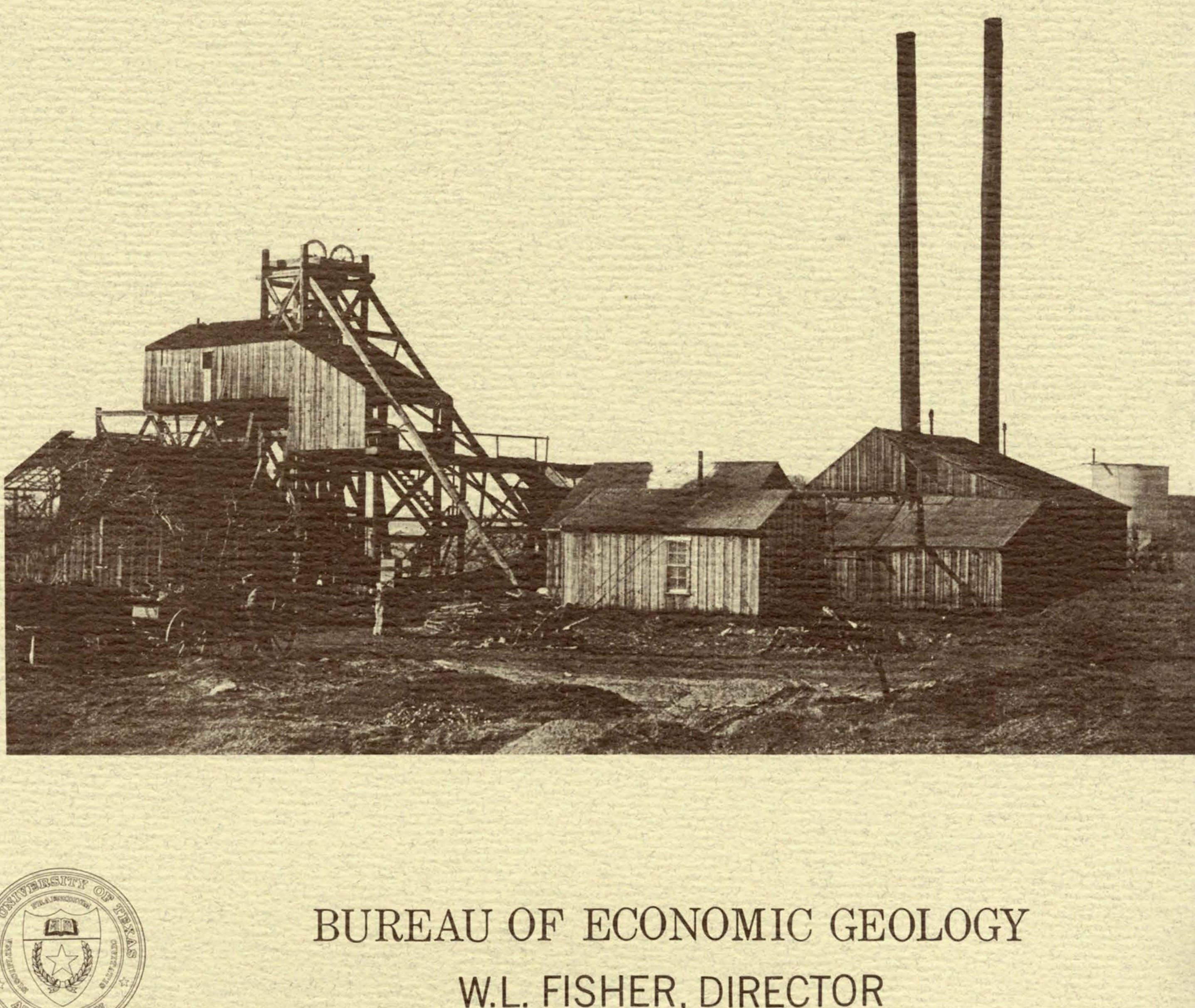
HANDBOOK 4

BITUMINOUS COAL IN TEXAS

Thomas J. Evans



BUREAU OF ECONOMIC GEOLOGY

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By

Thomas J. Evans

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Cover photograph: Belknap Coal Company, mine no. 2, Newcastle, Young County. Phillips and Worrell, 1913.

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ABSTRACT

Bituminous coal in Texas is found in six coalfields located west of Fort Worth in North-Central Texas, in the Eagle Pass and Santo Tomas regions in South Texas, and in the Eagle Spring, San Carlos, and Big Bend areas in West Texas. Because of the indicated quantity or the particular characteristics of the coals, the coalfields of North-Central Texas, Maverick County, and Webb County have greatest significance.

Texas bituminous coal occurs predominantly in thin beds (36 inches or less), under thin to thick, unconsolidated to consolidated overburden, and is generally high-volatile C bituminous coal with some subbituminous and high-volatile B bituminous coal present. Recent U. S. Geological Survey estimates of total original inferred resources of Texas bituminous coal indicate that more than 6.1 billion tons of coal is present in beds at least 14 inches thick and overlain by 0 to 3,000 feet of overburden.

Past mining development was locally extensive. Underground mines in Texas, using long-wall advancing and room-and-pillar methods, produced bituminous coal for 60 years from the 1880's into the 1940's. Coal production ceased because of successful competition from petroleum and natural gas.

Renewed interest in Texas bituminous coal is tied closely to the search for alternative energy resources as demands for energy increase and reserves of oil and gas decrease. Future development of bituminous coal in Texas depends on thorough evaluation of near-surface coal reserves to determine their quality and quantity, adequacy of potential markets and transportation arteries to support a coal industry, availability of water and other resources necessary to maintain industrial development for mine-mouth operations, as well as economic conditions favorable to bituminous coal development.

INTRODUCTION

Purpose and Scope of Report

Declines in availability of petroleum and natural gas have recently focused attention on other energy sources. Heightened interest in the coal resources of the United States is one example of the search for alternative fuel supplies that are necessary to meet expected demands. Texas has long been known for its production of oil and gas; now, the presence of abundant coal and lignite in the State is gaining recognition.

Recent studies of Texas lignite deposits (Fisher, 1963; Kaiser, 1974) greatly increase our understanding of the occurrence of lignite as an important energy resource. This companion report is a survey of bituminous coal in Texas and constitutes an initial step toward delineating the occurrence of another potentially valuable energy resource in the State. It is a compilation of existing information, both published and unpublished, supplemented by field observations.

Bituminous Coalfields in Texas

Definition.—Bituminous coal is one rank in a spectrum of coal varieties based on degree of metamorphism, or degree of coalification. Commonly recognized ranks of coal, in increasing degree of metamorphism, are: (1) lignite, (2) subbituminous, (3) bituminous, (4) semi-bituminous, (5) semianthracite, and (6) anthracite. As defined by the American Society for Testing Materials specifications based on proximate analyses (Fieldner and Selvig, 1938), bituminous coal contains fixed carbon (dry basis) of 86 percent or less, volatile matter (dry basis) of 14 percent or more, and heating values (moist condition) of 11,000 or more Btu's per pound of coal. Subvarieties within the bituminous rank are defined on ranges of dry fixed carbon, dry volatile matter, and moist Btu values. Subbituminous coal is a transitional variety between lignite and high-volatile (lowest rank) bituminous coal. Subbituminous coal has a minimum Btu value of 8,300 and a maximum value of 13,000 (dry fixed carbon less than 69%; dry volatile matter more than 31%). Bituminous coal generally is black with dull to bright luster and has splintery to subconchoidal fracture. It is harder and less likely to disintegrate on exposure than the soft, friable lignite.

Cannel coal is a variety that is not considered in most classification schemes. Composed of spores, pollen, algae, leaf cuticles, or other waxy, resinous substances, cannel coals have a very high volatile-matter content. Megascopically, cannel coals are distinguished from other coal varieties by massive structure, fine-grained texture, gray to black color, greasy luster, and conchoidal fracture.

Location and age.—Six bituminous coalfields in Texas are recognized—three minor and three major (fig. 1). Major coalfields in Texas include (1) Eagle Pass area, Maverick County, (2) Santo Tomas district, Webb County, and (3) the North-Central Texas region west of Fort Worth. These fields have potentially significant coal resources and were extensively developed at one time. Major fields in Texas are located in somewhat remote areas, but past production and potentially recoverable reserves of coal set these areas favorably apart from other bituminous coalfields in the State.

Minor coalfields are the (1) San Carlos region, Presidio County, (2) Big Bend (Terlingua) region, Brewster County, and (3) Eagle Spring prospect, Hudspeth County. These coalfields are considered minor because they supported only limited mining in the past and have relatively little potential for future development. Factors which diminish prospects for potential development in these areas include (1) lack of substantial coal reserves; (2) occurrence of coal seams in thin and/or discontinuous layers, under thick overburden, or in unfavorable structural settings (steep dips or numerous faults); and (3) remote geographic locations of coalfields (inadequate transportation arteries and far-removed potential markets).

North-Central Texas bituminous coal is found in several seams within Strawn, Canyon, and Cisco Groups. Though coal seams are thin (about 5 feet maximum), the possible presence of significant reserves and a rich history of past mining suggests that future development may be feasible in certain areas under appropriate economic conditions.

Two 24- to 36-inch coal seams northwest of Laredo in the Santo Tomas district were mined from the 1880's into the 1930's. These middle Eocene (Claiborne Group) coal seams are predominantly cannel coal and although indicated coal resources are not large, may be a source of coal by-products.

An Olmos Formation (Upper Cretaceous, Navarro Group) coal seam, up to 7 feet thick, was extensively mined near Eagle Pass, Maverick County, for 30 years around the turn of the century. The unfavorable geographic location may be offset by the presence of potentially large coal resources.

Coal mining near San Carlos, Presidio County, produced coal from the San Carlos Formation (Upper Cretaceous) during 1896. Structural complexity of the geologic setting, lack of significant reserves, and remote geographic location brought an abrupt end to massive financial investments in the development of this coal.

Bituminous coal was briefly mined from the Aguja Formation of Upper Cretaceous age near Terlingua in Brewster County to support local quicksilver processing plants in the 1930's and early 1940's. The marginal quality of this coal, which is found in thin seams, and the remote geographic location negated further development.

Coal seams were mined in steeply dipping beds of the Chispa Summit Formation (Upper Cretaceous) near Eagle Spring, Hudspeth County, in the 1880's. Geographically remote and located in an obviously unfavorable structural setting, these seams never stimulated significant development.

Bituminous Coal Production in Texas

In 1917, more than 1.25 million tons of bituminous coal was produced in Texas—it was the largest annual production recorded for the State (fig. 2). This peak production followed 30 years of relatively steady increase and was followed in the early twenties by a sharp decline, related to competition from oil and gas. In 1943, after nearly 15 years with production less than 100,000 tons per year, bituminous coal mining in Texas came to an end.

Figure 1. Location of Texas bituminous coalfields and generalized outcrop of coal-bearing strata.

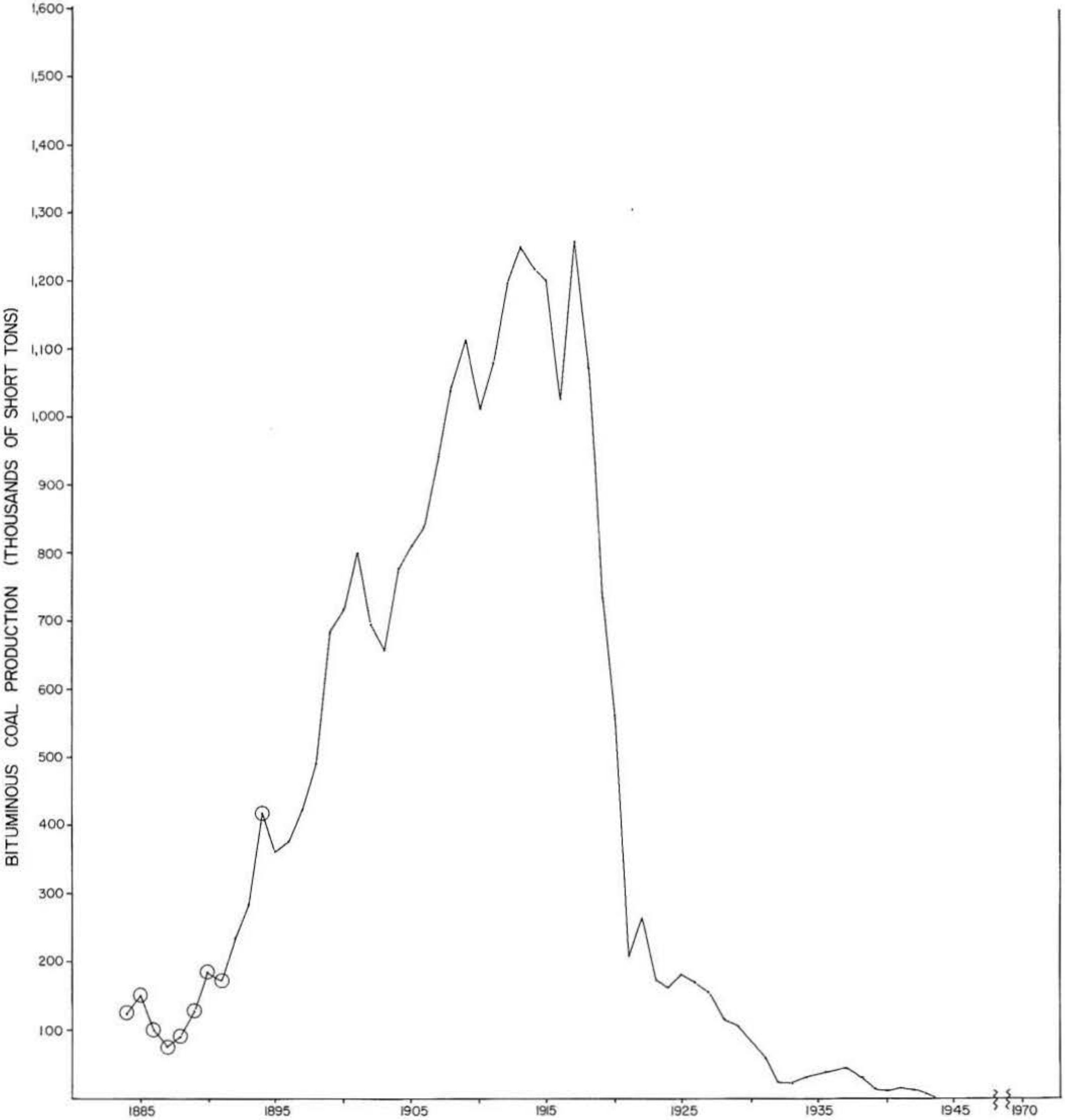

Figure 2. Total annual production of Texas bituminous coal. Circled values indicate years that bituminous coal and lignite production were reported together. Data from "Mineral Resources of the United States" volumes (U. S. Geological Survey) and U. S. Bureau of Mines "Minerals Yearbooks".

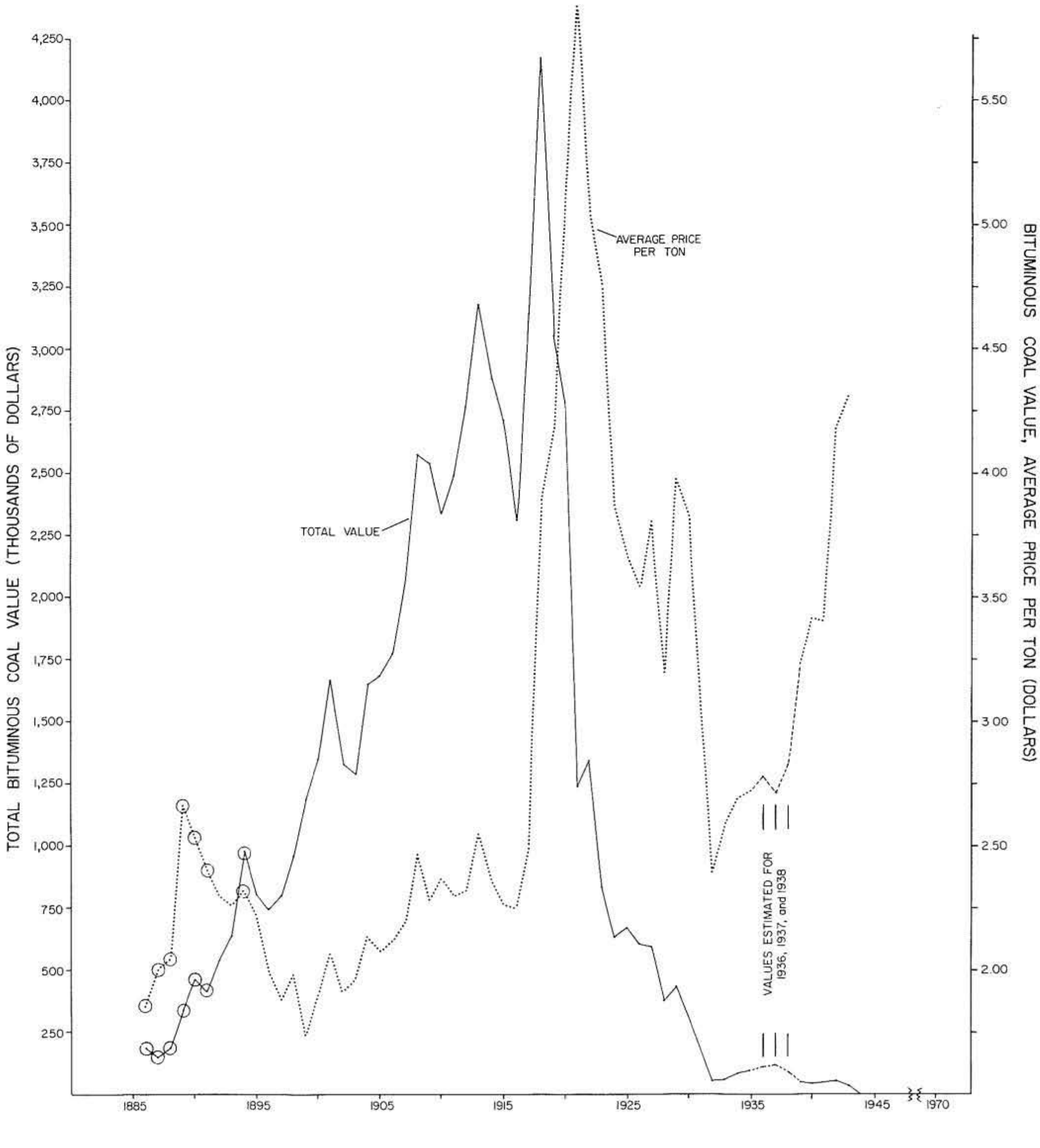

Figure 3. Total annual value and average price per ton for Texas bituminous coal. Circled values indicate years that bituminous coal and lignite values were reported together. Data from "Mineral Resources of the United States" volumes (U. S. Geological Survey) and U. S. Bureau of Mines "Minerals Yearbooks".

Bituminous coal mining was never a major Texas industry. Total annual contribution to the State's economy closely reflected fluctuations in yearly production, which was sharply influenced by strikes, mine fires, and other interferences with coal output. Yearly value of statewide coal production is shown in figure 3. The general pattern of bituminous coal production (fig. 2) was a microcosm of the displacement of coal by petroleum and natural gas fuels common throughout the United States. The flood of cheaper petroleum-based fuel and the end of flaring of natural gas meant that coal—mined underground and handled as a bulk material—could not compete economically in the fuels market. Railroads, once fueled by coal, switched rapidly to oil burners. Industrial and domestic use followed this trend away from coal. Coal production declined across the country and, in Texas, bituminous coal production ceased altogether.

The history of Texas coal mining is a colorful chapter in the State's growth around the turn of the century. Steady increase in bituminous coal production is reflected in early proliferation of privately owned, small-scale mine operations. In the face of stiff competition from oil and gas, consolidation of mining efforts into more efficient, corporate-owned developments maintained production increases in the early 1900's. These major developments centered on the few large coal deposits near markets or adequate transportation arteries. Finally, rapid declines in production occurred as mines closed. Texas bituminous coal was eliminated as a viable, economic fuel by the State's own oil and gas production.

Acknowledgments

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BITUMINOUS COAL IN STRAWN, CANYON, AND CISCO GROUPS, NORTH-CENTRAL TEXAS

Historical Background

Pennsylvanian-age bituminous coal in North-Central Texas was the first potentially commercial bituminous field to be recognized in the State (Kennedy, 1841). Though estimates of future production, coalfield size, and coal quality were often overoptimistic, this largest of Texas bituminous coalfields did account for the bulk of production throughout the period of development (mid-1880's to 1943).

Information on mining history and coal characteristics is fragmentary at best. Reports of thick coal seams and extensive coal deposits (Marcou, 1854; Boll, 1880) were tempered by detailed mapping and description (Shumard, B. F., 1859; Shumard, G. C., 1886; Buckley, 1866, 1874, 1876; Ashburner, 1881). "Mineral Resources of the United States" (1883-1923), "Minerals Yearbook" (1924-1973), State Mine Inspector Reports (1911, 1914, 1919, 1920, 1921, 1924, 1928), and Texas Geological and Mineralogical Survey studies (Cummins, 1889, 1890, 1891; Tarr, 1890; Dumble, 1891) as well as reports from later Texas surveys (Phillips, 1902a) and U. S. Geological Survey reports (Taff, 1902) provide additional information on mining development in the bituminous coalfields of North-Central Texas.

Trinity Coal and Mining Company, incorporated in 1840, was Texas' first mining company and was formed to exploit "anthracite and semi-bituminous" coal along the Trinity River (Taylor, 1848; Phillips and Worrell, 1913). Early military expeditions across Texas (Shumard, G. C., 1853; Hitchcock, 1853; Marcou, 1854) focused attention on other coal seams, exploited locally by soldiers from Fort Belknap, in central Young County along the Brazos River.

Coal mining in North-Central Texas remained a minor enterprise, however, until the latter part of the century when efforts centered on the larger deposits. Many early mines and exploration shafts were privately financed (and short-lived) operations. Larger scale mining by corporations was more efficient and could most economically develop thin seams of low-quality bituminous coal. Mines were opened at one time in Cisco Group rocks in McCulloch, Coleman, Eastland, Young, Jack, and Montague Counties, in Canyon Group strata in Wise County, and in Strawn Group rocks in Erath, Palo Pinto, and Parker Counties. By the late 1890's, however, coal development focused on the Thurber coal in Erath and Palo Pinto Counties, the Bridgeport coal in Wise County, and, some 10 years later, the Newcastle coal in Young County. The names of the early mines, tunnels, and exploration shafts—Fincastle, J. S. Young, Fink, Carson and Lewis, Swank, A. S. Johnson, Gilfoil, Chaffin—were a colorful prelude to the austere names of later, more successful mining corporations—Texas and Pacific, Strawn Coal Mining, Wise County Coal, Belknap Coal, Bridgeport Coal, and Texas Coal and Fuel Companies.

By the early 1920's, most major companies had failed and others were in decline as abundant, readily available petroleum and natural gas fuels undercut the coal market. From around 20 active mines in the 1880's to 16 mines (operated by five companies) in 1911 to only three "working and temporarily closed" mines in 1928, the downward trend of coal development reflects the decreasing demand for coal as a fuel for railroad, industry, and domestic use, and the tenuous economic position of thin (<3 feet), high-sulfur (>2%), high-ash (~15%) bituminous coal expensively mined in underground operations. Mining struggled along until 1943 when the last significant coal production, from Palo Pinto and Wise Counties, came to an end. Plate I shows the distribution of major coal-bearing units in Middle and Late Pennsylvanian rocks in North-Central Texas. Also indicated on plate I are mines, shafts, and measured sections containing coal seams. Appendix I describes each of the localities on plate I.

Geologic Setting

Geologic study of Pennsylvanian strata in North-Central Texas has been extensive. Attempts to unravel the complex stratigraphic relationships of these rocks and additional information on the coal units are described by Drake (1893, 1917), Plummer and Moore (1921), Scott and Armstrong (1932), Plummer and Hornberger (1935), Lee and others (1938), Cheney (1940), Plummer and others (1949), and Brown (1959, 1960a, 1960b, 1962). The literature bulges with names of divisions, groups, formations, members, and key beds with the most recent effort (Brown and Goodson, 1972) followed in this report (pl. I). Extensive facies changes south to north along the strike of Pennsylvanian units result in stratigraphic complexity. Recent information gained from study of modern depositional analogs of these ancient rocks provides some understanding of the significance of the facies relationships as well as the environments of coal deposition. Parallel-to-strike correlations of major lithologic units are not only difficult, but actually transect physically and temporally distinct depositional systems and associated facies complexes. Middle and Late Pennsylvanian rocks were deposited in dip-oriented fluvial-deltaic facies tracts extending across basin margins onto shallow shelves and into deeper basin slope environments (Galloway, 1970; Galloway and Brown, 1972; Brown and others, 1973). Coal deposits originated on delta plains in swamps and marshes where organic material could grow, die, accumulate, and be preserved, as well as in interdeltaic embayments such as lagoons and bays. Environments favorable to coal deposition associated with Strawn, Canyon, and Cisco Group deltas produced both in situ coal deposits (rooted underclay present) and "detrital" coal deposits (no rooted substrate present).

STRAWN GROUP

Coal seams are restricted to upper Strawn (Desmoines Series) units which crop out from northwestern Erath County across southeast Palo Pinto County into western Parker County (pl. I). These units, as well as younger Canyon and Cisco Group units, dip gently (less than 1 degree) northwest. Upper Strawn strata comprise fluvial and deltaic depositional systems which extend westward from Ouachita foldbelt source areas (Brown and others, 1973). Coal associated with these deposits formed during several periods of delta progradation.

Sunday Creek coal is one of three coal seams found in upper Strawn Group rocks. The Sunday Creek bed is impure, highly weathered, uniformly 18 to 22 inches thick, and crops out along Sunday Creek southeast of Santo in Palo Pinto County (Plummer and Hornberger, 1935). Sunday Creek coal occurs in the Grindstone Creek Formation about 65 feet below Santo Limestone (pl. I). This coal is probably related to areally restricted delta-plain marshes or small interdeltaic embayments associated with Buck Creek Sandstone fluvial-deltaic systems. A few local residents mined this coal on a small scale for blacksmiths' forges (Plummer and Hornberger, 1935).

Thurber coal represents the major Strawn Group coal deposit. It was extensively mined in northern Erath and southern Palo Pinto Counties from the late 1880's into the 1920's. Thurber coal crops out discontinuously, due to slope wash and talus cover, from the Eastland-Erath county line into western Parker County along Dry and Rock Creeks (pl. I; Plummer and Hornberger, 1935). The coal seam ranges from 12 to more than 30 inches thick. Thurber coal occurs about 200 feet stratigraphically below the Brazos River Formation (pl. I). Its subsurface extent is reasonably well known within old mining areas (Plummer and Hornberger, 1935) but occurrences beyond these areas are not well defined. Figure 4 shows coal distribution maps prepared in two studies (Mapel, 1967; Brown and others, 1973) but based on different subsurface information. Whereas good agreement exists in the area of northwestern Erath and southwestern Palo Pinto Counties, subsurface distribution of Thurber coal beyond this area is contradictory. Potential mining development seems most likely in the area of agreement because coal occurs nearest the surface in this region. Development in other areas will require reconciliation of the different interpretations of Thurber coal subsurface extent.

Thurber coal formed in an interdeltaic embayment south of major deltation sites in northern Palo Pinto and Jack Counties (Brown and others, 1973). Following delta abandonment, embayment sediments were partially reworked by marine processes and onlapped by marine deposition, as shown by a marine, fossiliferous siltstone immediately overlying the Thurber coal (Brown and others, 1973).

Abbott coal is a minor seam, 26 inches thick, exposed 5 miles southeast of Mineral Wells. It occurs in the middle Brazos River Formation interdistributary bay facies (Brown and others, 1973). Where exposed, the coal is impure and highly weathered (Plummer and Hornberger, 1935). Subsurface extent of the Abbott coal is very restricted (Mapel, 1967).

CANYON GROUP

Canyon Group (Missouri Series) strata record several periods of northwestward delta

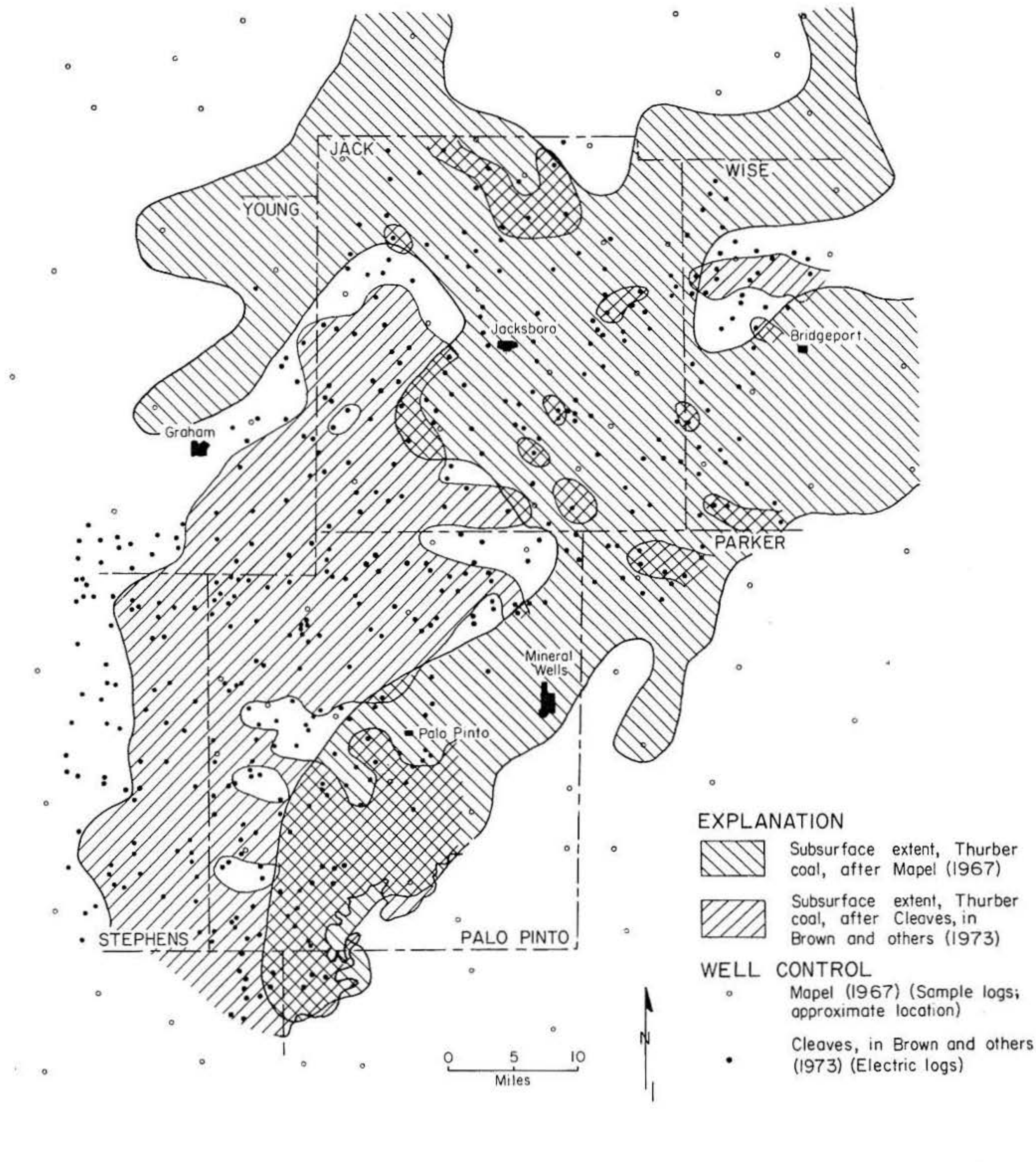


Figure 4. Subsurface distribution of Thurber coal and approximate equivalents after Mapel (1967), and A. W. Cleaves in Brown and others (1973). Note lack of agreement.

progradation. Contemporaneous with this terrigenous clastic system were various carbonate systems (including bank, shelf, and shelf-edge reef), some of which extended eastward during times of reduced clastic influx (Brown and others, 1973). Associated delta-plain sediments were thin and only rarely preserved because marine processes easily reworked these units following delta abandonment. Two coal deposits are recognized in Canyon Group strata; however, the depositional framework of the two seams is poorly understood.

The Bridgeport coal is an 18- to 22-inch-thick coal of good quality that was extensively mined around Bridgeport, Wise County, from the early 1890's until 1943—it was the last active bituminous coal mine in Texas (Stenzel and Fountain, 1948). Coal occurs 32 to 55 feet below the Willow Point Limestone, which forms the upper unit in the Palo Pinto Formation. Along outcrop, Bridgeport coal extends from Bridgeport southwestward to near Perrin (Plummer and Hornberger, 1935). In the subsurface, Bridgeport coal is very restricted, as shown by information from wells located downdip from outcrop (Plummer and Hornberger, 1935; Mapel, 1967).

The Dalton coal comprises the thickest coal occurrence (up to 10 feet) in North-Central Texas. This coal seam occurs in the lower Wolf Mountain Shale along the topographically prominent Merriman Limestone escarpment in northwest Palo Pinto County. Though generally covered, the Dalton coal where exposed is highly weathered and impure. It rests on fossiliferous limestone and is overlain by a marine shale (Plummer and Hornberger, 1935). Extending discontinuously for only 4 miles along the escarpment, Dalton coal is also restricted in subsurface extent (Mapel, 1967).

CISCO GROUP

Numerous fluvial-deltaic progradations fed by eastern source areas in the Ouachita foldbelt mark Cisco Group strata (Virgil and Wolfcamp Series). Sites of organic accumulation were mainly interdeltaic embayments lateral to main delta trends. During periods of progradation, delta-flank embayments moved basinward due to strike-fed mudflat and strandplain accretion. Brackish-bay mudstones and limestones and thin coal beds accumulated shoreward of these mudstones and sandstones. Organic accumulation took place both as in situ marsh or swamp deposition in shallow portions of delta-flank embayments and as detrital accumulations in deeper portions of lagoons or lakes behind the strike-fed barriers. Upon delta abandonment, marine processes reworked portions of the interdeltaic embayment sediments with eventual marine limestone deposition onlapping former sites of delta-flank deposition (Brown and others, 1973).

Many thin, discontinuous coal seams occur in the Cisco Group, particularly Harpersville Formation. Four stratigraphic horizons contain laterally persistent coal seams—Chaffin coal, Bull Creek coal, Newcastle coal, and Saddle Creek coal. These four coal horizons are considered by some to be mappable units in both surface and subsurface extent (pl. I; Mapel, 1967). Cisco Group rocks crop out along a generally south to north trend which becomes southwest to northeast in Young County (pl. I). Gentle northwest dips of about one-half degree characterize Cisco as well as younger Canyon and Strawn Group rocks.

The Chaffin coal occurs as a 20-inch-thick seam immediately below the Chaffin Limestone of the Harpersville Formation. This seam was mined in the late 1880's near Waldrip, McCulloch County. Although the seam is very local in extent (Drake, 1893; Mapel, 1967), coal is found below the Crystal Falls Limestone, a Chaffin Limestone equivalent, as far north as Eastland (Plummer and others, 1949) and Stephens (Brown, 1960a) Counties.

The Bull Creek coal is an areally restricted seam mined before the turn of the century in northern McCulloch and southern Coleman Counties. Ranging from 12 to 30 inches thick, the Bull Creek seam occurs 25 to 50 feet above the Chaffin Limestone. Coal seams at approximately the same horizon are reported by Brown (1960a) and Plummer and others (1949) in Stephens County. Subsurface extent of Bull Creek coal and approximate equivalents is shown by Mapel (1967).

Newcastle coal is the major Harpersville Formation coal horizon. Newcastle coal was mined from 1908 into the early 1920's near Newcastle, Young County, by the Belknap Coal Company. It ranges from 20 to more than 50 inches thick in old mine areas (Ledbetter, 1964). Seams at similar stratigraphic horizons—about 50 feet below Saddle Creek Limestone and equivalents—are reported as far south as Cisco in Eastland County (Plummer and others, 1949). Mapel (1967) illustrates the subsurface occurrence of Newcastle coal and equivalents.

A fourth coal horizon in the Harpersville Formation occurs just below the Saddle Creek Limestone. Saddle Creek coal is an impure coal occurring locally in Young County (Lee and others, 1938) and possibly in Eastland County (Brown, 1969); however, Saddle Creek coal is apparently widespread in the subsurface (Maple, 1967).

One persistent coal seam occurring in Cisco Group rocks is not a part of the Harpersville Formation. Below the Blach Ranch Limestone in the Graham and Thrifty Formations (undivided) is a 2- to 17-inch-thick seam of impure coal (equivalent to Eddleman coal, Stone, 1969) commonly exposed in Young and Jack Counties (Brown, 1962).

Coal Characteristics and Quality

Adequate megascopic descriptions of fresh samples of bituminous coal in North-Central Texas are nonexistent. Buckley (1866) mentions some samples displaying conchoidal fracture and most workers characterize the mined coal as black, laminated, containing shale partings, and of good quality. Coking quality is only fair due to large percentages of ash and sulfur.

Many chemical analyses of Strawn, Canyon, and Cisco Group coals are recorded in the literature (tables 1 and 2). Strawn Group coals (table 1)—Thurber coal mainly—are fairly low in moisture (2 to 8%), high in ash (10 to 25%), high in sulfur (1.5 to 4%) and rank as high-volatile B bituminous coal. Btu values (dry basis) range from 10,390 to 13,755 per pound of coal. Canyon Group Bridgeport coal (table 1) is high in moisture (12 to 15%), high in ash (11 to 16%), high in sulfur (1.6 to 3.4%), and ranks as high-volatile C bituminous or subbituminous A coal. Btu values (dry basis) range from 11,160 to 12,190 per pound of coal. Cisco Group coals show more variable proximate analysis values due to the inclusion of several different coal seams (table 2). Moisture values range from 2 to 18 percent; ash content is generally high with most values in the "mid-teens" range; sulfur content is high (1.1 to 8.9%). Btu values (dry basis) range from 10,213 to 12,709 per pound of coal.

Based on chemical analyses, North-Central Texas bituminous coal ranges from subbituminous A to high-volatile B bituminous coal with high percentages of ash and sulfur. In outcrop the Pennsylvanian-age bituminous coal is highly weathered, impure, and fissile.

Estimates of Coal Resources and Reserves

U. S. Geological Survey estimates of coal resources in North-Central Texas indicate the presence of 5,400 million short tons of coal in beds 14 or more inches thick and under 3,000 feet or less overburden (Mapel, 1967). Strawn Group coals represent over half of the total original inferred resources (2,800 million short tons); Cisco Group coals contain one-third of the total for North-Central Texas (1,853 million short tons); and Canyon Group coals contain only about 16 percent of the total original inferred resources (818 million short tons). Within 1,000 feet of the surface, 3,400 million tons of coal are present; 1,300 million tons occur from 1,000 to 2,000 feet; and 680 million tons exist under 2,000 to 3,000 feet of overburden (Mapel, 1967).

Figure 5 shows the subsurface distribution of Strawn, Canyon, and Cisco Group (generalized) bituminous coals as determined by Mapel (1967). Estimates based on these maps represent the best evaluation of total original inferred resources; however, comparison with other subsurface distribution maps based on other data (fig. 4) indicates that contradictions exist. Reconciliation of such contradictions requires utilization of all available subsurface information and constitutes a useful restudy of North-Central Texas bituminous coal resources.

Estimates of reserves for particular coal seams are not available though such determinations were probably made by mining companies active at one time in North-Central Texas. E. S. Britton, Strawn Coal Company, estimated that 40,000 acres of commercially productive coal lands containing 28-inch coal in the "Strawn coal basin" (equivalent to about 165 million short tons) remained for future development (Plummer and Hornberger, 1935). Determination of actual coal reserves in this and other potentially minable regions requires detailed exploratory drilling programs using geophysical logging and coring techniques. Coring of intervals of interest would yield samples suitable for analysis, and thus an evaluation of coal quality

Table 1. Chemical analyses of Strawn and Canyon Groups bituminous coal, North-Central Texas. Data from original sources where available; see Appendix II for sample descriptions and sources of analyses. Values not shown were not determined in original analyses.

Sample No.[1]	Proximate Analysis (as received)							Proximate Analysis (dry basis)						Ultimate Analysis (dry basis)					
	Moisture	Volatile Matter	Fixed Carbon	Ash	Total	S	Btu	Volatile Matter	Fixed Carbon	Ash	Total	S	Btu	C	H	O	N	S	Ash
STRAWN GROUP																			
ER-1	0.85	31.23	56.98	9.30	98.36	1.64													
ER-2	0.90	30.96	60.01	6.85	98.72	1.28													
ER-3	0.90	33.51	53.46	10.65	98.52	1.48													
ER-4	0.88	31.57	56.81	8.93	98.19	1.47													
ER-5	5.83	33.20	43.15	17.82	100.00	1.51	11,448	35.26	45.83	18.91	100.00	2.77	12,157	64.68	4.25	6.65	2.74	2.77	18.91
ER-6	2.70	40.82	48.73	7.75	100.00	1.93	12,188												
ER-7	2.51	35.68	46.34	15.47	100.00	3.08	11,788												
ER-8	2.2	31.0	39.7	27.1	100.0	3.1	10,220												
ER-9	2.2	31.1	39.3	27.4	100.0	3.0	10,160	31.8	40.2	28.0	100.0	3.1	10,390						
PP-1	5.36	31.91	43.03	19.70	100.00	2.04	11,450	33.72	45.47	20.81	100.00	2.16	12,099	62.43	4.19	8.83	1.58	2.16	20.81
PP-2	5.46	35.66	49.17	9.71	100.00	1.61	12,003	37.72	52.01	10.27	100.00	1.71	13,755	74.56	5.24	6.99	1.23	1.71	10.27
PP-3	4.31	35.61	44.55	15.53	100.00	3.00	12,264	37.22	46.56	16.22	100.00	3.14	12,817	66.57	5.11	7.05	1.91	3.14	16.22
PP-4	4.00	31.78	42.04	22.18	100.00	2.39	11,524	33.11	43.80	23.09	100.00	2.49	12,005	60.43	4.23	6.90	2.86	2.49	23.09
PP-5	2.90	38.46	48.13	10.51	100.00	2.08	10,910	39.60	49.56	10.84	100.00	3.17	12,265	70.00	5.15	8.14	2.70	3.17	10.84
PP-6	1.06	39.28	50.12	9.54	100.00	2.88	13,421	39.70	50.65	9.65	100.00	2.91	13,563						
PP-7	3.30	34.11	49.88	12.71	100.00	1.81	11,871												
PP-8	4.0	32.8	45.6	17.6	100.0	4.1	11,560												
PP-9	3.3	35.8	47.9	13.0	100.0	3.2	12,360	37.0	49.6	13.4	100.0	3.3	12,780						
PP-10	3.3	37.8	46.8	12.1	100.0	2.8	12,560	39.1	48.4	12.5	100.0	2.9	12,990						
PP-11	3.7	33.5	42.8	20.0	100.0	2.6	11,240	34.8	44.5	20.7	100.0	2.7	11,670						
PR-1	5.31	31.24	38.69	24.76	100.00	4.76	11,170	33.00	40.86	26.14	100.00	5.03	11,797	60.34	4.12	2.58	1.79	5.03	26.14
PR-2	8.12	29.62	46.84	15.42	100.00	1.56	11,515	32.24	49.90	17.86	100.00	1.70	12,533	65.52	3.99	9.05	1.88	1.70	17.86
PR-3	5.95	33.08	44.79	16.18	100.00	2.00	11,450	35.18	47.63	17.19	100.00	2.13	12,175	61.52	4.18	13.72	1.22	2.13	17.19
PR-4	6.84	29.17	42.48	21.51	100.00	2.82	11,493	31.32	45.60	22.08	100.00	3.03	12,338	62.08	4.29	5.62	2.90	3.03	22.08
PR-5	3.50	38.12	49.21	9.17	100.00	2.03	11,976	39.50	50.99	9.51	100.00	2.10	12,410	70.91	4.85	9.29	3.34	2.10	9.51

[1] Letters indicate county: ER = Erath, PP = Palo Pinto, PR = Parker. See Appendix I for exact locations.

Table 1 (continued).

Sample No.[1]	Proximate Analysis (as received)							Proximate Analysis (dry basis)						Ultimate Analysis (dry basis)					
	Mois- ture	Volatile Matter	Fixed Carbon	Ash	Total	S	Btu	Volatile Matter	Fixed Carbon	Ash	Total	S	Btu	C	H	O	N	S	Ash
CANYON GROUP																			
WI-1	2.00	31.47	56.32	8.15	97.94	2.06													
WI-2	12.50	31.72	42.98	12.80	100.00	1.84	10,656	36.26	49.12	14.62	100.00	2.11	12,190	64.88	4.45	12.71	1.23	2.11	14.62
WI-3	12.21	31.93	41.12	14.74	100.00	1.73	10,575	37.52	46.83	15.65	100.00	1.98	12,047	67.67	3.73	9.17	1.80	1.98	15.65
WI-4	12.56	34.13	41.99	11.32	100.00	1.63	10,373	39.04	48.03	12.93	100.00	1.87	11,864	66.72	4.30	12.78	1.40	1.87	12.93
WI-5	9.40	34.65	42.53	13.42	100.00	3.09	10,144	38.30	46.94	14.76	100.00	3.41	11,196	65.42	4.40	9.21	2.80	3.41	14.76
WI-6	9.20	33.96	43.02	13.82	100.00	1.82	10,233	37.40	47.37	15.23	100.00	2.00	11,269	63.80	4.67	11.40	2.90	2.00	15.23
WI-7	9.81	33.06	48.66	12.47	100.00	2.03	10,396												
WI-8	13.7	32.5	39.3	14.5	100.0	2.0	9,690												
WI-9	14.0	32.4	39.2	14.4	100.0	1.9	9,660												
WI-10	14.9	31.4	40.8	12.9	100.0	1.6	9,820												
WI-11	13.8	31.8	37.7	16.7	100.0	1.9	9,210												
WI-12	14.3	31.5	39.5	14.7	100.0	1.8	9,560	36.8	46.1	17.1	100.0	2.1	11,160	63.6	4.4	11.0	1.8	2.1	17.1
WI-13	13.9	33.1	40.1	12.9	100.0	3.4	10,210												
WI-14	12.4	31.9	40.5	15.2	100.0	2.0	9,930												
WI-15	13.2	32.7	39.7	14.4	100.0	2.7	10,070	37.6	45.9	16.5	100.0	3.1	11,600	64.9	4.6	9.2	1.7	3.1	16.5

[1] Letters indicate county: WI = Wise. See Appendix I for exact locations.

Table 2. Chemical analyses of Cisco Group bituminous coal, North-Central Texas. Data from original sources where available; see Appendix II for sample descriptions and sources of analyses. Values not shown were not determined in original analyses.

Proximate Analysis (as received)

Sample No.[1]	Moisture	Volatile Matter	Fixed Carbon	Ash	Total	S	Btu
CO-1	4.05	40.40	46.75	8.80	100.00	2.87	
CO-2*	10.41	35.94	49.46	4.20	100.00	1.54	
CO-3	6.90	36.00	41.10	16.00	100.00	4.56	
CO-4	2.26	39.75	44.87	13.12	100.00	2.94	
CO-5	2.46	37.31	42.89	17.34	100.00	8.89	
CO-6	4.71	39.26	46.24	9.79	100.00	2.22	
CO-7	3.98	37.36	40.58	18.08	100.00	5.06	
CO-8	2.67	38.79	46.12	12.42	100.00	4.17	
CO-9	2.63	39.43	43.49	14.45	100.00	2.90	
CO-10	3.23	37.54	42.80	16.40	100.00	3.67	
CO-11	3.07	33.05	39.10	24.78	100.00	3.10	
CO-12	2.36	38.55	43.88	15.21	100.00	5.91	
EA-1	13.44	34.86	36.37	15.33	100.00	2.54	9,609
JK-1	10.24	34.28	35.02	20.46	100.00	1.66	9,434
JK-2	10.28	25.49	55.10	9.13	100.00		
MC-1*	8.25	38.28	47.28	6.20	100.00	3.25	
MC-2*	4.55	38.51	44.80	12.14	100.00	7.96	
MN-1	2.30	34.48	61.28	0.60	98.66	1.14	
MN-2	9.00	28.00	47.22	14.04	98.26	1.74	
SH-1	4.12	31.98	35.10	28.80	100.00		9,993
ST-1	6.90	38.07	37.03	18.00	100.00	6.49	
ST-2	3.15	41.95	43.60	11.30	100.00	3.75	
ST-3	5.02	40.01	40.46	14.51	100.00	5.12	
YO-1*	7.87	36.27	52.81	3.06	100.00		
YO-2	1.10	35.50	43.00	15.60	95.20	4.60	
YO-3	11.00	34.22	37.99	16.79	100.00	3.77	9,090
YO-4	7.00	37.56	40.18	15.26	100.00	1.99	10,203
YO-5	9.00	35.79	39.08	16.13	100.00	2.88	9,601
YO-6	9.04	48.90	30.28	11.78	100.00		
YO-7	18.00	30.91	40.18	10.91	100.00	1.11	10,421
YO-8	18.50	31.70	37.10	12.70	100.00	1.92	10,442
YO-9	14.9	34.6	35.5	15.0	100.0	3.8	9,640
YO-10	14.5	34.7	35.1	15.7	100.0	3.7	9,540
YO-11	15.0	34.3	34.2	16.5	100.0	3.5	9,380
YO-12	14.8	34.6	34.9	15.7	100.0	3.7	9,500

Proximate Analysis (dry basis)

Sample No.[1]	Volatile Matter	Fixed Carbon	Ash	Total	S	Btu
EA-1	40.28	42.02	17.70	100.00	2.94	11,101
JK-1	38.18	39.01	22.81	100.00	1.84	10,510
JK-2	28.11	60.77	11.12	100.00		
SH-1	33.35	36.61	30.04	100.00		10,422
YO-3	38.45	42.68	18.87	100.00	4.24	10,213
YO-4	40.38	43.20	16.42	100.00	2.13	10,970
YO-7	37.70	49.00	13.30	100.00	1.35	12,709
YO-8	38.90	45.52	15.58	100.00	2.36	12,651
YO-12	40.6	41.0	18.4	100.0	4.3	11,160

Ultimate Analysis (dry basis)

Sample No.[1]	C	H	O	N	S	Ash
EA-1	58.86	5.10	13.71	1.69	2.94	17.70
JK-1	60.28	3.77	9.88	1.42	1.84	22.81
YO-3	58.25	4.17	12.35	2.12	4.24	18.87
YO-4	61.21	5.09	12.15	3.00	2.13	16.42
YO-12	62.7	4.3	9.1	1.2	4.3	18.4

[1]Letters indicate county: CO = Coleman; EA = Eastland; JK = Jack; MC = McCulloch; MN = Montague; SH = Shackelford; ST = Stephens; YO = Young.

*Figures shown have been rounded off from original published analysis.

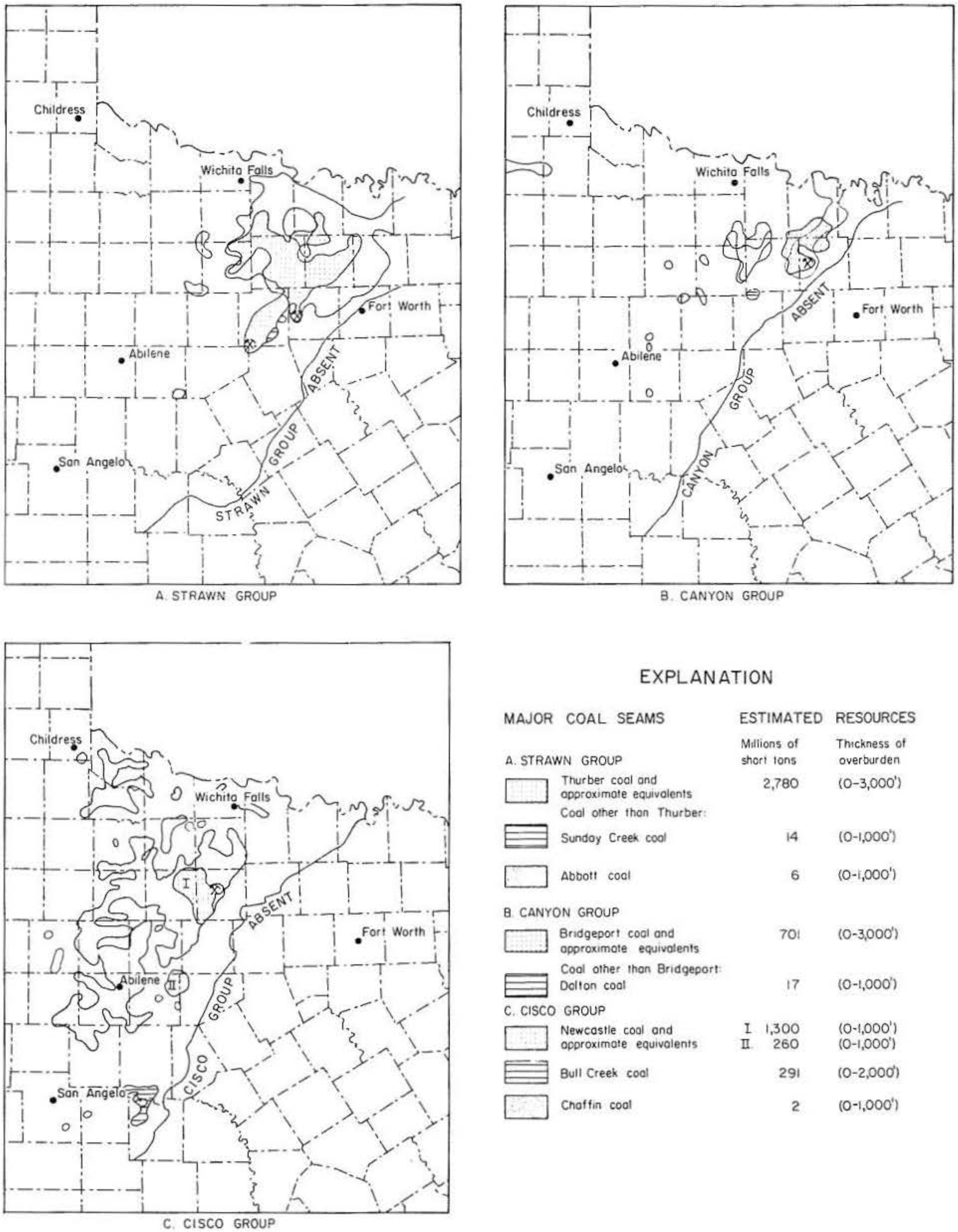


Figure 5. Distribution and estimated resources of major North-Central Texas bituminous coal seams, after Mapel (1967). Depth to coal increases from southeast to northwest. Areas without patterns not included in resource estimate.

relative to potential use (e.g., direct combustion or production of synthetics) would be possible.

Potential for Development

Though reserve estimates are not available, it appears that economic coal deposits may exist in North-Central Texas, particularly in areas of past mining. The major drawback to potential production remains the nature of the coal itself. Strawn, Canyon, and Cisco Group coals are rarely more than 36 inches thick and generally no more than 30 inches thick. Poor coal quality, particularly high sulfur content, limits use. Direct combustion would produce environmentally unacceptable amounts of dangerous sulfur oxide compounds. Thus, preparation of the coal prior to combustion, or use of other expensive techniques to remove sulfur oxide compounds after combustion, would be necessary. Coal conversion techniques such as liquefaction and gasification do not produce sulfur oxide compounds, but neither conversion process has as yet attained widespread use in the United States. An additional drawback to utilization of North-Central Texas coal is the consolidated strata overlying the coal seams. Consolidated overburden poses serious problems for surface mining and mined-land reclamation techniques because of the difficulty in handling large-sized rock debris.

Whereas considerable amounts of coal do exist, coal quality, seam characteristics, and consolidated nature of overlying strata require evaluation before development potential can be determined. Geographic locations of potential mine areas are favorable because of low population densities and nearby high-population markets (Fort Worth-Dallas, Abilene), but present-day transportation facilities may need updating before a coal industry can develop.

EOCENE (CLAIBORNE) CANNEL COAL, SANTO TOMAS DISTRICT, WEBB COUNTY

Historical Background

Santo Tomas district, located along the Rio Grande northwest of Laredo, is a unique Texas coalfield comprised predominantly of volatile-rich cannel coal. Described as the "largest cannel coal field in the United States" (Ashley, 1919), these Eocene-age coals were mined for more than 50 years. Webb County cannel coals were among the first bituminous coals noted in Texas as government surveys (Egerton, 1835; Emory, 1857; Schott, 1857) and early reviews of Texas resources (Kennedy, 1841; Taylor, 1848) brought attention to exposures of this unusual coal along the breaks of the Rio Grande.

Commercial mining began in 1881 with Rio Grande Coal and Irrigation Company's drift mines in outcrops along the hills northeast of Minera Station (Rio Grande and Eagle Pass Railway). A total of 13 mines were worked near Minera (fig. 6). Production figures for these operations are not available but Vaughn (1900) reports a 90- to 100-ton-per-day drift mine at Santo Tomas, owned by Rio Grande Coal and Irrigation Company. This mine is probably one of the Minera mines.

The Santo Tomas coal district gradually expanded. The Hunt mine was a small drift(?) operation owned by the Carr Brothers and opened around 1887 in the Dolores area southeast of Minera, about 20 miles from Laredo. Cannel Coal Company opened several shaft mines near Dolores; the first shaft, Darwin mine, opened in 1895 and was followed by two more shafts, San Jose mine and Dolores mine. The northernmost mine in the district was Santo Tomas Coal Company's shaft, opened and operated in the early 1900's near Santo Tomas, 27 miles northwest of Laredo. (See figure 6 for locations of all the aforementioned mines.) Small villages of miners and their families sprang up around the Minera, Santo Tomas, Darwin, and Dolores mines. As oil and gas competition forced many mines to close, entire villages were dismantled and moved near newer mines to the southeast at Darwin and Dolores (Fred Hopson, oral communication, 1973).

By the mid-1920's, Minera Mine No. 4 and Dolores mine were the only mines operating in the district. With the closing of Dolores mine in 1939, cannel coal production ended. Though oil and gas competition closed the Santo Tomas district, minable (but uneconomic) reserves of cannel coal were still present in 1939.

The Santo Tomas district mines were worked by room-and-pillar methods. Thickest coal seams were only 3 feet, so the 5½- to 6-foot-high drifts required the handling of as much waste as coal. Large mine dumps still visible near Dolores and Darwin mines testify to the large volume of waste moved during mining. Efficient mining practices reportedly secured nearly 100 percent of the coal by retrieving pillars and either allowing roof collapse or gobbing in mined-out areas.

Geologic Setting

Cannel coal in western Webb County occurs in the Bigford Formation and the overlying El Pico Clay of Eocene (Claiborne Group) age (fig. 7). The Bigford Formation (Trowbridge, 1923; Eargle, 1968) corresponds to the Bigford member of the Mt. Selman Formation of Lonsdale and Day (1937). El Pico Clay (Eargle, 1968) corresponds to the post-Bigford member of Mt. Selman Formation (Lonsdale and Day, 1937), and Mt. Selman Formation of Trowbridge (1923). Santo Tomas and San Pedro coal seams are recognized as zones of cannel coal, lignite, bone coal, and shale or clay present in the El Pico Clay and Bigford Formation, respectively.

San Pedro coal zone occurs from 16 to 60 feet below the top of the Bigford Formation (figs. 7, 8). Eleven coal beds 6 or more inches thick are found in Bigford strata but only coal in the San Pedro zone is thick enough to have been successfully mined. Two benches of 2-foot-thick coal are present, with only the upper bench previously developed. The San Pedro seam crops out from near Palafox (now abandoned) 30 miles northwest of Laredo, northward in a discontinuous band for 16 to 20 miles into the headwaters region of Tordillo Creek (Lonsdale and Day, 1937). Subsurface extent of San Pedro coal is not known but appears discontinuous as this seam was mined in some shafts near Dolores but was not found in other mines (e.g., Santo Tomas mine) in the district. The 660-foot-thick Bigford Formation dips regionally to the southeast at a rate of 120

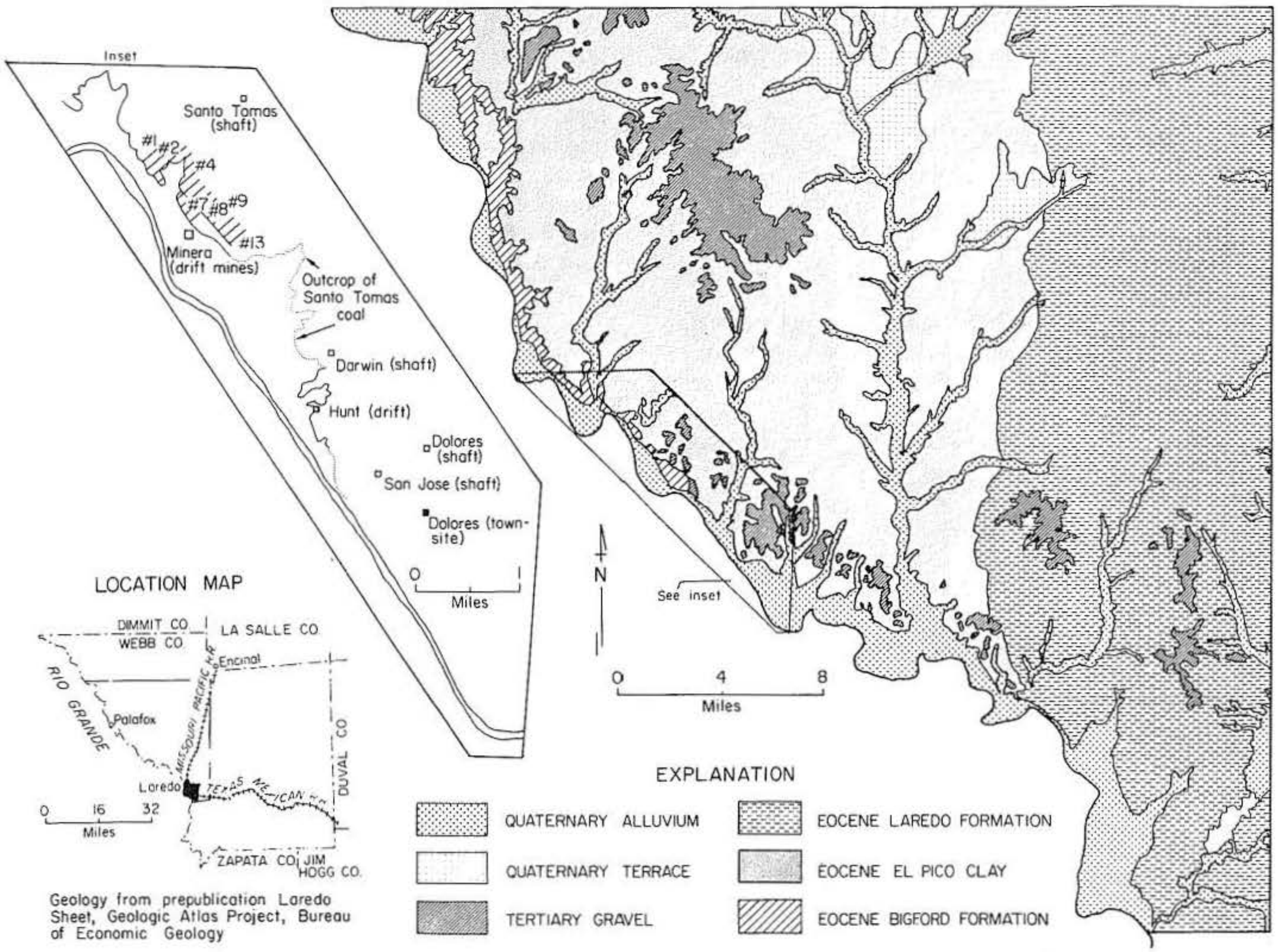


Figure 6. Surface geology and mine locations in Santo Tomas district. Mine locations after Ashley (1919).

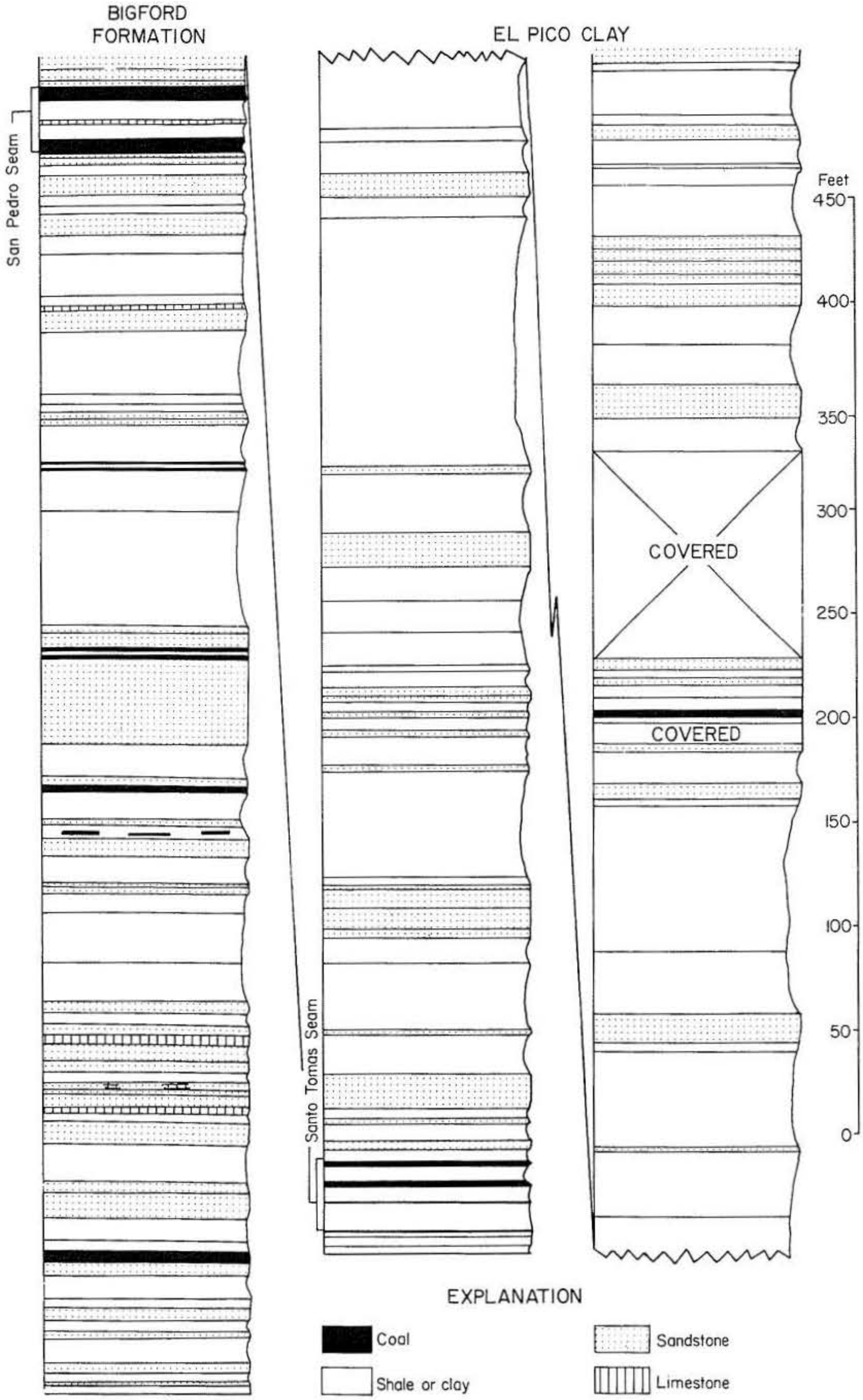


Figure 7. Lithology of Bigford Formation and El Pico Clay, Santo Tomas district. Data from Lonsdale and Day (1937). Coal units shown for Bigford Formation are mostly coaly shale with coal layers only about 1 to 2 feet thick. El Pico Clay coal units are mostly cannel coal with minor amounts of coaly shale.

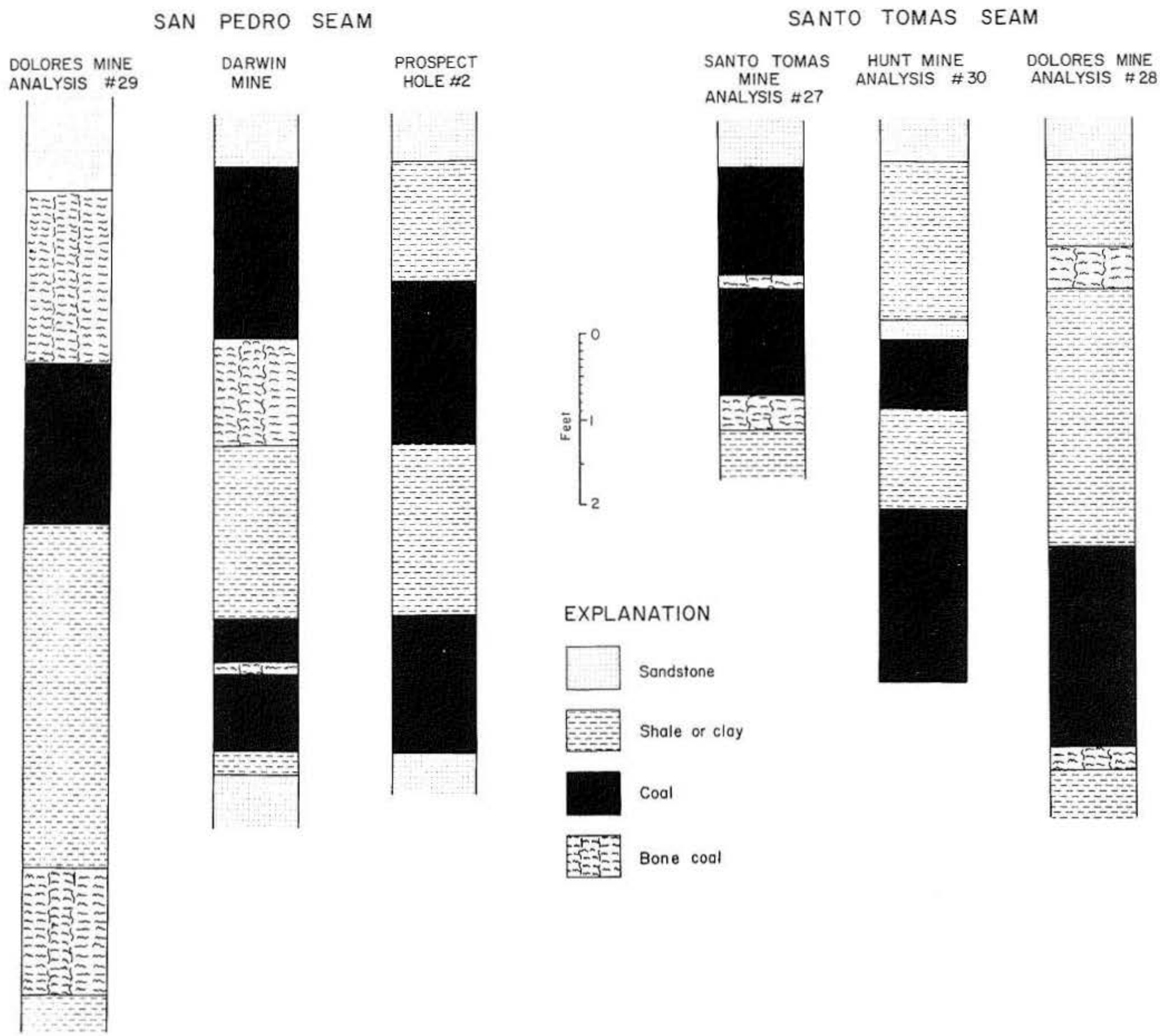


Figure 8. Measured sections of Santo Tomas and San Pedro cannel coal seams, Santo Tomas district. Analysis numbers refer to table 3. Data from Ashley (1919).

feet per mile (1.3 degrees). Local, minor folds have resulted in dips as high as 45 degrees near surface exposures (Lonsdale and Day, 1937).

Santo Tomas coal zone occurs 30 feet stratigraphically above the Bigford-El Pico Clay contact leaving as much as 90 feet separating the two major coal zones (figs. 7, 8). The El Pico Clay contains at least seven coal seams 6 or more inches thick. Surface exposures of Santo Tomas zone extend from near Palafox south along the breaks of the Rio Grande to a point just southeast of Dolores where the outcrop trend is crossed by the river. Subsurface extent of Santo Tomas coal is not well known; however, extensive mining of 2- to 3-foot-thick beds of cannel coal occurred from Dolores northwest to Santo Tomas. Farther north, cannel coal beds are replaced by several lignite seams in addition to clays and bone coal (Lonsdale and Day, 1937). Southeasterly regional dip is about 90 feet per mile (~1 degree), but steeper dips to the east, northeast, and northwest are noted in the mining district. Several minor-displacement faults are present locally (Lonsdale and Day, 1937).

Mine records indicate that exploitable coal seams are carried about 100 feet deep for every surface mile downdip from outcrops. In the Santo Tomas mine, Santo Tomas coal occurs at 165 feet (mine located more than 1 mile downdip from outcrop). In Darwin mine, Santo Tomas coal is encountered at 50-foot and San Pedro coal at 140-foot depths (mine located about one-half mile downdip from outcrop). In Dolores mine, Santo Tomas coal is at 110 feet and San Pedro coal at 200 feet (mine located 1 mile downdip from outcrop).

Early estimates that the cannel coalfield extended north into Dimmit and Zavala Counties do not appear justified. Well records from northwestern Webb County do not indicate coal extending beyond northwesternmost surface exposures (Lonsdale and Day, 1937). Reports of coal in Eocene (Claiborne Group) strata in Dimmit and Zavala Counties may represent local accumulations of age-equivalent deposits formed within the same depositional basin as the Webb County cannel coal (Maxwell, 1962). Recent preliminary review of data available from Texas Water Development Board well records shows the presence of coal several miles downdip from surface exposures, but correlation of widely spaced well data with Santo Tomas or San Pedro seams is not yet possible. Cannel coal and associated lignite minable with present technology is probably restricted to areas near surface exposures.

Regional basin analysis of Eocene Queen City depositional systems show Bigford Formation strata represent meanderbelt and stacked coastal barrier facies associated with southeast-prograding high-destructive wave-dominated delta systems (Garcia-Solorzano, 1972; Guevara and Garcia, 1972). El Pico Clay units represent lagoonal muds genetically related to high-destructive deltas formed landward (northwest) of coastal barrier sand bodies. Associated coal probably formed from accumulations of finely divided organic matter (spores, pollen, cuticles, etc.) drifting into a lagoon behind a coastal barrier bar. Associated with the influx of organic material would be inorganic detritus, producing a high ash content in the coal. Until detailed study, including petrographic analysis, of the coal and associated strata is completed, the significance of the cannel nature of the Webb County coal in terms of depositional environments is conjectural.

Coal Characteristics and Quality

Cannel coal is not classified as to rank in the traditional lignite-bituminous-anthracite series because chemical and physical characteristics differ from more typical coal types. The inferred origin of cannel coals accounts for their unique properties. Generally, such coals are believed to be accumulations of finely divided organic matter formed in standing bodies of water. The organic matter is one or more of several particles—spores, pollen, cuticles, algae, or even plankton. As a result of the particular depositional environment and the waxy, resinous nature of the preserved organic material, such coals are characterized by very high volatile-matter and low moisture contents. Further, cannel coals have a distinctive physical appearance as typified by Webb County cannel coal—glossy black color, fine-grained massive appearance, physically very hard, and relatively nonweathering. Webb County cannel coal displays conchoidal fracture with parallel-to-bedding splitting common in ashy, less cannel-like seams. A vertical cleavage (cleat) oriented N 30° E is present and was utilized in mining as drifts followed cleat direction (Ashley, 1919). Lack of slacking tendency is confirmed in mine dumps where lumps of cannel coal still appear fresh after 40 years exposure.

Table 3. Chemical analyses of Eocene (Claiborne) cannel coal, Webb County, Texas. Data from original sources where available; see Appendix II for sample descriptions and sources of analyses. Values not shown were not determined in original analyses.

	Proximate Analysis (as received)							Proximate Analysis (dry basis)						Ultimate Analysis (dry basis)					
Sample No.	Moisture	Volatile Matter	Fixed Carbon	Ash	Total	S	Btu	Volatile Matter	Fixed Carbon	Ash	Total	S	Btu	C	H	O	N	S	Ash
1	2.50	51.05	39.10	7.35	100.00	1.50													
2	2.35	42.67	37.57	16.55	99.14	0.86													
3	2.26	48.64	36.15	12.95	100.00														
4	2.63	45.67	39.96	11.74	100.00														
5	2.70	49.99	37.55	9.76	100.00														
6	2.01	48.33	33.15	16.51	100.00														
7	2.33	49.35	38.08	10.24	100.00														
8	4.09	47.95	38.89	9.07	100.00	2.45	11,052	50.00	40.55	9.45	100.00	2.56	12,566	69.55	5.58	11.32	1.54	2.56	9.45
9	3.46	48.84	36.61	11.09	100.00	2.09	12,036	50.70	37.93	11.37	100.00	2.17	12,470	69.04	5.94	7.73	3.75	2.17	11.37
10	1.00	51.87	36.46	10.46	99.79		12,401												
11	2.30	52.78	37.10	7.82	100.00	2.20	12,315	54.00	37.97	8.03	100.00	2.25	12,604	71.04	5.65	10.03	3.00	2.25	8.03
12	2.80	49.05	37.04	11.11	100.00	2.04	11,412	50.45	38.10	11.45	100.00	2.09	11,740	66.06	5.72	12.18	2.50	2.09	11.45
13	3.97	43.63	36.15	16.25	100.00	4.18	11,588	45.43	37.65	16.92	100.00	4.35	12,067						
14	3.00	48.87	39.52	8.61	100.00	3.52	13,107	50.34	40.71	8.95	100.00	3.63	13,509						
15	4.00	45.50	37.67	12.83	100.00	1.97	12,000	47.52	39.18	13.30	100.00	2.05	12,470						
16	2.60	46.49	38.98	11.93	100.00	2.34	12,339	47.70	40.00	12.30	100.00	2.40	12,660						
17	2.50	45.27	29.27	22.96	100.00	2.44	10,917	46.40	30.00	23.60	100.00	2.50	11,190						
18	2.96	47.42	35.69	13.93	100.00	2.32	11,863												
19	3.0	43.3	36.8	13.8	96.9														
20	4.45						10,889	42.54	36.88	20.58	100.00	2.87	11,396						
21	5.50	37.31	38.14	19.05	100.00	2.66	10,752	39.48	40.36	20.16	100.00	2.82	11,377						
22	10.10	36.59	32.09	21.22	100.00	0.62	8,617	40.70	35.70	23.60	100.00	0.69	9,585						
23	6.00	40.23	29.52	24.25	100.00	0.62	10,182	42.80	31.40	25.80	100.00	0.67	10,832						
24	3.8	42.8	35.5	17.6	99.7	1.4	11,400	44.6	37.0	18.3	99.9	1.5	11,850						
25	4.2	42.8	37.2	15.9	100.1	1.9	11,550	44.6	38.8	16.5	99.9	2.0	12,060						
26	3.9	44.5	36.9	14.4	99.7	1.7	11,870	46.4	38.4	15.0	99.8	1.8	12,360						
27*	4.4	44.2	33.6	17.7	99.9	1.7	11,230	46.2	35.2	18.5	99.9	1.7	11,750						
28*	4.4	46.0	30.5	19.0	99.9	2.0	11,070	48.1	31.9	19.8	99.8	2.1	11,580	64.0	5.5	9.1	1.2	2.1	19.8
29*	3.9	48.8	34.9	12.2	99.8	1.9	12,230	50.9	36.4	12.8	100.1	2.0	12,740	68.3	6.0	9.5	1.3	2.0	12.8
30*	3.6	31.6	20.9	43.7	99.8	1.3	7,230	32.8	21.7	45.4	99.9	1.4	7,510	40.4	4.1	7.9	0.6	1.4	45.4
31	4.1	46.0	35.6	14.3	100.0	1.4	11,900												
32	4.1	47.0	39.5	9.4	100.0	2.0	12,660	49.0	41.2	9.8	100.0	2.1	13,200						
33	3.6	47.1	38.3	11.0	100.0	2.5	12,510	48.9	39.7	11.4	100.0	2.6	12,980						
34	4.4	47.6	39.0	9.0	100.0	1.7	12,640	49.8	40.8	9.4	100.0	1.8	13,220						
35	3.6	45.3	39.7	11.4	100.0	2.6	12,540	47.0	41.2	11.8	100.0	2.7	13,010						
36	4.0	47.9	38.8	9.3	100.0	2.2	12,770	49.9	40.4	9.7	100.0	2.3	13,300						
37	3.8	44.2	39.6	12.4	100.0	2.7	12,220	45.9	41.2	12.9	100.0	2.8	12,700						
38	4.2	44.1	40.1	11.6	100.0	2.8	12,360	46.0	41.9	12.1	100.0	2.9	12,900						
39	3.7	46.2	35.8	14.3	100.0	1.4	11,950	48.0	37.1	14.9	100.0	1.5	12,410						
40	3.8	47.0	36.4	12.8	100.0	2.7	12,080												
41	4.7	44.8	39.2	11.3	100.0	2.7	12,070												
42	3.1	44.7	37.1	15.1	100.0	3.1	11,720												
43	4.7	44.2	36.9	14.2	100.0	3.0	11,670												
44	4.1	44.8	37.8	13.3	100.0	2.8	11,900	46.7	39.4	13.9	100.0	2.9	12,400	66.1	5.7	10.0	1.4	2.9	13.9

*More detailed analyses of these same samples found in Fieldner and others (1922) and U. S. Bureau of Mines (1948).

Chemical analyses of Santo Tomas district coal reflect the unusual chemical properties of cannel coal (table 3). Moisture content varies from 2.0 to 4.4 percent; ash (as received), 7.8 to 22.9 percent; volatile matter (as received), 40.6 to 52.7 percent; fixed carbon (as received), 29.2 to 39.5 percent; and sulfur, 1.0 to 4.0 percent. Moist Btu values per pound of coal range from 10,900 to 13,100. Summarizing, proximate analyses indicate that Webb County cannel coals are low-moisture, high-ash, and high-sulfur coals. Ultimate analyses show no unusual trends; however, early analyses indicated a high nitrogen content which subsequent analyses did not confirm (Ashley, 1919; Fieldner and others, 1922).

High volatile-matter content is distinctive for cannel coals and Santo Tomas district cannel coal yields significant amounts of gaseous hydrocarbons (high-temperature distillation) and liquid hydrocarbons (low-temperature distillation). See table 4 for a summary of distillation tests. High-temperature distillation produces a methane-hydrogen gas mixture suggesting that these coals could produce significant quantities of potentially useful gas. Low-temperature distillation yields large amounts of liquid hydrocarbons. Oil produced in this manner is suitable mainly as a heating oil, flotation oil, or other special-use oil. Catalytic cracking would be necessary to produce gasoline and other low-weight hydrocarbon products (Maxwell, 1962).

Estimates of Coal Resources and Reserves

Accurate evaluation of Webb County cannel coal resources and reserves is not possible without regional subsurface study to identify total coal resources, and a detailed exploration program involving geophysical logging and coring techniques to determine actual coal reserves.

Early estimates of total coal resources (Owen, 1889) suffered from a lack of knowledge of coalfield size. Cannel coals in Webb County were considered part of the "Nueces coal field"—including Cretaceous bituminous coal in Maverick County, lignite from Wilcox strata in northern Zavala County, as well as possible cannel coal equivalents in Dimmit County (Ashburner, 1889; Dumble, 1892; Jeffreys, 1920). A recent estimate (Mapel, 1967) of "inferred original resources" utilizes subsurface information that limits coalfield extent (Lonsdale and Day, 1937) and clarifies the stratigraphic position of Webb County coal delineated by several previous workers. Following certain assumptions, Mapel (1967) inferred original resources for Santo Tomas district as follows: Santo Tomas seam (2.0 feet thick over 40 square miles)—90 million short tons; San Pedro seam (1.5 feet thick over 10 square miles and 1.2 feet thick over 5 square miles)—24 million short tons. In rounded figures, total coal resources are 115 million short tons.

Estimates of coal reserves, however, require more detailed information than is presently available to the public. An exploration program, using geophysical logging techniques to identify coal intervals and then coring the intervals of interest, is a minimum step toward reserves evaluation.

Potential for Development

Cannel coal in Webb County comprises an interesting and unusual deposit. High volatile content is reflected in large yields of gaseous and liquid hydrocarbons, as indicated by distillation tests. It is conceivable that future use of these coals may be in production of various petrochemical products rather than in direct combustion. High sulfur content in Webb County cannel coals presents a troublesome problem in development considerations, but various techniques (e.g., gasification) exist or are being tested which ameliorate deleterious effects of sulfur oxide emissions and at the same time exploit the significant chemical character of these cannel coals.

Major considerations for potential development of Webb County cannel coals are: (1) necessity for a detailed exploratory drilling program to identify coal reserves, (2) transportation problems caused by moderate to large distances from potential markets, (3) high sulfur content requiring either remedial measures to insure appropriate mine and processing plant operations or utilization techniques that do not produce sulfur oxide emissions, and (4) potential lack of a readily available water supply that would support major industrial development and mine-mouth operations.

TABLE 4. Results of low- and high-temperature distillation tests of Eocene (Claiborne) cannel coal, Webb County, Texas (after Phillips and Worrell, 1913; and Ashley, 1919).

LOW-TEMPERATURE DISTILLATION

Oil:	
gallons per ton of coal	52.2
percent by weight of coal	20.2
specific gravity at $\frac{60^\circ}{60}$ F	0.938
nonliquid at 60° F.	
Gas:	
cubic feet per ton of coal, collected over water at 0° C and 760 mm Hg pressure	5,672
Water:	
percent by weight of coal condensed	9.5
Loss in distillation:	
percent by weight	44.3

HIGH-TEMPERATURE DISTILLATION

Mine and Analysis Number from table 3	Darwin 11	Santo Tomas ?	Santo Tomas 12
Gas yield per ton of coal (cubic feet)	7,320	6,600	7,147
Composition of gas:			
Illuminants (percent)	5.5	5.4	5.4
Carbon monoxide (percent)	2.1	11.8	6.6
Hydrogen (percent)	42.0	40.0	43.6
Methane (percent)	43.9	39.0	36.2
Nitrogen (percent)	6.5	3.5	8.2
Specific gravity	0.385	0.428	0.424
Candlepower	16.0	6.5	15.4
Heating value per cubic foot:			
Observed	687	724	702
Calculated	630	702	667
Composition and character of residue:			
Volatile matter (percent)	3.51	---	8.11
Fixed carbon (percent)	78.31	---	73.63
Ash (percent)	18.18	---	18.26
Sulfur (percent)	2.01	---	1.35
Btu/lb coal (percent)	12,050	---	11,664
Yield (percent)	61.25	---	62.5
Character of coke	Fair	---	Fair

OLMOS FORMATION (CRETACEOUS) COAL, NEAR EAGLE PASS, MAVERICK COUNTY

Historical Background

The Eagle Pass area coalfield was one of Texas' most productive fields. Coal was mined for more than 70 years, with major production limited to 40 years between the mid-1880's and mid-1920's. Mining in Maverick County apparently began with the establishment of Fort Duncan in 1849 (Plummer, J. B., 1851). Fort Duncan soldiers mined coal seams 6 miles north of their encampment. United States - Mexican boundary surveys mention Eagle Pass coals and tie the origin of the name of Eagle Pass' sister town, Piedras Negras ("black rocks"), to the outcrops of 3- to 4-foot layers of "bitumen-rich coal" along the river (Schott, 1857). Utilization of nearby coal fueled early dreams of coal-fired steamboats plying their way up and down the Rio Grande (Cazneau, 1852). Though Eagle Pass never became a "riverport," coal use continued as a local blacksmith mined coal for markets as far away as San Antonio (Emory, 1857). Such far-ranging enterprise, however, was doomed by transportation expenses and Indian interference.

Geologic aspects of Eagle Pass coal were studied first by W. H. Adams and E. J. Schmitz. Adams described coal-bearing rocks as "Permian" (Adams, 1882). Schmitz was the first worker to recognize a Cretaceous age, calling these coals "mid-Cretaceous" (Schmitz, 1885). He estimated coalfield extent (10 by 20 miles, dipping 1 to 4 degrees southeast) and described the first measured section of Eagle Pass coal seams. Two mines—Eagle mine along Rio Escondido 5 miles west of Piedras Negras, Mexico, and Riddle and Hartz mine 3 miles northwest of Eagle Pass—were the initial large-scale mining operations. The fate of Eagle mine is not recorded in available references. Riddle and Hartz mine (commonly referred to as "Hartz mine") opened prior to 1885 and closed sometime between 1893 and 1895.

Hartz mine produced upward of 100 tons per day from its drift (tunnel) mine workings. Reports on seam thickness vary from 4½ feet to as much as 7 feet (Schmitz, 1885; Ashburner, 1887, 1889; Owen, 1888, 1889). The coal zone, including partings, ranges upward to 7 or 8 feet in thickness. Hartz mine was the largest producing mine in Texas for many years. However, a five-month fire in 1892 drastically decreased production for 1892 and 1893 (Parker, 1893, 1894) and probably contributed to the closing of the mine shortly thereafter. F. H. Hartz continued his coal mining activities by opening Maverick County Coal Company's 210-foot shaft (underground mine) in 1895.

L. F. Dolch and two associates expanded Eagle Pass area coal activity with the opening of a shaft 3 miles northeast of Eagle Pass. Work began in 1893 and with two 16-foot-wide, 18-foot-long drifts driven from the 210-foot shaft, production began as the Eagle Pass Coal and Coke Company in January, 1899 (Vaughn, 1900; "Eagle Pass Guide," 1898). Southern Pacific railroad interests formed the Rio Bravo Coal Company in 1899 and leased the 150-tons-per-day operation from Eagle Pass Coal and Coke Company to supply coal for their engines. However, when railroads began to switch from coal-fired engines, Southern Pacific gave up the lease. The mines continued to flourish, producing as much as 500 tons per day near the time L. F. Dolch died in 1907. International Coal Mine Company took over the Dolch operations, increased production to 1,000 tons per day, expanded markets into San Antonio and Mexico, and sank a new shaft (International No. 2). Coal production stopped in Shaft No. 1 between 1911 and 1914 with Shaft No. 2 producing until sometime between 1921 and 1924 (Annual Reports of State Mine Inspector, 1911, 1914, 1921, and 1924).

The Maverick County Coal Company, owned by Hartz and others and located 5 miles northeast of Eagle Pass, became the Olmos Coal, Coke, and Oil Company, owned by Pasquale and Rocco DeBona. Operations were subsequently expanded. Around 1907, a washing plant was built along Lamar Spur and a new shaft, only 50 to 55 feet deep, was opened near Olmos Siding. The Olmos mines reached a maximum production of 1,200 tons per day before oil and gas competition began to force production cutbacks. The older shafts closed between 1911 and 1914, but Lamar mine continued production until between 1924 and 1928. See figure 9 for locations of mining operations near Eagle Pass.

Inadequate records limit accuracy of accounts of mining history. Some reports indicate

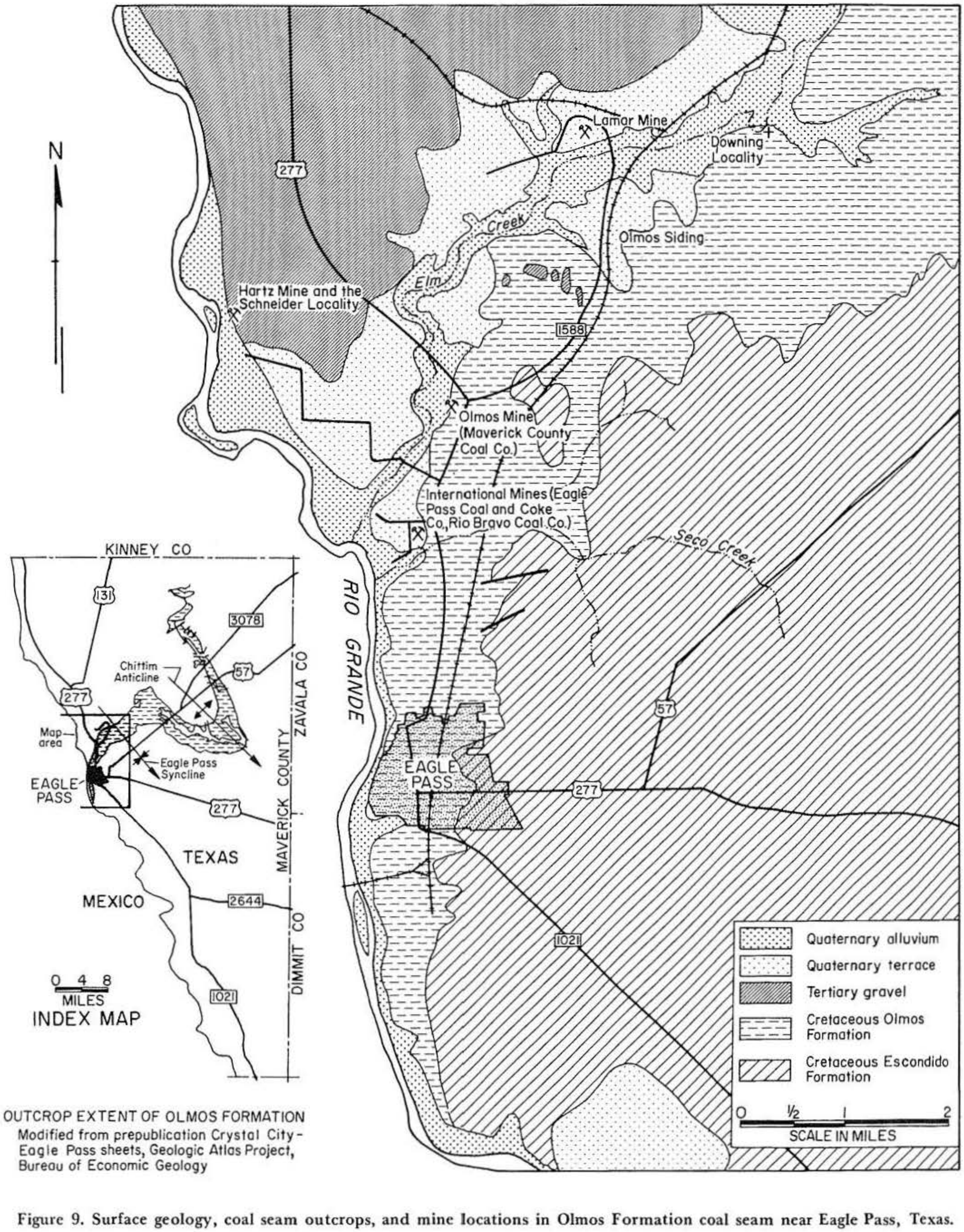
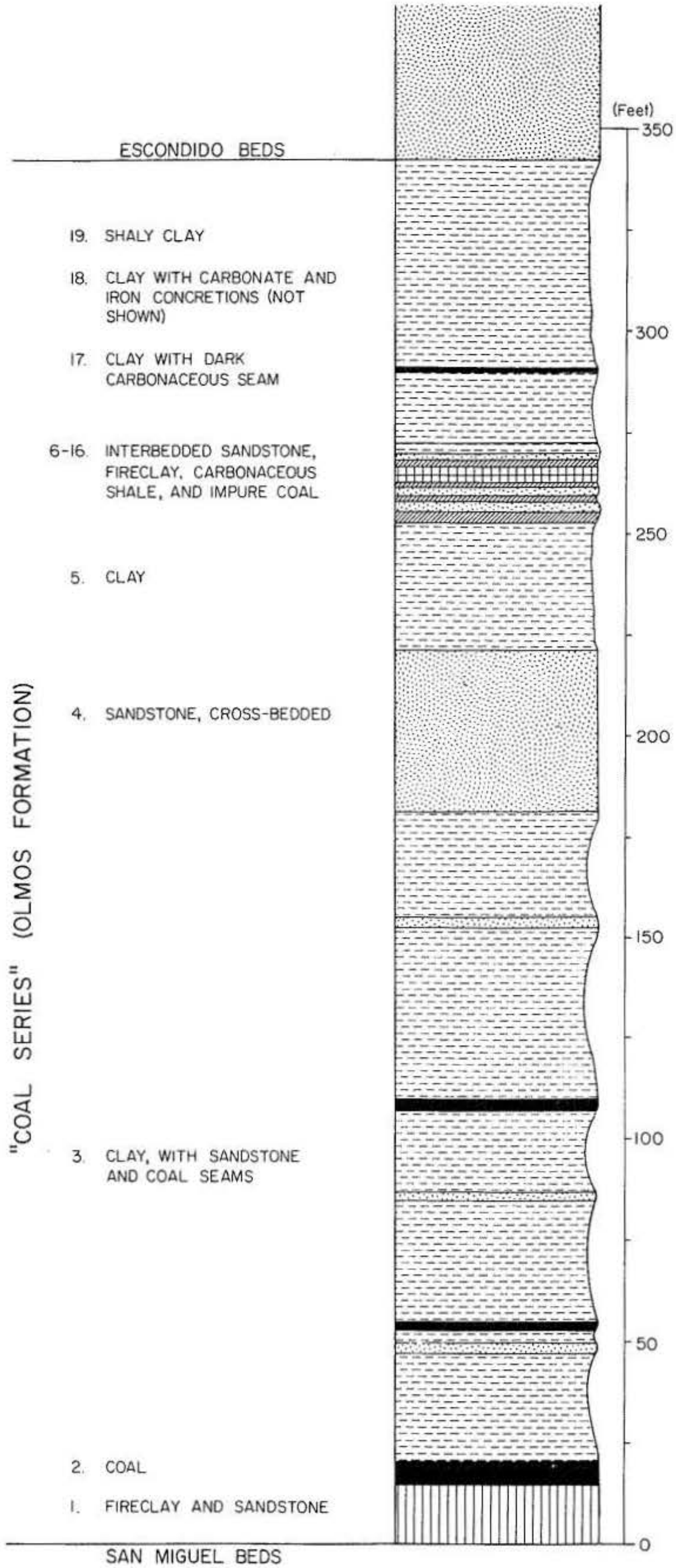


Figure 9. Surface geology, coal seam outcrops, and mine locations in Olmos Formation coal seam near Eagle Pass, Texas.



production continued until 1925 and 1927 (Maxwell, 1962) though local historians claim production ended before World War I (Ben Pingenot and Charles Downing, oral communication, 1973). Since State Mining Board and Mine Inspector's Reports (available only for the years 1911, 1914, 1919, 1920, 1921, 1924, and 1928) indicate some production possibly as late as 1928, it seems reasonable to conclude that Eagle Pass area mines experienced major production declines prior to World War I with minor production lasting into the 1920's when oil and gas competition finally forced a complete shutdown of coal mining operations.

Geologic Setting

Eagle Pass area bituminous coals occur in Upper Cretaceous (Navarro Group) Olmos Formation. Olmos lithologies include interbedded shales and crossbedded and rippled sandstones, carbonaceous shale, fireclay, and coal (fig. 10; Udden, 1907a). Thickness varies from 300 to 600 feet in outcrop and increases downdip to the southeast (Adkins, 1932).

Outcrop distribution in Maverick County is controlled by major structural features. Olmos Formation rocks extend from 3 miles south of Eagle Pass, northward some 8 miles along Elm Creek, then east and south along Chittim anticline turning north into north-central Maverick County, 25 miles northeast of Eagle Pass (fig. 9).

Structural setting of Olmos coal-bearing strata not only influences outcrop distribution, but also results in steep southeasterly dips that carry coal seams to great depths over short surface distances. Coal crops out along the northwest and north rim of Eagle Pass syncline with the southeast-plunging axis located some 10 miles east of Eagle Pass (fig. 9). Farther to the east, Olmos units occur in surface expressions of Chittim anticline, a major oil-producing structure in central Maverick County. Dips along major structures vary (Comstock, 1892) with coal beds plunging 200 feet or more in depth within 2 miles of surface exposures (as indicated by shaft depths in mines shown on figure 9—International mine, 215 feet; Olmos mine, 210 feet; Lamar mine, 55 feet; and Hartz mine, outcrop on hillside with 30-65 feet overburden).

Figure 10. (left) Composite measured section of Olmos Formation ("Coal Series") from Udden (1907a).

Many workers (Schmitz, 1885; Vaughn, 1900) felt that Navarro-age coal-bearing strata were equivalents of coal-bearing rocks located some 80 miles to the southwest in Sabinas Coal Basin in northern Mexico. A 4- to 5-foot coal seam in Olmos-equivalent strata is mined 5 miles west of Piedras Negras. Upper Cretaceous coals in Mexico are better quality than Olmos Formation coals. This leads some workers to conclude that Maverick County coals were formed along the northern edge of a Cretaceous deltaic swamp environment, resulting in thinner, more numerous, lower quality (high ash) coal seams (fig. 11).

Actually, detailed analysis of Olmos Formation and equivalent units in terms of depositional environments has not been attempted. Understanding the Olmos depositional framework could yield more definitive information on coalfield extent and coal quality.

Recent investigation indicates two major outcrops near Eagle Pass with Olmos Formation bituminous coal under thin overburden (Maxwell, 1962). Thirty to 65 feet of Tertiary gravel covers a 4½- to 8-foot zone of coal exposed in a small canyon on Topat Ranch (Tom Schneider, owner) 6 miles northwest of Eagle Pass. This outcrop occurs near the opening (now concealed) of the old Hartz mine. Thirty-two inches of coal and 13 inches of carbonaceous shale are exposed at water level along Elm Creek 8 to 9 miles northeast of Eagle Pass on property owned by Charles Downing. Only 20 to 40 feet of fine-grained clastic material overlies this coal. Both exposures of surface and near-surface coal suggest that exploration in these and other areas may be justified.

Coal Characteristics and Quality

Olmos Formation coal appears dark brownish black with a lustrous surface on fresh samples. Subcubical cleavage is common. Reports on lack of air-slacking tendency (Vaughn, 1900) are borne out by examining coal samples near Lamar mine which still appear relatively fresh after 40 years' exposure on mine dumps.

All proximate and ultimate analyses reported in available literature are presented in table 5. Proximate analyses indicate that Eagle Pass area bituminous coals are high in ash content and moderate in moisture and sulfur content. Btu values range from 8,792 to 14,020 per pound of coal (weathered-outcrop analyses excluded). More than 30 proximate analyses indicate that Olmos coal ranks as a high-volatile B bituminous coal. Analyses of channel samples from weathered outcrop (table 5, samples 39-42) are probably not indicative of actual coal quality.

Estimates of Coal Resources

The most recent estimate of Eagle Pass area Olmos Formation coal resources is 525 million short tons (Mapel, 1967). This estimate of "total inferred original resources," based on several assumptions, includes two coal seams with resource values of 125 million short tons (6.0-foot-thick bed) and 400 million short tons (2.0-foot-thick bed), respectively. Information on coal bed thickness, structural attitude, and areal extent come from major literature sources (Mapel, 1967) including Vaughn (1900), Baker (1934), and U. S. Bureau of Mines (1948). Subsurface information from these and other sources is limited and the data for estimates based on these sources are likewise limited. However, Mapel's estimate is the best evaluation presently available of total resources for Eagle Pass bituminous coal.

Recent preliminary review of well logs on file at Texas Water Development Board in Austin indicates that coal seams may be present in the subsurface in areas not previously reported to contain coal (specifically, east of Chittim anticline). Limited aerial reconnaissance of surface exposures of coal east of Chittim anticline lends support to interpretations of the presence of coal beds in the subsurface (see well records for T. G. Shaw, Chittim Estate No. 11; Southworth and Wood, Mrs. Fritz Tessman No. 2; and Southern Union Production Company, H. A. Franke No. 7). Detailed analysis of well logs, surface exposures, and depositional framework of coal-bearing units is necessary before modification of published resource estimates is justified.

Potential for Development

Evaluation of development potential of Eagle Pass area bituminous coal is dependent on first delineating coalfield size, seam thickness, and coal quality. Early estimates of coalfield size ranged up to 120 square miles, extending into nearby counties to the east and southeast (Owen, 1888). Such estimates did not consider structural effects or actual stratigraphic setting of coal beds

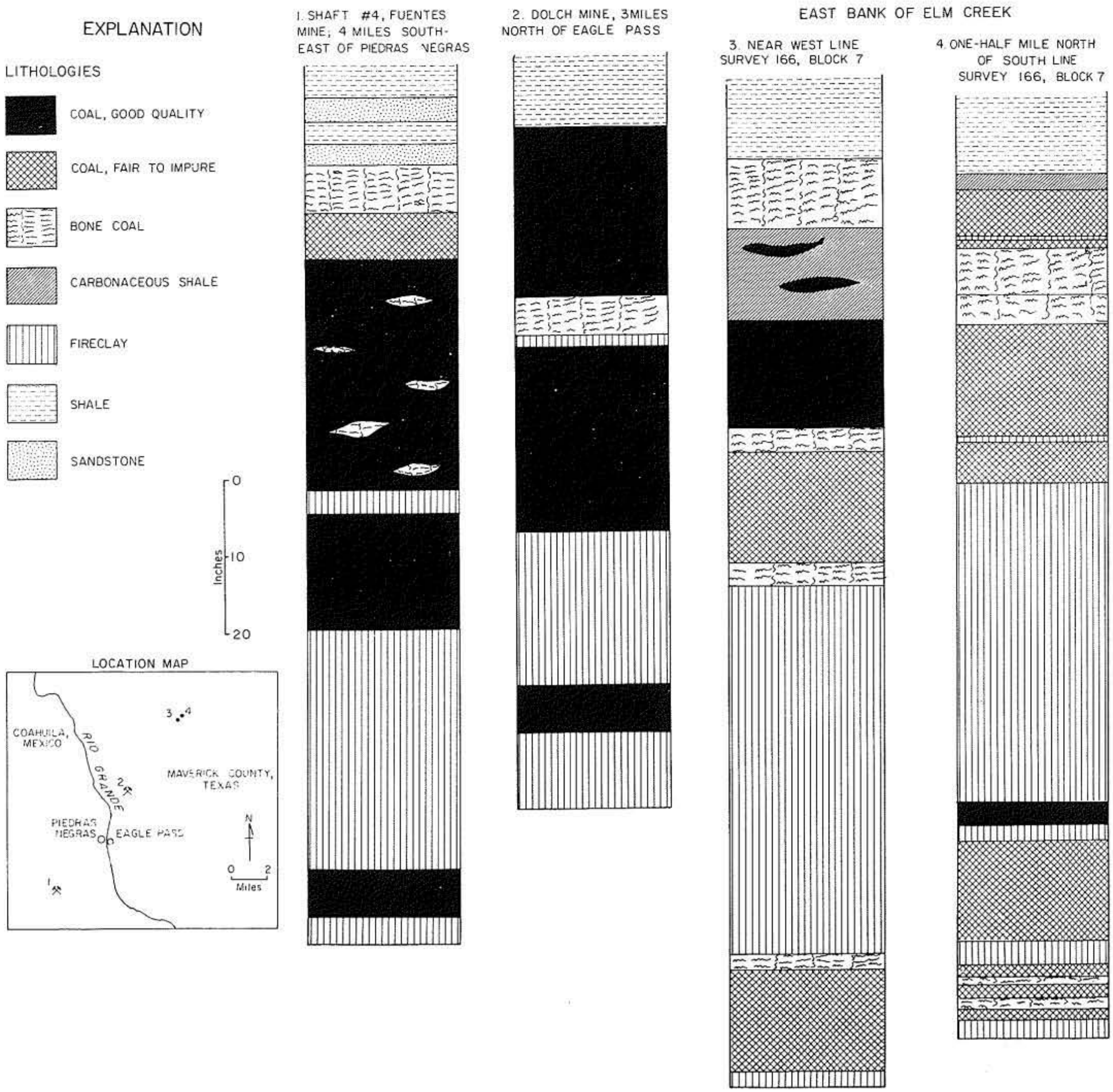


Figure 11. Measured sections of Olmos Formation coal seam. Data from Udden (1907a).

Table 5. Chemical analyses of Cretaceous (Navarro) Olmos Formation bituminous coal, Maverick County, Texas. Data from original sources where available; see Appendix II for sample descriptions and sources of analyses. Values not shown were not determined in original analyses.

Sample	Proximate Analysis (as received)							Proximate Analysis (dry basis)						Ultimate Analysis (dry basis)					
No.	Moisture	Volatile Matter	Fixed Carbon	Ash	Total	S	Btu	Volatile Matter	Fixed Carbon	Ash	Total	S	Btu	C	H	O	N	S	Ash
1*	3.68	39.42	41.70	15.21	100.00	0.81		40.92	43.29	15.79	100.00								
2	2.50	40.60	42.72	14.18	100.00														
3	9.40	33.08	40.09	17.43	100.00	1.28	11,149	36.52	44.26	19.22	100.00	1.42	12,317	64.06	4.57	8.92	1.81	1.42	19.22
4	6.91	38.16	36.82	18.11	100.00	1.96	11,472	41.11	39.56	19.44	100.00	1.28	12,324	63.22	4.87	10.32	0.87	1.28	19.44
5	4.85	38.30	46.30	10.55	100.00	2.04	11,128	40.25	48.65	11.10	100.00	2.14	11,695	67.38	4.83	13.08	1.47	2.14	11.10
6	8.20	35.99	53.00	2.81	100.00	1.66	11,500	39.20	57.73	3.07	100.00	1.80	12,527	74.74	5.08	13.67	1.64	1.80	3.07
7	6.50	31.51	37.37	24.62	100.00	1.87	9,070	33.70	39.96	26.34	100.00	2.00	9,636	55.44	4.14	9.56	2.52	2.00	26.34
8	5.40	35.95	42.09	16.56	100.00	1.23	10,921	38.00	44.49	17.51	100.00	1.30	11,545	64.12	4.92	10.41	1.74	1.30	17.51
9	5.30	35.58	38.35	20.77	100.00	1.61	10,235	37.58	40.49	21.93	100.00	1.70	10,807	60.01	4.63	9.93	1.80	1.70	21.93
10	5.70	33.48	36.93	23.89	100.00	1.70	9,819	35.50	39.16	25.34	100.00	1.80	10,412	57.20	4.40	7.96	3.30	1.80	25.34
11	4.20	36.55	32.35	26.95	100.05	1.71	9,772	38.15	33.76	28.09	100.00	0.74	10,200	50.44	4.04	13.96	2.73	0.74	28.09
12	3.64	28.82	37.20	30.34	100.00	0.54	10,600	29.90	38.60	31.50	100.00	0.56	11,000	51.23	3.73	11.78	1.20	0.56	31.50
13	4.90	33.10	37.28	24.72	100.00	1.55	9,871	34.80	39.19	26.01	100.00	1.62	10,380	56.08	4.00	10.98	1.31	1.62	26.01
14	5.20	34.53	40.94	19.23	99.90	1.48	10,163	36.42	43.07	20.51	100.00	1.56	10,720	56.72	4.13	14.95	2.13	1.56	20.51
15	5.30	37.11	41.69	15.90	100.00	1.14	10,808	39.18	44.02	16.80	100.00	1.20	11,412	62.08	4.20	14.00	1.72	1.20	16.80
16	1.60	32.40	58.95	7.05	100.00	1.70	14,020												
17	2.80	32.80	55.55	8.85	100.00	0.80	13,165	33.74	57.15	9.11	100.00	0.82	13,544						
18	11.11	28.53	42.26	18.10	100.00	1.06	9,698	32.10	47.54	20.36	100.00	1.19	10,910						
19	7.98	30.00	40.06	21.96	100.00	0.94	9,681	32.60	43.54	23.86	100.00	1.02	10,520						
20	8.68	30.94	42.94	17.44	100.00	0.90	10,361	33.88	47.02	19.10	100.00	1.02	11,455						
21	8.83	32.68	44.89	13.60	100.00	0.90	10,941	35.84	49.24	14.92	100.00	0.99	12,001						
22	7.48	32.18	45.67	14.67	100.00		11,530												
23	6.43	32.43	42.88	18.26	100.00		11,240												
24	6.43	29.33	40.73	23.51	100.00		10,146												
25	1.50	33.40	58.95	6.15	100.00	1.70	14,020	33.91	59.85	6.24	100.00	1.73	14,213						
26	7.10						11,323	37.73	47.02	15.25	100.00	1.00	12,188						
27	6.76	27.04	33.66	32.54	100.00	1.79	8,792	29.00	36.10	34.90	100.00	1.92	9,429						
28	5.20							32.13	41.92	25.95	100.00	0.91	10,147						
29	5.22							36.57	45.76	17.67	100.00	0.90	12,165						
30	4.50							37.70	42.30	20.00	100.00	2.10	11,250						
31	9.10	29.20	38.90	22.80	100.00	1.39	10,754	32.12	42.79	25.09	100.00	1.53	11,831						
32	8.70	32.90	38.20	20.20	100.00	1.26	9,819												
33	8.96	32.60	40.64	17.80	100.00	1.27	10,084												
34	9.40	32.70	39.80	18.10	100.00	1.35	10,068												
35	10.76	29.84	37.10	22.30	100.00	1.46	9,008												
36	8.16	32.26	36.98	22.60	100.00	1.24	9,975	35.12	40.28	24.60	100.00	1.25	10,860						
37	7.01							35.35	40.23	24.42	100.00	1.00	10,624						
38	6.26							30.97	35.71	33.32	100.00	0.77	9,200						
39	12.76	24.82	12.18	50.24	100.00	0.17	3,060	28.45	13.96	57.59	100.00	0.20	3,506						
40	13.40	33.66	18.21	34.73	100.00	0.29	4,940	38.87	21.03	40.10	100.00	0.33	5,704						
41	20.30	39.76	17.14	22.80	100.00	0.38	5,265	49.89	21.51	28.60	100.00	0.48	6,606						
42	17.70	37.82	6.22	38.26	100.00	0.31	3,635	45.95	7.56	46.49	100.00	0.38	4,417						

*Figures shown have been rounded off from original published analysis.

and are not indicative of minable coal extent. All literature references and available well log descriptions indicate that coal thickness varies from 4 to 7 feet. Numerous analyses of coal show that, in areas of past mining activity, Olmos Formation coal was of fair quality, though with high ash content.

The Eagle Pass area was a major bituminous coal producer in the past. Reasonably thick beds of fair-quality coal occur in the area and, following a detailed exploration program, could prove indicative of a significant coal reserve for future development. Exploration should be guided by an analysis of Olmos depositonal environments for maximum effectiveness and should include an evaluation of the ease of stripping Quaternary, Tertiary, and Cretaceous units overlying Olmos coal. Recent recognition of coal outcrops on the eastern flank of Chittim anticline and preliminary review of well logs indicate that coal seams are present at the surface and in the subsurface in regions not known to have been explored previously.

Other considerations affecting major production from Eagle Pass area coals are the long haulage distances via railways or highways and the availability of water resources. Transportation costs could be high and would require an evaluation based on present and future transportation facilities. Availability of an adequate water supply to support mine-mouth operations or other industrial growth also requires evaluation before major mining development should be undertaken.

SAN CARLOS FORMATION (UPPER CRETACEOUS), NORTHWEST PRESIDIO COUNTY

Historical Background

Coal in Presidio County has been known since the mid-1880's (White, 1887; Owen, 1888). Most attention has focused on areas near San Carlos (now abandoned) located about 21 miles north-northwest of Candelaria (fig. 12). An ambitious mining effort in the 1890's quickly failed and interest in San Carlos coals has been minimal ever since.

Efforts preliminary to mining began with the filing of the San Carlos Coal Company charter in February, 1893. A major concern of mining interests was transportation from remote San Carlos to major railroad right-of-ways. Thus, Rio Grande Northern Railway was established to build a spur to Chispa Siding on the Galveston, Harrisburg, and San Antonio extension (Southern Pacific). Later, when coal production faltered, the Rio Grande Northern withdrew from its agreement to haul coal for the San Carlos Coal Company, but did agree to supply the coal company with an engine and some cars. This second agreement dissolved by the end of June, 1896, after only six months of coal production. The San Carlos Coal Company and Rio Grande Northern Railway both went out of business.

According to Bilbrey (1957), San Carlos Coal Company failed due to lack of reserves and large distances from potential markets, but naivete concerning structural complexities near San Carlos contributed significantly to the company's problems. Early reports from R. E. Russell, general manager of the coal company, predicted production of 800 to 1,200 tons per day from coal seams present in "gently dipping strata" in a "structurally uncomplicated" area (Parker, 1894). However, when a development shaft was sunk to intercept the coal seam, no coal was found; the shaft was unknowingly located near one of several faults in the area (Vaughn, 1900).

A drift mine about 1 mile east-southeast of San Carlos was the center of mining efforts, but after commencing production on January 3, 1896 (Parker, 1896), the mine closed before July of that same year. No official production figures were ever reported. A later, privately owned mine reportedly produced 400 tons of coal from a drift located 2 miles south-southeast of San Carlos (Udden, 1913). The 400-ton figure is not confirmed by other sources. By 1956, all that remained of mining operations near San Carlos were the old railroad bed with rotting ties and trestles, an old dump, an 80- to 100-foot adit, and the old shaft with 175 feet still open (Bilbrey, 1957).

Geologic study of San Carlos coals is confined to the work of T. W. Vaughn in 1895, Johan A. Udden in 1913, and several University of Texas graduate students under the direction of Ronald K. DeFord during the mid-1950's.

Vaughn (1896, 1900) expanded on the work of E. T. Dumble (1895), describing Cretaceous coal-bearing units west of Sierra Vieja as well as Tertiary sediments, volcanics, and pyroclastics forming the surrounding mountain ranges. Vaughn measured several stratigraphic sections, noted many faults and folds, and defined the San Carlos Formation (coal-bearing strata). T. W. Stanton (Vaughn, 1900) confirmed his own earlier determination (Dumble, 1895) of the age of San Carlos Formation fossils as Upper Cretaceous, presumably Taylor Group equivalent.

Udden (1913) studied coal exposures and structural features near San Carlos in detail. Noting that structural complexity increased away from mining areas and that previous mining efforts were unsuccessful, Udden concluded that prospects for development of San Carlos coal deposits were bleak.

Additional studies near San Carlos, beyond brief notations in the literature (Udden and others, 1916; Baker, 1927, 1934; Adkins, 1932; Stenzel, 1944; DeFord, 1958), were detailed mapping efforts concentrating on structural, stratigraphic, and economic aspects of Rim Rock Country geology (Miller, 1957; Bilbrey, 1957; Ferguson, 1959). Such studies update information concerning San Carlos coals.

Geologic Setting

Coal beds occur in middle to upper San Carlos Formation (redefined by Wolleben, 1966) which crops out mainly along the western flank of Sierra Vieja. Figure 12 illustrates the distribution

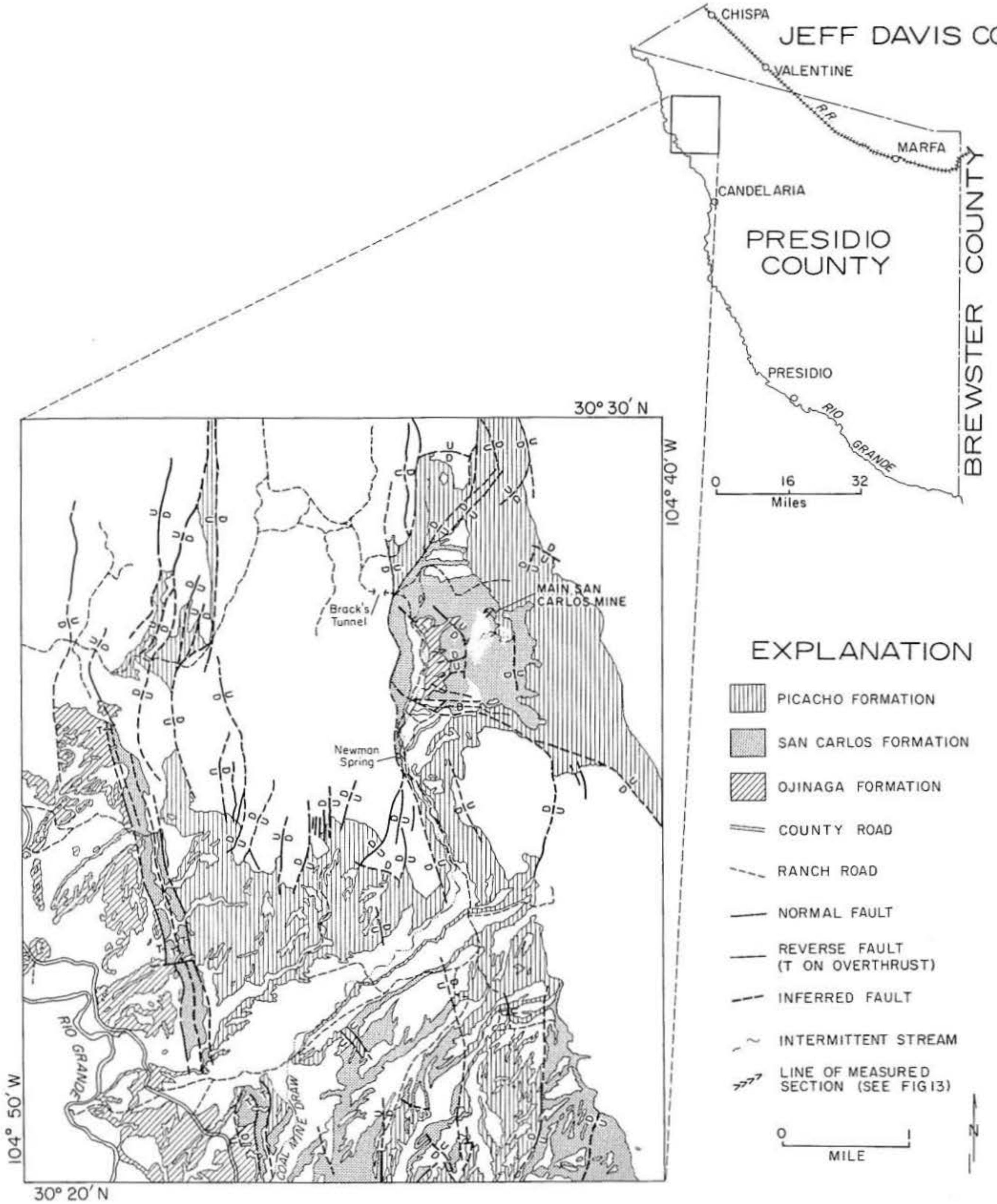


Figure 12. Surface geology and distribution of Upper Cretaceous units in San Carlos area, northwest Presidio County. Coal seams restricted to middle and upper San Carlos Formation. Geology from Miller (1957).

of San Carlos Formation near San Carlos Coal Company mining areas (modified from Wolleben, 1966). Miller (1957) and Wolleben (1966) both characterize coal seams as generally 8 to 10 inches thick. However, early workers (Vaughn, 1900; Udden, 1913) indicated that coal seams were thicker (fig. 13).

Additional discrepancies in the literature include the number of coal zones in the area. Vaughn (1900), Miller (1957), and Wolleben (1966) all report one coal zone, though several individual layers are noted. Udden (1913), however, indicates a second 12- to 18-inch-thick coal seam located 150 to 200 feet stratigraphically below the main coal zone. This lower seam is not mentioned by other workers. Also, "400 ton slope" is one of at least two mines worked by James Ingle prior to 1913, when he served as guide to Udden's field party. No subsequent worker mentions these openings, located near the old San Carlos Coal Company shaft. Figure 14 is taken from Jon A. Udden's (Johan Udden's son) detailed map (1:12,000 scale) of coal seams and pertinent structures near San Carlos coalfield, showing locations of drifts in San Carlos Formation coal beds.

Structural complexity of the San Carlos area was first alluded to by Vaughn (1900) and later studied by Ferguson (1959). Figure 12 is based on mapping by Ferguson (1959) and Miller (1957). Twiss and DeFord's geologic map (in preparation) updates the complex geologic framework of coal-bearing strata near San Carlos. Briefly, San Carlos coals crop out in an asymmetric dome (Ferguson, 1959) that is cut by numerous normal faults of the Rim Rock fault zone.

Detailed study of coal seams and coal-bearing strata indicate that coal within the valley of Arroyo Viejo west of Sierra Vieja is covered by 0 to 1,200 feet of overburden. Depth to coal increases away from exposures along Arroyo Viejo gradually to the east and more sharply to the west. South of Newman Springs, San Carlos coal occurs within 500 feet of the surface for a distance of 3 miles along the main valley (Udden, 1913).

Though detailed depositional environments analysis is lacking for San Carlos Formation units in the San Carlos area, general stratigraphic study allows some limited conclusions. Lower San Carlos Formation beds are marine, as indicated by presence of marine fossils (Miller, 1957). Upper San Carlos Formation units are nonmarine, as indicated by presence of petrified wood and dinosaur bones, and absence of marine fossils (Wolleben, 1966). The transition between marine and nonmarine deposition is gradual (no abrupt breaks in clay and other minerals composition) and is marked by a zone of sandstone, coal, and carbonaceous shale. The transition zone most likely represents shallow lagoonal or estuarine deposition along a fluctuating shoreline (Miller, 1957).

Coal Characteristics and Quality

Megascopic descriptions of San Carlos coal are brief (Vaughn, 1900; Udden, 1913). The coal is described as being lustrous black, having subcubical to cubical cleavage and dark brown streaks, and containing lenticular layers of lignitic material.

Eleven published analyses indicate that San Carlos area coal is high-volatile C bituminous or subbituminous A coal and is characterized by low moisture and high ash content (table 6). Only three analyses include Btu determinations and show values varying from 8,348 to 12,157 (as received). Sulfur content is low to moderate. Inadequate sampling and incomplete analyses hinder extensive evaluation of coal characteristics on even a general basis. Analysis of coke characteristics (Vaughn, 1900) indicated 93.7 percent combustible matter and 6.2 percent ash in 48-hour coke burned in an oven at San Carlos mine. Coke tests completed at Connelsville, Pennsylvania, in the 1890's also suggest favorable coking qualities.

Potential for Development

San Carlos Coal Company failed because of financial difficulty (coping with high transportation costs and sinking a 300-foot shaft without striking coal) and inability to identify sizeable coal reserves. These two factors embody the major obstacles to successful development of San Carlos coals: (1) inadequate information on extent of coal seams, (2) apparent thinness (<3 feet) of observable coal seams, (3) complex structural framework in San Carlos region, and (4) isolated, nearly inaccessible coalfields located west of Sierra Vieja in Trans-Pecos Texas.

One estimate of San Carlos area coal resources indicates 25 million short tons present in beds thicker than 14 inches at depths 3,000 feet or less (Mapel, 1967). This resource estimate is

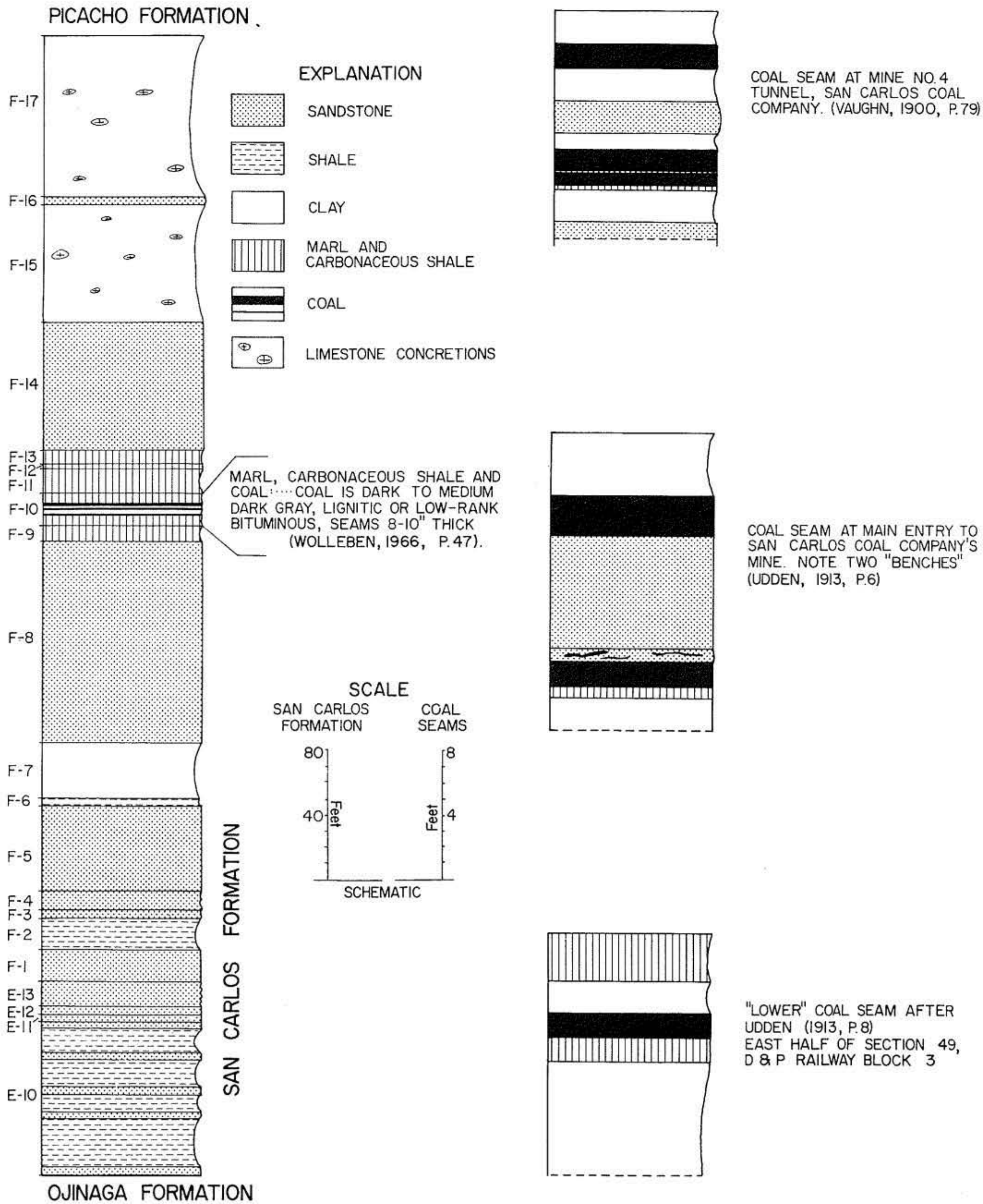


Figure 13. Lithology of San Carlos Formation and San Carlos coal. Letter-numeral combinations to left of columnar section refer to measured sections and sedimentation unit descriptions from Wolleben (1966).

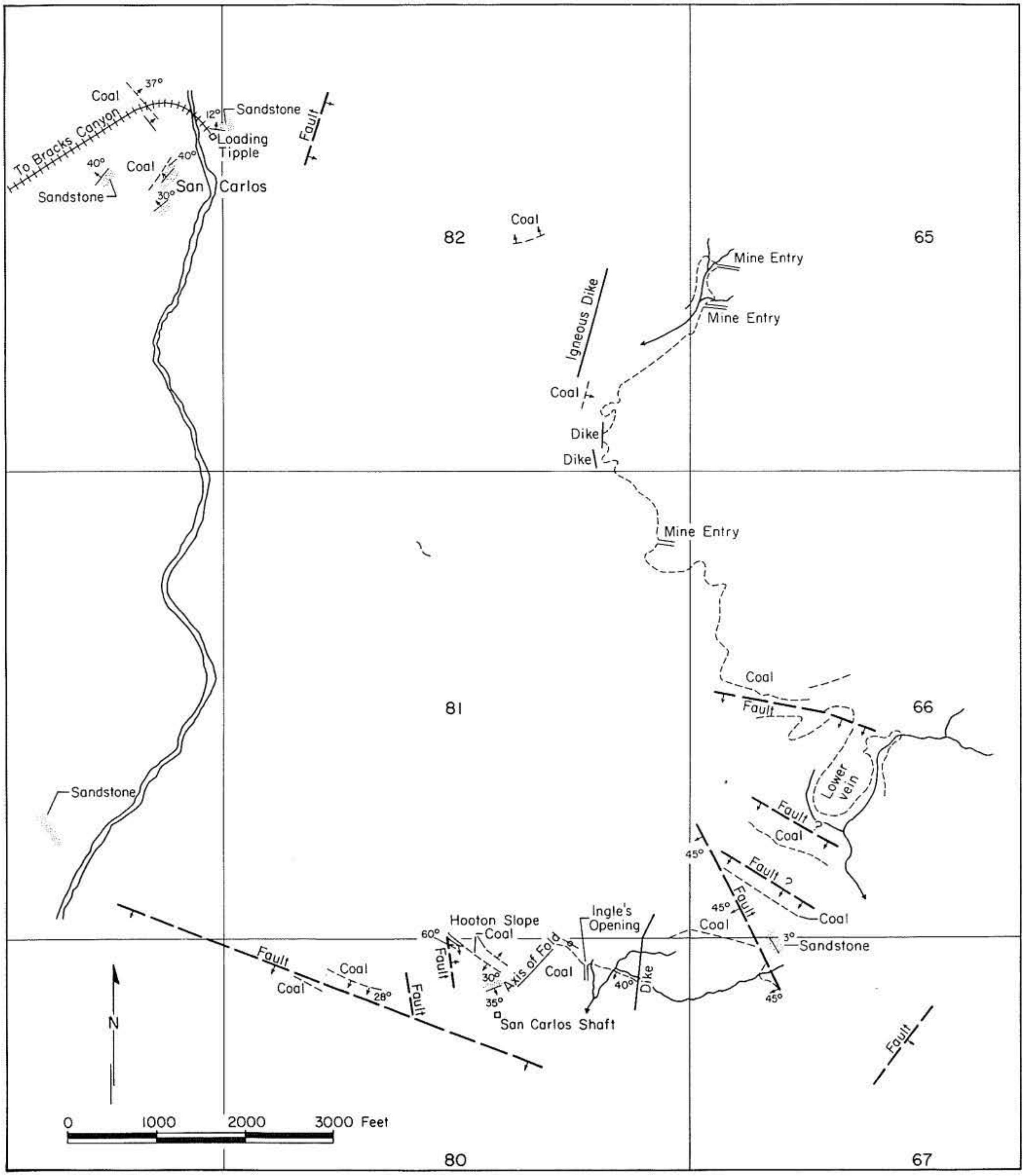


Figure 14. Detailed map of coal seam outcrop and related structures compiled by Jon A. Udden and Johan A. Udden in 1913 (Udden, 1913).

TABLE 6. Chemical analyses of San Carlos Formation (Upper Cretaceous) bituminous coal, Presidio County, Texas. Data from original sources where available; see Appendix II for sample descriptions and sources of analyses. Values not shown were not determined in original analyses.

	Proximate Analysis (as received)							Proximate Analysis (dry basis)					
Sample No.	Moisture	Volatile Matter	Fixed Carbon	Ash	Total	Sulfur	Btu	Volatile Matter	Fixed Carbon	Ash	Total	Sulfur	Btu
1	1.09	39.61	35.29	24.01	100.00								
2	1.17	39.93	35.39	23.51	100.00								
3	1.19	39.73	40.30	18.78	100.00								
4	1.68	60.37	24.89	13.06	100.00								
5	0.97	40.95	43.77	14.31	100.00								
6	1.00	39.05	49.05	10.00	99.10	Trace							
7	0.94	34.48	58.96	5.62	100.00	0.64							
8	4.60	39.20	50.10	6.10	100.00	0.62	12,157	41.13	52.47	6.40	100.00	0.64	12,757
9	4.90	32.80	43.04	19.26	100.00	0.85	9,663	34.49	45.26	20.25	100.00	0.88	10,161
10	2.47	34.84	32.36	30.33	100.00	1.61	8,348	35.72	33.18	31.10	100.00	1.65	9,585
11	5.67	14.58	4.66	75.09	100.00	0.32		15.46	4.94	79.60	100.00	0.34	

presumably based on literature descriptions of coal seam thickness and extent. Until major reserves of fair-quality coal can be proved by a detailed exploration program, excessive mine to market distances and nearly inaccessible location of potential mining sites will deter successful development of San Carlos Formation coal.

To the southwest near the Rio Grande, outcrops of obviously poor-quality coal and carbonaceous shale occur in the steeply dipping San Carlos Formation (Bilbrey, 1957). Possible use of these coals and coaly shales as a soil amender has been suggested; however, no development along these lines is known.

AGUJA FORMATION (UPPER CRETACEOUS) COAL, BIG BEND REGION, SOUTHERN BREWSTER COUNTY

Historical Background

Coal seams in Cretaceous (Gulfian Series) Aguja Formation comprise a former, locally productive coalfield near Terlingua in Brewster County. Coal beds of variable quality and limited extent and thickness were mined as a fuel supply for nearby quicksilver mining interests and, on a very minor scale, as a household fuel for local residents.

The first reference to Big Bend area coals notes a 4-foot bed located 60 miles south of Presidio del Norte, about 20 miles north of the Rio Grande (Buckley, 1876). These "Los Chisos" coals were part of the "Mountainous district" coalfield of Texas (Ashburner, 1887). Studies of quicksilver deposits and mining activity in Brewster County around the turn of the century include references to coal beds occurring in Cretaceous strata (Hill, 1902; Phillips, 1902b). Johan A. Udden and W. B. Phillips studied Big Bend regional geology in the early 1900's, sampled several coal exposures, and published analyses of these coals (Udden, 1907b; Phillips and Worrell, 1913). Udden designated coal-bearing rocks as the Rattlesnake Formation and described the general area of coal outcrops. Adkins (1932) proposed the name Aguja Formation for these strata, as the name "Rattlesnake" was used for a unit prior to Udden's designation. Phillips noted coal beds "within 8 to 10 miles of the quicksilver area" including some exposures located within 2 miles of mercury refining furnaces. He described the coal as limited to local consumption with the capability for use in steam boilers and for generation of producer gas. The Chisos Mining Company exploited nearby coal in a mine south of Adobe Walls Creek during the 1930's and early 1940's for producer gas to fuel their quicksilver refining activities.

Though Brewster County coals are mentioned in publications spanning several decades (Udden and others, 1916; Baker, 1934; Stenzel, 1944; U. S. Bureau of Mines, 1948; Lonsdale, 1950; Hopkins, 1965; Maxwell and others, 1967; McKnight, 1968), no substantive information on coal production is available.

Beginning as far back as 1945, poor-quality coal, lignite, and associated carbonaceous shales have been mined by open-pit methods for use as fertilizer and soil conditioner. This is the only known commercial utilization of Big Bend area coals and associated strata.

Geologic Setting

Aguja Formation occurs throughout the Big Bend region (figs. 15, 16; Maxwell and others, 1967) where it gradationally overlies the marine Cretaceous (Gulfian Series) Pen Formation. Though the basal Aguja contact is gradational over as much as 50 feet (Hopkins, 1965), the upper contact with nonmarine Cretaceous (Navarro Group equivalent ?) Javelina Formation is even more difficult to delineate due to a completely gradational contact (Maxwell and others, 1967).

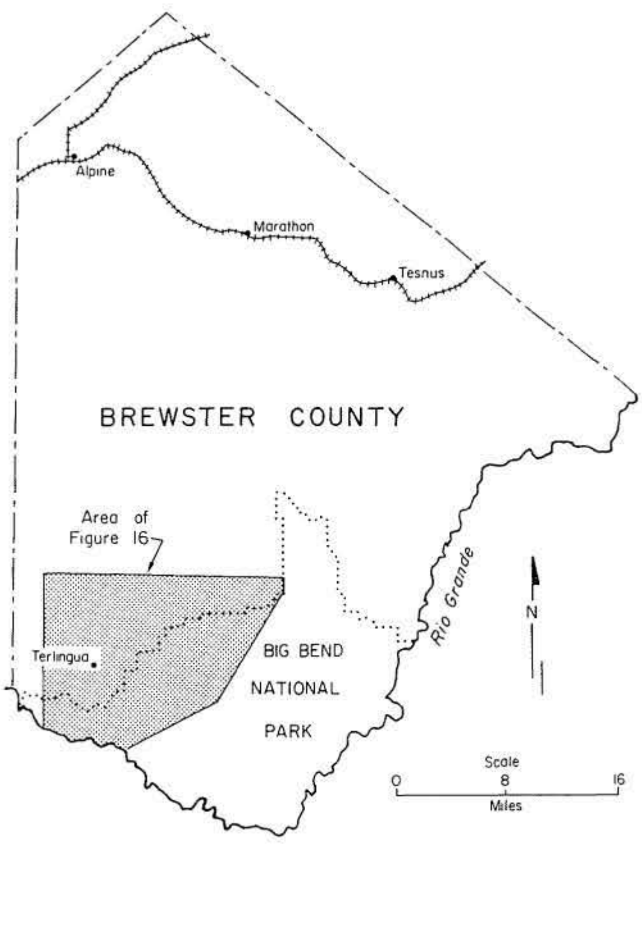


Figure 15. Location map of Aguja Formation coal region in southern Brewster County.

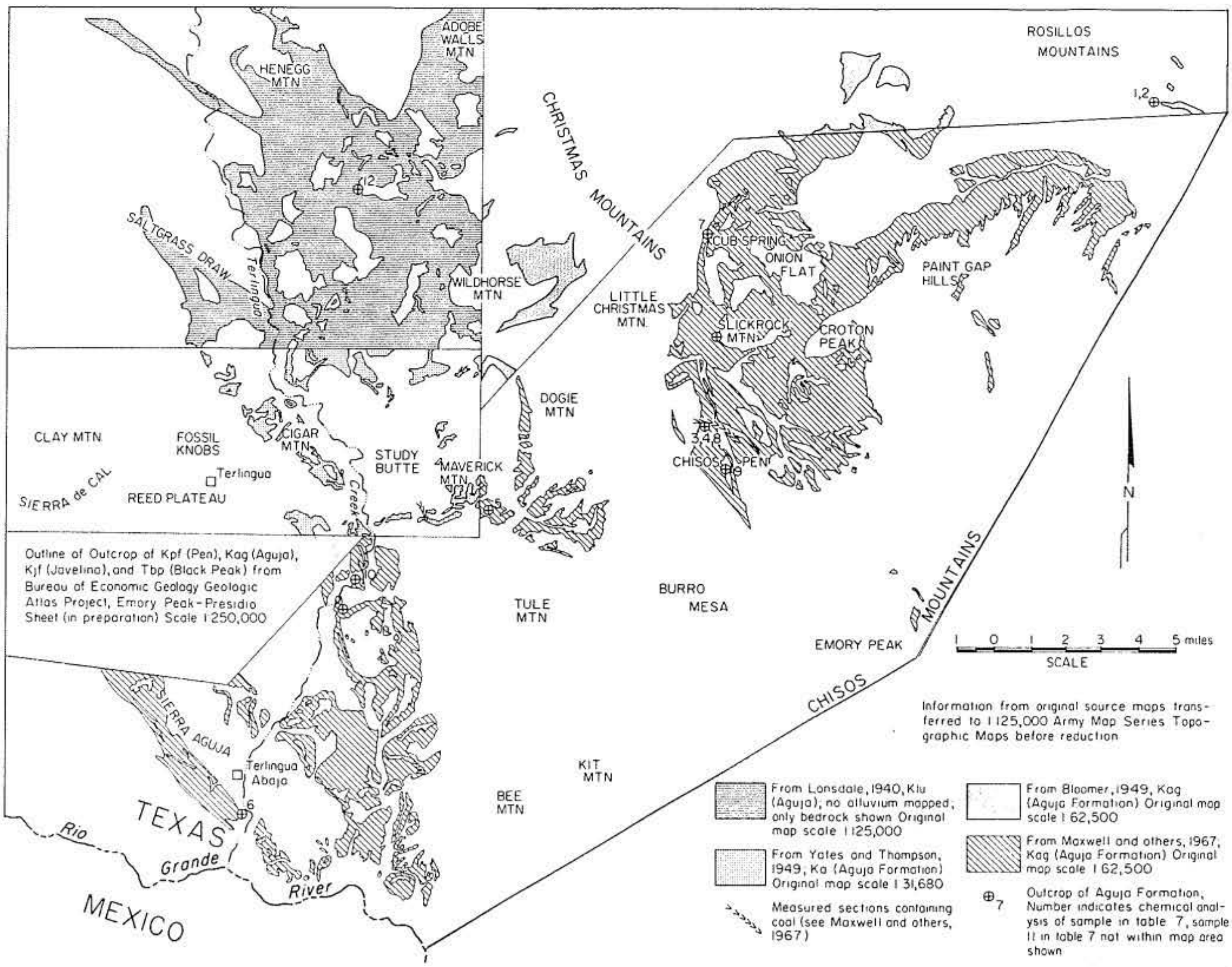


Figure 16. Distribution of Aguja Formation coal-bearing strata, coal outcrops, measured sections, and approximate location of samples collected for analysis. (See table 7.)

Aguja Formation thickness varies from 763 feet to 1,171 feet (Maxwell and others, 1967). Thickness variation is due in part to lack of definite basal and upper contacts. However, a regional northeastward thickening (coincident with inferred northeastward sediment transport and overall regressive trend) can be recognized. This regional trend results from southwestward thinning of lower Aguja tidal flat deposits (Hopkins, 1965).

Aguja Formation strata include a variety of lithologic types including sandstones, claystones, fresh-water limestone, conglomerates, shell beds, carbonaceous clay, and coal (fig. 17; Maxwell and others, 1967). Studies of Aguja sedimentologic parameters (lithology, directional sedimentary structures, nondirectional sedimentary structures, fossils, and petrography of sandstones and claystones) lead to interpretations of Aguja Formation depositional environments (Hopkins, 1965). Lower Aguja beds include shallow-water marine units grading upward into tidal flat deposits, representing (in a vertical sequence) tidal channel facies, lower tidal flat facies, upper tidal flat facies, and associated marsh deposits (Hopkins, 1965). Middle and upper Aguja beds are considered to include marsh, lagoon, and beach facies in addition to fluvial and estuarine deposits. Change from marine beds into intertidal and nonmarine units in a vertical direction is gradational. Coal beds and associated carbonaceous clays occur intermittently in middle and upper Aguja beds (fig. 17). The coal seams are believed to represent coastal swamp deposits (Hopkins, 1965).

Outcrops of coal extend from the southern Rosillos Mountains southwestward to the mouth of Terlingua Creek; thence, north along Terlingua Creek as far as Hen Egg Mountain and the Adobe Walls anticline. Coal is also reported in Aguja strata southeast of the Chisos Mountains. The largest known deposit occurs about 6 miles north of Study Butte (Sec. 242, Block G-4, H. E. and W. T. Ry. Co. survey; see general vicinity of outcrop of sample 12, fig. 16).

Coal Characteristics and Quality

Coal seams range from a few inches to 3 feet thick and are associated with carbonaceous clays up to 20 feet thick. Coal samples contain small, reddish pods of resinous material and yellowish stains (jarosite). Cubical fracture—due to breakage along joint surfaces and bedding planes—is common. Coal beds are characterized by faint laminations.

Published coal analyses (table 7) indicate that Aguja Formation coal quality is highly variable. Extreme ranges reported are due in part to alteration of coal seams near intrusive bodies, developing anthracite-like luster and quality. Sampling techniques may also have contributed to large variations in reported coal quality as admixtures of carbonaceous clay markedly decrease fixed carbon and increase ash contents in proximate analyses. Table 8 illustrates the effect of including carbonaceous shale units with coal units when sampling for subsequent chemical analysis at the site of the old underground mine (see outcrop 12, fig. 16). Proximate analyses in table 8 are based on two channel samples collected from the pit exposure and two samples from this pit operation collected at processing plants in Marathon, Texas. Higher ash percentages for samples from the Marathon grinding plant reflect removal of some coal prior to processing of carbonaceous material.

Coal quality as indicated from surface and near-surface sampling is obviously poor (see tables 7 and 8). Analyses of samples collected in presumably fresh mine faces from the underground coal mine operated by Chisos Mining Company (sample no. 12, table 7) indicate that nonweathered coal is subbituminous with high moisture, ash, and sulfur contents.

Potential for Development

Though coal is not rare in Aguja Formation outcrops in the Big Bend area, thin seams and variable quality hinder development. Generally, coal quality is poor. Lack of major nearby markets and resulting long haulage distances are additional drawbacks to large-scale exploitation.

Estimates of coal resources are not based on detailed field study nor substantial subsurface information. Mapel (1967) suggests that as much as 65 million short tons of bituminous coal may be present in Aguja Formation strata in Brewster County and extreme eastern portions of Presidio County. However, the Brewster-Presidio Aguja Formation coals are unexplored and reasonable estimates of coal resources await more detailed study.

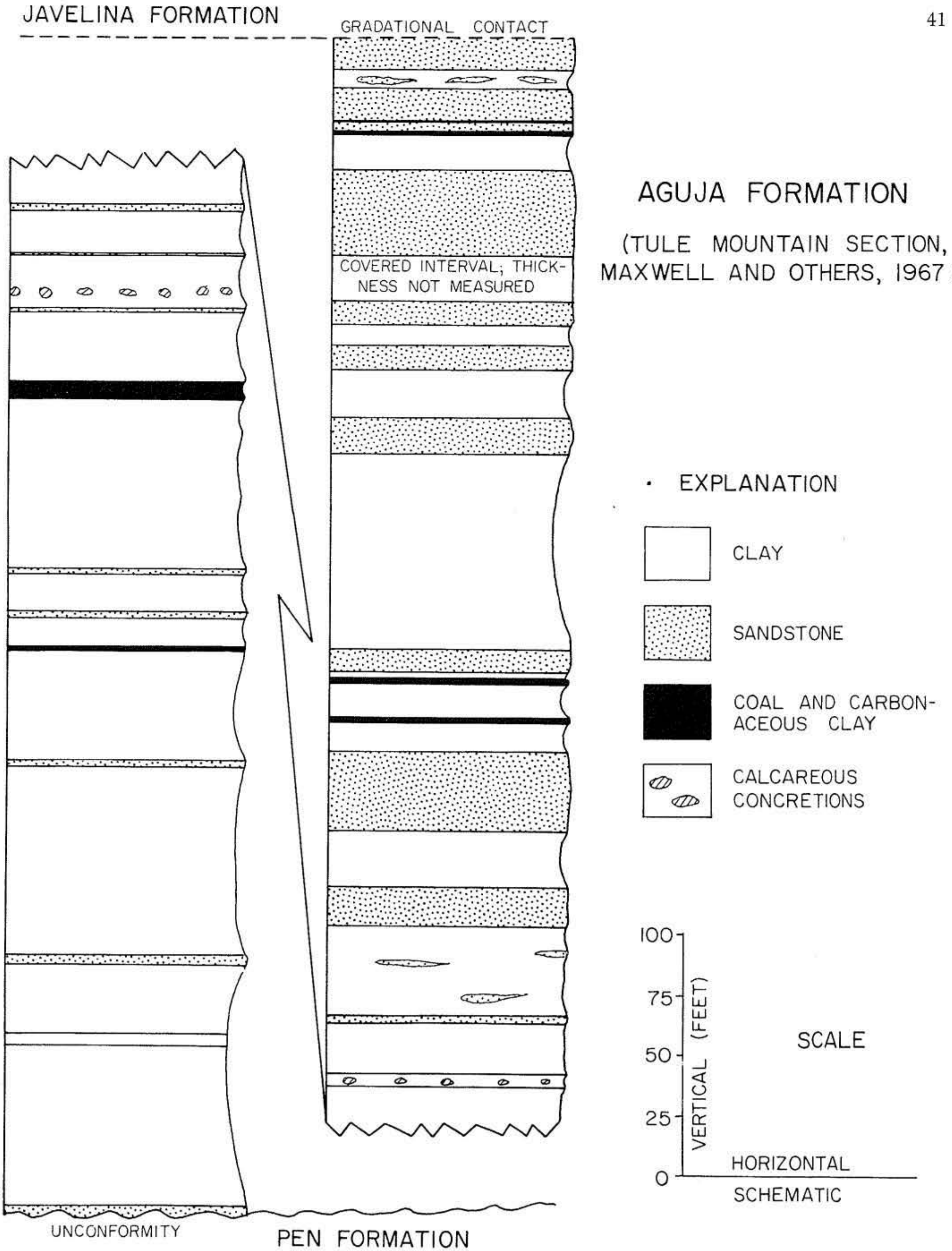


Figure 17. Lithology of Aguja Formation in southern Brewster County.

TABLE 7. Chemical analyses of Aguja Formation (Upper Cretaceous) bituminous coal, Brewster County, Texas. Data from original sources where available; see Appendix II for sample descriptions and sources of analyses. Values not shown were not determined in original analyses.

	Proximate Analysis (as received)							Ultimate Analysis			
Sample No.	Moisture	Volatile Matter	Fixed Carbon	Ash	Total	Sulfur	Btu	Carbon	Hydrogen	Oxygen	Nitrogen
1	2.44	15.38	77.95	4.23	100.00	0.93					
2	1.47	13.07	83.53	1.93	100.00	1.26					
3	4.68	24.20	54.52	16.60	100.00	0.88					
4	6.12	34.72	44.74	14.42	100.00	1.32					
5	6.46	34.88	32.76	25.90	100.00	1.00					
6	9.10	37.38	32.02	21.50	100.00	0.90					
7	10.65	50.91	19.52	18.92	100.00	0.86	8,432				
8	4.74	29.84	49.84	15.58	100.00	1.26	11,887				
9	1.16	32.79	44.52	21.52	99.99	3.39	11,958				
10	4.82	12.34	80.33	2.51	100.00	1.30					
11	6.57	49.00	31.85	12.58	100.00	1.22					
12	14.9	30.1	29.8	25.2	100.0	2.1	7,980	43.9	5.2	22.8	0.8
12[1]		35.4	35.0	29.6	100.0	2.5	9,380	51.5	4.1	11.3	1.0
12[2]		50.3	49.7		100.0	3.5	13,320	73.2	5.9	16.0	1.4

[1]Moisture-free

[2]Moisture- and ash-free

TABLE 8. Coal quality and measured sections from surface mining operations near Terlingua, Brewster County, Texas (from Lonsdale, 1950).

MEASURED SECTION OF SOUTHWEST WALL OF PIT, SECTION 242, BLOCK G-4

Top	Thickness in inches
7. Carbonaceous shale: brown to chocolate to black	21
6. Coal: weathered, impure; shiny black in places with films of jarosite, gypsum, and reddish amber pods of resin	9
5. Carbonaceous shale: brown to chocolate to black	10
4. Coal: weathered, impure; same as unit 6 except for presence of carbonaceous clay seams less than 1 inch thick	8
3. Carbonaceous clay: brown, powdery jarosite streaks ¼ inch wide	9
2. Coal: impure, with carbonaceous shale and gypsum films	6
1. Carbonaceous shale: brown	12

Sedimentation Unit	Ash Content	Total moisture, volatiles, and fixed carbon
7.	75.05	24.95
6.	36.70	63.30
5.	67.40	32.60
4.	22.45	77.66
3.	61.45	38.55
2.	22.30	77.70
1.	78.65	21.35

	Moisture	Volatiles	Fixed Carbon	Ash
Sample 1, channel sample, SW wall of pit	12.61	17.90	11.96	57.53
Sample 2, channel sample, NE wall of pit	10.94	28.47	18.97	41.35
Sample 3, from hopper at grinding plant	7.12	10.57	1.80	80.51
Sample 4, ground material from grinding plant	8.00	12.24	4.17	75.69

Current open-pit operations in carbonaceous shale and impure coal zones northeast of Terlingua indicate that stripping methods can be utilized in developing these deposits. Detailed geologic mapping of Aguja Formation (Udden, 1907b; Maxwell and others, 1967; Yates and Thompson, 1959) shows dips ranging from 5 to 45 degrees, however. Such high dips indicate that any workable coal seams present will be rapidly carried below strippable depths over very short surface distances. Gently dipping coal seams are probably present but require a detailed exploration program before they can be delineated.

Soil amending properties of Big Bend carbonaceous shale and impure coal zones in Aguja Formation strata are currently being utilized. Min-Sol Corporation (W. R. Manning, President) began surface mining this coal in the middle to late 1940's for use as fertilizer, soil neutralizer, and soil conditioner. Burtex Constructors Incorporated acquired the operation (now called Manning Minerals Corporation) in 1956 and has restricted sales to manufacturers of "organic shale" used as base material for organic fertilizer or soil conditioner (C. R. Burnett, written communication, 1973). A second company, Soylaid, Inc., operated in Brewster County from 1954 to 1960. Production figures are confidential but active exploitation of carbonaceous shale and impure coal zones has been nearly continuous for 25 years.

EAGLE SPRING COAL PROSPECT, CHISPA SUMMIT FORMATION (UPPER CRETACEOUS), EAGLE MOUNTAINS, HUDSPETH COUNTY

Historical Background

Existence of coal in El Paso County (pre-1917 county boundaries) was reported as early as the mid-1800's by J. F. Crosby (Shumard, B. F., 1859). This initial report was later repeated (Ashburner, 1881) and the first visit to Eagle Mountains (Eagle Spring area) coal by a geologist occurred sometime prior to 1885 (Schmitz, 1885). Figure 18 shows the location of coal in the area. Four coal seams were reported, though only one ("Big Seam, No. II") has been worked. The coal was reportedly of "fair quality." This seam varies from 20 inches to 7 feet thick (averaging 3½ feet) within a 400-foot unit. It is in 3,000-foot-thick "coal measures" exposed for a distance of 1 to 1½ miles (Schmitz, 1885). Schmitz noted that the coal measures were steeply dipping (60 to 80 degrees) and overturned to the west-northwest. A 230-foot shaft extended downdip along Big Seam, No. II, but this mine had not been operated for about one year prior to Schmitz's visit. The lower 100 feet of the shaft was filled with water, leaving only 130 feet accessible. One analysis of Eagle Spring coal has been published. The following analysis was completed on a sample collected about 70 feet below the shaft mouth (Schmitz, 1885, p. 392):

Moisture	3.537
Volatile combustible matter	30.843
Fixed carbon	50.694
Ash	14.926

Apparent renewed interest in Eagle Spring coal was reported by W. M. Chandler (Ashburner, 1887, 1888, 1889). This period of activity must have been very brief as the reports of W. H. von Streeruwitz (1889, 1890) and later "Mineral Resources of the United States" volumes (Parker, 1892, 1893) indicate no continuing development of the Eagle Spring coal mine.

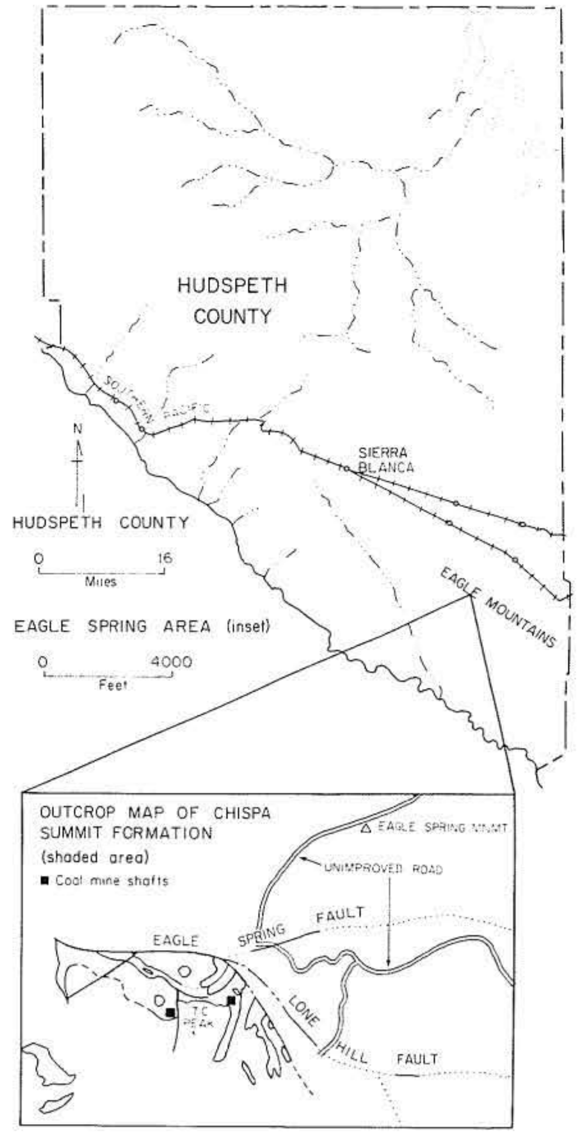


Figure 18. Location of Eagle Spring coal prospect. Location of shafts and distribution of Chispa Summit Formation from Underwood (1963).

Production figures are limited—reports list only 100 tons of coal shipped prior to 1887 (Ashburner, 1887) and a contract to mine 30 tons of coal per day, beginning in 1888 (Ashburner, 1888). This latter proposed production probably did not get off the ground, for Streeruwitz (1889) described the Eagle Spring shaft as abandoned and inaccessible due to cave-ins. Apparently disdainful of the "renowned Eagle Spring coal mine," Streeruwitz found the coal on nearby dumps to be mostly "slate" and "worthless as coal." He mentions no other coal seams at Eagle Spring, but does indicate a "duplicated" outcrop some 4 miles to the west. This duplicated outcrop probably refers to exposures of equivalent strata between Rattlesnake Draw and Goat Arroyo east of Speck Ranch (see geologic map, Underwood, 1963).

Referred to briefly in later Texas geology publications (Phillips, 1902a; Udden and others, 1916), the Eagle Spring mine area was not studied in detail again until 1922 (Baker, 1927, 1934). Baker notes one coal seam dipping 82°NE and striking N 75°W. The 3-foot seam is described as "partly metamorphosed into a semi-anthracite" with a high ash percentage. Because of the complex structure, he believed that there was "not much likelihood of . . . an extensive deposit of workable coal" (Baker, 1927).

Smith (1941) and Gillerman (1953) visited the Eagle Spring coal mine area in the 1940's noting "several thin seams of coal" exposed along Coal Mine Arroyo. Gillerman (1953) reported that more "recent" mining activity was indicated (with the last period of activity about 1927). Although not specifically mentioned, a second shaft within coal-bearing strata (Gillerman, 1953, pl. 2) is probably the evidence of these more "recent" workings.

The Eagle Mountains area has been mapped in detail by Underwood (1962, 1963). Only 6 feet of the main Eagle Spring coal mine shaft remained accessible in 1959. Another shaft—"a 30- to 40-foot shaft, clearly more recently worked"—was located 2,000 feet east-northeast of the original mine operation (Underwood, 1962). This second shaft is apparently the same shaft located by Gillerman (1953; see also fig. 18).

Geologic Setting

Schmitz (1885) refers to coal-bearing strata in the Eagle Mountains as "coal measures." It is not clear whether he believed Eagle Spring coals were equivalent to Carboniferous coals found in other places in the United States. Schmitz suggests the structural complexity of Eagle Spring geology in a diagram showing steeply dipping, overturned coal seams. Baker (1927, 1934) assigns coal-bearing strata to Lower Cretaceous (Trinity Group) Finlay Limestone, briefly mentions the folded and faulted geologic environment of coal-bearing strata, and suggests the possibility of local metamorphic alteration of coal by nearby igneous intrusions. Both Smith (1941) and Gillerman (1953) in their studies of structural and economic aspects of the Eagle Mountains considered coal-bearing units as the Eagle Ford Formation (Upper Cretaceous). The most recent detailed study of the Eagle Mountains (Underwood, 1962, 1963) outlines the structural complexity and history of the many faulting events indicated. Underwood assigns coal-bearing strata to the Upper Cretaceous Chispa Summit Formation (equivalent to Eagle Ford Formation of Central Texas).

No measured section of Chispa Summit Formation in the area where coal occurs is presently available. However, a measured section of "Eagle Ford" strata just east of Speck Ranch (Smith, 1940) indicates that the Chispa Summit Formation in that area is thin bedded and calcareous, grading upward from black shale and flaggy limestone through mostly covered shale and sandy shale beds and, finally, into interbedded brown sandstone and olive to gray shale near the top of the formation. According to Underwood (1962) the 1,420 feet measured by Smith is not a complete section and as much as 1,600 feet may actually be present. Coal seams are not observed in the area of the measured section, but Chispa Summit units are similar near Eagle Spring with coal seams present among the black, fissile shales (Underwood, 1962). Figure 18 shows location of Chispa Summit exposures near Eagle Spring.

Very little information concerning depositional environments of Chispa Summit Formation rocks near Eagle Spring is available. Underwood (1962) states that Chispa Summit "sediment was deposited in a changeable neritic sea" and the "organic material suggests that some was deposited along the shore in stagnant lagoons."

Potential for Development

Structural complexity of the Eagle Spring region and scattered, mostly covered occurrences of equivalent strata elsewhere in the Eagle Mountains pose difficult problems for potential coal mining development. Coal seams are reported only in the limited area near Eagle Spring where steep dips and a complex structural environment are notable. Though a major railroad is nearby, the remote geographic location from potential markets further hinders development potential. In addition, information on coal quality is scarce and contradictory. Estimates of coal resources and reserves in the Eagle Spring area are not available.

SUMMARY

Deposits of bituminous coal are located in six Texas localities: (1) North-Central Texas, (2) Santo Tomas district, Webb County, (3) Eagle Pass area, Maverick County, (4) San Carlos area, Presidio County, (5) Big Bend area, Brewster County, and (6) Eagle Spring in Eagle Mountains, Hudspeth County. These areas cover from nearly 3,000 (Mapel, 1967) to 8,200 (Campbell and Parker, 1909) square miles and include 6,100 million short tons of total original inferred bituminous coal resources (Mapel, 1967). Texas bituminous coal ranges from subbituminous to high-volatile B bituminous in rank with high ash, high sulfur, and low to moderate moisture contents (table 9).

Only the Eagle Pass area, Santo Tomas district, and North-Central Texas coalfields are judged to have potential for major economic development. San Carlos, Big Bend, and Eagle Spring area coals are far-removed from sizeable markets, include thin coal seams in structurally complex settings, and apparently lack coal reserves of major significance.

North-Central Texas coalfields comprise the largest area of bituminous coal in Texas. Several large mine operations were successful in the past, and, under appropriate economic conditions, renewed development of near-surface coal mines seems possible. Specifically, the area near Strawn-Gordon-Thurber in southern Palo Pinto and northern Erath Counties, the Newcastle-Ft. Belknap area in Young County, and the Bridgeport area in Wise County could offer potential for development in the North-Central

TABLE 9. Summary of proximate analyses: Texas bituminous coal. All parameters listed represent values determined on an "as received" basis and are expressed in weight-percent. $\overline{X}$ = arithmetic mean (average); S = standard deviation (indicating general distribution of values, not statistically significant); N = number of analyses.

Parameters	Coal Seams	North-Central Texas				Santo Tomas district	Eagle Pass	Big Bend	San Carlos
		Strawn Group (mainly Thurber)	Canyon Group (Bridgeport)	Cisco Group (Newcastle)	Cisco Group (others)	Claiborne Group cannel coal	Olmos Formation	Aguja Formation	San Carlos Formation
Moisture	$\overline{X}$ =	3.6	11.9	11.8	6.4	3.7	6.4	6.1	2.3
	S =	2.0	3.3	3.4	4.7	1.4	2.4	4.0	1.8
	N =	25	15	8	27	44	38	12	11
Volatile Matter	$\overline{X}$ =	33.9	32.6	35.3	36.5	45.6	33.2	30.4	37.8
	S =	3.2	1.1	1.2	4.6	4.0	3.4	12.6	10.6
	N =	25	15	8	27	43	32	12	11
Fixed Carbon	$\overline{X}$ =	47.1	42.2	38.7	43.0	36.4	42.0	48.4	38.0
	S =	5.5	4.7	6.1	6.3	3.6	6.5	21.7	14.5
	N =	25	15	8	27	43	32	12	11
Ash	$\overline{X}$ =	15.2	13.5	14.3	13.8	14.2	18.4	15.1	21.8
	S =	6.1	2.0	4.5	5.8	6.0	6.6	8.3	19.3
	N =	25	15	8	27	43	32	12	11
Sulfur	$\overline{X}$ =	2.4	2.1	3.3	3.7	2.2	1.4	1.4	0.8
	S =	0.9	0.5	0.7	2.1	0.8	0.4	0.7	0.5
	N =	25	15	7	24	36	28	12	5
Btu's/lb.	$\overline{X}$ =	11,641	10,038	9,565	9,980	11,640	10,682	10,064	10,056
	S =	736	414	336	459	1,125	1,262	2,154	1,935
	N =	21	14	7	5	36	31	4	3

Texas area. Sizeable markets lie reasonably close to the east (Dallas-Fort Worth) and west (Abilene). Though bituminous coal seams in North-Central Texas are rarely more than 30 inches thick, economic reserves of coal may lie close enough to the surface to allow development.

The Santo Tomas district northwest of Laredo, Webb County, contains marginally significant resources of cannel coal. Adversely affecting possible development are small size of identifiable resources, potential lack of a readily available water supply, and unfavorable geographic location of potential mine sites with respect to major transportation arteries. Unique high volatile-matter content of this cannel coal suggests possible value as a source of petrochemical products and susceptibility to coal conversion processes.

Olmos Formation coal crops out near Eagle Pass in Maverick County. The main coal seam is 4 to 7 feet thick, and sites favorable to mining can be identified. Counterbalancing the favorable resources picture for Eagle Pass area bituminous coal is the generally remote location of the coalfield from potential markets and the possibly inadequate transportation arteries. An exploration program to delineate coalfield size and coal quality, including areas previously unexplored (e.g. east of Chittim anticline), is a requisite first step towards development evaluation.

In short, existing information suggests that three areas in Texas contain bituminous coal in apparent quantity or of particular quality to warrant further investigation. However, significant information is lacking, including competent assessment of identified coal reserves, coal quality, and economic aspects surrounding potential coal development. Identification of coal reserves necessitates detailed (and expensive) exploration programs involving geophysical logging and coring techniques. Adequacy of transportation arteries and potential markets to support coal development require study by competent economic analysts. Determination of the adequacy or inadequacy of available water resources depends on the nature of mining development postulated and requires evaluation before industrial development can begin.

Research programs that would provide useful information include: (1) detailed study of all available subsurface information in order to accurately evaluate total original coal resources, (2) field study of coal and coal-related strata to assess controls on the occurrence and quality of coal related to depositional environments, and (3) regional stratigraphic study and sampling programs to accurately delineate bituminous coal seams, depths to coal seams (thickness of overburden), and coal quality.

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APPENDIX I
LOCALITIES AND DESCRIPTIONS OF MINES, EXPLORATION SHAFTS, AND MEASURED SECTIONS CONTAINING COAL IN NORTH-CENTRAL TEXAS

BROWN COUNTY

1. Composite section from 3 measured sections (8, 8a, 8b) in Grosvenor area. Plummer and others (1949, see plate I and plate VI). Columnar section indicates that 1 foot of coal occurs 20 feet below base of Saddle Creek Limestone.

COLEMAN COUNTY

1. Measured section from Silver Moon mine, located about 1 mile northwest of Santa Anna. Tarr (1890, p. 210). Measured section indicates 6-inch coal bed at 82-foot depth (seam not mined); 6- to 8-inch seam at 83-foot depth separated by 3- to 4-inch clay parting from another 8-inch seam (latter two seams mined). Tarr describes this mine as "just opened" and producing 1 to 2 tons per day. Drake (1893) implies Silver Moon mine was not being worked at the time of his study.
2. Measured section in "Milburn shales" located 12 miles north-northwest of Milburn. Section comes from 62-foot well. Tarr (1890, p. 206). One 4½-inch seam separated by 2 feet of "horseback coal" (carbonaceous shale) from a second 4-inch coal seam occurs at a depth of 28 feet.
3. Measured section of "seam no. 7" located in the vicinity of Home Creek. Cummins (1891, p. 549). 28-inch coal seam occurs 29 feet below top of 67-foot section exposed along Home Creek.
4. Shaft opened by J. W. Gibson near valley of Little Bull Creek. Cummins (1891, p. 549). Two coal seams, 24 and 10 inches, are separated by a 2-inch slate parting in this 48-foot shaft.
5. Measured section located near Gibson shaft, near mouth of Bull Creek, 3 miles northeast of Waldrip. Cummins (1891, p. 550). Upper 10-inch coal seam separated from lower 24-inch seam by 2-inch slate parting about 64 feet below limestone at top of measured section.
6. Measured section of coal seam in Silver Moon mine. Drake (1893, p. 43). Three coal seams present as indicated in #1. Analyses indicate high sulfur content (see tables 1, 4, 5).
7. Measured section of coal seam in Star and Crescent mine, located 1¼ miles south of Rockwood. Drake (1893, p. 434). Four coal seams present (1½, 4, 3, and 16 inches thick) with the latter three seams mined. Mine is described as "operative" but was probably only briefly mined as later publications make no reference to this operation.
8. Composite section of Harpersville Formation southwest of Rockwood. Lee and others (1938, p. 128-129). Two 1-foot coal seams are recorded as occurring 91 and 191 feet, respectively, below base of Saddle Creek Limestone. Total thickness of Harpersville Formation in this area is 238 feet.

EASTLAND COUNTY

1. Shallow shaft (?) mine located 2¼ miles northwest of Cisco along Sandy Creek. Cummins (1891, p. 544-546). Two coal seams ("seam no. 7") identified in this area. Upper 4-inch seam is separated by 4- to 10-inch slate parting from lower 20-inch seam. This is one of at least two shafts briefly worked by Texas Central Railway interests. Coal was too thin and too high in sulfur to warrant significant mining, according to Cummins.
2. Smith-Lee mine located 2 miles north of Cisco. Phillips (1902a, p. 48 and 50; see analysis EA-1, table 2, this report). Two major coal beds, 12 and 13 inches thick, produced about 15 tons per day for shipment to Cisco. The mine operated only briefly, probably no later than 1904, after opening in 1900 or 1901.
3. Measured section of Harpersville Formation located 3 miles northwest of Cisco. Plummer and Moore (1921, p. 123 and 164). Three feet of coal ("black, soft, poor") 45 feet below base of Saddle Creek Limestone and 2½ feet of coal ("black, medium, hard, good grade") 25 feet below the first coal seam.
4. Measured section of Harpersville Formation, 1 to 2 miles north of Cisco. Line of section located a quarter of a mile east of Lake Cisco spillway. Plummer and others (1949, plates 2 and 7, section #15). About 1 foot of coal approximately 25-30 feet below the Saddle Creek Limestone.
5. Measured section located on west side of Cisco-Rising Star road about 2 miles south of Cisco. Plummer and others (1949, p. 10-11). Two coal seams are shown within the Quinn Clay unit of the Harpersville Formation. An 8-inch seam occurs at road level and a 1-foot coal seam is located about 3 to 4 feet below.
6. Measured section of Quinn Clay unit of Harpersville Formation, 2 miles east of Cisco on north side of Cisco-Eastland highway. Plummer and others (1949, p. 11-12). Approximately 6 inches of coal occurs in 10-foot-deep gully north of road, 10 to 12 feet below road level.
7. Measured section of Craddock Clay unit of Harpersville Formation at spillway to Lake Cisco (see #4 above). Plummer and others (1949, p. 21-22). Three feet of coal occurs about 49 feet below base of Saddle Creek Limestone. This seam is referred to as "Newcastle coal."
8. Outcrop and measured section of upper part of Harpersville Formation exposed on U. S. 380 near Cisco Junior College. Brown (1969, p. 62-64, stop no. 3); and Brown (1960b, p. 7-8, stop no. 1). Two thin (less than 1 foot thick) zones of "impure coal" occur 25-28 feet and 45 feet, respectively, below Saddle Creek Limestone.
9. Measured section (partial) of Harpersville Formation about 4 miles south-southwest of Cisco. Galloway

(1970, p. 81; section #1). Black, shaly, detrital lignite, 1.5 feet thick, occurs 59 feet below Saddle Creek Limestone. Section measured from gully up hillslope southeast of road cut.

10. Measured section of Harpersville Formation, 5 miles north-northwest of Cisco. Galloway (1970, p. 82-83, section #3). Two feet of "lignite, powdery black, and fissile coaly claystone" occurs 28.5 feet below Saddle Creek Limestone and 1 foot of "lignite, powdery, black, and coaly clay-shale" occurs 5 feet below the upper lignite zone. Section measured along creek bed and then southward up hill located north of U. S. 380.
11. Measured section (partial) of Harpersville Formation located 5 miles north-northwest of Cisco. Galloway (1970, p. 84-85, section #4). "Lignite, powdery black and gray, fissile; and plant debris-bearing clayshale," 4.5 feet thick, occurs more than 6 feet below Saddle Creek Limestone. Section measured northward from private road up a hill to outlier of Saddle Creek Limestone.
12. Measured section of Harpersville Formation down to Crystal Falls Limestone about 8 miles north of Cisco. Galloway (1970, p. 85-86, section #6). Only 6 inches of "black powdery" lignite occurs 26 feet below Saddle Creek Limestone. Section measured up southeast side of isolated hill just south of Eastland-Stephens county line.

ERATH COUNTY

1. Fincastle mine, located 2 miles southeast of Thurber. Cummins (1891, p. 532, plate 11). Mine worked same seam as Texas and Pacific Company's shafts located in same area (see #2, #3, #4 below). Mine was only briefly operated and closed prior to Cummins' visit. A single shaft was opened but no depth-to-coal figures are available.
2. Texas and Pacific Coal Company's shaft no. 1, located just southeast of Thurber. Cummins (1891, p. 526-531). This mine worked "seam no. 1," known as Thurber coal, in this region. Formerly named the Johnson mine, this shaft operation began about 1886 (Weitzell, 1896) and closed prior to 1902. The mine apparently reopened before 1911 and closed again prior to 1924. The coal seam mined was 28 to 30 inches thick and long-wall advancing methods were used to extract the coal from a one-half mile radius about the main shaft.
3. Texas and Pacific Coal Company's shaft no. 2, located just northeast of Thurber. Cummins (1891, p. 526-531). This mine probably opened in 1889 and closed before 1902. In operation, the 28- to 30-inch Thurber coal was extracted by long-wall advancing methods.
4. Texas and Pacific Coal Company's shaft no. 3, located 1¼ miles west-southwest of Thurber. Cummins (1891, p. 526-530). This mine opened in 1889 and closed before 1902. The same Thurber coal (28 to 30 inches thick) was mined as in T & P mines #1 and #2 described above.

5, 6, 7. Texas and Pacific Coal Company's shafts no. 4, 5, and 6, located as shown on plate I (this report) and plate 7 of Plummer and Hornberger (1935). Phillips (1902a, p. 40-43). These shafts were opened shortly after 1891 and closed prior to 1902. Closing was due to completion of economic coal extraction in a one-half mile radius about main shafts. Thurber coal 28 to 30 inches thick developed in all three mines.

8. Texas and Pacific Coal Company's shaft no. 9 ("The Colonel"), located 3 miles west-southwest of Thurber. Phillips (1902a, p. 42). Coal 27¼ inches thick was worked with two "slaty clay" partings of ¾- and ½-inch thickness. Shaft is 190 feet deep and utilized long-wall advancing methods. Mine opened after 1891 (and before 1902) and closed prior to 1933. See analysis ER-5, table 1, for an analysis of coal taken from this mine.
9. Texas and Pacific Coal Company's shaft no. 12, located 3½ miles west-southwest of Thurber. Plummer and Hornberger (1935, plate 7). This 189-foot shaft was opened sometime between 1902 and 1910 and closed in 1919 (based on State Mine Inspector Reports for 1911 and 1919).

JACK COUNTY

1. Measured section of "seam no. 7" located on east side of creek on McDonald Survey, 1 mile north of mouth of Lodge Creek. Cummins (1891, p. 511). Two coal seams, 6 inches and 1 foot thick, are indicated as occurring 74 feet below top of an 80-foot exposure.
2. Measured sections of "seam no. 7" located on NE¼, sec. 2, of file 2379, Texas and Pacific Railway Survey. Cummins (1891, p. 512). Two feet of "coal and shale" occurs 21 feet below top of 33-foot exposure. This is the easternmost exposure of this coal in Jack County, according to Cummins.
3. Brannon mine is located 2 miles southeast of mouth of Lodge Creek on south side of West Fork of Trinity River. Cummins (1891, p. 513). Tunnel set into hillside on "thickest" exposure of "seam no. 7" observed by Cummins. Seam thickness is not recorded; mine history is not known.
4. Measured section of "seam no. 7" in 30-foot exposure located 3 miles southwest of Antelope, on south side of West Fork of Trinity River. Cummins (1891, p. 514). Fourteen inches of "bituminous shale with thin seams of coal" occurs 23 feet below top of exposure. Wells in the Antelope area reportedly encounter an 8- to 18-inch coal seam at depths varying from 50 to 60 feet.
5. Composite section measured about 2 miles southeast of Jermyn. Brown (1962, p. 29-30, section #24). A thin (0.3-foot) coal seam occurs in an unnamed shale member of the Thrifty Formation, about 15 feet below the Blach Ranch Limestone.
6. Measured section located about 10 miles northwest of Jacksboro on north side of U. S. 281. Brown (1962, p. 30, section #25). Impure coal, 0.2 foot thick, occurs in unnamed shale member of Thrifty Formation, about 15 feet below Blach Ranch Limestone.

7. Measured section located 8 miles northeast of Jacksboro on FM 2190. Brown (1962, p. 30-31, section #26). Impure coal, 0.2 foot thick, occurs in unnamed shale member of Thrifty Formation, about 15 feet below Blach Ranch Limestone.
8. Measured section 10 miles north-northeast of Jacksboro, west of State Highway 148. Brown (1962, p. 31, section #28). Impure coal, 0.2 foot thick, occurs 19 feet below Blach Ranch Limestone in an unnamed shale member of Thrifty Formation.
9. Measured section 11 miles north of Jacksboro, east of State Highway 148. Brown (1962, p. 32, section #29). Impure coal, 0.2 foot thick, occurs in unnamed shale member of Thrifty Formation about 18 feet below Blach Ranch Limestone.

McCULLOCH COUNTY

1. Measured section comprised of outcrops near Fink's mine and strata in shaft of mine, located "near Waldrip." Tarr (1890, p. 209). A 2-foot-thick coal seam occurs at depth of 49 feet in a 55-foot-deep shaft. (See #2 below.)
2. Description of Fink's mine, located "about one-half mile west of Waldrip." Cummins (1891, p. 550). A 28-inch coal seam contains two slate partings in 84-foot-deep shaft. (Compare to #1 above). Mine had been closed "for some time" prior to visit. A 50-foot drift was driven east into the seam and worked for several feet on either side.
3. Chaffin mine, a slope operation, located about 2 miles southeast of Waldrip. Cummins (1891, p. 551). A 20-inch seam crops out below a shaly limestone along a small creek. Mining followed seam into hillside "a few feet." Drake (1893) describes this mine as "inoperative" at the time of his study.

MONTAGUE COUNTY

1. Stephens' mine is located 4 miles southwest of Bowie on Josepha Diaz Survey. Cummins (1891, p. 508). This mine was a complex of four shafts (up to 150 feet deep about 1½ miles northwest of the outcrop) and a 400-foot tunnel driven into the outcrop. A measured section at mouth of tunnel indicates 40 inches of coal (not including a 6-inch slate parting) was worked in this area. The mine opened sometime prior to 1888 but was apparently closed shortly after 1891 as later publications do not mention this operation.

PALO PINTO COUNTY

1, 2, 3. Three mines located 3 miles northeast of Gordon. Cummins (1891, p. 532-533) and Plummer and Hornberger (1935, p. 198, plate 7). These were tunnel operations on a coal seam equivalent to the Thurber coal mined to the southwest. Mines were opened in the early 1880's by W. W. Johnson and operated successfully for several years. Six hundred tons per day were reportedly produced but, by 1891, the mines—then called Gordon mine—closed and Coalville, the community of miners who worked these three mines, was abandoned.

4. Swank mine is located 1 mile west of Gordon on west side of Palo Pinto Creek. Cummins (1891, p. 534). This 40-foot shaft worked the Thurber coal, but no seam characteristics are described. The history of the mine is unknown.
5. Texas and Pacific Coal Company's shaft no. 7 ("Queen Bess Mine"), located about 2 miles northwest of Thurber, Erath County. Phillips (1902a, p. 42). This shaft was 7½ by 13 feet in cross section and 140 feet deep. Coal, 26¾ inches thick, was mined, not including two "slaty clay" partings of three-fourths and one-fourth inch each. Long-wall advancing methods were used. This shaft opened sometime after 1891 and before 1902. It apparently ceased production before 1910. See analysis PP-1 (table 1) for an analysis of coal mined.
6. Texas and Pacific Coal Company's shaft no. 8 located near Erath-Palo Pinto county line about 2½ miles northwest of Thurber, Erath County. Phillips (1902a, p. 42). Coal, 27¾ inches thick, was mined with two "slaty clay" partings each less than 1 inch thick. The shaft was 230 feet deep. This long-wall advancing mine opened sometime after 1891 but before 1902 and apparently closed in 1914. See analysis PP-2 (table 1) for an analysis of coal mined.
7. Texas and Pacific Coal Company's shaft no. 10 ("The Old Girl Mine") located 2 miles southeast of Strawn. Phillips (1902a, p. 42). This shaft was 235 feet deep. Coal, 24¼ inches thick, was worked by long-wall advancing methods. One of the T & P Coal Co.'s most successful mines, no. 10 opened sometime after 1891 and before 1902 and operated at least through 1928 before closing prior to 1933. See analysis PP-3 (table 1) for an analysis of coal taken from this mine.
8. Strawn Coal Mining Company's Lyra Siding mine, located 1½ miles east of Strawn. Phillips (1902a, p. 43 and 48). Twenty to 22 inches of coal was mined in this 330-foot shaft operation. The mine opened in 1897 and closed sometime between 1910 and 1914. See analysis PP-4 (table 1) for an analysis of coal from this mine.
9. Texas and Pacific Coal Company's shaft no. 11, located near intersection of Eastland-Erath-Palo Pinto county lines. Plummer and Hornberger (1935, plate 7). Little is known about this mine except that it opened sometime between 1902 and 1910 and ceased production after 1914 and before 1919.
10. Mt. Marion mine, located just south of Strawn. Plummer and Hornberger (1935, p. 198). Mt. Marion Coal Company opened this 415-foot-deep shaft operation about 1895. The mine was later (1900) sold to Strawn Coal Mining Company. Although not mentioned as an operating mine by Phillips (1902a), State Mine Inspector Reports indicate that the Mt. Marion mine operated off and on through 1928, closing prior to 1933. A 28-inch seam was worked.
11. Strawn Coal Mining Company's shaft no. 2, located at the north edge of Lyra Siding. Plummer and Hornberger (1935, p. 198). A 32-inch coal seam was mined in this 400-foot-deep shaft by long-wall advancing methods. This shaft was worked briefly sometime after 1902 and before 1919.

12. Strawn Coal Mining Company's shaft no. 3, located half a mile north of Lyra. Plummer and Hornberger (1935, p. 198). Little is known of this mine beyond its depth of 365 feet and the 30-inch coal seam exploited by long-wall advancing methods.
13. Strawn Coal Mining Company's shaft no. 4 is located 1¼ miles northwest of Lyra Siding. Plummer and Hornberger (1935, p. 198-201). This deepest of shaft mines (485 feet) worked a 26- to 36-inch coal seam for many years. Records indicate that the mine opened sometime between 1902 and 1910 and was worked beyond 1924. In 1933, this mine was being worked only one day per week, producing 580 tons/day.
14. Measured section of Sunday Creek coal about 3 miles south-southeast of Santo, south of Interstate 20. Plummer and Hornberger (1935, p. 203). Coal, 1.7 feet thick, occurs 30 feet below top of the exposure. The Sunday Creek coal occurs 65 feet below the Santo Limestone of the Mingus Formation and varies from 18 to 22 inches thick. This seam is stratigraphically the lowest coal described in the Strawn Group.
15. Measured section of Dalton coal located on the McMurrey Ranch along the Merriman Limestone escarpment. Plummer and Hornberger (1935, p. 193). Coal, 9¾ feet thick, occurs in the section located 800 feet northeast of the northwest corner of D. B. Brooks Survey. Dalton coal occurs in the Wolf Mountain Shale. No fresh samples of the coal have been described and exposures of Dalton coal are highly weathered and impure.
16. Drift mine in Abbott coal located near center of the south half of Mahoney Survey, 5 miles southeast of Mineral Wells. Plummer and Hornberger (1935, p. 194). "Black, soft, impure" coal, 2.2 feet thick, occurs in 100-foot exposure near mine workings. Apparently explored between 1890 and 1900, no major mining was ever attempted. Abbott coal occurs in the Brazos River Formation—stratigraphically above the Thurber coal.
17. Drift mines. Plummer and Hornberger (1935, plate 7). These two drifts are located on plate 7 but no further description or discussion of these openings is known. These mines were probably located on the Thurber coal.

PARKER COUNTY

1. Carson and Lewis mine on NW¼, section 359, Texas and Pacific Railway Survey, east side of Dry Creek. Cummins (1891, p. 519-520). Incline mine on "seam no. 1," which is 18 to 26 inches thick. Mine abandoned as of 1891 and year of initial production is not known. Coal reportedly shipped to Weatherford, Texas.
2. Lake mine on SW¼, section 359, Texas and Pacific Railway Survey. Cummins (1891, p. 520-521). Coal seam, 18 to 26 inches thick, worked in two drifts along outcrops in small valley. Mine abandoned as of 1891.
3. Brown mine is located half a mile west of Lake mine (see #2 above). Cummins (1891, p. 520-521). Shaft and tunnel sunk to coal seam but little coal was actually mined. Mine not operative in 1891.
4. Helms shaft is located 1 mile northwest of Lake mine (see #2 above). Cummins (1891, p. 520-521). This 40-foot shaft was apparently intended for private use.

*5. Texas Coal and Fuel Company's Rock Creek shaft no. 1, located about 17 miles west of Weatherford along the old Weatherford, Mineral Wells and Northwestern Railway. Phillips (1902a, p. 35-40). This shaft was 150 feet deep at time of operation and a 20-inch seam with 1-inch clay parting was mined. Analysis PR-2 (table 1) is a chemical analysis of coal extracted from mine. This mine opened between 1891 and 1902 and closed prior to 1910.

*6. Texas Coal and Fuel Company's Rock Creek shaft no. 2, located about 17½ miles west of Weatherford along the Weatherford, Mineral Wells and Northwestern Railway. Phillips (1902a, p. 35-40). Twenty-one inches of coal with a ½-inch clay parting was worked in this 153-foot-deep shaft mine. Analysis PR-3 (table 1) is from sample of coal produced from this mine. Apparently this mine opened between 1891 and 1902 and closed before 1910.

*7. Texas Coal and Fuel Company's Rock Creek shaft no. 3, located about 18 miles west of Weatherford (see #5 and #6 above). Phillips (1902a, p. 35-40). This mine was 230 feet deep. Twenty-seven inches of coal was worked in the mine. Three clay partings of 1¼, 1, and 2 inches occur within the coal seam. Analysis PR-4 (table 1) is a chemical analysis of coal taken from the operation. Like #5 and #6 above, this mine opened in the 1890's and closed before 1910.

8. J. S. Young mine, located at Keeler Siding on the Gulf and Brazos Valley Railway. Phillips (1902a, p. 40). A thin (12-inch?) seam was worked by a tunnel operation that extends 500 feet into hillside. Exact location is not known nor is any history of mine opening or closing recorded. Analysis PR-1 is a chemical analysis of coal removed from this mine.

* Locations of these mines courtesy of W. H. Cunningham, Weatherford, Parker County (oral communication, 1973).

STEPHENS COUNTY

1. Measured section of "Belknap coal-bed" located three-fourths of a mile southwest of Crystal Falls. Ashburner (1881, p. 499). Section occurs under 5- to 15-foot cover and includes 3½ feet of coal with a 7-inch slate ("very sulphurous") parting splitting the seam into 6-inch and 3-foot seams.
2. Measured section of "Belknap coal-bed at Ballard's opening," east bank of Clear Fork of Brazos River at northwest corner of J. T. Pinkney tract. Ashburner (1881, p. 500). Section shows 1 foot of "coal and slate" overlying 1 foot of "clay and slate" which in turn overlies 18 inches of "sulphurous" coal.
3. Measured section of "Belknap coal-bed" at base of Coal Mountain between Hubbard and Gonzales Creeks, 7 miles southwest of Crystal Falls. Ashburner (1881, p. 501). Under 65 feet of cover, the section shows 24 inches of coal overlain by 6 inches of "sulphurous slate" and 6 inches of "slaty coal." Two 1-foot coal

beds occur above these seams separated by a 15-foot sandstone overlain by 12 feet of sandstone and shale.

4. Jake Wizeart mine, three-fourths of a mile southwest of Crystal Falls. Cummins (1891, p. 537-538). A 400-foot tunnel and a 100-foot drift from this tunnel are located in the hill at the outcrop. Coal, 2½ feet thick and separated by 4 inches of shale, occurs at this locality. No exact dates are available but "coal has been taken from this mine for several years" (Cummins, 1891, p. 538). No mention of the mine occurs in later publications.
5. Berry Meadows mine, half a mile "west" (see p. 539) of Jake Wizeart mine. Cummins (1891. p. 538). A 50-foot tunnel was made into seam described in #4 (above). Coal was mined for use in Breckenridge, Texas. No later mention of this mine has been found.
6. Sloan shaft located just south of Clear Fork of Brazos River about 1 mile north of Jake Wizeart mine (see #4 above). Cummins (1891, p. 540). Seam same as that found at Jake Wizeart mine.
7. Wasson mine on north side of Brazos (Clear Fork) about 1½ miles north of Crystal Falls. Cummins (1891, p. 540). A 100-foot tunnel was driven into the exposure on a hillside. The coal seam was 36 inches thick. A 6-inch shale parting is not included in coal seam thickness.
8. A. S. Johnson mine, 6 miles "west" of Crystal Falls (see #2 above). Cummins (1891, p. 540). Soldiers from Fort Griffin mined this coal along its exposure in the bed of Clear Fork. No actual measurements are available, but 4 feet of coal has been reported. This is "seam no. 7."
9. Measured section of Harpersville Formation along Clear Fork of Brazos River west of Crystal Falls. Plummer and Moore (1921, p. 123, 163-164). A 1-foot coal bed occurs about 138 feet below the Saddle Creek Limestone and 80 feet above the Breckenridge Limestone.
10. Measured section of Harpersville Formation from railroad cuts northwest of Crystal Falls. Lee and others (1938, p. 62, section 2b). Eight feet of coal is shown occurring about 150 feet below the Saddle Creek Limestone. Most likely this represents a zone of coal and coaly shale together.
11. Measured section of Craddock Clay unit in Harpersville Formation, about 1 mile north of Crystal Falls. Plummer and others (1949, plates 4 and 7; section 24). Two feet of coal ("Newcastle coal") occurs about 70 to 75 feet above the Breckenridge Limestone.
12. Measured section of Craddock Clay of Harpersville Formation, on U. S. 80, 1.8 miles west of Breckenridge. Plummer and others (1949, p. 22). The 2-foot-thick "Newcastle coal" occurs about 8 feet above road bed. Section measured on north side of road.
13. Measured section of Craddock Clay of Harpersville Formation, 0.2 mile west of Crystal Falls. Plummer and others (1949, p. 23). The "Newcastle coal" is 2 feet thick and occurs 75 to 80 feet above the Breckenridge Limestone, about 5 to 8 feet above the road bed. Section measured on south side of road.
14. Measured section (partial) of Harpersville Formation, about 5 miles northeast of Crystal Falls. Brown (1960a, p. 34, section #17). Six inches of "shaly" coal occurs within the Curry Clay unit about 10 feet above a sandstone, which is the lateral equivalent of the Crystal Falls Limestone. Section measured up steep bluff above Clear Fork of Brazos River.
15. Measured section (partial) of Harpersville Formation about 4 miles northeast of Crystal Falls. Brown (1960a, p. 33, section #16). Six inches of coal occurs in Curry Clay unit about 43 feet above the Breckenridge Limestone. Section measured generally westward from road crossing east-west creek.
16. Type section of Crystal Falls Limestone, about 3 miles northeast of Crystal Falls. Brown (1960a, p. 24-25). Coal, 1½ feet thick, occurs in Curry Clay unit about 60 feet above Breckenridge Limestone.
17. Measured section (partial) of Harpersville Formation, 4 miles south of Crystal Falls. Brown (1960b, p. 22, stop no. 7). Four coal beds (½ to 1 foot thick) occur in this part of the Harpersville. Three of the beds occur within 40 feet above the "Upper Crystal Falls limestone, " whereas one bed occurs 2½ feet below this same limestone. The coal is generally "shaly" and poorly exposed.
18. Measured section (partial) of Harpersville Formation, half a mile south of FM 1032 and 1 mile west of north-south county road. Galloway (1970, p. 87-88, section #7). A 6-inch lignite bed occurs 19 feet below Saddle Creek Limestone. Section measured up isolated hill east of pasture road.
19. Measured section (partial) of Harpersville Formation, just southeast of FM 1032 in area of type section of Harpersville Formation. Galloway (1970, p. 90-91, section #10). Lignite, 1.0 foot thick, occurs 141 feet below top of exposure (a massive sandstone). Section measured up northwest side of Double Mountain.
20. Measured section (partial) of Harpersville Formation, half a mile west of Big Sandy Creek. Galloway (1970, p. 91-92, section #11). Lignite, 0.8 foot thick, occurs 33 feet below top of exposure on north end of hill west of county road.
21. Measured section (partial) of Harpersville Formation, 2 miles west of Stephens County courthouse in Breckenridge. Galloway (1970, p. 95, section #16). Reddish-brown lignite, 0.6 foot thick, occurs 12.4 feet above base of exposure on hillslope just north of U. S. 180.
22. Measured section (partial) of Harpersville Formation, 5½ miles north-northwest of Breckenridge. Galloway (1970, p. 95-96, section #17). Six inches of lignite occurs 21 feet above base of outcrop. Three feet of bituminous coal and coaly claystone occurs at base of exposure in small, isolated hill just west of U. S. 183.
23. Measured section (partial) of Harpersville Formation, located just below Hubbard Creek dam ½ to 1 mile west of U. S. 183. Galloway (1970, p. 96-97, section

#18). Lignite, 1.5 feet thick, is exposed 4.0 feet above base of outcrop along hillslope in road cut adjacent to gravel road.

24. Measured section (partial) of Harpersville Formation, 6 miles north of Breckenridge and half a mile west of FM 578 (see #17 above). Galloway (1970, p. 98-99, section #20). Four lignite beds observed, 0.5, 0.2, 0.8, and 0.5 foot thick, at 6.0, 9.0, 25.3, and 43.1 feet, respectively, above base of exposure in creekbed on the southwest side of small hill.

WISE COUNTY

1. Wise County Coal Company's shaft no. 1, East Bridgeport, half a mile east of Chicago, Rock Island and Texas Railway. Phillips (1902a, p. 34). Long-wall advancing methods were used in this 55-foot-deep shaft mine. Twenty inches of coal mined as a single seam. Analysis WI-2 (table 1) is a chemical analysis of coal taken from this shaft. Location of this shaft is uncertain. According to State Mine Inspector's Reports (1911, 1914, 1921, and 1924), Wise County Coal Company opened six shafts but no reference to the exact location of these shafts is known to this writer.

2, 3, 4. Bridgeport Coal Company's shafts no. 1, 2, and 3, located along northwest margin of Bridgeport. Phillips (1902a, p. 34-35). In shafts #1 and #2, 56 and 112 feet deep respectively, a 19-inch coal seam ("Bridgeport Coal") was worked for several years. A third shaft apparently was opened after 1902 as State Mine Inspector's Reports (1911, 1914, 1921, 1924, and 1928) refer to no. 3 shaft. Time of initial production in shaft no. 1 and no. 2 is not known, but both shafts apparently closed in the early 1920's. Analyses WI-3 and WI-4 (table 1) are from samples collected from Bridgeport Coal Co.'s shafts #1 and #2, respectively.

5, 6, 7. These are undescribed coal mines located on plate 1 and figure 7 of Scott and Armstrong (1932). Mines #5 and #6 are described as slope mines but #7 is not further identified. Apparently these mines are located on the 18- to 22-inch-thick Bridgeport coal.

YOUNG COUNTY

1. Measured section at Flat Top Mountain, about 8 miles northeast of Graham. Cummins (1891, p. 492). A 20-inch coal seam ("seam no. 7") occurs 47 feet below a 3-foot-thick conglomerate bed at top of exposure. Thirty-eight inches of carbonaceous shale and slate separate this upper coal bed from an 8-inch coal seam below.
2. Measured section about 5 miles west of Flat Top Mountain on Coal Bank Branch and Colony Survey no. 604, approximately 6 miles north of Graham. Cummins (1891, p. 493). Several shallow pits dug down to coal. Four coal beds (8, 8, 24, and 8 inches thick) occur 11, 12, 14, and 18 feet below top of exposure.
3. Measured section near mouth of Coal Creek on Colony survey no. 426, about 5 miles northeast of Newcastle. Cummins (1891, p. 493-494). Thirty-four inches of coal ("seam no. 7"), not including a 1-inch slate parting, are exposed below 3 feet of "heavy shales."
4. Graham shaft located 200 yards southeast of #3 (above), about 5 miles northeast of Newcastle. Cummins (1891, p. 494). A 42-inch coal seam and a 1½-inch slate parting occur 49 feet below surface. A thin coal seam (2 to 3 inches) occurs about 13 feet below main coal seam ("seam no. 7").
5. Lewis mine is located 1 mile north of Graham shaft (see #4 above) on Colony Survey no. 616, about 6 miles northeast of Newcastle. Cummins (1891, p. 495). A small surface (strip) mine operated here, presumably working coal similar to that described in #4 ("seam no. 7").
6. Measured section located 3 miles south of mouth of Coal Creek on Bradwell Survey, about 5 miles east of Newcastle. Cummins (1891, p. 495). A 4-inch coal seam occurs 5½ feet below a 3-foot-thick limestone bed. Coal seam not considered correlative to "seam no. 7" (Cummins, 1891, p. 495).
7. Measured section of "seam no. 7" at mouth of Whiskey Creek, 2 miles north of (Fort) Belknap. Cummins (1891, p. 495). See also Buckley (1866, p. 23-24) and Ashburner (1881, p. 504). Two 1-foot coal beds occur 42 and 51 feet below top of exposure and one 14-inch coal seam occurs at about 78 feet below top of outcrop. Older references listed above contain measured sections from same area.
8. Measured section of "seam no. 7" 200 yards above mouth of Whiskey Creek. Cummins (1891, p. 495). One foot of coal occurs 9 feet below top of exposure. Buckley (1866, p. 24) reports a 4-foot coal seam at about this same location.
9. Measured section 1 mile above mouth of Whiskey Creek at "new road crossing." Cummins (1891, p. 496). An 18-inch coal seam is described as occurring 14 feet below top of the exposure.
10. Measured section located half a mile south of the mouth of Whiskey Creek, on east side of Brazos River. Cummins (1891, p. 496). A 20-inch coal seam occurs 10 feet below top of exposure. "In all the wells at Belknap they reach the coal seam at a depth of about forty feet."
11. Measured section about 3 miles upstream along Brazos River from mouth of Whiskey Creek. Cummins (1891, p. 496-497). At this point, coal-bearing strata pass beneath the Brazos River into the subsurface. A 2-foot "shaly" coal seam occurs 4 feet above exposure base and a 4-inch seam occurs 18 feet above the "shaly" coal.
12. Russell shaft located near southwest corner of J. P. Williams Survey. Cummins (1891, p. 497-498). This is a 26-foot shaft which struck 7½ inches of coal at 20.5 feet, an 8-inch coal bed at 22 feet, a 24-inch coal seam at 23 feet, and a 3-inch seam at 26 feet. Two locations (2 shafts) are indicated on plate 6, page 498 of Cummins' report.
13. Graham shaft on Survey no. 19,556 of Beaty, Seale, and Forwood. Cummins (1891, p. 497-499). Four coal seams located, 10, 8½, 27, and 3 inches thick, in a zone ranging from 28 to 33 feet deep. Total depth of shaft is 33¼ feet.

14. Kendall shaft located on Beaty, Seale, and Forwood Survey no. 6460, school section no. 2. Cummins (1891, p. 498-499). Coal is same as that found in Graham shaft (#13 above).
15. Donnell Brother's tunnel on Texas and Pacific Railroad Survey no. 2 (file no. 6460). Cummins (1891, p. 498-499). Exploration tunnel into coal zone similar to that described for the Graham shaft (#13 above).
16. Gilfoil shaft situated near southwest corner of Gilfoil Survey. Cummins (1891, p. 498-499, 501). Coal observed is similar to that found in nearby shafts (#'s 12-15 above).
17. Jones mine located on J. C. Jones Survey, half a mile southeast of Carbondale. Cummins (1891, p. 500-501). A tunnel mine about 100 feet long. Coal, 3½ feet thick, is indicated (not including a 4-inch slate parting). Sandstone directly overlies this thick coal seam. Several outcrops of coal are reported in the general vicinity of old Carbondale. (Village now abandoned.)
18. Measured section of "seam no. 7" coal about 4 miles from Gertrude "near the corner of Loving's pasture." Cummins (1891, p. 515). A 1-foot seam of coal occurs 119 feet below top of exposure with a 4-inch coal bed 30 feet below the exposure top. Location of section uncertain.
19. Measured section of Harpersville Formation on Graham Ranch, 7 miles south of Newcastle. Plummer and Moore (1921, fig. 13, p. 123; p. 163). A 2-foot-thick coal bed occurs 78 feet below top of conglomeratic sandstone which forms upper unit of Harpersville in this area. Location of section uncertain due to map location (p. 123) contradicting verbal description of location. Map location indicated on plate I (this report).
20. Measured section of Blach Ranch Limestone and related units of Thrifty Formation. Half a mile west of McCann Bridge over Brazos River, 7½ miles west of Graham. Lee and others (1938, p. 59). A 6-inch coal seam occurs just 3 inches below base of Blach Ranch Limestone.
21. Composite section of Harpersville Formation on Donnell Ranch in southwestern Young County. Lee and others (1938, p. 73-74). One 2-foot bed and a 3-foot bed of "coal and shale" are present 146 and 163 feet below the Saddle Creek Limestone. Lower coal seam is 23 feet above Crystal Falls Limestone and 55 feet above Breckenridge Limestone.
22. Composite section of part of Harpersville Formation on west side of Wagon Timber Branch, south of Eliasville-Woodson highway. Lee and others (1938, p. 69). A 2-foot bed of coal and shale ("one of Newcastle coals") occurs 12 feet above the "Upper Crystal Falls limestone."
23. Stover mine on T. E. and L. Co. Survey 1947, near Loving. Criswell (1942). Two coal seams identified with an upper 1-foot bed 60 feet below Belknap limestone and a 2-foot coal seam just 3 feet below the first coal bed. Coal is described as "poor" in upper bed and "average" in lower bed. Analysis YO-8 (table 2) is a chemical analysis of the coal from this general area.
24. Measured section of Harpersville Formation at Salt Creek on center of NW¼, T. E. and L. Co. Survey 616; section measured southeast to south line of Survey 606. Criswell (1942). A 3-foot coal seam is located 69 feet below Belknap limestone.
25. Measured section of Harpersville Formation (in part) at spillway of Newcastle Lake. Criswell (1942). One 3-foot coal bed occurs 35 feet below Belknap limestone and a second seam (1 foot thick) is present about 20 feet below the upper bed, just below the "Middle Waldrip limestone."
26. Two measured sections of Harpersville Formation taken close together on T. E. and L. Co. Surveys 19 and 358, on west bank of Brazos River. Criswell (1942). Both sections indicate that an 18- to 24-inch coal seam is present just below the "Middle Waldrip limestone."
27. Measured section of Harpersville Formation on northeast part of T. E. and L. Co. Survey, Block 3410, fractional "B". Criswell (1942). A 2-foot coal bed occurs 60 feet below the Belknap limestone.
28. Measured section of Harpersville Formation on Washington Co. Railroad Survey A-1280. Criswell (1942). Two coal seams occur at 42 and 80 feet above Breckenridge Limestone. The seams are 2 and 3 feet thick, respectively.
29. Measured section of part of Harpersville and Thrifty Formations on east bank of Brazos River; section measured up southwest end of steep bluff. Brown (1962, p. 25, section #9). Impure coal, 0.2 foot thick, is present in the unnamed shale member of Thrifty Formation about 1 foot below Blach Ranch Limestone.
30. Measured section of upper part of Thrifty Formation along west bank of creek, 20 yards east of county road. Brown (1962, p. 24, section #6). One foot below Blach Ranch Limestone is 1-foot-thick coal ("very shaly") in an unnamed shale member of Thrifty Formation.
31. Measured section (partial) of Harpersville Formation on southeast flank of Belknap Mountain. Galloway (1970, p. 100-101, section #22). Lignite, 0.3 foot thick, occurs 47.5 feet above Breckenridge Limestone.
32. Measured section (partial) of Harpersville Formation just west of State Highway 251, about 1 mile north of Newcastle. Galloway (1970, p. 101, section #23). A 2.5-foot bed of lignite and plant debris-rich "clayshale" occurs 7.0 feet above base of exposure.
33. Measured section (partial) of Harpersville Formation 1 mile east of State Highway 16, about 3 miles northeast of Loving. Galloway (1970, p. 101-102, section #24). Coaly clayshale, 0.3 foot thick, occurs about 7.0 feet above base of exposure.
34. Measured section (partial) of Harpersville Formation on small hill just north of State Highway 179, near Young-Jack county line. Galloway (1970, p. 102, section #25). A bed of lignite, 1.2 feet thick, occurs 87 feet above Breckenridge Limestone. An 8.0-foot zone of coaly clayshale and a thin lignite bed occurs 50 feet above Breckenridge Limestone.

35. Measured section (partial) of Harpersville Formation along lease road up hill just west of Young-Jack county line. Galloway (1970, p. 103-104, section #26). A thick bed of coal and clayshale (7.5 feet) occurs 57 feet above base of exposure. Several thin coaly zones are present from base of exposure up to thicker coal and plant debris-rich clayshale beds.
36. Belknap Coal Company's no. 1 mine on W. B. Pope Survey, about 1 mile southeast of Newcastle. Information from Belknap Coal Company mine maps on open file, Bureau of Economic Geology, The University of Texas at Austin. A 52-inch coal seam was mined. Depth of shaft was 140 feet (Ledbetter, 1964). Mine was opened about 1908 and worked until sometime between 1910 and 1914. Mining was accomplished using room-and-pillar methods.
37. Belknap Coal Company's no. 2 mine on T. E. and L. Co. Survey 8, about 1 mile northeast of Newcastle. Information from Belknap Coal Company mine maps on open file, Bureau of Economic Geology, The University of Texas at Austin, and from Ledbetter (1964). A 44-inch coal seam occurs at a 55-foot depth. Shaft opened sometime between 1908 and 1910 but closed in 1914. Room-and-pillar mining techniques were used.
38. Belknap Coal Company's no. 3 mine on T. E. and L. Co. Survey 6, about half a mile north of Newcastle. Information from Belknap Coal Company mine maps on open file, Bureau of Economic Geology, The University of Texas at Austin. No information available on seam thickness or shaft depth. Dates of opening and closing not available.
39. Belknap Coal Company's no. 4 mine on northeast corner of T. E. and L. Co. Survey 3, about 1.1 miles southeast of Newcastle. Information from Belknap Coal Company mine maps on open file, Bureau of Economic Geology, The University of Texas at Austin. According to State Mine Inspector's Reports (1911, 1914, and 1921), this shaft began production between 1910 and 1914 but closed in 1919. Seam thickness and shaft depth not available. Room-and-pillar mining methods were employed in this mine.
40. Belknap Coal Company's no. 5 mine on T. E. and L. Co. Survey 8, about 1.2 miles northeast of Newcastle. Information from Belknap Coal Company mine maps on open file, Bureau of Economic Geology, The University of Texas at Austin. Shaft was opened about 1915, but closed before 1924. Ledbetter (1964) indicates that shaft may not have closed until 1927. Seam thickness and shaft depth not available. In 1920, the no. 5 mine produced almost 29,000 tons of coal. Mining was accomplished by room-and-pillar methods.

APPENDIX II

DESCRIPTION OF SAMPLES USED FOR CHEMICAL ANALYSES

Chemical analysis of coal includes proximate and ultimate analyses. Proximate analysis measures parameters that reflect a particular coal sample's behavior when used as a fuel. Ultimate analysis measures percentages of the elements sulfur, carbon, hydrogen, oxygen, and nitrogen present in the coal sample.

Though a discussion of the many variables involved in both proximate and ultimate analyses is beyond the scope of this report, two aspects deserve elaboration here. First, the reliability of coal analyses is strongly dependent on sampling technique and sample condition. Variations in sampling technique (inclusion or exclusion of shale partings, size of sample collected, "freshness" of coal sample, susceptibility to moisture variations in transit, and so on) can affect analytical results. Further, analysis of "mine" samples will differ from "outcrop" samples which differ from "delivered" or "tipple" samples. Delivered or tipple samples closely approximate the coal sold commercially. Such coal is affected by inclusion of impurities that require too much time and effort to remove, as well as variations in moisture content of coal while in transit or in storage. Chemical analyses of delivered or tipple samples generally reflect the character of coal actually in use as a fuel. If the coal has been mechanically cleaned prior to delivery, it is referred to as a washed sample and chemical analyses should reflect the exclusion of impurities as a result of cleaning or washing. Outcrop samples may include portions of the coal seam that have been weathered through exposure and are susceptible to collector bias by the inclusion or exclusion of shale partings or other impurities. Mine-face samples tend to reflect coal characteristics in coal collected under optimum conditions. Mine samples generally are "fresh," though handling of the sample after collection and before analysis may affect this particular feature.

A second major aspect involving chemical analysis of coal is the significance of parameters determined in proximate analyses. Elaboration on these parameters is justified as they reflect the behavior of a sample as a fuel.

Moisture.—Moisture wastes heat as coal is burned because some heat is required to convert the moisture to water vapor. Also, the presence of moisture displaces an equivalent weight of combustible material.

Volatile matter.—Gaseous combustibles include hydrogen, carbon monoxide, methane, and other hydrocarbons, as well as some incombustible gases (carbon dioxide and water vapor). Since measurement of the gaseous yield of coal depends on the temperature at which coal is heated (current analytical technique calls for volatile-matter determination at 950-1,000°C), volatile-matter percentages are susceptible to variations in analytical technique.

Fixed Carbon.—Solid combustible material that remains after gaseous combustibles are driven off is the fixed carbon. Amount of fixed carbon is directly related to heating value and fixed carbon content, together with ash content, determines the coking qualities of the coal.

Ash.—After all combustibles have been ignited, the inorganic residue is the ash content. Amount of ash present is highly dependent on sampling techniques and sample condition at time of collection. Ash adversely affects combustion efficiency and causes problems in furnace care and disposal of incombustible refuse. Also, the presence of ash displaces an equivalent weight of combustible material.

Sulfur.—Pyritic and organic sulfur are the most common forms of sulfur in coal. In some cases, the pyritic sulfur can be removed before use, but organic sulfur and disseminated pyritic sulfur generally cannot be excluded. Pyritic sulfur causes problems by increasing clinker formation, but the most serious effect of sulfur content is the formation of sulfur oxide compounds in flue-gas during combustion, which contributes significantly to air-quality degradation. Sulfur content of 1 percent or more is considered serious enough to require remedial steps in use of the coal.

Heating value.—Reported as Btu's per pound of coal, the heating value reflects the quantity of heat liberated in complete combustion. Heating value can be determined directly using a bomb calorimeter or indirectly using calculations involving ultimate analysis values.

Analytical values listed in tables are percent by weight of original sample. Some analyses do not add up to 100 percent and probably reflect differences in analytical technique or rounding of measured values.

Analyses within stratigraphic groups are arranged by counties. Within counties, analyses are arranged in chronological order according to date of original publication.

TABLE 1

ER-1 Mine sample. Texas and Pacific Coal Co. shaft no. 1, near Thurber, Erath County. Cummins (1891, p. 551).

ER-2 Mine sample. Texas and Pacific Coal Co. shaft no. 2, near Thurber, Erath County. Cummins (1891, p. 551).

ER-3 Mine sample. Texas and Pacific Coal Co. shaft no. 3, near Thurber, Erath County. Cummins (1891, p. 551).

ER-4 Mine sample (?). Texas and Pacific Coal Co., Thurber, Erath County. Taff (1902, p. 408).

ER-5 Mine sample. Texas and Pacific Coal Co. mine no. 9, near Thurber, Erath County. Phillips (1902a, p. 52; sample no. 1531).

ER-6 Mine sample (?). Texas and Pacific Coal Co., Thurber, Erath County. Phillips and others (1911, p. 29; sample no. 10).

ER-7 Outcrop samples (?). Average of eight analyses, near Thurber, Erath County. Udden and others (1916, p. 136).

ER-8 Delivered samples. "Typical" analysis of several different samples, near Thurber, Erath County. Fieldner and others (1942, p. 38; item no. 560).

ER-9 Delivered sample. Average of 12 deliveries of 1-inch lump totaling 680 tons shipped to Camp Marfa, Texas, in 1924-25. Texas and Pacific Coal Co. mine no. 3, bed no. 1, near Thurber, Erath County. U. S. Bureau of Mines (1948, p. 99; index no. 131).

PP-1 Mine sample. Texas and Pacific Coal Co. mine no. 7, in Palo Pinto County, 2½ miles northwest of Thurber, Erath County. Phillips (1902a, p. 52; sample no. 1529).

PP-2 Mine sample. Texas and Pacific Coal Co. mine no. 8, in Palo Pinto County, 3½ miles northwest of Thurber, Erath County. Phillips (1902a, p. 52; sample no. 1530).

PP-3 Mine sample. Texas and Pacific Coal Co. mine no. 10, in Palo Pinto County, 4 miles northwest of Thurber, Erath County. Phillips (1902a, p. 52; sample no. 1532).

PP-4 Mine sample. Strawn Coal Mining Co. shaft, near Strawn, Palo Pinto County. Phillips (1902a, p. 52; sample no. 1533).

PP-5 Mine sample (?). Strawn Coal Mining Co., near Strawn, Palo Pinto County. Phillips and others (1911, p. 29; sample no. 9).

PP-6 Mine sample (?). Strawn Coal Mining Co., near Strawn, Palo Pinto County. Analysis from Detroit Testing Laboratory was made on December 12, 1912. Phillips and Worrell (1913, p. 28).

PP-7 Mine sample (?). Average analysis from mines near Strawn, Palo Pinto County. Udden and others (1916, p. 136).

PP-8 Mine sample. "Typical" analysis made from several samples, Palo Pinto County. Fieldner and others (1942, p. 38; item no. 563).

PP-9 Delivered sample. Average of 11 deliveries of 2½-inch lump totaling 546 tons shipped to CCC camps in Texas in 1941-42. Strawn Coal Mining Co. mine no. 4, bed no. 1, near Strawn, Palo Pinto County. U. S. Bureau of Mines (1948, p. 99; index no. 133).

PP-10 Tipple sample. 85-ton delivery of 2-inch lump to tipple, sampled on February 17, 1941. Strawn Coal Mining Co. mine no. 4, bed no. 1, near Strawn, Palo Pinto County. U. S. Bureau of Mines (1948, p. 99; index no. 134).

PP-11 Tipple sample. 25-ton delivery of 1- by 2-inch lump to tipple, sampled on February 17, 1941. Strawn Coal Mining Co. mine no. 4, bed no. 1, near Strawn, Palo Pinto County. U. S. Bureau of Mines (1948, p. 99; index no. 135).

PR-1 Mine sample. J. S. Young mine, near Keeler Siding, western Parker County. Phillips (1902a, p. 52; sample no. 1528). (Erroneously located in Palo Pinto County in original publication.)

PR-2 Mine sample. Texas Coal and Fuel Co. mine no. 1, near Rock Creek, Parker County. Phillips (1902a, p. 52; sample no. 1525).

PR-3 Mine sample. Texas Coal and Fuel Co. mine no. 2, near Rock Creek, Parker County. Phillips (1902a, p. 52; sample no. 1526).

PR-4 Mine sample. Texas Coal and Fuel Co. mine no. 3, near Rock Creek, Parker County. Phillips (1902a, p. 52; sample no. 1527).

PR-5 Mine sample (?). Santo Mining and Developing Co., Weatherford, Parker County. Phillips and others (1911, p. 29; sample no. 7).

WI-1 Mine sample (?). Bridgeport, Wise County. Cummins (1891, p. 551).

WI-2 Mine sample. Wise County Coal Co., East Bridgeport, Wise County. Phillips (1902a, p. 52; sample no. 1522).

WI-3 Mine sample. Bridgeport Coal Co. mine no. 1, near Bridgeport, Wise County. Phillips (1902a, p. 52; sample no. 1523).

WI-4 Mine sample. Bridgeport Coal Co. mine no. 2, near Bridgeport, Wise County. Phillips (1902a, p. 52; sample no. 1524).

WI-5 Mine sample. Bridgeport Coal Co., Bridgeport, Wise County. Phillips (1902a, p. 29; sample no. 2).

WI-6 Mine sample. Wise County Coal Co., Bridgeport, Wise County. Phillips (1902a, p. 29; sample no. 11).

WI-7 Mine sample. Average of six analyses. Bridgeport, Wise County. Udden and others (1916, p. 136).

WI-8 Mine sample. "Typical" analysis from several analyses, presumably near Bridgeport, Wise County. Fieldner and others (1942, p. 38; item no. 565).

WI-9 Mine sample, collected November 7, 1940. High-volatile C bituminous coal. Byrns and Byrns mine, near Bridgeport, Wise County. U. S. Bureau of Mines (1948, p. 62; laboratory no. B57800).

WI-10 Mine sample, collected November 7, 1940. High-volatile C bituminous coal. Byrns and Byrns mine, near Bridgeport, Wise County. U. S. Bureau of Mines (1948, p. 62; laboratory no. B57801).

WI-11 Mine sample, collected November 7, 1940. High-volatile C bituminous coal. Byrns and Byrns mine, near Bridgeport, Wise County. U. S. Bureau of Mines (1948, p. 62; laboratory no. B57802).

WI-12 Composite analysis of samples WI-9, 10, and 11. Byrns and Byrns mine, near Bridgeport, Wise

County. U. S. Bureau of Mines (1948, p. 62; laboratory no. B57803).

WI-13 Mine sample, collected November 7, 1940. High-volatile C bituminous coal. Singleton mine, near Bridgeport, Wise County. U. S. Bureau of Mines (1948, p. 62; laboratory no. B57797).

WI-14 Mine sample, collected November 7, 1940. High-volatile C bituminous coal. Singleton mine, near Bridgeport, Wise County. U. S. Bureau of Mines (1948, p. 62; laboratory no. B57798).

WI-15 Composite analysis of samples WI-13 and 14. Singleton mine, near Bridgeport, Wise County. U. S. Bureau of Mines (1948, p. 62; laboratory no. B57799).

TABLE 2

CO-1 Mine sample (Outcrop sample?). "Bull Creek and Coleman County" (Tarr, 1890, p. 215), but ascribed to "Vining mine" by Taff (1902). Southern part of Coleman County.

CO-2 Outcrop sample ("made from large quantity"). Bull Creek, southern Coleman County. Tarr (1890, p. 215).

CO-3 Mine sample ("made from 15 pounds powdered"). Silver Moon mine, near Santa Anna, Coleman County. Tarr (1890, p. 215).

CO-4 Mine sample (from 6-inch coal seam). Silver Moon mine, near Santa Anna, Coleman County. Drake (1893, p. 431; sample "c").

CO-5 Mine sample (from 8-inch coal seam). Silver Moon mine, near Santa Anna, Coleman County. Drake (1893, p. 431; sample "a").

CO-6 Mine sample. Star and Crescent mine, near Rockwood, Coleman County. Drake (1893, p. 434; analysis no. 1).

CO-7 Mine sample. Star and Crescent mine, near Rockwood, Coleman County. Drake (1893, p. 434; analysis no. 2).

CO-8 Mine sample. Star and Crescent mine, near Rockwood, Coleman County. Drake (1893, p. 434; analysis no. 3).

CO-9 Mine sample. Star and Crescent mine, near Rockwood, Coleman County. Drake (1893, p. 434; analysis no. 4).

CO-10 Weighted average of CO-6, 7, 8, and 9 based on relative abundance in coal seam actively mined. Star and Crescent mine, near Rockwood, Coleman County. Drake (1893, p. 435).

CO-11 Outcrop sample (?). Near Rockwood, Coleman County. Phillips (1914, p. 96).

CO-12 Mine sample. Silver Moon mine, near Santa Anna, Coleman County. Phillips (1914, p. 96).

EA-1 Mine sample. Smith-Lee mine, just north of Cisco, Eastland County. Phillips (1902a, p. 52; sample no. 1534).

JK-1 Mine sample. Stewart Creek Coal Co., Jermyn, Jack County. Phillips and others (1911, p. 29; sample no. 37).

JK-2 Outcrop sample (?). Lost Valley, Jack County. Phillips and Worrell (1913, p. 25).

MC-1 Outcrop sample (?), made from "large quantity." Near Waldrip, McCulloch County. Tarr (1890, p. 215).

MC-2 Outcrop sample (?), made from "one small piece." Near Waldrip, McCulloch County. Tarr (1890, p. 215).

MN-1 Mine sample. Sheuber shaft, near Bowie, Montague County. Cummins (1891, p. 551).

MN-2 Outcrop sample (?). "Average composition of coal in a vein of coal near Bowie. Anal. 1895. Name of analyst not given. Eng. & Min. Jour. vol. 60, no. 19, p. 443." Schoch (1918, p. 89; analysis no. 1483).

SH-1 "Mine sample." 5-foot coal seam at 675-foot depth struck in oil well boring, Smaulm Ranch, near Albany, Shackleford County. Schoch (1918, p. 90; analysis no. 1491).

ST-1 Outcrop sample. Along Coal Branch, west of Crystal Falls, Stephens County. Upper 12-inch bench, sampled on December 13, 1906. Phillips and others (1911, p. 35).

ST-2 Outcrop sample. Along Coal Branch, west of Crystal Falls, Stephens County. Lower 12-inch bench, sampled on December 13, 1906. Phillips and others (1911, p. 35).

ST-3 Outcrop sample. Along Coal Branch, west of Crystal Falls, Stephens County. Entire 24-inch seam sampled. Phillips and others (1911, p. 36).

YO-1 Outcrop sample (from 3½-foot seam). Whiskey Creek, north of Fort Belknap, Young County. B. F. Shumard (1859, p. 10).

YO-2 Mine sample. Gilfoil shaft, Young County. Cummins (1891, p. 551).

YO-3 Mine sample. Belknap Coal Co., Newcastle, Young County. Phillips and others (1911, p. 29; sample no. 1).

YO-4 Mine sample. Belknap Coal Co., Newcastle, Young County. Phillips and others (1911, p. 29; sample no. 53).

YO-5 Mine sample (?). Average of two analyses. Newcastle, Young County. Udden and others (1916, p. 137).

YO-6 Mine sample. Lower vein in W. K. Gordon mine, Young County. Schoch (1918, p. 90; analysis no. 1497).

YO-7 Outcrop sample (?). 5-foot vein near Loving, Young County. Sent in by H. L. Kniffin of Dallas. Schoch (1918, p. 90; analysis no. 1498).

YO-8 "Mine sample." 22- to 23-inch vein at 105-foot depth, near Loving, Young County. Sent in by

E. M. Gleason, Dallas. Schoch (1918, p. 90; analysis no. 1499).

YO-9 Mine sample. High-volatile C bituminous coal. Deep Vein mine, near Newcastle, Young County. Sampled on February 19, 1943. U. S. Bureau of Mines (1948, p. 62; laboratory no. B95485).

YO-10 Mine sample. High-volatile C bituminous coal. Deep Vein mine, near Newcastle, Young County. Sampled on February 19, 1943. U. S. Bureau of Mines (1948, p. 62; laboratory no. B95486).

YO-11 Mine sample. High-volatile C bituminous coal. Deep Vein mine, near Newcastle, Young County. Sampled on February 19, 1943. U. S. Bureau of Mines (1948, p. 62; laboratory no. B95487).

YO-12 Composite analysis of YO-9, 10, and 11. Deep Vein mine, near Newcastle, Young County. U. S. Bureau of Mines (1948, p. 62; laboratory no. B95488).

TABLE 3

1. Mine sample. "Altered lignite" from "San (sic) Tomas" mine, near Laredo, Webb County. Penrose (1889, p. 98).
2. Outcrop sample. "Pitch" coal "thoroughly air dried" collected by J. Owen, 25 miles northwest of "San (sic) Tomas," Webb County. Dumble (1892, p. 190; sample no. 1).
3. Mine sample. Upper bench, Rio Grande Coal and Irrigation Company, Santo Tomas, Webb County. Peter J. Fireman, analyst. Vaughn (1900, p. 64).
4. Mine sample. Lower bench, Rio Grande Coal and Irrigation Company, Santo Tomas, Webb County. Peter J. Fireman, analyst. Vaughn (1900, p. 64).
5. Mine sample. Upper bench, Cannel Coal Company, near Santo Tomas, Webb County. Peter J. Fireman, analyst. Vaughn (1900, p. 65).
6. Mine sample. Upper part of lower bench, Cannel Coal Company, near Santo Tomas, Webb County. Peter J. Fireman, analyst. Vaughn (1900, p. 65).
7. Mine sample. Lower part of lower bench, Cannel Coal Company, near Santo Tomas, Webb County. Peter J. Fireman, analyst. Vaughn (1900, p. 65).
8. Mine sample. Rio Grande Coal Co., Minera, Webb County. Phillips (1902a, p. 52; sample no. 1518).
9. Mine sample. Cannel Coal Co., Darwin, Webb County. Phillips (1902a, p. 52; sample no. 1519).
10. Mine sample. Rio Grande Coal Company, Minera, Webb County. D. P. Jones, analyst, Chicago. Phillips (1902a, p. 52).
11. Mine sample. Cannel Coal Co., Laredo, Webb County. Phillips and others (1911, p. 29; sample no. 3).
12. Mine sample. Rio Grande Coal Co., Laredo, Webb County. Phillips and others (1911, p. 29; sample no. 8).
13. Mine sample. 1,000-pound lot with impurities not picked out. Sampled by U. S. Geological Survey on February 21, 1910. Cannel Coal Co., Laredo, Webb County. Phillips and Worrell (1913, p. 33).
14. Mine sample (?). "Llave coal," "Laredo district," Webb County. Analysis provided by Otto Stolley of Austin. J. R. Bailey, University of Texas, analyst. Phillips and Worrell (1913, p. 33).
15. Delivered sample. 25 pounds of crushed ¼- to ½-inch coal received from Santo Tomas Coal Co. shaft no. 1, Laredo, Webb County. Phillips and Worrell (1913, p. 34).
16. Delivered sample. "Special," delivered to University of Texas Powerhouse from Santo Tomas Coal Co., Laredo, Webb County. Phillips and Worrell (1913, p. 34).
17. Delivered sample. "Carloads," delivered to University of Texas Powerhouse from Santo Tomas Coal Co., Laredo, Webb County. Phillips and Worrell (1913, p. 34).
18. Mine sample. Subbituminous coal, average of 13 analyses. Mines at Darwin, Cannel, Minera, etc., Webb County. Phillips (1914, p. 242).
19. Mine sample (?). Average analysis of "Minera lignite," Minera, Webb County. Udden and others (1916, p. 139).
20. Delivered sample. Average of 10 analyses of bituminous coal delivered to Fort McIntosh, Texas, in 1911-12. Contract guaranties: 16.53% ash, "dry coal"; 11,588 Btu, "as received." Price, $5.60 per ton. Pope (1916, p. 38-39; index no. 495).
21. Mine sample. Cannel coal from San Jose Cannel Coal Co., San Jose, Webb County. Received from Dr. Bredlick. S. H. Worrell, analyst. Schoch (1918, p. 198; analysis no. 1566).
22. Outcrop sample. "Cannel coal from lands of Mrs. Shaw, in the northwestern part of the county, between San Lorenzo and San Ambrosia Creeks. Thickness of seam 6 inches." Sampled by J. A. Udden. S. H. Worrell, analyst. Schoch (1918, p. 198; analysis no. 1567).
23. Outcrop sample. "Cannel coal from lands of Mrs. Shaw in northwestern part of county. Thickness of seam 4 inches." Sampled by J. A. Udden. S. H. Worrell, analyst. Schoch (1918, p. 198; analysis no. 1568).
24. Delivered sample. Average of 12 samples from 4,336 tons of 4-inch lump delivered to Fort Sam Houston, Texas, 1916-1917. Contract guaranties: 3.7% moisture, "as received"; 47% volatile matter, "dry coal"; 13.5% ash, "dry coal"; and 12,500 Btu, "dry coal." Price, $5.25 per ton. Ashley (1919, p. 257; sample no. 20).
25. Delivered sample. Average of 3 samples from 173 tons of lump coal delivered to Fort McIntosh, Texas, 1916-17. Contract guaranties: 2.7% moisture, "as received"; 47% volatile matter, "dry coal"; 13.5% ash, "dry coal." Price, $4.50 per ton. Ashley (1919, p. 257; sample no. 21).

26. Delivered sample. Average of 5 samples from 165 tons of lump coal, over 3-inch screen, delivered to Fort McIntosh, Texas, 1915-16. Contract guaranties: 4% moisture, "as received"; 50% volatile matter, "dry coal"; 13.5% ash, "dry coal"; and 12,000 Btu, "as received." Price, $4.50 a ton. Ashley (1919, p. 258; sample no. 22).

27. Mine sample. Santo Tomas mine no. 1, Santo Tomas seam, Santo Tomas, Webb County. 30-inch seam sampled by G. H. Ashley. Ashley (1919, p. 258; sample no. 23).

28. Mine sample. Dolores shaft, Santo Tomas seam, Cannel Coal Co. (?), Dolores, Webb County. 28-inch seam sampled by G. H. Ashley. Ashley (1919, p. 258; sample no. 24).

29. Mine sample. Dolores shaft, San Pedro seam, Cannel Coal Co., Dolores, Webb County. 22-inch seam sampled by G. H. Ashley. Ashley (1919, p. 258; sample no. 25).

30. Outcrop sample. 26-inch coal seam sampled in weathered coal 30 feet into Hunt mine drift, near Darwin, Webb County. Sampled by G. H. Ashley. Ashley (1919, p. 258; sample no. 26).

31. Tipple sample. "Typical" analysis of Webb County cannel coal. Fieldner and others (1942, p. 38; item no. 564).

32. Delivered sample. Averaged from 35 shipments of 2½-inch lump to various Army stations in Texas totaling 5,591 tons in 1927-28. Dolores mine, Santo Tomas and San Pedro seams, Dolores, Webb County. U. S. Bureau of Mines (1948, p. 60; index no. 136).

33. Delivered sample. Averaged from 4 shipments of 2½-inch lump to Kelly Field, Texas, totaling 910 tons in 1932-33. Dolores mine, Santo Tomas and San Pedro seams, Dolores, Webb County. U. S. Bureau of Mines (1948, p. 60; index no. 137).

34. Delivered sample. Averaged from 42 shipments of 2-inch lump to various Army stations in Texas, totaling 3,627 tons in 1926-27. Dolores mine, Santo Tomas and San Pedro seams, Dolores, Webb County. U. S. Bureau of Mines (1948, p. 60; index no. 138).

35. Delivered sample. Averaged from 2 shipments of 2-inch lump to Brooks Field, Texas, totaling 900 tons in 1933-34. Dolores mine, Santo Tomas and San Pedro seams, Dolores, Webb County. U. S. Bureau of Mines (1948, p. 60; index no. 139).

36. Delivered sample. Averaged from 3 shipments of 2- by 5-inch coal to Brooks Field, Texas, totaling 1,352 tons in 1931-32. Dolores mine, Santo Tomas and San Pedro seams, Dolores, Webb County. U. S. Bureau of Mines (1948, p. 60; index no. 140).

37. Delivered sample. Averaged from 3 shipments of 1- by 3½-inch coal to Fort Sam Houston, Texas, totaling 1,201 tons in 1927-28. Dolores mine, Santo Tomas and San Pedro seams, Dolores, Webb County. U. S. Bureau of Mines (1948, p. 60; index no. 141).

38. Delivered sample. Analysis of one 201-ton shipment of 1- by 3½-inch lump coal to Fort Sam Houston, Texas, in 1931-32. Dolores mine, Dolores, Webb County. U. S. Bureau of Mines (1948, p. 60; index no. 142).

39. Tipple sample. Analysis of 3 ton run-of-mine sample collected February 20, 1941 at tipple of Cannel mine, Laredo, Webb County. U. S. Bureau of Mines (1948, p. 61; index no. 143).

40. Mine sample. Cannel coal, San Pedro seam, Dolores mine no. 3, Dolores, Webb County. 19 inches sampled from 20-inch bed, March, 1922, by Homer Cote (USBM). U. S. Bureau of Mines (1948, p. 61; index no. 84739).

41. Mine sample. Cannel coal, San Pedro seam, Dolores mine no. 3, Dolores, Webb County. 24 inches sampled from 25-inch bed, March, 1922, by Homer Cote (USBM). U. S. Bureau of Mines (1948, p. 61; index no. 84740).

42. Mine sample. Cannel coal, Santo Tomas seam, Dolores mine no. 3, Dolores, Webb County. 14½ inches sampled from 29-inch bed, March, 1922, by Homer Cote (USBM). U. S. Bureau of Mines (1948, p. 61; index no. 84741).

43. Mine sample. Cannel coal, Santo Tomas seam, Dolores mine no. 3, Dolores, Webb County. 27 inches sampled from 28-inch bed, March, 1922, by Homer Cote (USBM). U. S. Bureau of Mines (1948, p. 61; index no. 84742).

44. Composite sample of samples 40 through 43. Cannel coal, Santo Tomas and San Pedro seams, Dolores mine no. 3, Dolores, Webb County. U. S. Bureau of Mines (1948, p. 61; index no. 84743).

TABLE 5

1. Mine sample (?). "Eagle Pass" coal, Eagle Pass, Maverick County. Penrose (1889, p. 98).

2. Mine sample (?). "Eagle Pass" coal, Eagle Pass, Maverick County. Peter J. Fireman, analyst. Vaughn (1900, p. 60).

3. Mine sample. Maverick County Coal Co., Eagle Pass, Maverick County. Phillips (1902a, p. 52; sample no. 1520).

4. Mine sample. Rio Bravo Coal Co., Eagle Pass, Maverick County. Phillips (1902a, p. 52; sample no. 1521).

5. Mine sample. International Coal Mine Co., Eagle Pass, Maverick County. Phillips and others (1911, p. 29; sample no. 4).

6. Mine sample. "Special", International Coal Mine Co., Eagle Pass, Maverick County. Phillips and others (1911, p. 29; sample no. 5).

7. Mine sample. Olmos Coal Co., Eagle Pass, Maverick County. Phillips and others (1911, p. 29; sample no. 6).
8. Washed sample. "Egg" coal, Olmos Coal Co., Eagle Pass, Maverick County. Phillips and others (1911, p. 29; sample no. 31).
9. Washed sample. "Nut" coal, Olmos Coal Co., Eagle Pass, Maverick County. Phillips and others (1911, p. 29; sample no. 32).
10. Washed sample. "Pea" coal, Olmos Coal Co., Eagle Pass, Maverick County. Phillips and others (1911, p. 29; sample no. 33).
11. Delivered sample. Washed "nut" coal, sampled at McNeil, Texas. Olmos Coal Co., Eagle Pass, Maverick County. Phillips and others (1911, p. 29; sample no. 42).
12. Delivered sample. "Run-of-mines," sampled at McNeil, Texas. Olmos Coal Co., Eagle Pass, Maverick County. Phillips and others (1911, p. 29; sample no. 43).
13. Washed sample. "Pea" coal, Olmos Coal Co., Eagle Pass, Maverick County. Phillips and others (1911, p. 29; sample no. 50).
14. Washed sample. "Nut" coal, Olmos Coal Co., Eagle Pass, Maverick County. Phillips and others (1911, p. 29; sample no. 51).
15. Washed sample. "Egg" coal, Olmos Coal Co., Eagle Pass, Maverick County. Phillips and others (1911, p. 29; sample no. 52).
16. Mine sample. Dolch mine, near Eagle Pass, Maverick County. Analysis made March 7, 1911, by U. S. Bureau of Mines personnel. Phillips and Worrell (1913, p. 26).
17. Delivered sample. 400-ton shipment from International Coal Mine Co. to Ft. Sam Houston, Texas, in September, 1911. Analysis by U.S. Bureau of Mines. Phillips and Worrell (1913, p. 26 and 28).
18. Washed sample. Washed "pea" coal, Olmos Coal Company, Eagle Pass, Maverick County. Phillips and Worrell (1913, p. 27).
19. Washed sample. Washed "nut" coal, Olmos Coal Company, Eagle Pass, Maverick County. Phillips and Worrell (1913, p. 27).
20. Washed sample. Washed "egg" coal, Olmos Coal Company, Eagle Pass, Maverick County. Phillips and Worrell (1913, p. 27).
21. Tipple sample. "Lump" coal, Olmos Coal Company, Eagle Pass, Maverick County. Phillips and Worrell (1913, p. 27).
22. Delivered sample. "Choice lump" coal shipped to the Sunset-Central lines, Fuel Service, by Olmos Coal Company, Eagle Pass, Maverick County. Phillips and Worrell (1913, p. 28).
23. Delivered sample. "Ordinary lump and slack" coal shipped to the Sunset-Central lines, Fuel Service, by Olmos Coal Company, Eagle Pass, Maverick County. Phillips and Worrell (1913, p. 28).
24. Delivered sample. Washed "egg" coal shipped to the Sunset-Central lines, Fuel Service, by Olmos Coal Company, Eagle Pass, Maverick County. Phillips and Worrell (1913, p. 28).
25. Delivered sample. From 400-ton shipment to Ft. Sam Houston, Texas, from International Coal Mine Company, Eagle Pass, Maverick County, in October, 1911. Phillips and Worrell (1913, p. 28).
26. Delivered sample. Shipped to Fort McIntosh, Texas, in 1911-12. Contract guaranties: 16.53% ash, "dry coal"; 11,588 Btu, "as received". Price, $5.60 per ton. Pope (1916, p. 85; sample no. 494).
27. Mine sample. International Coal Mine Co., Eagle Pass, Maverick County. S. H. Worrell, analyst. Schoch (1918, p. 197; analysis no. 1528).
28. Delivered sample. Screened "nut" coal, International Coal Mine Co., Eagle Pass, Maverick County. Received from W. B. Smith of Austin, Texas. S. H. Worrell, analyst. Schoch (1918, p. 197; sample "A" and no. 1529).
29. Delivered sample (?). Screened "egg" coal, International Coal Mine Co., Eagle Pass, Maverick County. S. H. Worrell, analyst. Schoch (1918, p. 197; sample "B" and no. 1530).
30. Mine sample (?). Olmos Coal Co., Eagle Pass, Maverick County. S. H. Worrell, analyst. Schoch (1918, p. 197; analysis no. 1531).
31. Mine sample (?). Olmos Coal Co., Eagle Pass, Maverick County. J. E. Siebel, analyst. Schoch (1918, p. 198; analysis no. 1541).
32. Washed sample. "Egg" coal, Olmos Coal Co., Eagle Pass, Maverick County. J. E. Siebel, analyst. Schoch (1918, p. 198; analysis no. 1542).
33. Washed sample. "Nut" coal from the Lamar mine, Olmos Coal Co., near Eagle Pass, Maverick County. J. E. Siebel, analyst. Schoch (1918, p. 198; analysis no. 1543).
34. Washed sample. "Pea" coal from the Lamar mine, Olmos Coal Co., near Eagle Pass, Maverick County. J. E. Siebel, analyst. Schoch (1918, p. 198; analysis no. 1544).
35. Washed sample. "Barleycorn" coal from the Lamar mine, Olmos Coal Co., near Eagle Pass, Maverick County. J. E. Siebel, analyst. Schoch (1918, p. 198; analysis no. 1545).
36. Delivered sample. "Washed egg" coal shipped to University of Texas Powerhouse by Olmos Coal Co., Eagle Pass, Maverick County. Coal exposed to several days of rain. Sampled March 1-5, 1915. J. E. Siebel, analyst. Schoch (1918, p. 198; analysis no. 1546).
37. Delivered sample. Shipped to Fort Clark, Texas, in 1915-16. Contract guaranties: 8.16% moisture, "as received"; 20.20% ash, "dry coal"; 10,500 Btu, "dry coal." Price, $5.25 per ton. Snyder (1923, p. 34-35; index no. 362).
38. Delivered sample. Shipped to Camp Eagle Pass, Texas, in 1920-21. Contract guaranties: 6.5% moisture, "as received"; 23.86% ash, "dry coal"; 10,520 Btu, "dry coal." Price, $6 per ton. Snyder (1923, p. 34-35; index no. 363).

39. Outcrop sample. Channel sample, Kincaid ranch (now Charles Downing property?), near Eagle Pass, Maverick County. Maxwell (1962, p. 77; sample no. 1-A; lab. no. 60105).
40. Outcrop sample. Channel sample, 100 yards below sample #39, Kincaid ranch (now Charles Downing property?), near Eagle Pass, Maverick County. Maxwell (1962, p. 77; sample no. 1-B; lab. no. 60106).
41. Outcrop sample. Channel sample, including only coal beds, Hart ranch (now Topat ranch), near Eagle Pass, Maverick County. Maxwell (1962, p. 77; sample no. 2; lab. no. 60107).
42. Outcrop sample. Channel sample, including all partings and coal, Hart ranch (now Topat ranch), near Eagle Pass, Maverick County. Maxwell (1962, p. 77; sample no. 2-A; lab. no. 60108).

TABLE 6

1. Mine sample. "Upper part of seam above binder," mine no. 4, San Carlos Coal Company, San Carlos, Presidio County. Peter J. Fireman, analyst. Vaughn (1900, p. 87).
2. Mine sample. "Just above binder," mine no. 4, San Carlos Coal Company, San Carlos, Presidio County. Peter J. Fireman, analyst. Vaughn (1900, p. 87).
3. Mine sample. "Below binder," mine no. 4, San Carlos Coal Company, San Carlos, Presidio County. Peter J. Fireman, analyst. Vaughn (1900, p. 87).
4. Mine sample. "In clay above lower seam," mine no. 4, San Carlos Coal Company, San Carlos, Presidio County. Peter J. Fireman, analyst. Vaughn (1900, p. 87).
5. Mine sample. Sample collected from shaft, mine no. 4, San Carlos Coal Company, San Carlos, Presidio County. Peter J. Fireman, analyst. Vaughn (1900, p. 87).
6. Mine sample (?). Collected by R. E. Russell, former manager of mines, San Carlos Coal Company, San Carlos, Presidio County. Vaughn (1900, p. 88) characterized this as an analysis from "picked samples." Parker (1893, p. 385; sample no. 1).
7. Mine sample (?). Collected by R. E. Russell, former manager of mines, San Carlos Coal Company, San Carlos, Presidio County. Vaughn (1900, p. 88) characterized this as an analysis from "picked samples." Parker (1893, p. 385, sample no. 2).
8. Outcrop sample. "Upper vein, 300 yards S. E. of old Ingle tunnel, San Carlos Coal Field, Presidio County." Collected by J. A. Udden in 1913. Phillips and Worrell (1913, p. 31).
9. Outcrop sample. "Upper vein, near S.W. corner Sec. 67, San Carlos Coal Field, Presidio County." Collected by J. A. Udden in 1913. Phillips and Worrell (1913, p. 31).
10. Outcrop sample. Lower 18-inch-thick coal seam, Section 47, Block 3 (D. and P. Ry. survey), San Carlos area, Presidio County. Sampled by J. A. Udden in 1913. Schoch (1918, p. 198; analysis no. 1556).
11. Outcrop sample. Near Stinking Spring, north area of San Carlos Formation outcrops, 20-inch coal seam. Sampled by J. A. Udden in 1913. Schoch (1918, p. 198; analysis no. 1557).

TABLE 7

1. Outcrop sample. Anthracite, from 2 miles southwest of Stroud's Ranch, southern Rosillos Mountains, Brewster County. O. H. Palm, analyst. Udden (1907b, p. 95).
2. Outcrop sample. Anthracite with jet luster, from 2 miles southwest of Stroud's Ranch, southern Rosillos Mountains, Brewster County. O. H. Palm, analyst. Udden (1907b, p. 95).
3. Outcrop sample. 20-inch seam, Kimble pits, 2 miles north of Rough Run in Chisos Pen, Brewster County. Udden (1907b, p. 96).
4. Outcrop sample. 18-inch seam, bottom of Cottonwood Creek at Chisos Pen, Brewster County. Udden (1907b, p. 96).
5. Outcrop sample. 8-inch seam, 1¼ miles southeast of Maverick Mountain, Brewster County. Udden (1907b, p. 97).
6. Outcrop sample. 18-inch seam (weathered), flats between Terlingua Abaja and mouth of Terlingua Creek, Brewster County. O. H. Palm, analyst. Udden (1907b, p. 97).
7. Outcrop sample (?). Cub Spring, "Rough Run district," Brewster County. Phillips and others (1911, p. 36).
8. Outcrop sample (?). Kimble Pits, "Rough Run district," Brewster County. Phillips and others (1911, p. 36).
9. Outcrop sample (?). Chisos Pen, "Rough Run district," Brewster County. Phillips and others (1911, p. 36).
10. Outcrop sample (?). "Bone coal," 3 miles south of Study Butte. Sampled by J. A. Udden. O. H. Palm, analyst. Schoch (1918, p. 197; analysis no. 1510).
11. Outcrop sample (?). "Lignitic structure coal-bearing horizon," north of Talley's Ranch, southern Brewster County, near Rio Grande. Sampled by J. A. Udden. O. H. Palm, analyst. Schoch (1918, p. 197; analysis no. 1511).
12. Mine sample. Subbituminous A coal, Chisos mine (incline mine), 10 miles northeast of Terlingua, Brewster County. 3 feet 9 inches sampled from bed 4 feet 6 inches thick by C. P. Ross (USGS) on August 4, 1934. U. S. Bureau of Mines (1948, p. 58-59; laboratory no. A99251).