with minor glauconite and calcite cement	12	4
14	Siltstone with very fine quartz sand, light-gray (N7); weathers to grayish orange (10YR 7/4)	3	0
13	Limestone, calcarenite, fine-grained, medium-light-gray (N6); weathers to grayish orange (10YR 7/4)	0	2
12	Shale, silty, light-gray (N7); weathers to grayish orange (10YR 7/4) or light gray (N7)	15	8
11	Sandstone, very fine grained quartz; well-sorted, light-gray (N7)	0	4
10	Shale, silty, light-gray (N7) to medium-gray (N5); weathers to grayish orange (10YR 7/4) or light gray (N7): interstratified with several thin beds (4 inches) of white (N9) bentonitic(?) clay	21	6
9	Sandstone, silty, calcareous, thin-bedded, composed of very fine grained quartz and calcite with calcite cement; subrounded grains, fair sorting: color on fresh surface medium-light-gray (N6) to light-gray (N7); weathers to grayish orange (10YR 7/4)	5	6
8	Covered interval	8	10
7	Shale, silty, light-gray (N7); weathers to pale yellowish orange (10YR 8/6): contains thin beds of white (N9) bentonitic(?) clay	10	0
6	Sandstone, very fine grained quartz with silt and clay; poorly sorted; sand grains subangular to subrounded: rock has medium laminae (¼ inch to ½ inch) and is light gray (N7); weathers to grayish orange (10YR 7/4)	9	2
5	Covered interval from top of Dakota Sandstone	95	0
	Dakota Sandstone (total measured thickness)	74	7
4	Sandstone, well-sorted, very rounded to subrounded grains of quartz; color on fresh surface light-brownish-gray (5YR 6/1); weathered surface dark-yellowish-orange (10YR 6/6) to moderate-brown (5YR 3/4): bedding is thin, regular in thickness laterally, but varies in thickness for vertically adjacent beds; beds vary from poorly cemented to well cemented with calcite; staining with limonite and manganese is common; internally the beds have medium ripple lamination; horizontal burrows present	5	0
3	Siltstone, with very fine quartz sand; fair to well-sorted grains; thin subrounded bedding; color on weathered surface varies from grayish red purple (5RP 4/2) to medium or light gray (N6–N7)	12	11
2	Sandstone, composed of fine, well-sorted, subrounded to rounded quartz grains; bedding uneven, ranging from thin to medium thickness; individual beds vary in thickness laterally: beds contain medium to thick cross-laminations with tangential lower surfaces; cross-laminae occur in high-angle, wedge-shaped sets with an E-W strike and a dip to the SW.; impression of woody plant material occurs near top of this interval	54	10
1	Shale, silty, light-gray color (N7) on both fresh and weathered surfaces	1	10
	Base of Dakota Sandstone		

Jornada del Muerto section 2—Bustos Well 7½-minute quadrangle, sec. 5, T. 3 S., R. 3 E., Socorro County, New Mexico, measured September 15, 1978, by S. Hook, G. Massingill, B. Robinson, and D. Tabet using a Jacob staff and Abney level. Section covers interval from base of Tres Hermanos Sandstone Member to base of Mesaverde Group. All colors from fresh surface unless otherwise indicated.

Unit	Lithology	Thickness ft	Thickness inches
	Top of measured section		
	Mesaverde Group (total measured thickness, incomplete)	19	0
37	Sandstone, fine-grained, moderately sorted, very calcareous, subangular quartz with minor chert and opaques (10YR 8/2 to 10YR 7/4): medium-bedded with medium-parallel planar lamination; basal contact sharp undulating or irregular surface	19	0
	D-Cross Tongue of the Mancos Shale (total measured thickness)	360	9

36	Shale (5Y 6/2), noncalcareous, fissile	15	0
35	Limestone, micritic concretions (N5–fresh, 5Y 8/4–weathered) USGS Mesozoic locality D10571: *Lopha sannionis* White	1	0
34	Shale (N6), noncalcareous, fissile	20	6
33	Limestone (5Y 7/2), calcarenite, silty, thinly laminated, burrowed bed with gradational top and base	0	6
32	Shale (5YR 6/1), silty, fissile	15	0
31	Shale (5Y 5/1), noncalcareous, fissile	18	0
30	Shale (5Y 5/1), fissile, contains many oblate spheroidal limey concretions 1–2 ft thick and 3–5 ft long (5Y 5/1)	47	0
29	Shale (5Y 5/1), noncalcareous, fissile; contains thin 1–2 inch siltstone beds at 20 ft, 30 ft, and 34 ft above base of unit; siltstones very calcareous and thinly laminated (5Y 6/2)	44	10
28	Limestone (10YR 7/4), micritic	0	2
27	Shale (5Y 5/1), fissile, contains three ½-inch-thick silty, calcarenite beds (5Y 7/2); calcarenite beds burrowed; occur at 128 ft, 130 ft, and 132 ft above base of the unit	137	0
26	Limestone concretions forming almost complete bed USGS Mesozoic locality D10604: *Baculites yokoyami* Tokunaga and Shimizu *Prionocyclus* sp.	0	6
25	Shale (5Y 5/1), noncalcareous, fissile	9	0
24	Limestone, concretions, similar to unit 20	0	6
23	Shale (5Y 5/1), noncalcareous, fissile	6	4
22	Limestone, concretions, similar to unit 20	0	8
21	Shale (5Y 5/1), noncalcareous, fissile	2	6
20	Limestone, oblate spheroidal concretions up to 2 ft long	0	6
19	Shale (5Y 5/1), noncalcareous, fissile, contains gypsum crystals	23	0
18	Limestone (10YR 7/2), silty, calcarenite, fossiliferous USGS Mesozoic locality D10466: *Scaphites whitfieldi* Cobban *Prionocyclus novimexicanus* (Marcou) *Inoceramus perplexus* Whitfield	0	3
17	Shale (5Y 6/1), noncalcareous, non-silty, fissile	9	8
16	Limestone (10YR 7/4), silty, calcarenite, very fossiliferous USGS Mesozoic locality D10255: *Scaphites whitfieldi* Cobban *Prionocyclus novimexicanus* (Marcou) *Inoceramus perplexus* Whitfield	0	4
15	Shale, mostly covered	8	6
	Tres Hermanos Sandstone Member (total thickness)	244	4
14	Sandstone, noncalcareous, very fine grained at base to fine-grained at top; subrounded moderately sorted to well-sorted quartz grains: weathered color ranges from 5Y 8/1 at base to 10YR 8/4 to 7YR 8/2 and finally 10YR 7/6 at top; upper surface of unit is rippled; unit burrowed throughout, more so toward top; bedding appears massive	41	0
13	Shale, fissile, silty and less fissile near top, contains gypsum crystals; color ranges from medium gray (N5) in lower portion to light gray (N7) and finally to 10YR 7/4 in uppermost 3 ft; septarian limestone concretions throughout unit; has gradational upper contact USGS Mesozoic locality D10603: *Lopha bellaplicata* (Shumard) *Ostrea* sp.	35	0
12	Shale with sandstone beds 4 inches to 1 ft thick interbedded and composing up to 50 percent of interval; poorly exposed interval; sandstone beds moderately calcareous (5YR 7/4), fine-grained with angular to subangular quartz	15	0
11	Sandstone, mostly 10YR 8/2, with large concretions (5Y 5/4); both sands moderately calcareous and contain petrified wood or wood impressions; thick-bedded with cross-lamination at base and planar parallel lamination at top; grain size ranges from medium to fine, with fining upward; upper part of unit less well exposed	7	6
10	Shale (N6), fissile, noncalcareous, silty; has gradational contact with unit 9 below and sharp contact with unit 11 above	4	0
9	Sandstone, light-gray (N8) when fresh, weathers to orange yellow; composed of subangular, moderately to poorly sorted grains of quartz, whitish-weathering feldspar with minor chert, and opaque minerals: unit thick-bedded with planar and signoidal, low- to high-angle cross-lamination; contains sparse petrified wood and large dark-brown calcareous concretions up to 4 ft thick and 20 ft long near top; basal contact of unit sharp but irregular surface	11	0
8	Siltstone, sandy, friable, poorly sorted, interbedded with thin fine-grained sandstones and some thin non-fissile, very calcareous mudstone	20	0
7	Sandstone (10YR 7/4), noncalcareous with subrounded to subangular, fine-grained quartz; medium-bedded with very low angle planar cross-lamination or mottled and structureless showing some knobby walled ophiomorpha	5	0
6	Shale (5YR 6/2), silty, micaceous, fissile, very slightly calcareous to noncalcareous	5	0
5	Sandstone (10YR 7/4), very fine grained, silty, slightly calcareous; moderately burrowed	0	10
4	Shale, very poorly exposed especially near top and bottom of unit	12	0
3	Sandstone (10YR 7/4), slightly calcareous with moderately sorted, fine- to medium-grained quartz and some weathered feldspar, medium-bedded with low- to high-angle planar cross-lamination; unit better sorted at top	4	0
2	Shale (N6), fissile, with a few thin beds of sandstone; interval poorly exposed	5	0
1	Sandstone (10YR 6/6 to 10YR 8/2), moderately to slightly calcareous with moderately well sorted, fine to medium, subangular grains of quartz and minor feldspar: medium- to thick-bedded; beds are structureless and mottled or show thick planar parallel or ripple lamination near the base of the unit; near the top low- to high-angle cross-lamination is more common: uppermost bed of the unit is very clean quartz sand with quartz overgrowths; upper surface of this bed has cuspate ripples: some beds of this unit contain clay clasts; two horizons of large brown-weathering (10YR 6/4), calcareous, fossiliferous concretions occur at 23 ft and 50 ft from the base of unit; lower concretions 2 ft thick, upper ones 1.5 ft thick USGS Mesozoic locality D10254 (from concretions): *Collignoniceras woollgari woollgari* (Mantell)	79	0

Note: A specimen of *Mammites depressus* Powell (USGS Mesozoic locality D10377) occurred as float 110 ft below the base of the Tres Hermanos Member.

APPENDIX 2—DRILL-HOLE DATA

Paul Stackhouse Well No. 1 SW¼SW¼NW¼ sec. 1, T. 5 S., R. 2 E.
T.D. 1,037 ft Drilled 5/18/23 to 10/10/23

Lithology	Bottom (ft., in.)		Thickness (ft., in.)		Comments
Shale	255	0	255	0	
Sandstone	275	0	20	0	
Shale	295	0	20	0	
Shale and sandstone beds	337	0	42	0	
Sandstone	355	0	18	0	
Shale	415	0	60	0	
Sandstone	420	0	5	0	
Shale	455	0	35	0	
Sandstone	465	0	10	0	
Shale	505	0	40	0	
Sandstone	520	0	15	0	
Shale and thin coal beds	600	0	80	0	
Shale and sandstone	775	0	175	0	
Shale and thin coal bed	795	0	20	0	
Sandstone	800	0	5	0	
Shale and two thin coals	830	0	30	0	
Sandstone	836	0	6	0	
Shale and sandstone	870	0	34	0	
Sandstone and 6 inches coal	890	0	20	0	
Shale	943	0	53	0	
Coal	944	6	1	6	
Shale and sandstone	1,000	0	55	6	
Shale and sandstone; 4 inches coal	1,013	0	13	0	
Coal	1,018	0	5	0	
Shale	1,037	0	19	0	

Robert E. Law Well No. 1 SE¼SE¼NE¼ sec. 4, T. 4 S., R. 3 E.
T.D. 374 ft Drilled 7/23/27 to 8/13/27

Lithology	Bottom (ft., in.)		Thickness (ft., in.)		Comments
Clay, hard	11	0	11	0	
Clay, hard, contains gravel	18	0	7	0	
Sandstone	21	0	3	0	
Sandstone, hard, broken	31	0	10	0	
Shale	35	0	4	0	
Shale, blue	36	0	1	0	
Shale	55	0	19	0	
Shale, sandy	75	0	20	0	
Sandstone	78	0	3	0	
Shale, blue	80	0	2	0	
Shale	86	2	6	2	
Coal	86	6	0	4	
Shale	89	4	2	10	
Coal	89	7	0	3	
Shale	91	0	1	5	
Shale, sandy	99	0	8	0	
Shale, sticky	101	0	2	0	
Shale, sandy	105	0	4	0	
Sandstone	108	0	3	0	
Shale, sandy	112	0	4	0	
Shale, blue	114	0	2	0	
Shale, sandy	117	0	3	0	
Shale	126	0	9	0	
Sandstone	134	0	8	0	
Shale, blue	145	0	11	0	
Shale	153	0	8	0	
Shale, blue	174	0	21	0	
Shale	198	0	24	0	
Shale, blue	202	0	4	0	
Sandstone	212	0	10	0	
Shale, blue	224	0	12	0	
Shale	229	0	5	0	
Coal	230	3	1	3	
Shale, sandy	242	0	11	9	
Shale	246	0	4	0	
Coal	247	4	1	4	
Shale	253	8	6	4	
Limestone	255	8	2	0	
Shale	261	0	5	4	
Shale, blue	265	0	4	0	
Shale, sandy	267	0	2	0	
Shale, blue	271	0	4	0	
Coal	271	4	1	4	
Shale, blue	281	0	9	8	
Shale	293	0	12	0	
Shale, sandy	298	0	5	0	
Shale	300	0	2	0	
Shale, blue	301	0	1	0	
Sandstone, white	305	8	4	8	
Shale, blue	306	4	0	8	
Coal	307	5	1	1	correct elevation for main coal
Shale, sandy	316	0	8	7	
Shale	333	7	17	7	
Coal (?)	333	11	0	4	no core
Shale	336	1	2	2	
Bone coal	337	4	1	3	
Shale, sandy	364	0	26	8	
Shale	367	1	3	1	
Limestone	367	7	0	6	
Shale	371	0	3	5	
Bone coal	371	3	0	3	
Shale	374	0	2	9	

Robert E. Law Well No. 2 SW¼NE¼SE¼ sec. 4, T. 4 S., R. 3 E.
T.D. 674.5 ft Drilled 8/17/27 to 9/26/27

Lithology	Bottom (ft., in.)		Thickness (ft., in.)		Comments
Gravel and clay	3	6	3	6	
Sandstone	12	0	8	6	
Shale	17	0	5	0	
Sandstone	33	0	16	0	
Shale	50	0	17	0	
Sandstone	52	6	2	6	
Limestone	53	0	0	6	
Limestone, sandy	58	0	5	0	
Sandstone	70	0	12	0	
Shale, rotten, clayey	94	0	24	0	
Shale, sandy	96	0	2	0	
Shale	102	0	6	0	
Sandstone	105	0	3	0	
Shale, blue	108	0	3	0	
Sandstone	112	0	4	0	
Shale	115	0	3	0	
Sandstone	125	0	10	0	
Shale, blue	129	0	4	0	
Sandstone	140	0	11	0	
Shale	150	0	10	0	
Shale, blue	173	0	23	0	
Sandstone	176	0	3	0	
Shale, blue	184	0	8	0	
Sandstone	190	0	6	0	
Shale	205	0	15	0	
Shale, blue	215	0	10	0	
Shale, sandy	224	0	9	0	
Sandstone	241	0	17	0	
Shale, blue	246	0	5	0	
Sandstone	248	0	2	0	
Shale, sandy	256	0	8	0	
Shale	258	0	2	0	
Shale, blue	268	0	10	0	
Shale	283	0	15	0	
Shale, blue	295	0	12	0	
Shale, sandy	297	0	2	0	
Limestone, sandy	298	0	1	0	
Sandstone	304	0	6	0	
Shale, sandy	309	0	5	0	
Shale	318	10	9	10	
Bone coal	319	6	0	8	
Shale	321	0	1	6	
Sandstone	345	0	24	0	
Shale, blue	348	0	3	0	
Shale	350	0	2	0	
Shale, sandy	357	0	7	0	
Shale, blue	375	0	18	0	
Shale	378	0	3	0	
Shale, sandy	387	0	9	0	
Limestone	388	6	1	6	
Sandstone	397	0	8	6	
Shale, blue	405	0	8	0	
Shale, sandy	415	0	10	0	
Shale	423	0	8	0	
Shale, blue	429	0	6	0	
Sandstone	432	0	3	0	
Shale, sandy	447	0	15	0	
Sandstone	457	0	10	0	
Shale, blue	461	0	4	0	
Coal	461	6	0	6	
Shale, blue	467	0	5	6	
Shale	469	0	2	0	
Shale, sandy	471	2	2	2	
Coal	471	10	0	8	
Shale	473	0	1	2	
Shale, blue	480	0	7	0	
Coal	480	5	0	5	
Shale, blue	482	0	1	7	
Sandstone, broken	484	0	2	0	
Shale, sandy	487	0	3	0	
Shale, sandy	487	0	3	0	
Sandstone	490	0	3	0	

Shale, blue	498	0	8	0
Sandstone	499	0	1	0
Shale, sandy	504	7	5	7
Bone coal	504	11	0	4
Shale, blue	515	0	10	1
Sandstone	520	0	5	0
Shale, blue	523	0	3	0
Shale	530	0	7	0
Sandstone	538	0	8	0
Shale	552	6	14	6
Sandstone	553	0	0	6
Shale, blue, sticky	560	0	7	0
Shale, sandy	564	0	4	0
Sandstone	570	0	6	0
Shale	573	6	3	6
Coal	574	0	0	6
Shale	575	0	1	0
Shale, blue	581	2	6	2
Bone coal	581	10	0	8
Shale, blue	587	0	5	2
Sandstone	591	0	4	0
Shale	598	0	7	0
Sandstone	600	0	2	0
Shale	605	0	5	0
Shale, blue	607	0	2	0
Sandstone	611	0	4	0
Shale, sandy	616	0	5	0
Shale, blue	619	0	3	0
Coal	619	4	0	4
Shale, blue	628	0	8	8
Coal	628	7	0	7
Shale, blue	642	6	13	11
Coal	642	10	0	4
Shale, blue	644	2	1	4
Coal	647	6	3	4
Sandstone, blue	673	6	26	0
Shale, blue	674	6	1	0

Robert E. Law Well No. 3 SW¼SW¼SE¼ sec. 4, T. 4 S., R. 3 E.
T.D. 987 ft Drilled 10/1/27 to 11/21/27

Lithology	Bottom (ft., in.)		Thickness (ft., in.)		Comments
Clay and gravel	4	0	4	0	
Sandstone	53	0	49	0	
Shale	68	0	15	0	
Bone coal	68	5	0	5	
Shale	81	0	12	7	
Sandstone	111	0	30	0	
Shale, blue	121	0	10	0	
Sandstone	139	0	18	0	
Coal	139	4	0	4	
Shale, sandy	146	0	6	8	
Shale	156	0	10	0	
Shale, blue	186	0	30	0	
Shale	194	0	8	0	
Sandstone	196	0	2	0	
Shale, sandy	218	0	22	0	
Sandstone	219	0	1	0	
Shale, blue	222	0	3	0	
Sandstone	224	0	2	0	
Shale, blue	235	0	11	0	
Shale, sandy	248	0	13	0	
Shale	256	8	8	8	
Bone coal	258	0	1	4	
Shale	272	0	14	0	
Shale, blue	278	0	6	0	
Sandstone	288	0	10	0	
Shale, blue	292	0	4	0	
Sandstone	295	0	3	0	
Shale, blue	296	0	1	0	
Sandstone	332	0	36	0	
Shale, blue	333	0	1	0	
Sandstone	340	0	7	0	
Shale, blue	363	0	23	0	
Sandstone	384	0	21	0	
Shale, blue	396	0	12	0	
Sandstone	419	0	23	0	
Shale	430	0	11	0	
Sandstone	438	0	8	0	
Shale, blue	442	8	4	8	
Coal	443	0	0	4	
Shale, blue	448	0	5	0	
Sandstone	456	0	8	0	
Shale, sandy	476	0	20	0	
Shale, blue	487	0	11	0	
Shale, sandy	513	0	26	0	
Shale, blue	514	0	1	0	
Shale, sandy	520	0	6	0	
Bone coal	521	2	1	2	
Shale, blue	528	0	6	10	
Shale, sandy	538	0	10	0	
Shale, blue	548	0	10	0	
Sandstone	558	0	10	0	
Shale, blue	559	0	1	0	
Coal	559	4	0	4	
Shale, blue	577	0	17	8	
Sandstone	583	0	6	0	
Shale, blue, sticky	598	0	15	0	
Bony coal	599	0	1	0	
Sandstone	600	0	1	0	
Shale, blue	617	0	17	0	
Coal	618	6	1	6	
Shale, blue	642	0	23	6	
Shale, sandy	645	0	3	0	
Shale, blue	647	0	2	0	
Sandstone	674	0	27	0	
Shale, blue	676	0	2	0	
Shale, clay	686	0	10	0	
Shale, blue	692	0	6	0	
Shale, sandy	698	0	6	0	
Shale, blue	707	0	9	0	
Shale, sandy	710	0	3	0	
Shale, blue	721	0	11	0	
Sandstone	725	0	4	0	
Shale, clay	728	0	3	0	
Shale, blue	729	0	1	0	
Sandstone	741	0	12	0	
Shale, sandy	743	0	2	0	
Shale, blue	749	0	6	0	
Sandstone	756	0	7	0	
Coal	757	3	1	3	
Shale, blue	763	0	5	9	
Sandstone	765	0	2	0	
Shale, blue	766	6	1	6	
Sandstone	769	0	2	6	
Shale, sandy	771	0	2	0	
Shale, blue	776	0	5	0	
Shale	779	0	3	0	
Shale, blue	792	0	13	0	
Sandstone	795	6	3	6	
Shale, sandy	796	0	0	6	
Shale, blue	806	8	10	8	
Coal	807	0	0	4	
Shale, blue	816	0	9	0	
Sandstone	819	0	3	0	
Shale, blue	821	0	2	0	
Sandstone	825	0	4	0	
Shale, blue	826	0	1	0	
Sandstone	828	0	2	0	
Shale, blue	840	0	12	0	
Shale, sandy	846	0	6	0	
Shale, blue	864	0	18	0	
Sandstone	882	0	18	0	
Shale, blue	890	0	8	0	
Sandstone	892	7	2	7	
Coal	893	0	0	5	
Shale, blue	898	8	5	8	
Coal	899	0	0	4	
Sandstone	900	3	1	3	
Coal	901	0	0	9	
Shale, blue	906	0	5	0	
Sandstone	908	0	2	0	
Shale, sandy	912	0	4	0	
Shale, blue	916	0	4	0	
Sandstone	923	0	7	0	
Shale, sandy	924	0	1	0	
Shale, blue	936	0	12	0	
Shale, sandy	937	9	1	9	
Coal	938	8	0	11	
Shale, blue	942	8	4	0	
Shale, sandy	959	9	17	1	
Coal	960	5	0	8	
Shale, blue?	968	7	8	2	3 ft 5 inches of core was lost, thought to be coal ground away in drilling
Coal	969	0	0	5	
Sandstone	987	0	18	0	No water came to surface while drilling last 100 ft

Robert E. Law Well No. 4 NW¼SW¼SW¼ sec. 3, T. 4 S., R. 3 E.
T.D. 689 ft Drilled 11/29/27 to 12/28/27

Lithology	Bottom (ft., in.)		Thickness (ft., in.)		Comments
Gravel and boulders	15	0	15	0	
Clay and sand	24	0	9	0	
Shale, sandy	36	0	12	0	
Sandstone	52	0	16	0	
Shale	61	0	9	0	
Clay	71	0	10	0	
Sandstone	81	0	10	0	
Clay and shale	86	0	5	0	
Sandstone	90	0	4	0	
Shale, blue	115	0	25	0	
Sandstone	131	6	16	6	
Coal	132	0	0	6	
Shale, blue	153	7	21	7	
Bone coal	154	0	0	5	
Shale, blue	163	0	9	0	

Sandstone	169	0	6	0	
Shale, blue	186	0	17	0	
Sandstone	197	0	11	0	
Shale, sandy	202	5	5	5	
Coal	203	0	0	7	
Shale, blue	214	8	11	8	
Coal	215	0	0	4	
Sandstone	220	0	5	0	
Shale, blue	221	0	1	0	
Bony coal	221	4	0	4	
Shale, blue	234	4	13	0	
Coal	235	0	0	8	
Shale, blue	239	0	4	0	
Coal	239	5	0	5	
Shale, blue	240	0	0	7	
Shale, sandy	259	0	19	0	
Sandstone	260	0	1	0	
Shale, sandy	272	0	12	0	
Shale, blue	280	0	8	0	
Shale, sandy	298	9	18	9	
Bone coal	299	0	0	3	
Shale, sandy	300	0	1	0	
Shale, blue	302	6	2	6	
Coal	303	0	0	6	
Shale, sandy	308	0	5	0	
Limestone	308	6	0	6	
Shale, blue	316	7	8	1	
Coal	317	10	1	3	
Shale, blue	319	0	1	2	
Shale, sandy	329	0	10	0	
Shale, blue	342	9	13	9	
Coal	343	1	0	4	
Shale, blue	361	0	17	11	
Shale, sandy	363	0	2	0	
Sandstone	394	0	31	0	
Shale, sandy	396	0	2	0	
Coal	397	0	1	0	
Shale, blue	398	6	1	6	
Coal	399	0	0	6	
Shale, blue	401	0	2	0	
Sandstone	404	0	3	0	
Shale, blue	415	0	11	0	
Sandstone	419	0	4	0	
Shale, sandy	430	0	11	0	
Sandstone	439	0	9	0	
Shale, sandy	450	0	11	0	
Shale, blue	453	9	3	9	
Coal	454	0	0	3	
Shale, sandy	460	0	6	0	
Shale, blue	460	9	0	9	
Coal	461	7	0	10	
Shale, sandy	462	7	1	0	
Sandstone	466	7	4	0	
Shale, sandy	470	0	3	5	
Shale, blue	478	4	8	4	
Coal	479	0	0	8	
Shale, blue	490	0	11	0	
Shale, sandy	498	0	8	0	
Shale, blue	510	3	12	3	
Coal	510	8	0	5	
Shale, blue	526	0	15	4	
Sandstone	529	0	3	0	
Shale, sandy	531	0	2	0	
Shale, blue	533	2	2	2	
Coal	533	7	0	5	
Shale, blue	535	0	1	5	
Coal	535	2	0	2	
Shale, blue	536	6	1	4	
Coal	536	11	0	5	
Shale, blue	538	7	1	8	
Coal	540	3	1	8	
Shale, blue	542	0	1	9	
Sandstone	544	0	2	0	
Shale, sandy	548	0	4	0	
Shale, blue	554	0	6	0	
Sandstone	561	0	7	0	
Shale, blue	567	0	6	0	
Shale, sandy	571	0	4	0	
Sandstone	576	7	5	7	
Coal	577	0	0	5	
Shale, blue	581	0	4	0	
Sandstone	596	9	15	9	
Coal	597	1	0	4	
Shale, blue	601	7	4	6	
Coal	602	9	1	2	
Shale, blue	606	0	3	3	
Coal	606	6	0	6	
Shale, blue	615	8	9	2	
Coal	616	0	0	4	
Shale, blue	617	4	1	4	
Coal	619	0	1	8	Carthage seam
Sandstone	650	0	31	0	
Shale, blue	658	0	8	0	
Sandstone	661	0	3	0	
Shale, blue	662	11	1	11	
Coal	663	4	0	5	
Shale, blue	664	4	1	0	
Sandstone	684	0	19	8	
Shale, blue	687	0	3	0	
Shale, sandy	689	0	2	0	

E. C. Anderson — Well No. 1 SW¼SW¼NW¼ sec. 3, T. 4 S., R. 3 E.
T.D. 122 ft — Drilled 1960

Lithology	Bottom (ft., in.)	Thickness (ft., in.)	Comments
No coal reported	122 0	122 0	Hit old workings

Carl E. Dotson — Well No. 2A NW¼SW¼NE¼ sec. 4, T. 4 S., R. 3 E.
T.D. 243 ft — Drilled 1960

Lithology	Bottom (ft., in.)	Thickness (ft., in.)	Comments
No coal reported	243 0	243 0	

Carl E. Dotson — Well No. 2B NW¼NE¼NE¼ sec. 4, T. 4 S., R. 3 E.
T.D. 175 ft — Drilled 1960

Lithology	Bottom (ft., in.)	Thickness (ft., in.)	Comments
No coal reported	175 0	175 0	

Carl E. Dotson — Well No. 3 NW¼NE¼NW¼ sec. 4, T. 4 S., R. 3 E.
T.D. 302 ft — Drilled 1960

Lithology	Bottom (ft., in.)	Thickness (ft., in.)	Comments
No coal reported	302 0	302 0	

Carl E. Dotson — Well No. 4 NW¼NW¼NW¼ sec. 33, T. 3 S., R. 3 E.
T.D. 185 ft — Drilled 1960

Lithology	Bottom (ft., in.)	Thickness (ft., in.)	Comments
No coal reported	119 0	119 0	
Coal, approximate thickness	123 0	4 0	
No coal reported	185 0	62 0	

Carl E. Dotson — Well No. 5 SW¼SE¼SE¼ sec. 28, T. 3 S., R. 3 E.
T.D. 200 ft — Drilled 1960

Lithology	Bottom (ft., in.)	Thickness (ft., in.)	Comments
No coal reported	200 0	200 0	

Carl E. Dotson — Well. No. 6 NE¼SE¼SE¼ sec. 4, T. 4 S., R. 3 E.
T.D. 170 ft — Drilled 1960

Lithology	Bottom (ft., in.)	Thickness (ft., in.)	Comments
Three seams of coal, 3 inches, 2 inches, 18 inches, but no depth given	170 0	170 0	

Carl E. Dotson — Well No. 7 SE¼SE¼SW¼ sec. 4, T. 4 S., R. 3 E.
T.D. 320 ft — Drilled 1960

Lithology	Bottom (ft., in.)	Thickness (ft., in.)	Comments
No coal reported	320 0	320 0	

E.C. Anderson — Well No. 8 NE¼NW¼NE¼ sec. 10, T. 4 S., R. 3 E.
T.D. 205 ft — Drilled 1960

Lithology	Bottom (ft., in.)	Thickness (ft., in.)	Comments
No coal reported	205 0	205 0	

E.C. Anderson — Well No. 10 SE¼SE¼SE¼ sec. 7, T. 4 S., R. 3 E. T.D. 165 ft Drilled 1960

Lithology	Bottom (ft., in.)	Thickness (ft., in.)	Comments
Igneous rocks, no coal	165 0	165 0	

E.C. Anderson — Well No. 9 SW¼SW¼SW¼ sec. 7, T. 4 S., R. 3 E. T.D. 140 ft Drilled 1960

Lithology	Bottom (ft., in.)	Thickness (ft., in.)	Comments
Igneous rocks, no coal	140 0	140 0	

Carl E. Dotson — Well No. 12 SW¼NE¼NE¼ sec. 29, T. 3 S., R. 3 E. T.D. 245 ft Drilled 1960

Lithology	Bottom (ft., in.)	Thickness (ft., in.)	Comments
No coal reported	139 0	139 0	
Coal	146 0	7 0	Thickness estimated
No coal reported	245 0	99 0	

E.C. Anderson — Well No. 13 SW¼SW¼SW¼ sec. 32, T. 4 S., R. 3 E. T.D. 340 ft Drilled 1960

Lithology	Bottom (ft., in.)	Thickness (ft., in.)	Comments
No coal reported	340 0	340 0	

Carl E. Dotson — Well No. 14 NE¼NE¼NE¼ sec. 29, T. 3 S., R. 3 E. T.D. 200 ft Drilled 1960

Lithology	Bottom (ft., in.)	Thickness (ft., in.)	Comments
No coal reported	200 0	200 0	

E.C. Anderson — Well. No. 15 SW¼SE¼SE¼ sec. 19, T. 4 S., R. 3 E. T.D. 200 ft Drilled 1960

Lithology	Bottom (ft., in.)	Thickness (ft., in.)	Comments
No coal reported	200 0	200 0	

Carl E. Dotson — Well No. 16 NE¼NE¼NW¼ sec. 28, T. 3 S., R. 3 E. T.D. 200 ft Drilled 1960

Lithology	Bottom (ft., in.)	Thickness (ft., in.)	Comments
No coal reported	200 0	200 0	

E.C. Anderson — Well No. 17 NW¼NW¼NW¼ sec. 33, T. 4 S., R. 3 E. T.D. 200 ft Drilled 1960

Lithology	Bottom (ft., in.)	Thickness (ft., in.)	Comments
No coal reported	200 0	200 0	

Carl E. Dotson — Well No. 19 SE¼SE¼SE¼ sec. 17, T. 4 S., R. 3 E. T.D. 200 ft Drilled 1960

Lithology	Bottom (ft., in.)	Thickness (ft., in.)	Comments
No coal reported	200 0	200 0	

E.C. Anderson — Well No. 20 corner secs. 10, 11, 14, 15, T. 4 S., R. 3 E. T.D. 155 ft Drilled 1960

Lithology	Bottom (ft., in.)	Thickness (ft., in.)	Comments
No coal reported	155 0	155 0	

Great Nat'l. Corp. — Well No. 1 NE¼NW¼NW¼ sec. 33, T. 3 S., R. 3 E. T.D. 60 ft Drilled October 1975

Lithology	Bottom (ft., in.)	Thickness (ft., in.)	Comments
Alluvium	20 0	20 0	
Not reported	44 0	24 0	
Coal	45 6	1 6	
Not reported	60 0	14 6	

Great Nat'l. Corp. — Well No. 2 NW¼NE¼NW¼ sec. 33, T. 3 S., R. 3 E. T. D. 75 ft Drilled October 1975

Lithology	Bottom (ft., in.)	Thickness (ft., in.)	Comments
Alluvium	21 0	21 0	
Not reported	64 6	43 0	
Coal, thin streaks only	65 6	1 0	
Not reported	75 0	9 6	

Great Nat'l. Corp. — Well No. 4 NE¼NE¼NE¼ sec. 32, T. 3 S., R. 3 E. T.D. 135 ft Drilled October 1975

Lithology	Bottom (ft., in.)	Thickness (ft., in.)	Comments
Alluvium	1 0	1 0	
Shale, reddish-brown, silty	15 0	14 0	Cuttings
Siltstone, orange, well sorted	30 0	15 0	Cuttings
Sandstone, fine-grained, grayish-orange	45 0	15 0	Cuttings
Sandstone, fine-medium-grained, gray, dirty calcareous quartz sand	60 0	15 0	Cuttings
Shale, reddish-brown to gray interbedded with medium-grained sandstone	90 0	30 0	Cuttings
Shale, reddish-brown, sandy and silty	105 0	15 0	Cuttings
Siltstone, reddish-brown, sandy	120 0	15 0	Cuttings
Sandstone, reddish-brown, silty	135 0	15 0	Cuttings

Great Nat'l. Corp. — Well #58 SE¼SE¼SE¼ sec. 32, T. 3 S., R. 3 E. T.D. 105 ft Drilled October 1975

Lithology	Bottom (ft., in.)	Thickness (ft., in.)	Comments
Sand, silt and clay, with volcanic pebbles	30 0	30 0	Cuttings
Volcanic rock, gray to pink with a fragmental texture	75 0	45 0	Cuttings
Volcanic rock, gray to reddish-pink with a fragmental texture	105 0	30 0	Cuttings

New Mexico Bureau of Mines and Mineral Resources — Well No. 1 SW¼SW¼NW¼ sec. 3, T. 4 S., R. 3 E. T.D. 253 ft Drilled 3/8/76 to 5/13/76

Lithology	Bottom (ft., in.)	Thickness (ft., in.)	Comments
No core	29 5	29 5	
Shale, silty, light gray	33 1	3 8	
Sandstone, silty, gray	37 7	4 6	

Siltstone, shaley, gray	39	6	1	11	
Limestone, olive-gray	41	10	2	4	
Shale, medium-light-gray	42	0	0	2	
Sandstone, fine-grained, pinkish-gray	45	0	3	0	
No core	48	0	3	0	
Sandstone, fine-grained, pale-grayish-orange	52	0	4	0	
Siltstone, light-gray	52	4	0	4	
Concretion, iron-rich, red to orangish-yellow	52	6	0	2	
No core	54	2	1	8	
Shale, silty, gray	55	1	0	11	
Sandstone, fine-grained, shaley, grayish-green	56	1	1	0	
Shale, silty, light-gray	56	10	0	9	
Coal	58	0	1	2	
Shale, carbonaceous, dark to medium-gray	66	10	8	10	
Coal, top 2 inches shaley	69	2	2	4	
Siltstone, carbonaceous, dark- to light-gray	73	6	4	4	
Shale, carbonaceous, silty, medium-gray	79	8	6	2	
Sandstone, fine-grained, carbonaceous, dark-gray	82	0	2	4	
No core	82	4	0	4	
Sandstone, fine-grained, grayish-orange	82	8	0	4	
Siltstone, sandy and shaley, light-gray	85	2	2	6	
No core	85	10	0	8	
Sandstone, siltstone, and shale, light-gray	92	6	6	8	Interlaminated
Shale, silty, medium-gray	94	0	1	6	Poor recovery
Shale, silty, medium-gray and sandstone, fine-grained, carbonaceous, light-gray	107	0	13	0	Interbedded
No core	107	10	0	10	
Shale, silty, sandy, medium-gray	109	1	1	3	
No core	110	8	1	7	
Shale, silty, sandy, medium-gray	115	7	4	11	
No core	116	8	1	1	
Shale, silty, medium-dark-gray	117	10	1	2	
Sandstone, light-gray, fine-grained	122	0	4	2	
Shale, silty, light-gray	123	2	1	2	
Shale, medium dark-gray, silicified, hard	123	10	0	8	
No core	130	2	6	4	
Sandstone, carbonaceous, light-gray, fine-grained	131	10	1	8	
Shale, silty, dark-gray	132	0	0	2	
No core	133	2	1	2	
Sandstone, siltstone, and shale, interbedded, gray and carbonaceous	142	0	8	10	
No core	143	0	1	0	
Shale, silty, medium-gray and interbedded sandstone, fine-grained, light-gray	158	7	15	7	Lower few feet contain pelecypod shell fragments
Limestone, medium-dark-gray, silty	159	0	0	5	Fossiliferous
Shale, silty, medium-dark-gray and siltstone, medium-dark gray	162	0	3	0	Interbedded
Siltstone, medium-gray	163	5	1	5	Fossiliferous
Shale, silty, medium-gray	176	2	12	9	
Siltstone, light-gray and shale, medium-gray, silty	179	8	3	6	Interbedded
Shale, medium-gray, silty	190	11	11	3	Poor recovery
Sandstone, carbonaceous, silty, fine-grained, medium-light-gray	191	8	0	9	Contains pyrite
No core	193	0	1	4	
Siltstone, medium-gray, shaley	195	11	2	11	Contains pyrite, poor recovery
Shale, medium-dark-gray, silty	197	6	1	7	
No core	202	7	5	1	
Shale, medium-dark-gray, silty	204	2	1	7	Contains pyrite
Siltstone, medium-gray, carbonaceous	204	6	0	4	Contains pyrite
Coal, silty and shaley	205	4	0	10	
Siltstone, medium-gray, carbonaceous, shaley	207	7	2	3	
Shale, dark-gray, very carbonaceous	211	1	3	6	
No core	212	0	0	11	
Siltstone, medium-gray, carbonaceous	212	4	0	4	
Shale, medium-dark-gray, very carbonaceous	215	10	3	6	
Sandstone, light-gray, fine-grained, silty and shale, dark gray, silty, carbonaceous	222	8	6	10	Interbedded
No core	223	0	0	4	
Shale, medium-dark-gray, silty, carbonaceous	226	7	3	7	Contains some shell fragments
Shale, dark-gray, hard, silicified	226	10	0	3	
Shale, medium-dark-gray, silty, carbonaceous	227	10	1	0	Poor recovery
Limestone, medium-gray, coarsely crystalline	228	5	0	7	White calcite spar filling voids
Shale, medium-dark-gray, carbonaceous	229	6	1	1	
Sandstone, light-gray, fine-grained, shaley, carbonaceous	237	7	8	1	
Shale, medium-dark-gray, silty	243	4	5	9	Poor recovery
Sandstone, light-gray, fine-grained, shaley, carbonaceous	247	4	4	0	
Sandstone, light-gray, fine-grained, siltstone, light-gray and shale, dark-gray, carbonaceous	251	10	4	6	Thinly interbedded
Shale, medium-dark-gray, silty, carbonaceous	253	0	1	2	

Typefaces: Text in 10-pt. English times, leaded two points Subheads in 14-pt. Display heads in 24-pt.

Presswork: Miehle 38' Single Color Offset
Harris Single Color Offset

Paper: Cover on 65-1b. Beckett text Gray
Text and colored map on 60-lb. white offset

Ink: Cover—Black
Text—Black

Press run: 750