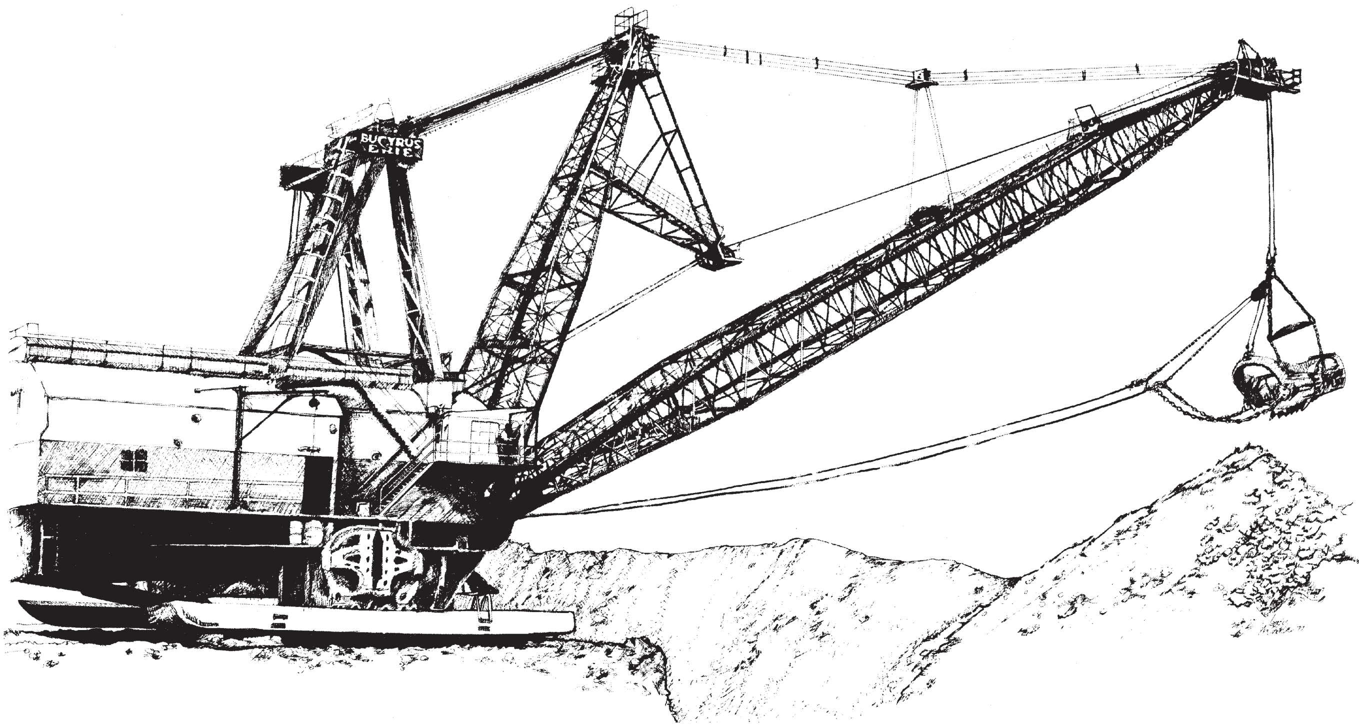
Desmoinesian Coal Deposits in part of the Arkoma Basin, Eastern Oklahoma

By Samuel A. Friedman



Guidebook 37

A Guide Prepared for Field Trip 2, April 8-9, 1978 for the AAPG National Annual Meeting, Oklahoma City, Oklahoma

Sponsored by the Oklahoma City Geological Society

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COVER: Drawing based upon a photograph by Samuel A. Friedman, showing a Bucyrus Erie 1250-B walking dragline, which operated 70 ft above the Stigler coal bed at the No. 9 Mine of Garland Coal and Mining Co. (See p. 34, stop 5).

This publication is issued by the Oklahoma Geological Survey as authorized by Title 70, Oklahoma Statutes 1981, Section 3310, and Title 74, Oklahoma Statutes 1981, Sections 231-238. It is available on-line and as photocopies. 250 copies have been printed at a cost of $280.50. Copies have been deposited with the Publications Clearinghouse of the Oklahoma Department of Libraries.

OKLAHOMA GEOLOGICAL SURVEY GUIDEBOOK 37
G. Randy Keller, *Director*

A field guidebook to

DESMOINESIAN COAL DEPOSITS
in part of the
ARKOMA BASIN, EASTERN OKLAHOMA

For
American Association of Petroleum Geologists
National Annual Meeting,
Oklahoma City Pre-convention Field Trip 2
April 8,9, 1978

Trip Leader

S. A. Friedman

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Published by the Oklahoma Geological Survey
Prepared by Samuel A. Friedman

PREFACE TO THE SECOND PRINTING

The author is grateful to Brian Cardott for his careful review and helpful suggestions and to Jim Anderson for improving the appearance of the figures and text. If Aaron Friedman had not performed magic on my home computer, I could not have completed detailed editing and numerous corrections and e-mailed them to Jim for inclusion in this second printing.

Samuel A. Friedman
March 17, 2010

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INTRODUCTION

Purpose and Scope

The purpose of this guidebook is to serve as a concentrated 2-day introduction to the coal geology of a part of the eastern Arkoma basin in Oklahoma. The scope is limited to visits to 8 or 9 strip mines and one fairly-recently constructed road cut, in rocks of Desmoinesian (middle Pennsylvanian) age, and to get quick, non-stop glimpses of some outcrops on the route between these stops as marked on the accompanying road log. The road log is integrated with illustrations, analyses, and descriptive text.

The first stop (Fig. 1) is at a mine in which the coal is in the Senora Formation (Fig. 2), and subsequent stops are at mines in which coals are in the Boggy, McAlester, and Hartshorne Formations. Thus,going eastward we progress downward stratigraphically. We skipped the Savanna Formation coals (no convenient exposures), but the route takes us over this formation.

If you plan to take this trip after the 1978 AAPG meeting, please be wise and first contact the mine company headquarters or stop at the mine-site company office. If you are attending the scheduled AAPG trip No. 2 and do not have a hard hat that meets safety specifications, you can borrow one from the trip leader, courtesy of the Oklahoma Geological Survey (OGS). The OGS and the Oklahoma City Geological Society (OCGS) plan to offer additional copies of this guidebook for sale at and following the convention.

ACKNOWLEDGMENTS

The author wishes to thank everyone connected with the field work and with the preparation of this guidebook. For interesting and helpful discussions, OGS colleagues C. J. Mankin, R. 0. Fay, and L. R. Wilson; B. R. Archinal, R. P. Lockwood, and M. W. McQuillan, former OGS graduate (coal) research assistants; D. R. Donica, present OGS graduate (coal) research assistant; Victor Agbe-Davies, present OGS technical (coal) research specialist. Special thanks for continued cooperation to the coal industry and the coal miners of Oklahoma, and to Kenneth Richardson, President, P & K Company, Ltd.; W. H. Burdett, President, the Burdett Company; Frank Podpechan, Jr., President, Carbonex Coal Corporation; Jerry Headrick, Bill’s Coal Co., Jeff Porter, III, E. S. Stephens, Clem Ballard, Les Wahl, Virgil Smith, and A. E. Smithson, of Garland Coal & Mining Company; J B. Avant, Jim Beam, and Bill Beam, Great National Corporation, A. G. Gossard, Kerr-McGee Coal Corp., and many others.

Special appreciation is expressed to Roy Davis and Joe Zovak, OGS cartographers; Laveda

Hensley and Betty Bellis OGS typists; and Polly Hewitt, OGS, for final printing and help in meeting the last deadline.

Posthumous acknowledgment goes to Carl C. Branson and Malcolm C. Oakes, whose geological spirits and maybe some of their geological knowledge live on in the present geological workers in the Oklahoma coal field. These two geological greats encouraged and inspired the present writer in his effort to understand the coal geology of Oklahoma.

DISCLAIMER

Coal geologists, mining engineers, and environmentalists know that surface coal mines may be closed by their owners, by State or Federal mine inspectors, by the EPA or other government agencies and by extreme weather or adverse labor conditions. The Surface Mining and Reclamation Act of 1977 and it's subsequent codifications, published as Public Law 95-87, require that all active surface mines must be reclaimed upon completion of mining. Therefore, the mines visited at Stops 1-8 in 1978 likely will not exist in 2011.

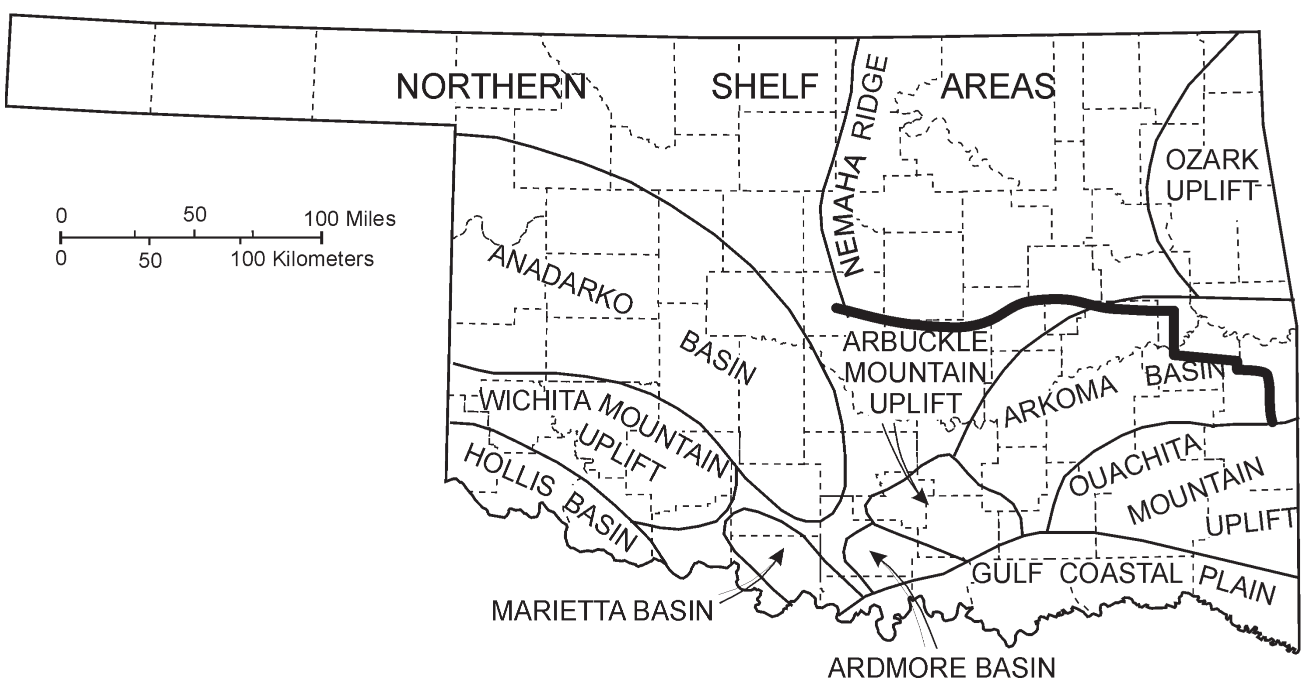


Figure A. Index map showing tectonic elements of Oklahoma. Heavy line indicates approximate route of AAPG field trip 2.

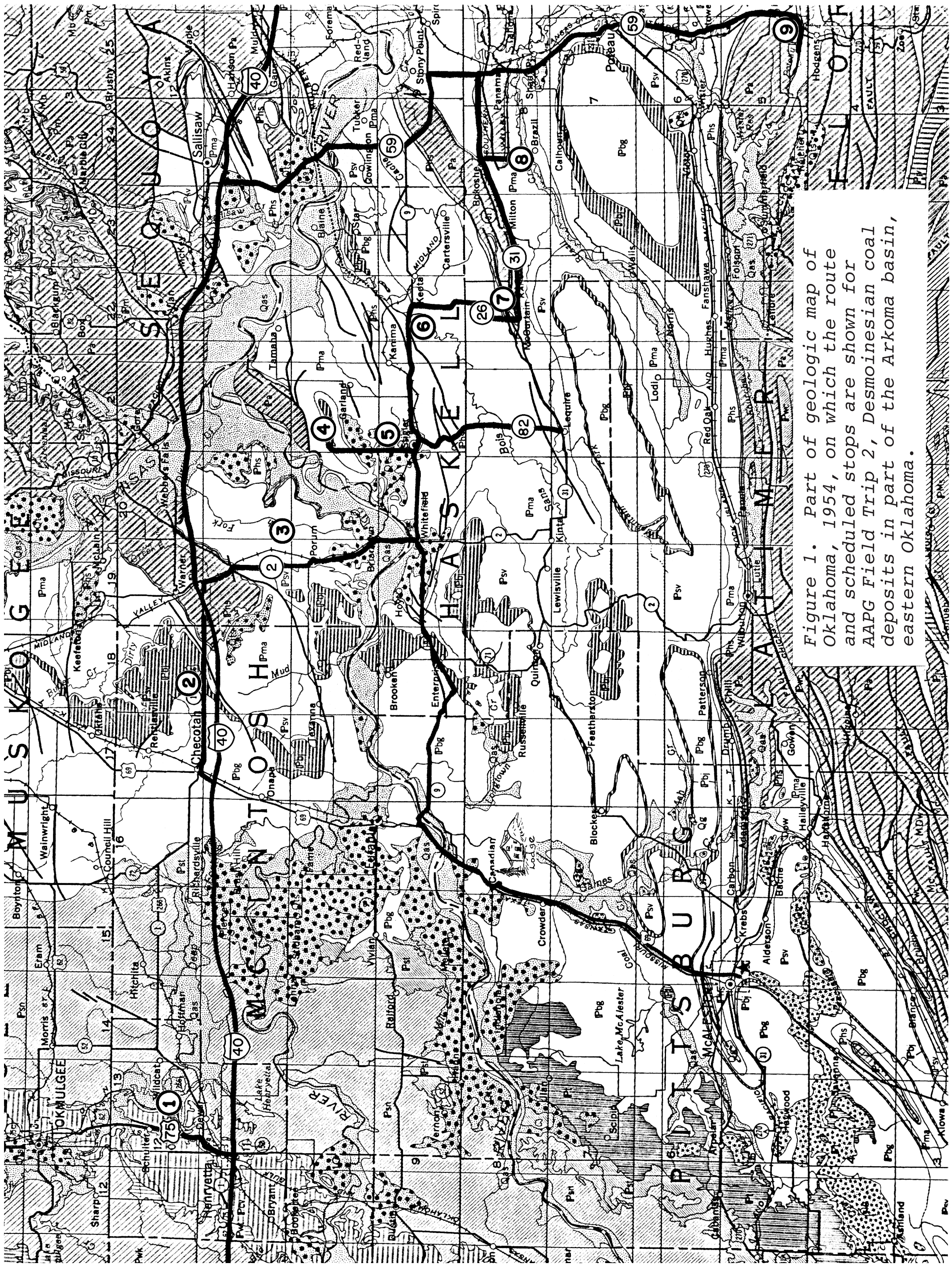


Figure 1. Part of geologic map of Oklahoma, 1954, on which the route and scheduled stops are shown for AAPG Field Trip 2, Desmoinesian coal deposits in part of the Arkoma basin, eastern Oklahoma.

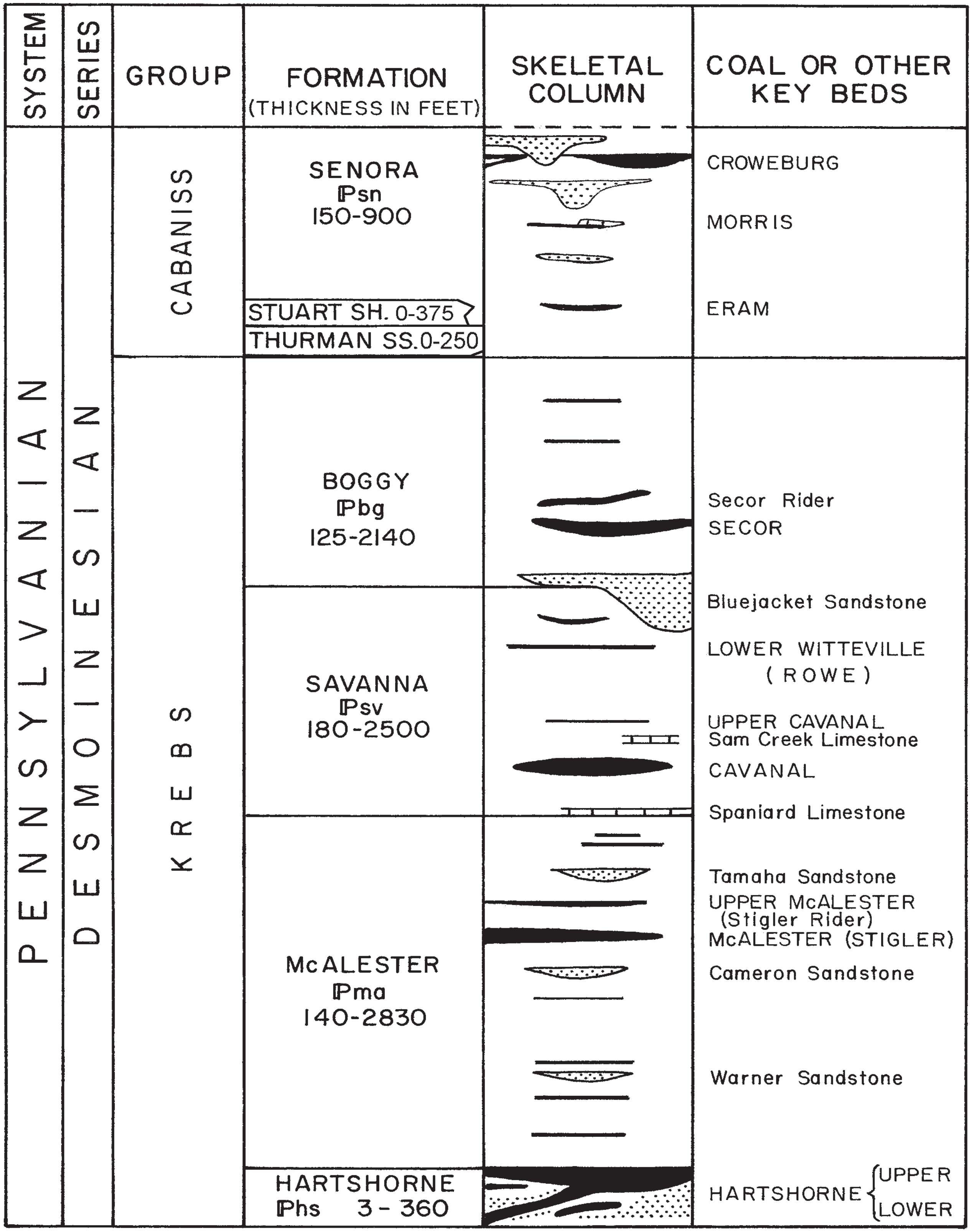
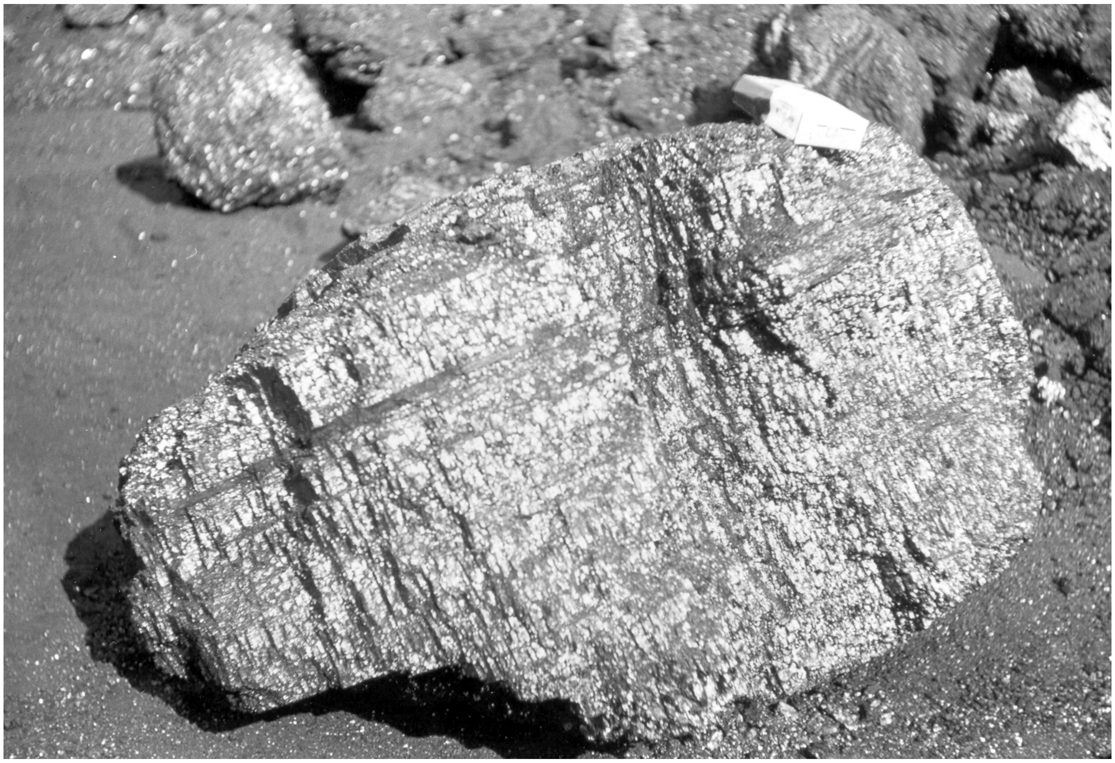


Figure 2. Generalized geologic column showing coals and other key beds of Desmoinesian age in part of the Arkoma basin, eastern Oklahoma.



Photograph by Samuel A. Friedman showing a ten-inch-thick chunk of the Stigler coalbed at the Number 9 surface mine, Garland Coal and Mining Co. (see p. 34-36).

Photograph by Samuel A. Friedman showing a hydraulic impact pick, producing boulder size chunks of the Hartshorne coalbed at the Karsh Pit, McCurtain Number 2 surface mine, Great National Corp. (see p. 41-43).

ROAD LOG AND TEXT
FIRST DAY

Interval (miles)	Cumulative (miles)	
0.0	0.0	Depart, north entrance, Myriad Convention center. I-40 is still being repaired; go south via I-40 detour. Enter I-40, head east. Remain on I-40 until reaching Henryetta.
1.9	1.9	Pass Norman and Dallas exit (I-35).
5.9	7.8	Tinker Air Force Base next 2 miles, south of I-40.
7.1	14.9	Junction with I-240 East. Oklahoma-Pottawatomie County line.
12.8	27.7	Lower Permian Garber Sandstone in roadcut on north side of I-40. The sandstone is red, cross-bedded, probably represents a channel fill.
1.9	29.6	North Canadian River and a railroad.
1.4	31.0	Shawnee-Tecumseh exit.
1.5	32.5	Pennsylvanian-Permian contact.
11.3	43.8	Pottawatomie-Seminole County line.
11.8	55.6	Exposure of brown sandstone covered with lichens, in road cut on south side of I-40. Rocks are Upper Pennsylvanian (Virgilian) Vamoosa Formation.
6.3	61.9	Wewoka exit. State Highway 56.
1.0	62.9	Seminole-Okfuskee County line.
3.9	66.8	Bristow-Holdenville exit. State Highway 48.
4.4	71.2	Okemah-Wetumka exit, State Highway 27.
6.0	77.2	Clearview Road.

1.0	78.2	Sandstone cuesta, whose surface dips westward. Middle Pennsylvanian (Desmoinesian) Wewoka Formation.
3.0	81.2	Weleetka U.S. Highway 75 South (view of more cuestas).
2.0	83.2	Okfuskee-Okmulgee County line. Dark-gray, calcareous shale, poorly exposed in roadcut and hill.
3.1	86.3	Desmoinesian Wewoka Formation.
0.9	87.2	West end of Henryetta. U.S. Highways 75 North and 62 East join I-40.
2.3	89.5	Exit for Henryetta. Enter intersection of Indian Nation Turnpike to McAlester. BUT TAKE RIGHT TURN EXIT TO HENRYETTA, going north on U.S. Highway 75. Then keep right.
1.1	90.6	Traffic light at intersection of Main Street and U.S. Highway 75.
0.6	91.2	Midland Glass Company's plant on left (west) at railroad bridge. View of railroad siding, coal stockpile, and burned gob piles from abandoned underground mines.
0.8	92.0	Traffic light at intersection of U.S. Highway 75 and State Highway 266.
0.2	92.2	Right (East) turn into mine property. Pass green block building and stop at mine office (trailer). This is a hard hat area.

STOP 1

The first pit of the Pollyana mine of P&K Company, Ltd. (figures 3, 4) was started in May, 1975 in the SW ¼ sec. 33, T. 12 N., R. 13 E., at the northern edge of Dewar, northeast of Henryetta, Okmulgee County. Two abandoned drift tunnels were intersected during strip mining operations. One of them contained water that temporarily flooded the mine, which nevertheless yielded 88,000 short tons of the Croweburg coal during 1975. Other abandoned underground mines are present in the hills of this area, and these mines limit the present recoverable strippable coal reserves. The first Pollyana pit reached a depth of 40 feet, and it was extended along a valley northwestward into sec. 32, where a second pit was begun on the

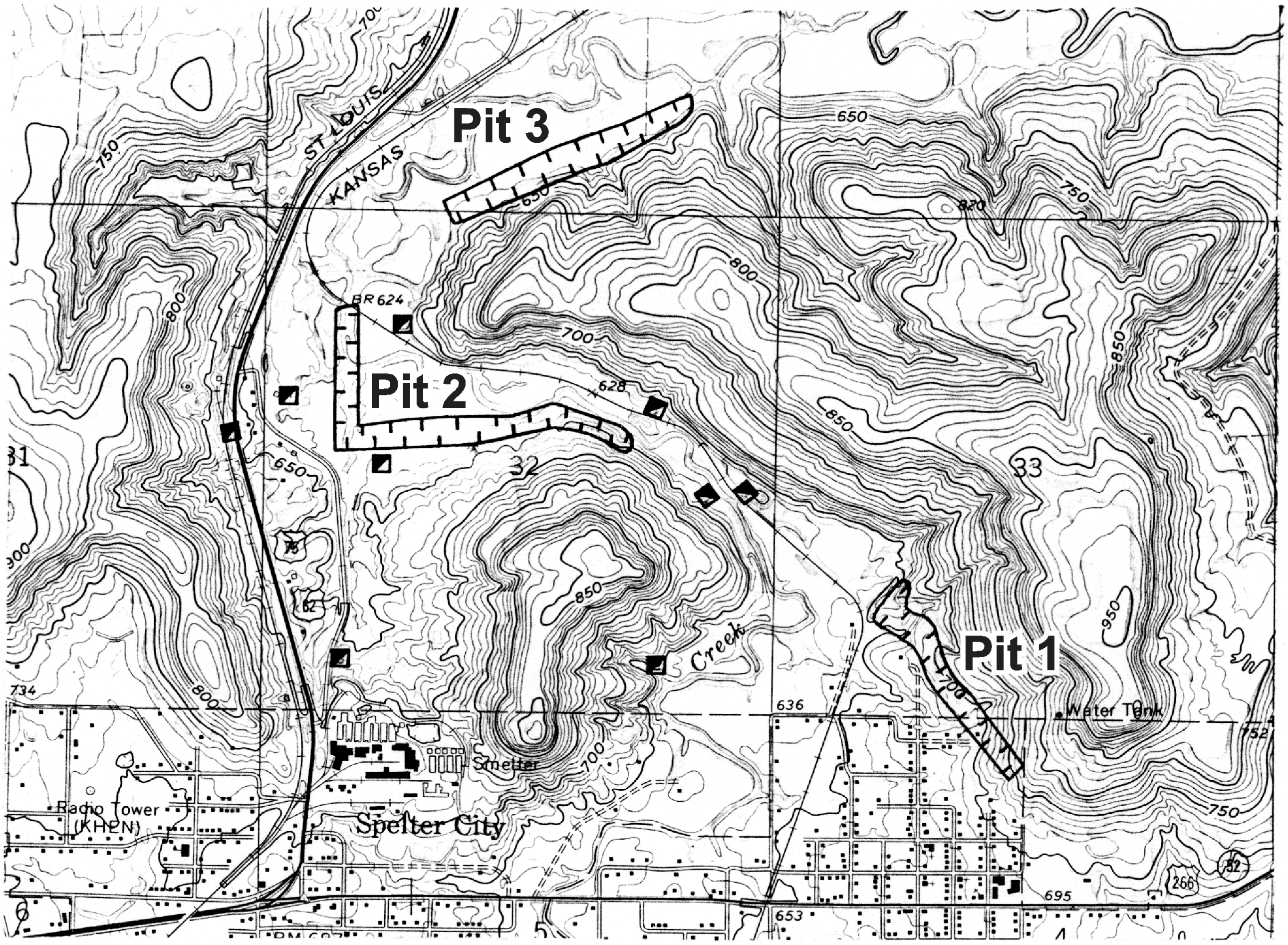


Figure 3. Part of Henryetta 7.5′ Topographic Quadrangle map showing areas mined by P & K Co. Ltd. Pits 1 and 2 have been reclaimed; pit 3 is active. Square symbols indicate abandoned shaft and drift mines, some of which also are present in Fig. 4.

south side of the valley. The No. 2 pit reached a depth of 65 feet and yielded approximately 200,000 tons of coal in 1976. An auger is used to recover additional reserves of the Croweburg coal when the maximum limit of overburden thickness is reached in the strip mine. Auger mining is reported to penetrate 200 feet into the coal bed. The 65-ft highwall was completely obscurred by backfilling in 1977. Two special types of grasses were planted, but because of the Oklahoma climate, Bermuda grass probably will be more effective in reducing erosion of the reclaimed hillside that consists of former overburden. The "dragline" pit is a northward continuation of the west end of the No. 2 pit, in which 10 to 20 feet of gray shale and Quaternary alluvium overlie the Croweburg coal. Part of the creek was diverted to prevent flooding of the pit. The No.3 pit was developed to a maximum depth of 85 feet,and production was reported as 296,000 tons in 1977. Most of the coal produced is shipped to three separate cement manufacturing plants in Oklahoma and

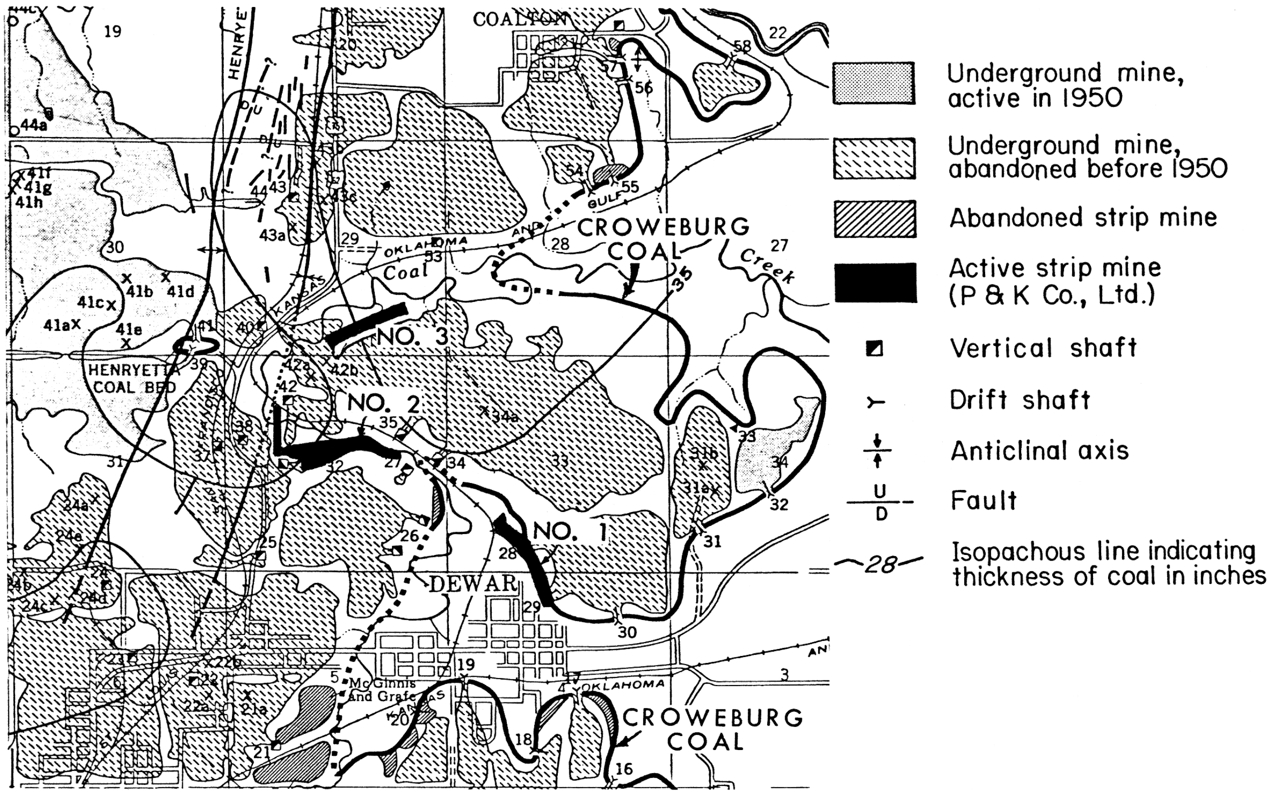


Figure 4. Map showing distribution, thickness, and mined areas of the Croweburg coal in the Henryetta mining district (modified from Dunham and Trumbull, 1955).

two in Texas. Shale and sandstone in the Senora Formation overlie the coal in the No.3 pit, where a few feet of sandstone is present in the upper part of the highwall. The sandstone is about 30 feet thick in the first two pits, thus demonstrating a local westward thinning of the sandstone. The detailed lithofacies variations in the shales and sandstones overlying the Croweburg coal in the Henryetta mining district are shown and described by Dunham and Trumbull(1955, p. 186-188, pl. 22). The sandstones increase in thickness south of Henryetta. Oakes (1963) described the surface rocks and coals of Okmulgee County, which includes the area of the Henryetta Mining district. A composite geologic column, Figure 5, was modified from the work of Dunham and Trumbull (1955, pl. 21), and it is representative of the areas of the Pollyana mine.

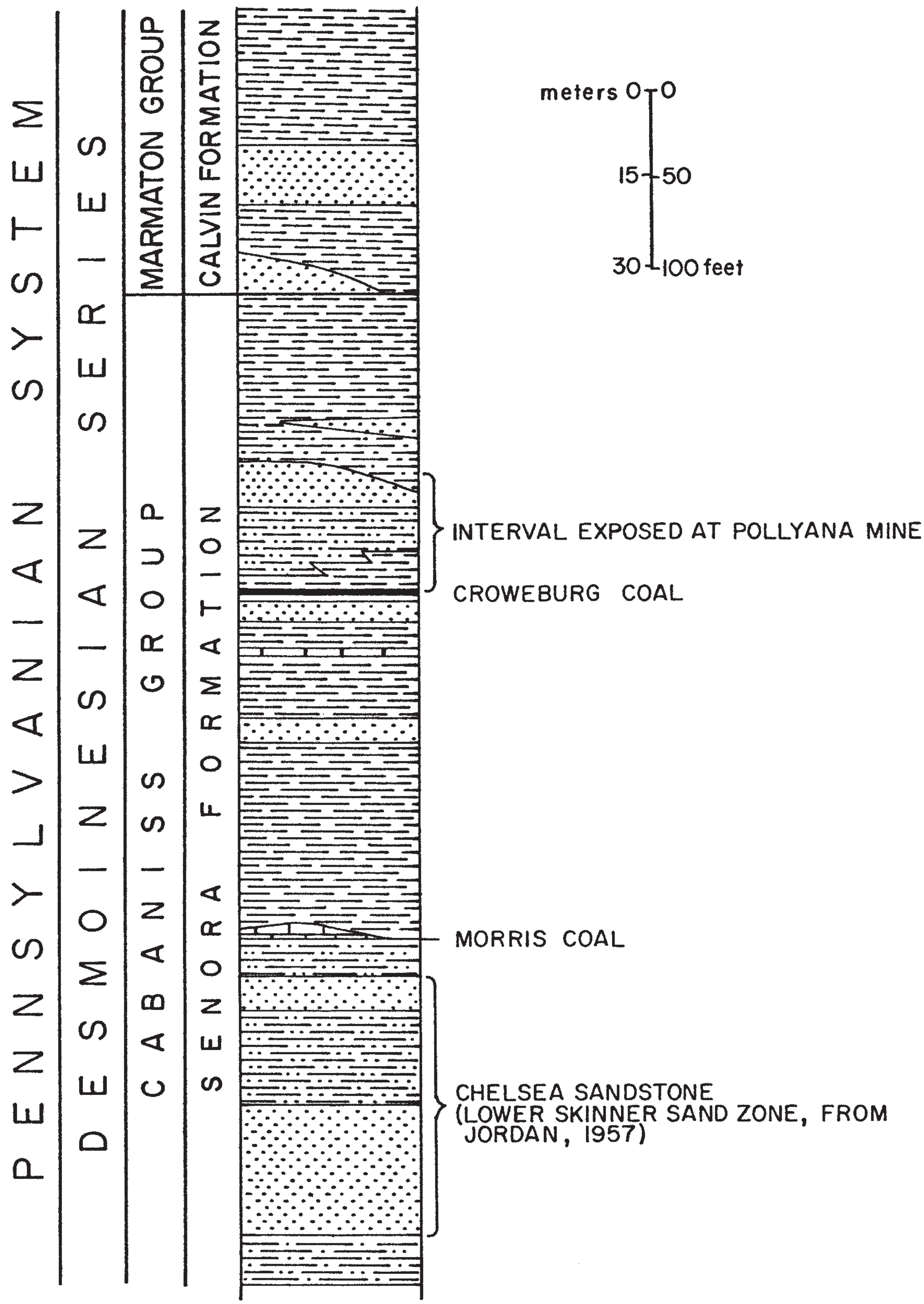


Figure 5. Columnar section showing lithologic sequence in the area of the Pollyana mine, Okmulgee County, Oklahoma (modified from Dunham and Trumbull, 1955).

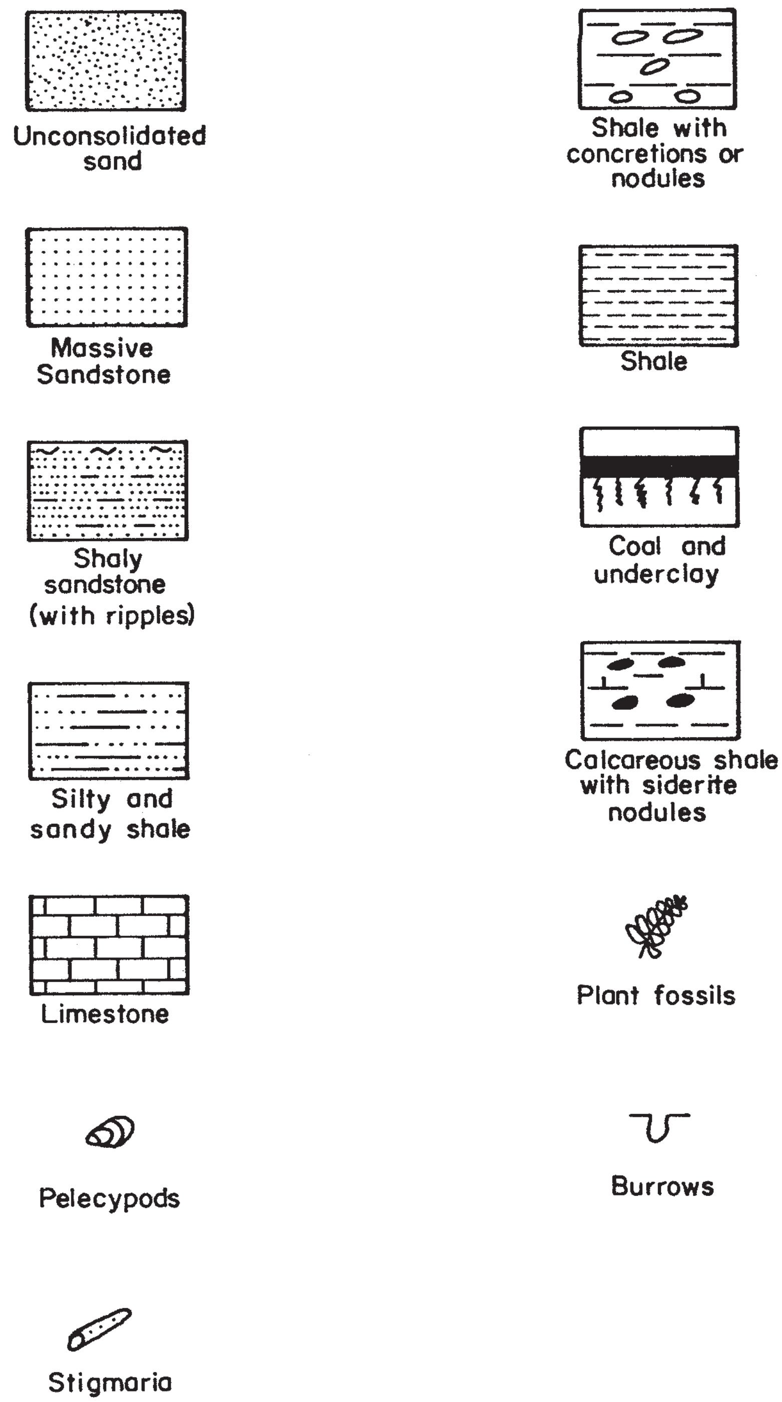


Figure 5a. Explanation of lithologies and symbols used in columnar sections.

These two authors described the stratigraphy in the measured section in an area close to the present active mine site. The measured section is given below with some modification indicated by brackets.

Measured section by Dunham and Trumbull (1955, p. 216, no. 18), starting about 1,000 feet east of the SW corner sec. 34 and continuing to the top of the hill at the center of the NW1/2 SW1/4, sec. 34, T. 12 N., R.13 E.

SENORA FORMATION:

	Feet
Sandstone, light gray-brown, massive, fine-grained, top eroded	13+
Covered, probably shale	55
Coal (Croweburg)	3
[Underclay, medium light-gray, silty 0.5 ft, included with underlying shale]	
Shale	1
Sandstone, light-gray, very thin bedded, very fine-grained, ripple-marked [in places interlaminated with medium-gray shale, and shows contorted bedding]	7
Shale, gray, weathers light-gray	9
Limestone, very shaly, fossiliferous	3
Covered, shale poorly exposed near top	38
Sandstone weathers brown, massive, very fine grained base not exposed	3+
Total	132.6

An average proximate analysis for the Croweburg coal, compiled from 25 separate analyses, from Okmulgee County (from Dunham and Trumbull, 1955, table 1, p. 200-201) follows:

	Percent
MOISTURE	7.1
VOLATILE MATTER	34.5
FIXED CARBON	52.8
ASH	5.6
	100.0
Btu	12,910
ASH SOFTENING TEMP (˚F)	2,020
SULFUR	1.6%

Approximately 679 million tons of remaining resources of Croweburg coal has been identified in Oklahoma (Friedman, 1974). The Croweburg has also been called the Henryetta coal, Broken Arrow coal, and “Sequoyah” coal. Oakes (1944) correlated the Henryetta and Broken Arrow coals with the Croweburg coal of Kansas.

Past uses of Croweburg coal from the Henryetta district was in locomotives for steam production, in industrial plants, and in greatest quantity by home furnaces for space heating (Dunham and Trumbull, 1955, p. 202). Tests of coking properties of the Croweburg coal from this area (alone or with 80:20 or 70:30 blends of low-volatile bituminous Hartshorne coal) indicated that satisfactory blast-furnace coke could be produced (Davis and Reynolds, 1941, p. 5; Davis and others, 1944, p. 1–93). Carbonization tests also showed that the high-volatile bituminous Henryetta (Croweburg) coal by itself produced a weak coke with lower crushing strength than high-volatile bituminous Appalachian coals. Armco's Sheffield Steel plant in Houston, Texas, produced coke in byproduct coke ovens from a blend of the Henryetta coal and a low-volatile bituminous coal in 1952 (Dunham and Trumbull, 1955, p. 203). These authors stated that the Henryetta (Croweburg) coal was characterized as containing "layers of coal having a vitreous appearance, more numerous layers of slightly duller coal, and a few layers of . . . fusain."

The present writer agrees with this description and adds that the coal contains a moderate quantity (15-30%) of thin (<2 mm) bands of vitrain (that exhibit a vitreous lustre) and attritus that is moderately bright. According to Dunham and Trumbull (1955, p. 198), Davis and others (1944, p. 17) showed its microscopic petrographic composition to be 74% anthraxylon (mostly equivalent to the modern term vitrinite), 17% translucent attritus, 4% opaque attritus, and 5% fusain (mostly equivalent to the modern microscopic term fusinite). They also noticed fine particles of pyrite (under the microscope) in this coal, and that nodules and veins of pyrite occur on fresh outcrops of the coal. Pyrite contributes significantly to the sulfur content of the Croweburg coal in areas in which the total sulfur is more than 2 percent.

The cleat directions in the Croweburg coal, measured at pit 3 of P & K Company, Ltd., are N. 45 W. (face cleat) and N32E (butt cleat).

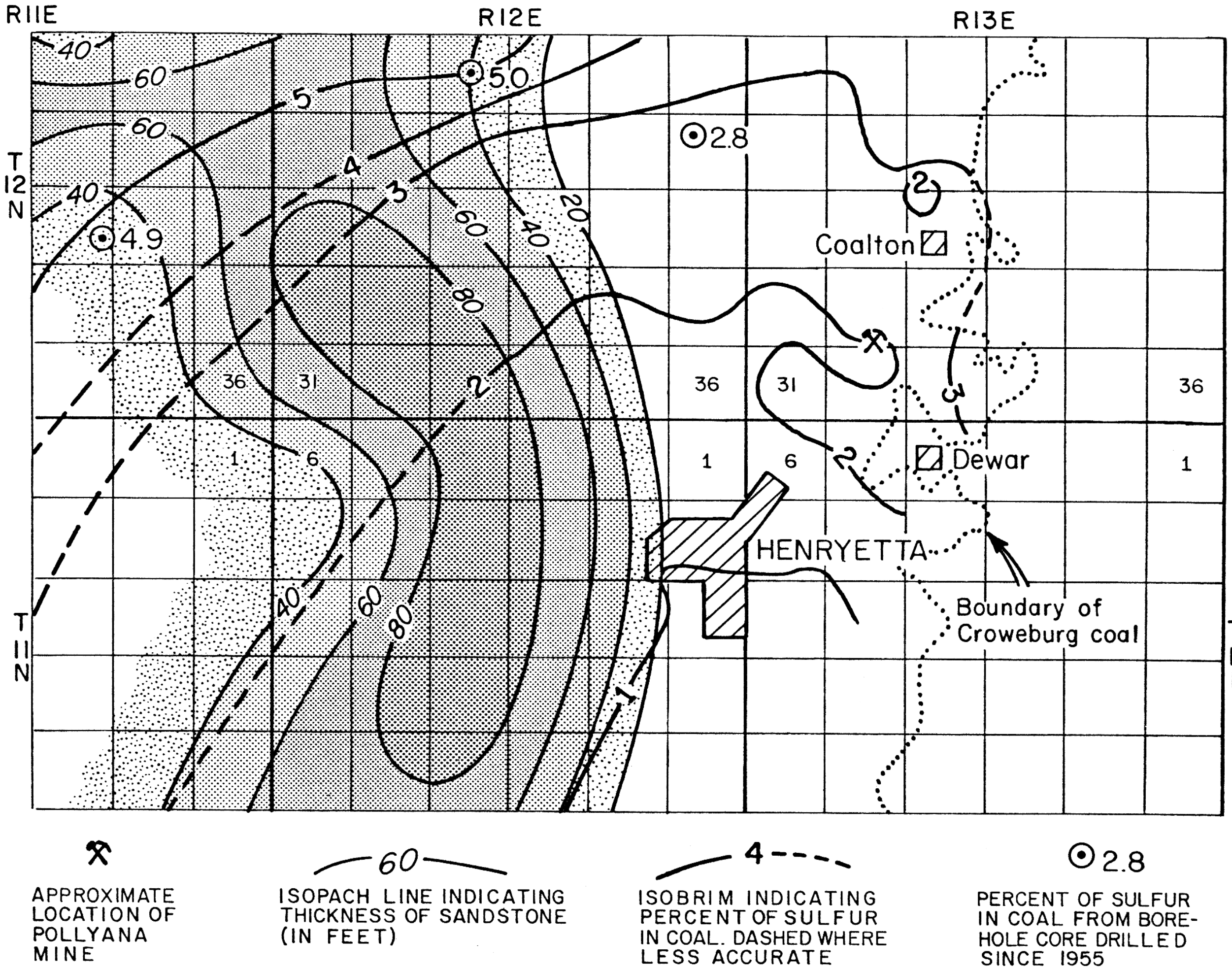


Figure 6. Map showing percentage of sulfur in the Croweburg coal (expanded from Dunham and Trumbull, 1955 in relation to the thickness of the lower Skinner sand (Chelsea Sandstone, stippled) (modified from Valderrama, 1976).

An unsubstantiated hypothesis is postulated herein to explain the geographic variation of sulfur in the Croweburg coal. A system of distributary channel-fill sandstones has been demonstrated by Valderrama (1976) in the Skinner sand zones (of Jordan, 1957) in a part of east-central Oklahoma. Part of these distributary sandstones are in Okmulgee County and the Henryetta area in particular. The present writer suggests that the sedimentary platform on which the Croweburg peat swamp developed greatly determined the composition and distribution of the Croweburg coal. Thus the writer superimposed a pertinent part of the lower Skinner sand (Chelsea Sandstone) isopachous map on a sulfur isopleth (isobrim) map of the Croweburg coal (Fig. 6). The sulfur content of the Croweburg coal is 1 to 5 percent, and it increases northwestward from Henryetta. Dunham and Trumbull (1955, p. 198) found it to be 0.7-4.3 percent, decreasing south- westward. The sulfur isopleths that attain 2 percent are parallel to

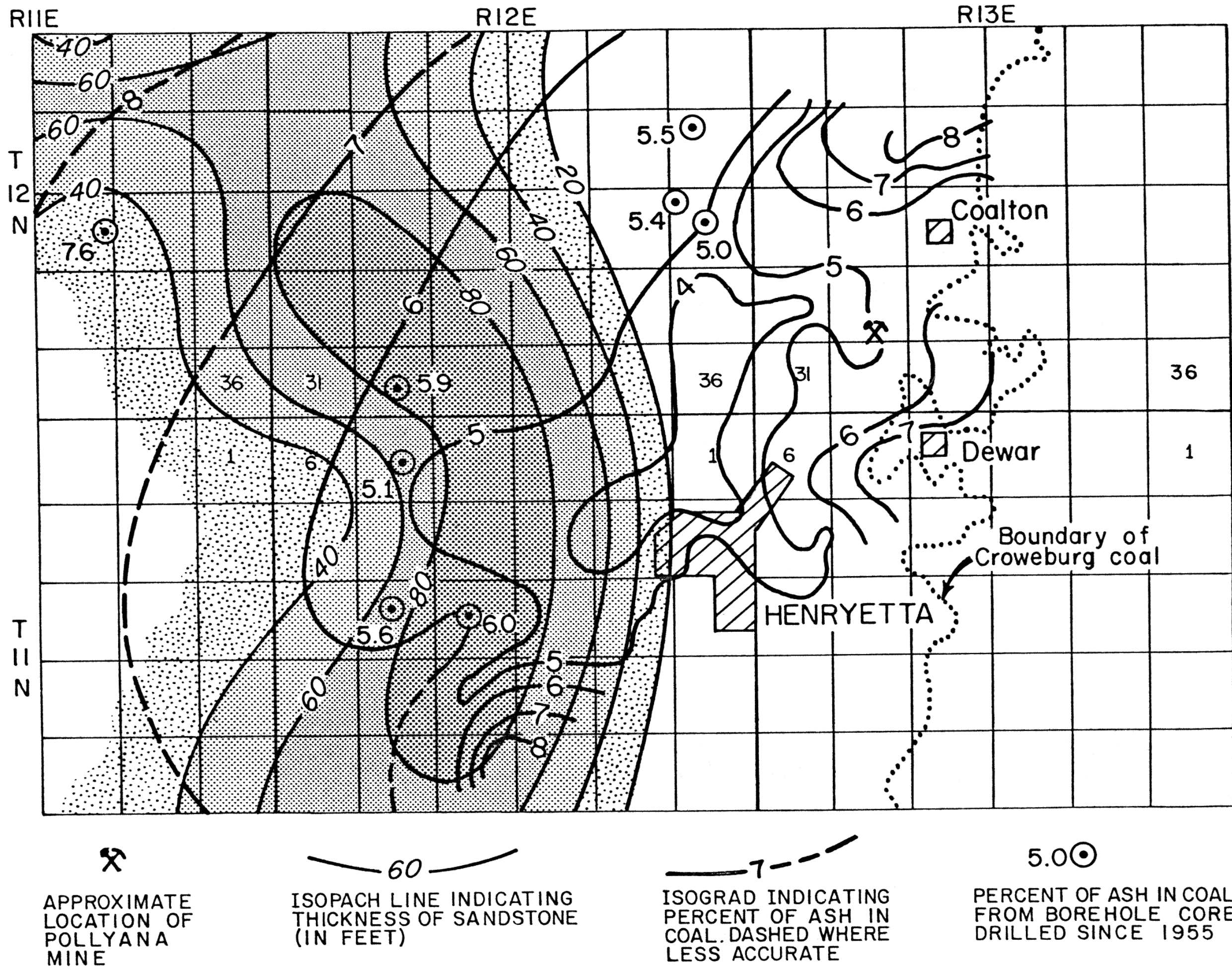


Figure 7. Map showing percentage of ash in the Croweburg coal (expanded from Dunham and Trumbull,1955) in relation to sandstone thickness in the lower Skinner sand (Chelsea Sandstone, stippled) (modified from Valderrama, 1976).

subparallel to part of a 40-80-ft-thick channel-fill sandstone, but another part of the sandstone trends northwestward, essentially normal to the 2-5 percent sulfur isopleths. Clearly a larger area encompassing at least one or two counties should be mapped in this manner before any valid conclusions can be reached on the relationship of the sulfur content of the coal and the thickness of the underlying sandstone. One could grab at a straw and state tentatively that in this small mapped area, the area of lowest sulfur in the coal is approximately parallel to a part of a distributary channel-fill sandstone.

The ash content of the Croweburg coal in the Henryetta mining district was shown by Dunham and Trumbull (1955, p. 199, fig. 30) as increasing northeastwards and southwestwards of Henryetta. Additional analytical data from samples of coal obtained from boreholes permitted the present writer to modify the map of the ash percentage by a westward extension (Fig. 7). The lowest ash percentage (4%) is in an area 1 mile west and 3 miles north of Henryetta. This percentage increases southwestwards and northwestwards as previously shown (Dunham and Trumbull, 1955, Fig. 30), but it also increases northwestwards from Henryetta. The extrapolated 8-percent-ash contour line may be inaccurate. But the nearest datum point shows a maximum ash of 7.6% (Fig. 7), which was in 2.0 feet of coal cored in a borehole. A positive correlation obviously is not present between the percentage of ash in the Croweburg coal and the location of the Chelsea Sandstone channel-fill. Perhaps a larger area might show that the ash content is lowest adjacent to or overlying areas of thick channel-fill sandstone of the Chelsea Member. Future investigations may shed light on this possibility. However, a direct positive correlation is clearly shown for the ash and sulfur content of the Croweburg coal (Figs. 6 and 7). The relation is logical because of the high pyrite content of the coal. The pyrite percentage increased, and thus the pyrite also contributed to the increased ash content.

Figure 8 shows a map area of 225 square miles in 6 townships of Okmulgee County, and it includes the Henryetta mining district. The eastern one-half of the map area is essentially the same as the coal isopachous map by Dunham and Trumbull (1955, pl. 23) which the present writer extended westward, based on data from at least 10 boreholes that penetrated the Croweburg coal. Clearly, the coal is thickest (35-48 inches) at, and northwest from, northern Henryetta, and the coal is thinnest north from Coalton and south from Henryetta. Additional information from Dunham and Trumbull (1955, pls. 22 and 24) shows that a channel-fill sandstone that overlies the coal and trends northwestward is in part responsible for the thinner coal north of Coalton. South of the map area 1 or 2 shale partings less than 1 inch thick in the Croweburg coal increases to 2 or 3 partings whose cumulative thickness is at least 15 inches. The thick shale partings decrease the prospects of mining the Croweburg profitably south of Henryetta, probably to the North Canadian River and vicinity.

The map (Fig. 8) was constructed primarily to test the correlation between the total thickness of the Croweburg coal bed and the thickness of the “underlying” Chelsea Sandstone. The writer believes a clear positive correlation is not demonstrated on the map. The thickest coal overlies and is also adjacent to the thickest channel-fill sandstone. However, comparison with coal thicknesses in other areas (north of the Henryetta mining district) in which this coal occurs and is mined at present, permits the conclusion that the Croweburg coal is thicker in the Henryetta district than anywhere else in eastern Oklahoma. A good question not yet answered is “Why?”. Future investigations of the depositional environments of this coal probably will answer the question.

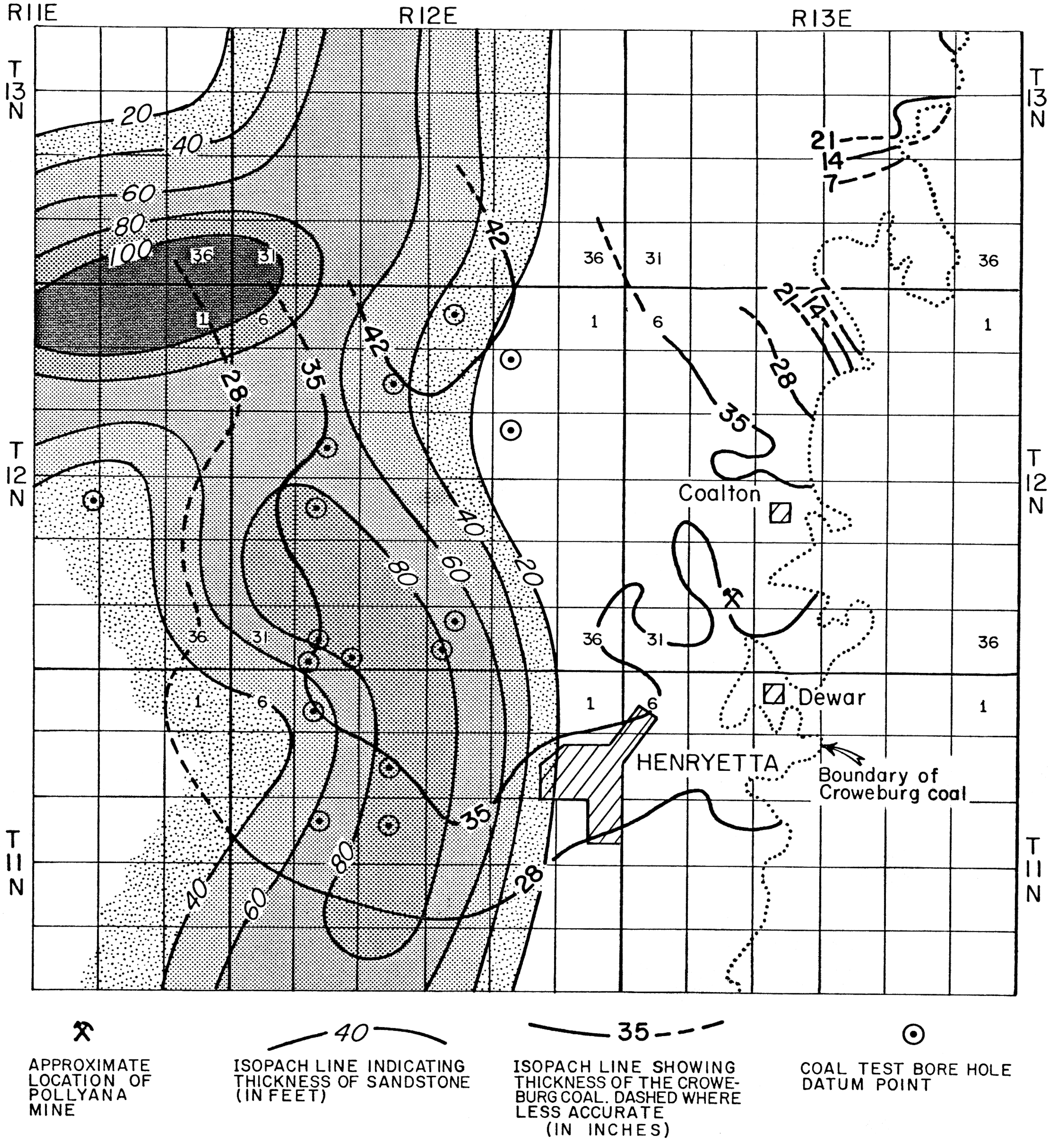


Figure 8. Map showing thickness (in inches) of the Croweburg coal (expanded from Dunham and Trumbull, 1955) in relation to the thickness of the lower Skinner sand (Chelsea Sandstone, stippled) (modified from Valderrama, 1976).

Leave STOP 1, P&K Company, Ltd. Retrace route south to I-40.

Interval (miles)	Cumulative (miles)	
5.9	98.1	Junction of U.S. Highways 62 and I-40. Continue eastward.
6.3	104.4	Okmulgee-McIntosh County line.
21.0	125.4	Take Checotah exit via U.S. Highway 69. North to Checotah.
1.0	126.4	Turn east on U.S. Highway 266.
0.1	126.5	Railroad crossing.
1.2	127.7	Bridge
0.4	128.1	Bridge
1.8	129.9	Bridge. Sandstone boulders beneath bridge. Boggy Formation
1.7	131.6	Abandoned strip mine area. Turn left into access road to Burdett Co. strip mine. STOP 2.

STOP 2

In 1971, the present writer investigated the Oklahoma coalfields for a deposit that would supply a gasification plant with ten million tons of coal annually for 20 years, that is, a 200-million-ton supply of coal. No operation in the Secor coal could be found. A market did not exist for this high-ash, high-sulfur bituminous coal. All the better, because the cost of production and the selling price probably would be lowest for the Secor than any other Oklahoma coal bed. Five boreholes out of a 10-hole OGS drilling project penetrated this coal in McIntosh and Pittsburg counties. From data obtained from these and other boreholes, most of the required 200 million tons of coal was determined to be present as remaining recoverable resources mostly in the Secor coal in these 2 counties (Friedman, 1974). The gasification plant was not built, however, and the coal bed was not developed. In 1976, the Secor coal at Porter, Wagoner County, was mined successfully, and the sulfur content of the coal averaged about 3 percent. Other localities soon were developed. At present 3 mines produce from the Secor coal bed.

Early in 1977 the Burdett Company started production on the updip, eastern edge of a former strip-mine site of Level Coal Company. The Level Coal Company began mining at this site in 1952 and produced coal until 1955, when Magic City Coal Company became the operator. The old mine closed in 1961, having shipped coal to utilities at Pryor and Harrah, Oklahoma, and to Iowa City and Kansas City, according to W. H. Burdett. Mr. Burdett stated that the Secor coal from this mine sold for $5.00 per short ton in 1955.

The present Burdett mine is a small operation by design (Fig. 9). Four miners produced 25,000 tons of Secor coal here in 1977. At this site the Secor coal is high-volatile C bituminous in rank. The coal is shipped by truck to a cement company in Dallas, Texas. The sulfur content is reported to be 3-4%. This percentage reflects some pyrite oxidation due to weathering. Sulfur in this coal is much greater in adjacent areas. For example the Secor coal from OGS borehole 8 (Fig.9) contains 6.4% sulfur. Sulfur is the subject of a discussion a few pages ahead. The as-received proximate analysis of coal core sample 75x43-44 from OGS borehole 8 analyzed by David Foster,OGS Chemist, follows.

Core Samples	75x43-44 (Weighted average) (percent)
Moisture	1.0
Volatile Matter	35.2
Ash	12.0
Fixed Carbon	51.8
	100.0

Calorific value, 12,709 Btu.; Sulfur, 6.4%

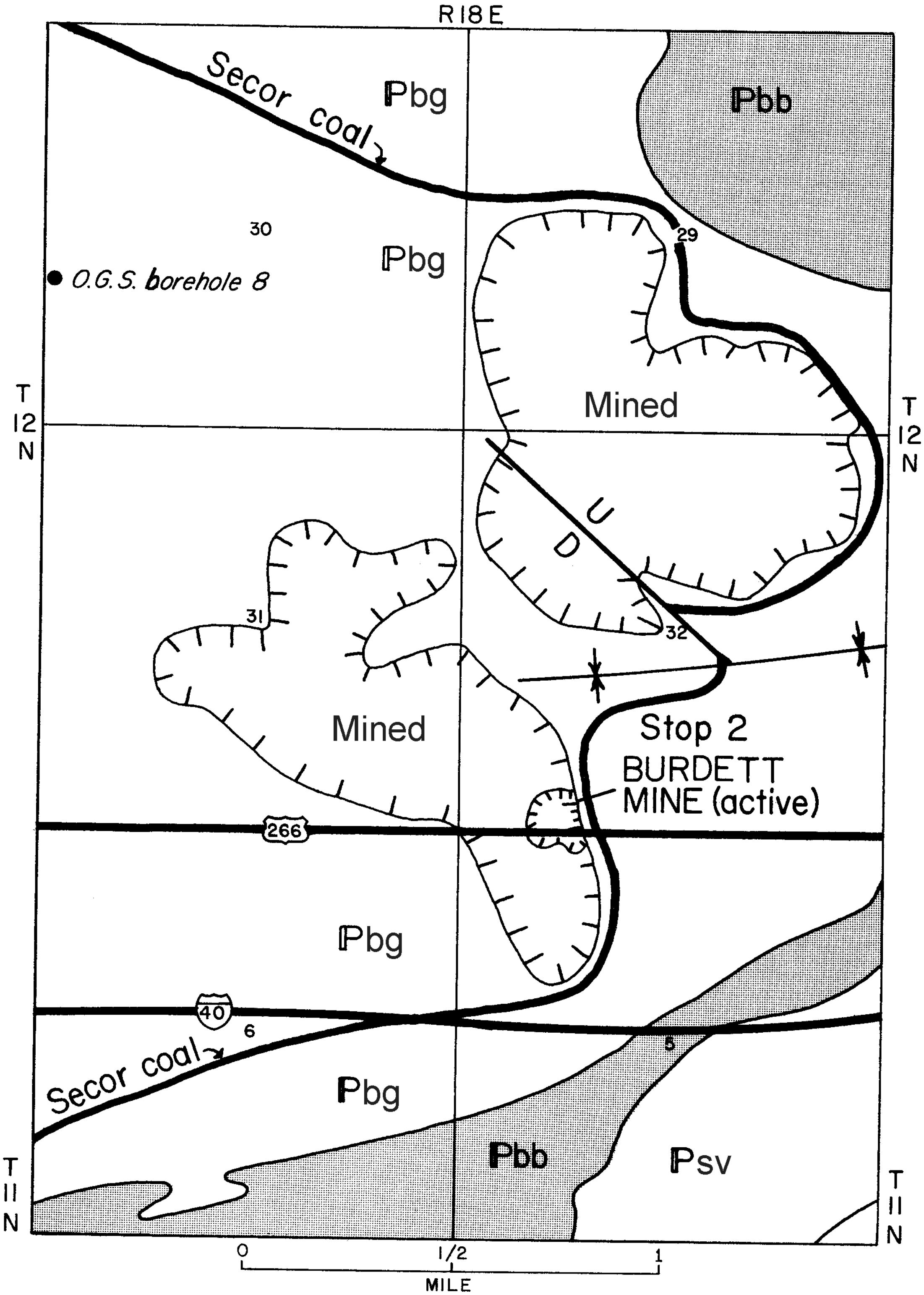


Figure 9. Map showing distribution of the Secor coal and the areas of previously mined and active strip mines in this coal, 5 miles east of Checotah, McIntosh County. Areas of Boggy shale (Pbg), Bluejacket Sandstone (Pbb) stippled, and Savanna Formation (Psv) (modified from Oakes and Loontz, 1967).

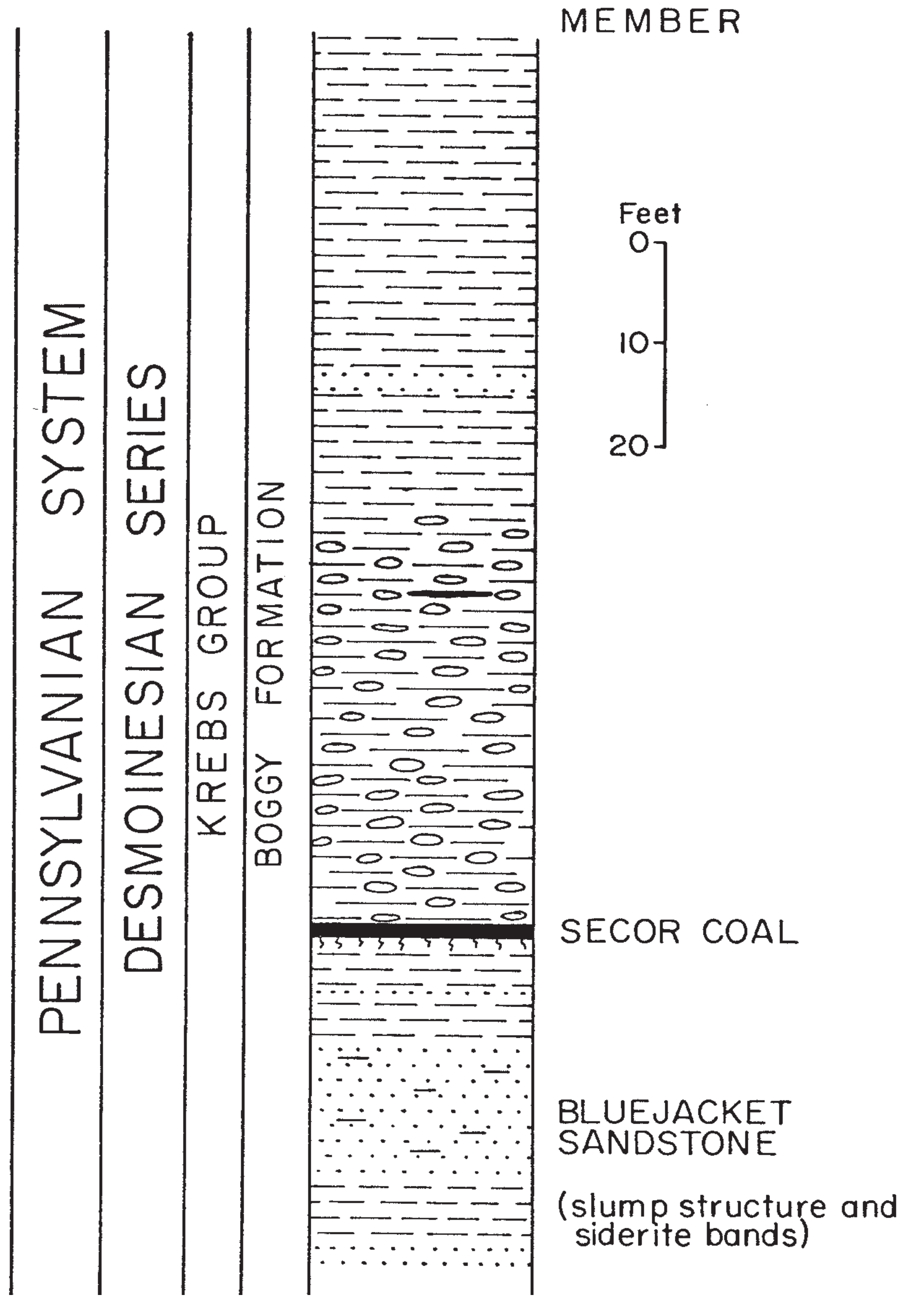


Figure 10. Generalized geologic column of the lower part of the Boggy Formation in the area shown in Fig. 9. (Lithologies are explained in Fig. 5a).

Stratigraphic Description from OGS Coal Borehole 8. Hole completed October 17, 1973. Location: 635 ft. south, 10 ft. east of NW cor SW ¼, sec. 30, T. 12 N., R. 18 E., 1.85 miles north of I-40, 3.5 miles east of Checotah, McIntosh County, Oklahoma. Drilled by Cullum Core Drilling Company. Description is modified from the driller's log and from R. O. Fay's field log. Depths are measured from land surface to base of each lithologic unit. Rockbit drill 0-85 ft, cored 85-118.5 ft.

Unit No.	Feet	
		Quaternary System
1.	10.0	Clay, brown and gray, in part soil
2.	14.5	Clay, brown, overlies bedrock unconformably
		Pennsylvanian System
		Desmoinesian Series, Krebs Group
		Boggy Formation
3.	23.0	Shale, brown
4.	33.3	Shale, gray. Water at 28 ft. (set 4 inch casing to 30 ft.)
5.	33.5	Sandstone, gray
6.	81.0	Shale, gray, contains siderite nodules from 46-81 ft
7.	84.9	Shale, dark-gray, contains siderite nodules
8.	86.75	Coal, black, banded, bituminous
9.	86.90	Shale, gray, forms parting in coal bed
10.	87.0	Coal, black, banded, bituminous
11.	88.0	Underclay, med-gray, nonbedded, noncalcareous, contains rootlets
12.	95.2	Shale, med-dk. gray, interlaminated with sandstone, bioturbated, slump structure, disturbed bedding
13.	107.8	Sandstone, lt. gray, fine grained, clayey, slightly miceaceous, contains shale laminae, contains 3 sideritic bands and some indistinct slump structures

14.	118.0	Shale, med-dk gray, interlaminated with gray sandstone laminae
15.	118.5	Sandstone, light gray, fine grained, clayey
	118.5	Total depth

Summary of named units

84.90-87.0	Secor coal
95.2-118.5	top of Bluejacket Sandstone Member

Megascopic Petrographic Characterization of Secor Coal, samples 75X43 and 75X44, from OGS Borehole 8

Vitrain	Attritus
sparse to moderate (<15-30%) thin to medium (<2mm-5mm)	moderately dull to moderately bright

cleat spacing: 4mm-1.2cm
cleat filling: Pyrite, calcite, iron oxide
partings: Pyrite, fusain, clay

Cleat directions in the coal bed at the Burdett mine have been determined at N45W (face cleat) and N40E (butt cleat). The coal is approximately 2 feet thick, with shale partings at 3.75 inches and at 13 inches above the base. The uppermost parting is removed by a separate bench-mining technique.

A light gray underclay is present below the coal, and it is similar in appearance to the underclay below the Secor coal in Pittsburg County. In both locations the underclay contains 5-6 percent iron oxides.

The Secor rider coal reaches 1.0 foot thick about 35 feet above the Secor coal in central and northern Pittsburg County, but it is absent in the area of Stop 2 in northeastern McIntosh County, as can be seen on the columnar section (Fig. 10). Apparently the rider coal was eliminated by northward offlap between the Canadian River at the McIntosh-Pittsburg County line and Checotah, McIntosh County.

If a trend in the distribution of the sulfur content in the normally high-sulfur (3%) Secor coal could be determined, the writer believes some low sulfur (1%) coal and intermediate sulfur (1.1-3.0%) coal might be discovered. Thus, Visher's 1968 map showing the interpreted depositional environments of the Bluejacket Sandstone was modified, and then sulfur percentages of this coal were plotted on it (Fig. 11).

The writer assumed that the distribution of the large alluvial-deltaic drainage system that deposited the Bluejacket Sandstone set the scene and resulted in environments in which peat developed that formed the Secor coal. Then it seemed reasonable to expect that the sulfur content of the coal, among other parameters, would be affected by the different environments of peat (coal) deposition (Spackman and others, 1974). Figure 11 is interpreted to mean that a clear correlation of sulfur with a particular environment cannot be determined. Perhaps additional sulfur analyses evenly distributed in the map area would result in a positive correlation. The 2.3% sulfur analysis is believed to be anomalous because of recent weathering of the coal bed. The 3.1% sulfur in the central part of the map, not far from an alluvial environment, suggests that the sulfur in the Secor coal may decrease northward. The sulfur content averages 4.4% over the pro-delta area of the Bluejacket Sandstone and 5.7% over the lower part of the large, lower deltaic plain area. The significance of these sulfur averages is uncertain but may reflect a marine (saline) influence. In the cores and at most of the mines from which the Secor coal samples were taken, dark gray marine shale, containing marine invertebrates, overlies the coal and suggests that a marine environment contributed to a high sulfur content of the peat in the Secor coal swamp.

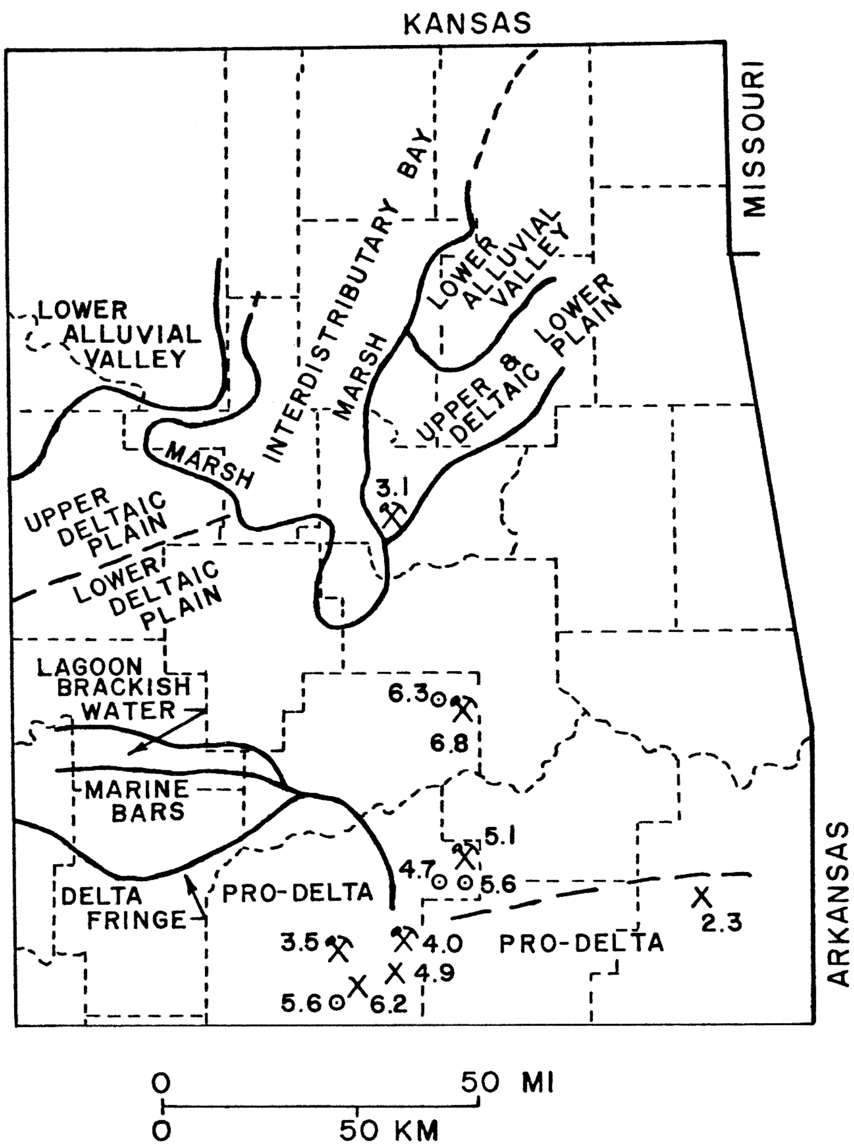


Figure 11. Percentage of sulfur in the Secor coal in relation to a map modified from Visher (1968) that shows depositional environments of the Bluejacket Sandstone in eastern Oklahoma.

Interval (miles)	Cumulative (miles)	Leave STOP 2 The Burdett Company strip mine. Return to U.S. Highway 266.
0.8	132.4	Turn left (east) onto U.S. Highway 266 and proceed to State Highway 2.
1.4	133.8	Outcrop of Bluejacket Sandstone and some shale, Boggy Formation.
0.3	134.1	Sandstone boulders at foot of bridge (Boggy Formation).
2.4	136.5	Cuesta ridges to the south.
0.2	136.7	Junction with I-40. Remain on U.S. Highway 266 East.
0.6	137.3	McIntosh-Muskogee County line. Atoka Formation on the Warner uplift.
1.1	138.4	Bridge
1.8	140.2	Junction with S.H. 2. Turn right (south) onto S.H. 2.
2.0	142.2	South edge of the Warner uplift. Atoka-Hartshorne Formations contact.
2.5	144.7	Left (east) turn onto county road. This is not easy.
1.0	145.7	Railroad intersection
1.05	146.75	Abandoned strip mine, which has become a strip-mine pond.
0.05	146.8	Section-line intersection
0.05	146.85	Turn right (south) at end of abandoned mine. Covered outcrop of Stigler coal.
0.2	147.05	Stop at mine building which contains a shop and an office, on the right *(west)*.

STOP 3

Porum strip mine, Carbonex Coal Company. **HARD HAT AREA**
The Porum strip mine is operated by Carbonex Coal Co. (formerly Sierra Coal Co.). The Stigler coal that is mined here was shipped on the McClellan-Kerr Arkansas River Navigation System from a loading dock at Webbers Falls to TVA's Allen generating plant at Memphis, Tenn. a few years ago. This high-sulfur coal has since been shipped to cement plants in Texas. The present production of coal is shipped, in large part, to a utility in Missouri. Production in 1976 was about 96,000 short tons, and in 1977 it was increased to 117,000 tons.

A map (Fig. 12) of the Porum strip mine shows the location of the active pit area and the reclaimed areas (mined since 1972). Previously mined areas have been reclaimed only on the Carbonex lease. The mining pattern is moving westward, in an area of a syncline where the overburden is 30-45 feet thick and is composed of blue gray, silty shale (Fig. 13). Small thrust faults may be observed in the west highwall at the north end of the mine.

The Stigler Coal has been mapped in the Porum area of Muskogee County (Wilson and Newell, 1937, and Oakes, 1977). But the increase in sulfur and ash content and the decrease in calorific value of the coal between Porum and Briartown in Muskogee County have caused some coal explorers and others to suspect or deny the correlation of the Stigler coal bed in these areas. The following is a composite analysis by Bob Powell, Chemist, OGS, of 2 benches collected from a channel sample of the Stigler coal in the Porum strip mine in 1976.

(OGS Sample 76C-44 & 45)	Percent (as received)		Forms of Sulfur	
Moisture	0.9	Proximate		
Volatile Matter	29.8		Organic	0.45
Ash	8.5		Pyritic	4.15
Fixed Carbon	60.8		Sulfate	0.00
	100.0		Total	4.60
Sulfur	4.6			
Btu	13,827			

A comparison of this analysis with that of the sample from the Stigler No. 9 mine (a few pages ahead) indicates that the coal at the Porum mine is a "steam" coal and that at the No. 9 mine is a coking coal of high quality. A cross section to demonstrate this correlation has not been prepared, but drillers' and electrical logs of 6 boreholes between the south end of the elongate strip mines at Porum and the Canadian River at the Muskogee-Haskell County line strongly suggest the continued presence of the Stigler coal. The Stigler rider coal is absent in the Porum district, but it is present in the Stigler area. The sharp difference in the sulfur content (4.6%) of the Stigler coal in the Porum area and the sulfur content(0.8%) of the Stigler coal in the Garland No. 9 Mine (see p.36-37 and Fig. 16) has yet to be explained or interpreted.

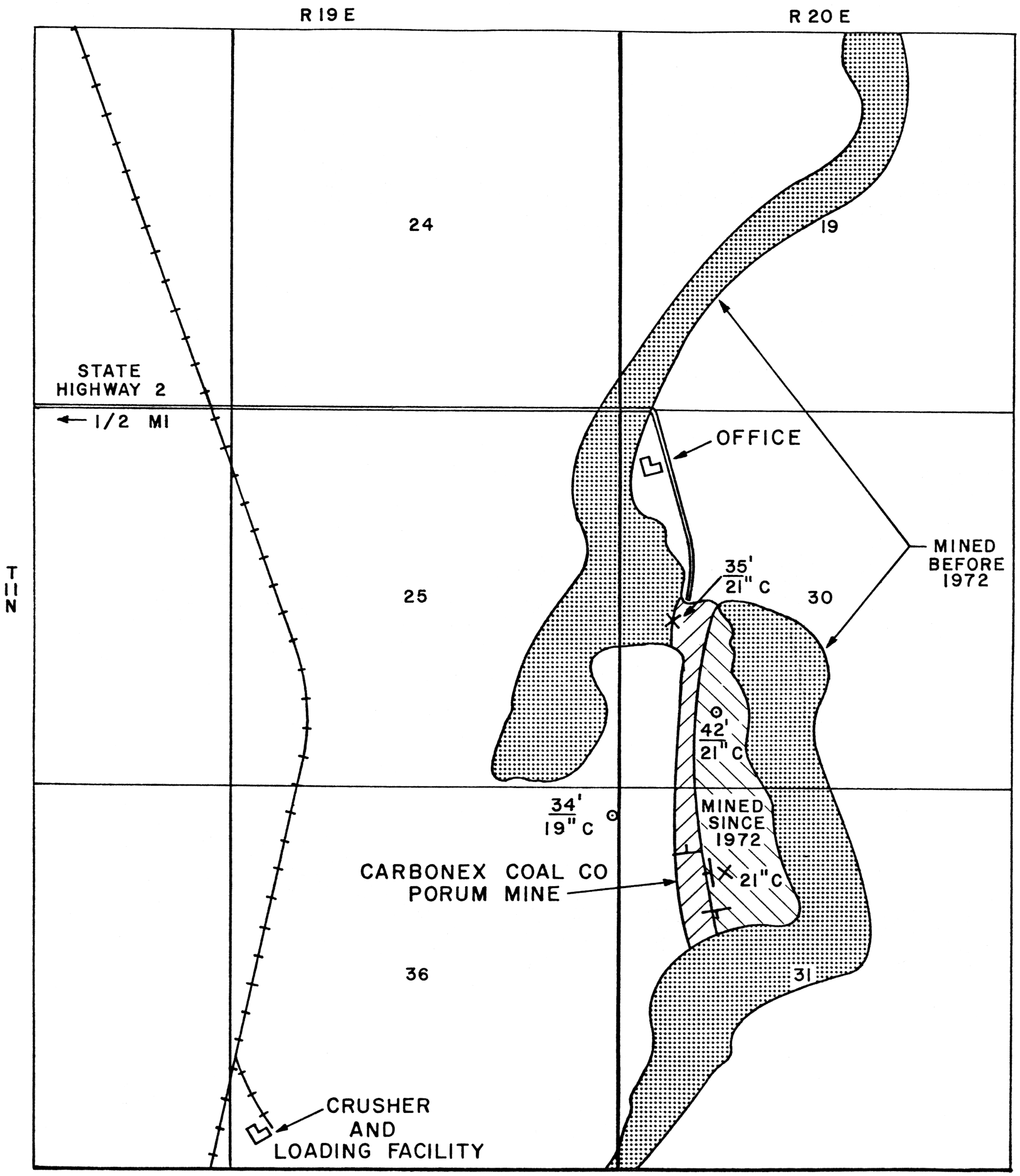


Figure 12. Map showing location of abandoned and active strip mines in the Stigler coal, Porum mining district, Muskogee County.

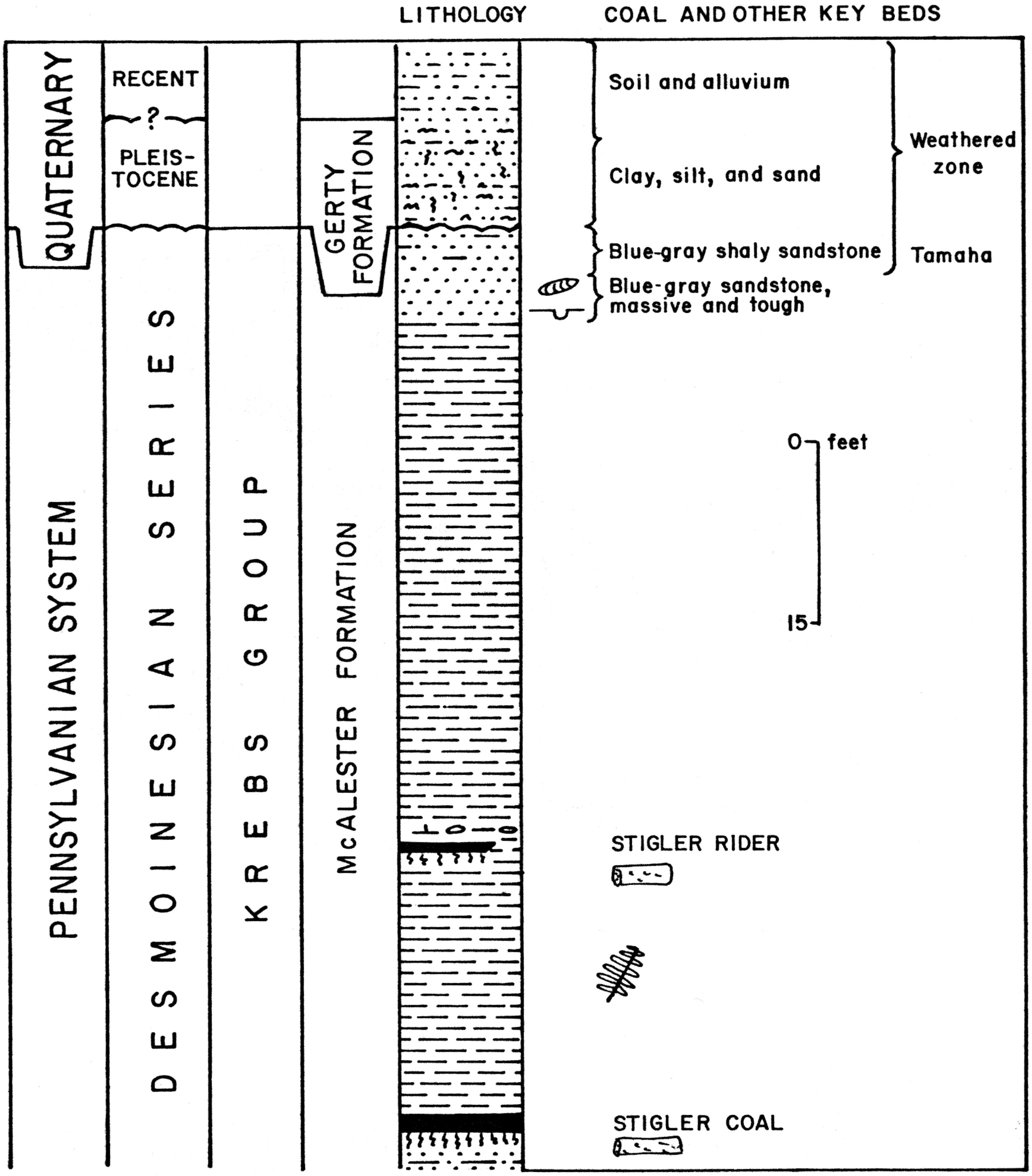


Figure 13. Generalized geologic column showing the exposed lower part of the McAlester Formation overlain by unconsolidated sand and clay in the areas of Porum, Muskogee County, and Stigler, Haskell County. Stigmaria are present in underclaystones, and abundant leaf compressions are present in shale in the interval between the two coals. (See Fig. 15).

Interval (miles)	Cumulative (miles)	
		Leave Porum mine (STOP 3), and return to State Highway 2 via east-west county road which is north of the mine office.
2.3	149.35	Intersection of county road and State Highway 2. Turn left (south) onto the highway.
3.1	152.45	Intersection with Lite Street, entering Porum.
2.0	154.45	Junction of U.S. Highway 71 and State Highway 2. Continue south on S.H. 2.
2.6	157.0	Briartown
1.5	158.5	Enter ONE LANE BRIDGE across Canadian River.
0.8	159.3	Whitefield. Junction of S.H. 2 with S.H. 9. Stop; then turn left (east) onto S.H. 9 and proceed to Stigler.
1.8	161.1	Abandoned strip mines and partly reclaimed shale gob piles that exhibit natural plant and tree vegetation. The Stigler Coal was mined here to a maximum depth of 25 feet.
1.3	162.4	View to right (south) of 2 hills that are outliers of Stigler coal and the upper part of the McAlester Formation. The coal was mined on Federal leases by surface methods most of the way around the hills.
2.5	164.9	Intersection with railroad. Enter Stigler.
0.1	165.0	Don's Restaurant & Motel LUNCH STOP. After lunch, turn left (north) at West 7th Street: proceed north to Stigler mine of Carbonex Coal Co. Pass by 2 pits that have been reclaimed on either side of road. County road turns east; then go 1,600 feet (0.3 mile) to western edge edge of east-west pit.

Interval (miles)	Cumulative (miles)	
5.8	170.8	Continue past the west entrance to the mine and enter the mine by turning north at the east end (second mine road). Inquire at the shop of the Stigler mine, Carbonex Coal Company. HARD HAT AREA

STOP 4

The Carbonex Coal Company began operations at its Stigler mine late in 1976, and only 6,000 tons of coal was produced that year. In 1977, however, 39,000 tons was produced and shipped to Texas for use by the steel industry in coke manufacture. The coal is less than 1% in sulfur content and about 2 feet thick. The coal contains slickensides in the east part of pit 2, and it exhibited a dip of 11° SE before mining. The strike of the coal in the SE corner of this pit is N40E.

A northeast-trending normal fault separates the Atoka Formation from the McAlester Formation (Fig. 1), and has a throw of at least a few hundred feet at the location of Stop 4. The fault lies between the northern boundary of the mine and the foot of the large hills north of the 3 mine pits (Fig 14). The relief is about 250 feet between these hills and the Canadian River, and it is about 300 feet in the area south of the mine at Jackson Creek and Morgan Mountain.

The Stigler coal occurs in the upper part of the McAlester Formation, and dips about 11°-13° southeastward into a syncline that trends northeastward. The Stigler coal crops out on the eastern flank of this syncline and dips 2°-3° northwestward at the location of the Stigler No. 9 mine of Garland Coal & Mining Company, at the next field stop (6 miles south of stop 4).

The Bluejacket Sandstone (Boggy Formation) is believed to form the steep bluffs in Morgan Mountain. Thus the entire Savanna Formation, which overlies the McAlester Formation, occurs at the base and in the lower part of Morgan Mountain (Figs. 1,2,13 and 14). Federal coal leases are south and east of the 3 pits of the Stigler mine of Carbonex Coal Company.

Considering the presence of Jackson Creek, and that the dip is southeastwards, and that the maximum depth reached by mining operations here was about 95 feet in the two pits that have been reclaimed, it is concluded that some, but not a great quantity of the Stigler coal, could be recovered profitably on the Federal leases adjacent to this mine.

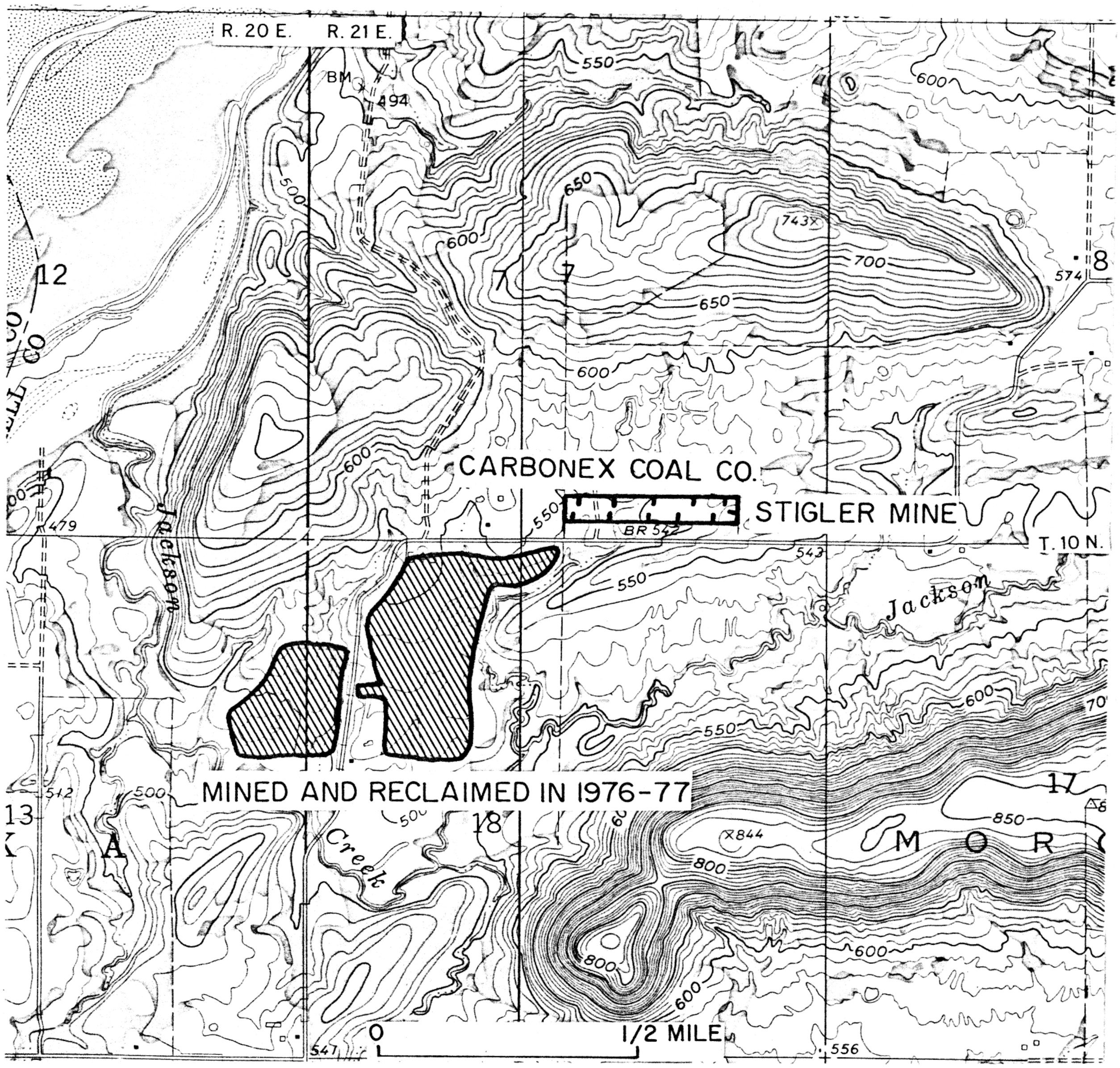


Figure 14. Parts of the Stigler East and the Stigler West 7.5' Topographic Quadrangle maps showing approximate location of three pits of the Stigler mine of Carbonex Coal Company.

This mine site was scheduled as a stop on the field trip because of the occurrence here of vast numbers of plant megafossils. Had it not been for the development of this strip mine these fossils would not have been discovered by the writer accompanied by OGS research assistant R. A. Holcomb, in August, 1977. Most likely the mine will be closed and the site reclaimed by next year, terminating easy access to these (Desmoinesian) plant fossils.

Figure 15 shows a few typical genera collected in August, 1977, at the site of pit 2. R. A. Holcomb photographed and he and the writer identified the genera. Dr. Coleman Robison (oral communication, January, 1978) temporary OGS research paleobotanist, confirmed them recently. During a visit to the west end of pit 3 in January, 1978, Dr. Robison and the writer collected a fine specimen of *Mariopteris*, not shown in Figure 15. *Cordaites* leaves were most abundant, and *Sphenopteris* was rare. The stratigraphic occurrence of the plants is in the medium gray shale (15 feet thick) that is medium- to thick-bedded, and immediately overlies the Stigler coal up to the underclay of the Stigler rider coal. It is not an ideal shale from which to extract the plant compressions and impressions, because the bedding is indistinct causing fragments to break, thus destroying the larger fossils. A few unidentified small brachiopod impressions occur in this shale. They are probably of one genus.

The great abundance of plants at this stratigraphic interval does not persist 6 miles southward at the Stigler No. 9 mine.

Interval (miles)	Cumulative (miles)	
		Leave STOP 4, the Stigler strip mine of Carbonex Coal Company. Turn right (west) at county road. Continue as road turns left (south).
1.5	172.3	Perry church. Stop at "T" junction E-W dirt road at Perry community. Turn left (east).
2.0	174.3	Turn right (south) at intersection of county roads.
2.6	176.9	Turn right (west) into shop area of the Stigler No. 9 strip mine of Garland Coal & Mining Company. This is a HARD HAT AREA. The mines of this company are operated by members of the United Mine Workers of America (UMWA).

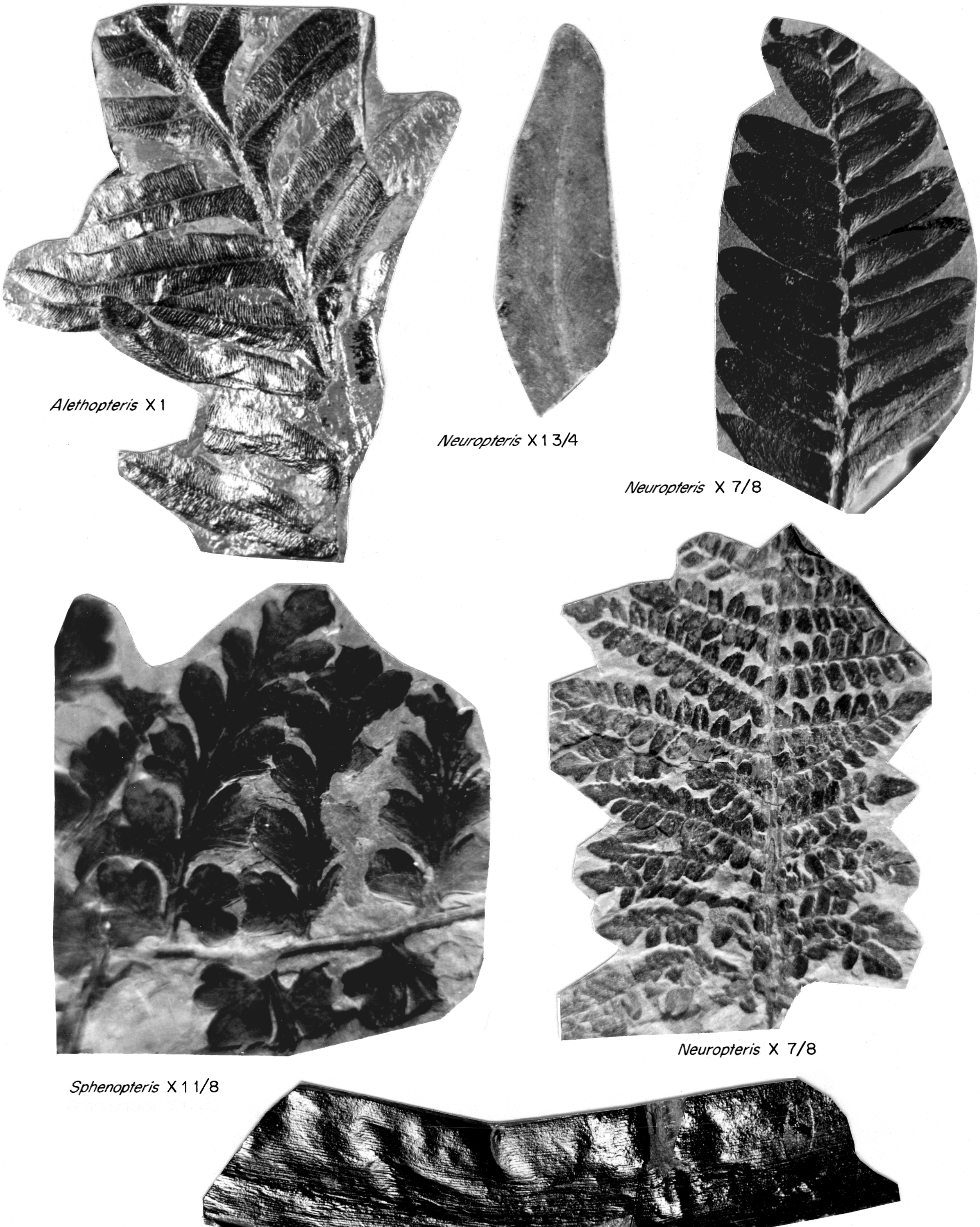


Figure 15. Photographs of typical leaf compressions collected by the writer from medium gray shale that overlies the Stigler coal at the Stigler mine of Carbonex Coal Co.

STOP 5

Stigler No. 9 (strip) mine of Garland Coal and Mining Company of Ft. Smith, Arkansas, also produces from the Stigler coal bed. The Stigler coal at this mine is medium-volatile bituminous in rank, low in sulfur content (0.5%), and is only 13-18 inches thick. Yet, the company removed up to 120 feet of overburden composed of unconsolidated clay, silt, sand, and silty or clayey medium-gray shale, to produce the coal. At present the overburden averages 90-100 feet thick. The Bucyrus Erie 1250-B dragline, whose boom is 200 feet, and whose bucket capacity is 30 cubic yards, moves on walking pontoons, and sets on shale overburden that has been shot, 70 feet above the coal bed. The dragline works southwards along the one mile-long highwall in about 6 weeks, and then it walks northwards in less than a day to its starting point. This method, along with the large dozers that rip and push the unconsolidated overburden and the Tamaha Sandstone, is the most efficient means of exposing the Stigler coal.

The coal from this Federal lease is shipped from Port Carl Albert by barge down the McClellan-Kerr Arkansas River Navigation System and reloaded into oceangoing ships at New Orleans. The ships pass through the Panama Canal later on their voyage to Japan. In 1976, about 159,000 short tons was produced at this large strip mine. In 1977 the production was reported as 187,000 tons, although very little was mined in December, because of the recently concluded UMWA strike.
This is not a large-size mine from the aspect of production. It is intermediate. The company reports a plan to reach a maximum overburden of 140 feet, as the mine progresses and deepens westward, following the dip (Fig. 16).

The Stigler coal is underlain by about 2 inches of underclay. The coal is overlain by crumbly, medium-light gray shale which contains rare carbonaceous stem? fragments. The gray shale is overlain by medium to dark gray shale, which contains siderite nodules and lenses.

The Stigler rider coal is 30-35 feet above the Stigler coal, and it is underlain by an underclay unit 3.5 feet thick that contains abundant *Stigmaria* (roots) that are parallel to the bedding. Long rootlet compressions and impressions occur below the *Stigmaria*. Cleats in the Stigler coal are so closely spaced (1/8 inch to 1/2 inch) that they contribute to the friability and high Hardgrove Grindability Index of the coal. The cleats also cause broken, large and small chunks of the coal commonly to have a long axis perpendicular to the top and bottom of the bed. These properties combined with its bright luster, thin, vitreous vitrain layers, and numerous fusain layers, makes the Stigler coal distinctive at most places.

Chemically the Stigler coal is similar to the Hartshorne coal except that the Stigler commonly contains no visible partings. A typical composite analysis of 2 samples (OGS Field Sample Nos. 74X5 and 74X6) of the Stigler coal, 18 inches thick, in the SE1/4 NE1/4 sec. 5, T. 9 N., R. 21 E., follows.

Proximate Analysis As-received (percent)	
Moisture	2.3
Volatile Matter	28.5
Ash	3.9
Fixed Carbon	65.3
	100.0

Ultimate Analysis (percent)	
Carbon	82.7
Hydrogen	5.1
Oxygen	5.7
Nitrogen	1.9
Sulfur	0.8
	96.2

Calorific value: 14,537 Btu.

F.S.I.: 9

Ash Fusion Temp.: I.D. 2,160 °F
½h 2,214 °F
Fluid 2,264 °F

OGS Analyst, D. Foster

Two periods of reclamation are represented at the mine. Most of the area mined in sec. 4 (Fig. 16) was reclaimed under a State law between 1968-1971. The area of sec. 5 was reclaimed during the period of the 1971-1978 State law. Neither law required preserving or returning the soil. The soil was returned, nevertheless, because of cooperation between the company and State and Federal regulatory agencies. At present soil conservation and return is part of the new Oklahoma and Federal requirements, but Garland Coal & Mining Company has been practicing soil rehabilitation since at least 1971. The company has benefited the city of Stigler, in numerous ways, the most evident of which are a city sanitary landfill and a city air strip on the reclaimed area (Fig. 16).

The Stigler coal is a low-sulfur (0.5-1.5%) coking coal in most of Haskell County and west of Briartown in Muskogee County. It is a medium-volatile bituminous coal in rank in most of the area except at Hoyt, west of Whitefield, where it is high-volatile B bituminous and also of use for blast-furnace coke manufacture. In east-central Haskell County and in most of Le Flore County the sulfur content in the Stigler coal reaches 4.5%, thus making it unsuitable for coke manufacture.

A laterally continuous depositional setting following a rapid lowering of sea level has been suggested for the origin of the Stigler coal (Karvelot, 1972, p. 118). Busch (1959) showed evidence for a southward orientation of the Booch delta of the Warner Sandstone. The relationship of the Stigler coal to this delta is not certain. The low-sulfur content of this coal is in large part confined to Haskell County, and it needs an explanation. Perhaps the low sulfur peat formed during regression when marine influence was greatly diminished or absent.

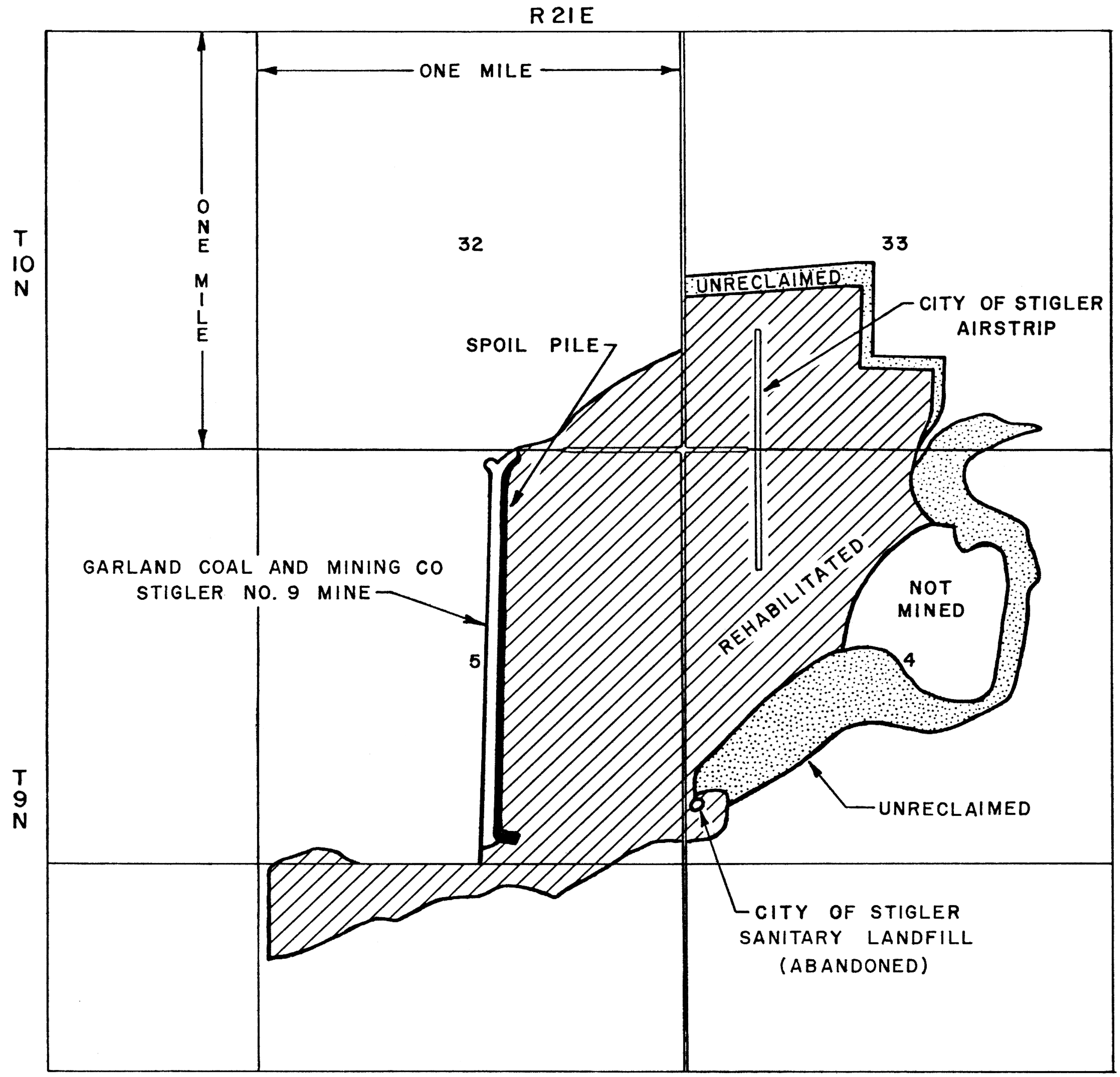


Figure 16. Map showing location of active pit and reclaimed areas at the Stigler No. 9 mine of Garland Coal and Mining Co.

The problem of determining environments of deposition of the remarkably high-quality Stigler coal in Haskell County, can not be solved without consideration of the total distribution of the McAlester-Stigler coal.

Early in the history of geologic studies when counties did not exist and the area was called the Indian Territory, the McAlester coal of Pittsburg, Latimer, and Le Flore counties was correlated with the Stigler coal of Haskell County (Drake, 1897). Taff (1899, p. 454) collected an abundant fossil flora from dark blue shale in the "roof" of the McAlester coal in the McAlester district. These plants are similar to those that occur at Stop 4. Taff (1905, p. 389-390) recognized that the Stigler coal, north of the Sans Bois Mountains and near the mouth of the Canadian River, is a northern extension of the McAlester coal.

On the other hand, Hendricks and others, (1936 and 1939) believed the Stigler coal was 30-80 ft above the McAlester coal. The present writer believes Hendricks' Stigler (?) to be the Upper McAlester-Stigler rider.
Oakes and Knechtel (1948, p. 6) indicated a tentative correlation of the McAlester coal with the Stigler coal of Haskell County. Knechtel (1949, p. 48) tentatively correlated the McAlester coal with the Stigler coal of Le Flore County. Results of a palynological study show an excellent correlation of the two coals (Morgan, 1955, p.40). Trumbull (1957, p. 348) nevertheless, considered them as separate coals but with some doubt.

The present writer concurs with Drake (1897), Taff (1905), Oakes and Knechtel (1948), and Morgan (1955) in correlating the Stigler with the McAlester coal. The present writer's stratigraphic cross-section (Fig. 17) shows the McAlester and Stigler coals correlated, the Stigler rider and Upper McAlester coals correlated, other thin, unnamed coals in the upper part of the McAlester Formation, and the lithofacies variations in the associated strata. The interval between the McAlester-Stigler coal bed and the Upper McAlester-Stigler rider coal bed (these are tentative terms) increases southward from 15 feet at the Stigler mine of Carbonex Coal Company (Stop 4) to approximately 60 feet in the Hughes-Fanshawe area (boreholes 7 and 8, Fig. 17). Evidence is lacking to suggest that the coals merge or are a split of a single coal bed northwards into Muskogee and McIntosh counties, where only the Stigler coal is present (Oakes, 1977).

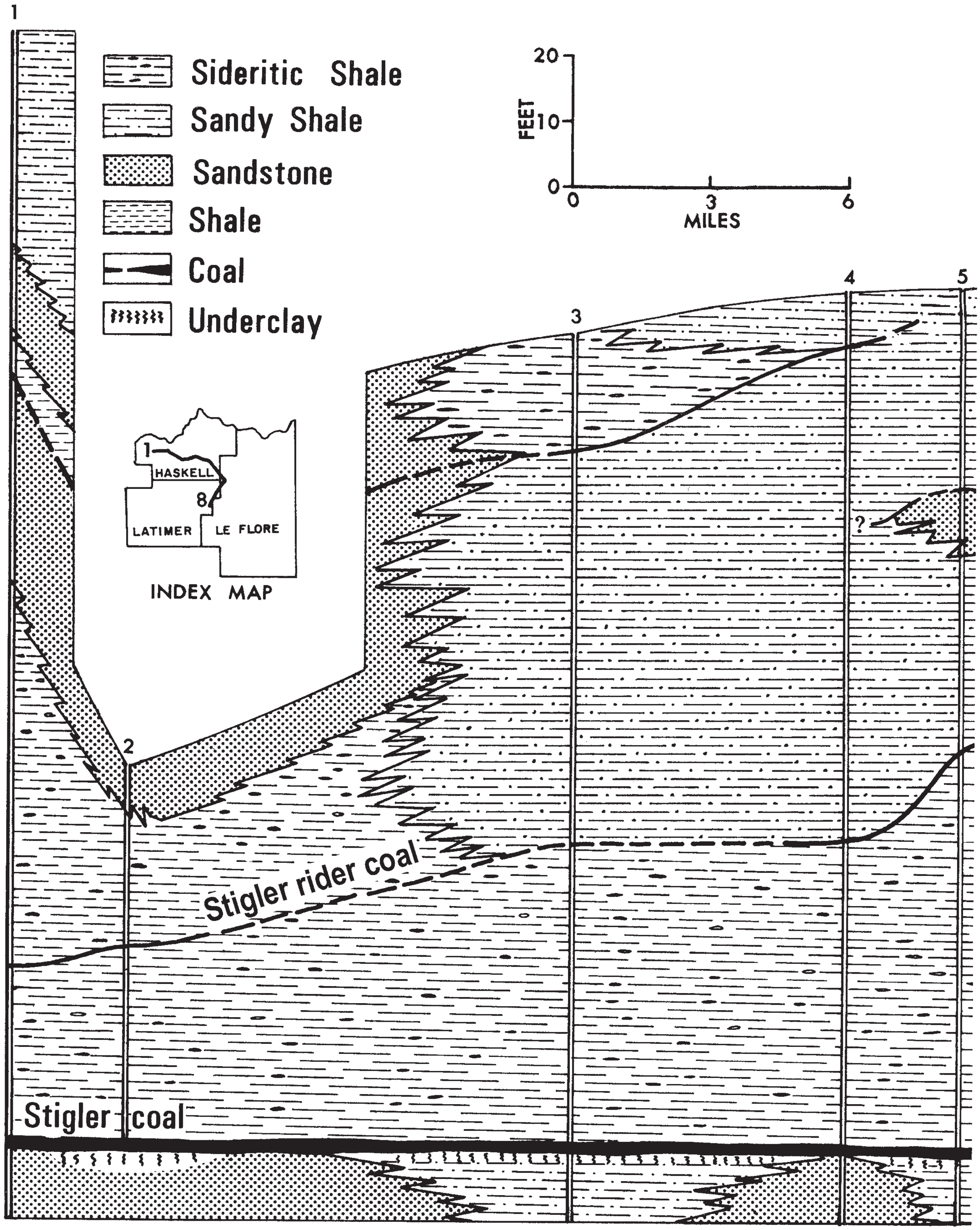
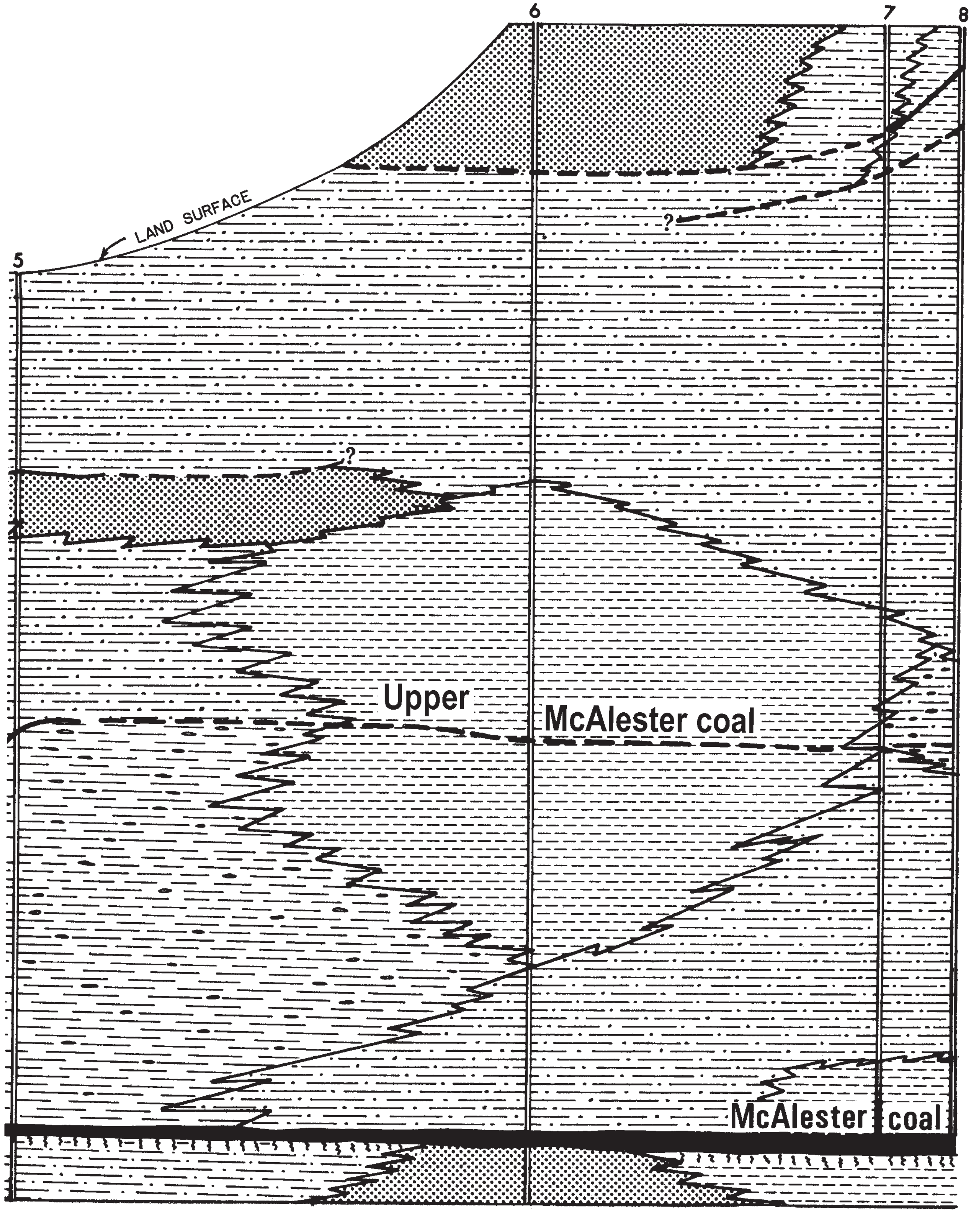


Figure 17. Stratigraphic cross section from western Haskell Co. to eastern Latimer Co. showing correlation of the Stigler coal with the McAlester coal and of the Stigler rider coal with the Upper McAlester coal.


6
7
8
LAND SURFACE
5
?
?
Upper
McAlester coal
McAlester
coal

Interval (miles)	Cumulative (miles)	
		Leave Stigler No. 9 mine, Garland Coal & Mining Company, and turn right (south) onto county road.
1.3	178.2	Intersection of county road and State Highway 9. Turn right (west)
1.2	179.4	Enter Stigler
1.2	180.6	Railroad Crossing. Leave Stigler
6.1	186.7	Whitefield
1.3	188.0	Enterprise
9.2	197.2	Canadian Fork
0.5	197.7	State Highway 9 divides. Take State Highway 9A (left) and head south to McAlester
3.5	201.2	Crowder
17.0	218.2	Holiday Inn, McAlester, **OVERNIGHT STOP**

ROAD LOG AND TEXT
SECOND DAY

Interval (miles)	Cumulative (miles)	
		Leave Holiday Inn, McAlester. Retrace route to Stigler via U.S. Highway 69 north and State Highways 9A and 9 east.
53.0	271.2	Railroad crossing. Stigler.
8.0	279.2	**STOP 6** Port Carl Albert (turn right, south). Bottom-dump trucks empty coal load into hopper. Coal is crushed to 2x0 (2 inches maximum size) and stored on pile. Maximum storage is 10,000 short tons. Barges contain 1,300 tons when full.
1.2	280.4	Leave Port Carl Albert. Turn right (east) onto S.H. 9, cross bridge over Sans Bois Creek. Turn right (south) onto State Highway 26.

7.0	287.4	Junction with east-west haul road. Turn left (east). Property of Lone Star Steel Company. Gob piles are partly reclaimed. Abandoned mines were in the Hartshorne coals.
0.8	288.2	Right (south) turn onto haul road. Then cross railroad mine spur. Enter Great National Corporation, McCurtain No. 2 mine. Stop at guard house. Beware of dog.

STOP 7

Great National Coal Corporation has operated the McCurtain No. 2 strip mine since 1974, at 2 pits on private leases, on which geologists had not shown any coal (Oakes and Knechtel, 1948). Federal coal leases separate the East pit from the Karsh pit. The Upper and Lower Hartshorne coals, produced at the mine, are used in coke manufacture. Production in 1974 was 45,000 tons, in 1975 it was 60,000, in 1976 it was only 9,000, and in 1977, 86,000.

A rather busy map (Fig. 18) (part of a current Hartshorne coals project in Le Flore County) shows the unlikely occurrence of the 2 pits on a down-dropped faulted sliver of the Hartshorne Formation on the Milton anticline at McCurtain. Not all the faults are shown. The throw of the northernmost normal fault at the East pit is at least 110 ft. Another fault passes through the pit, and the dip of the coals changes from 56°N to 32°N across this fault. The Karsh pit contains at least 2 faults. At the start up of this pit the dip was 45°. The Upper and Lower Hartshorne coals together are 6 feet thick; about 0.5-1.0 ft of clayey shale separates them. The operator recovered the coal with an innovative technique, employing a hydraulic impulse pick and a grade-all scoop.

At this point the coal was believed to have been absent in the next cut northward. Then it was found standing vertically. The next cut northward uncovered the coals dipping about 25°N close to the surface. See Lee Catalano's* sketch (Fig. 19) for a preliminary interpretation of this structurally complex area.

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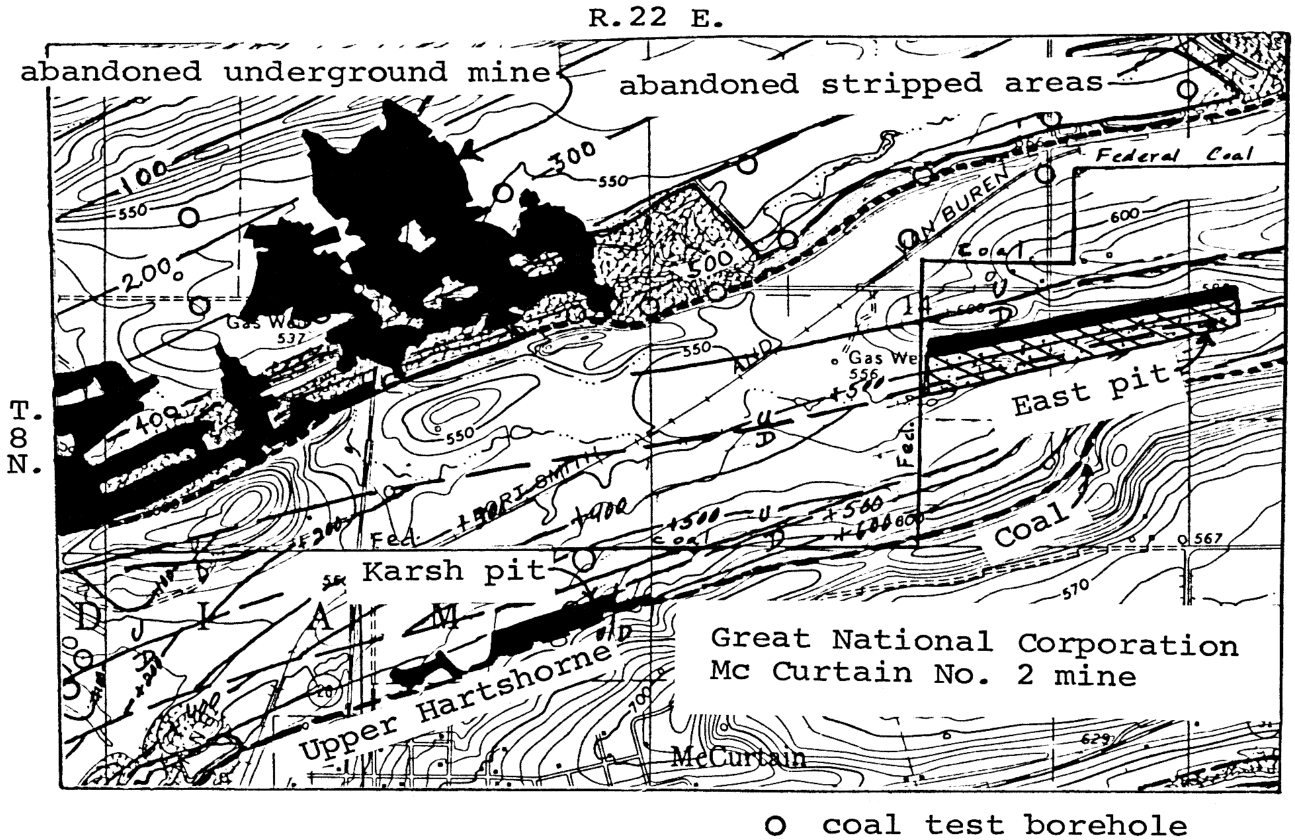


Figure 18. Map showing the Karsh pit and the East pit of the McCurtain No. 2 strip mine. Structural contours on top of the Hartshorne coal indicate the uplifted strata (including the coal bed) on the north side of the western end of the Milton anticline, Haskell County. Abandoned underground mines are shown in black. (The base map is part of the U.S.G.S. McCurtain 7.5' Topographic Quadrangle map.)

PROXIMATE ANALYSES

Upper Hartshorne Coal

OGS Sample and pit	M	V.M	Ash	F.C.	S	Btu
East pit 75X62,63	1.0	21.4	3.2	74.4	0.5	14,930
Karsh pit 75X66	1.1	21.2	2.1	75.6	0.7	15,300
Lower Hartshorne Coal						
East pit 75X64,65	2.8	19.6	3.5	74.1	0.5	14,560

These analyses indicate that both coal beds are medium-volatile bituminous in apparent rank.

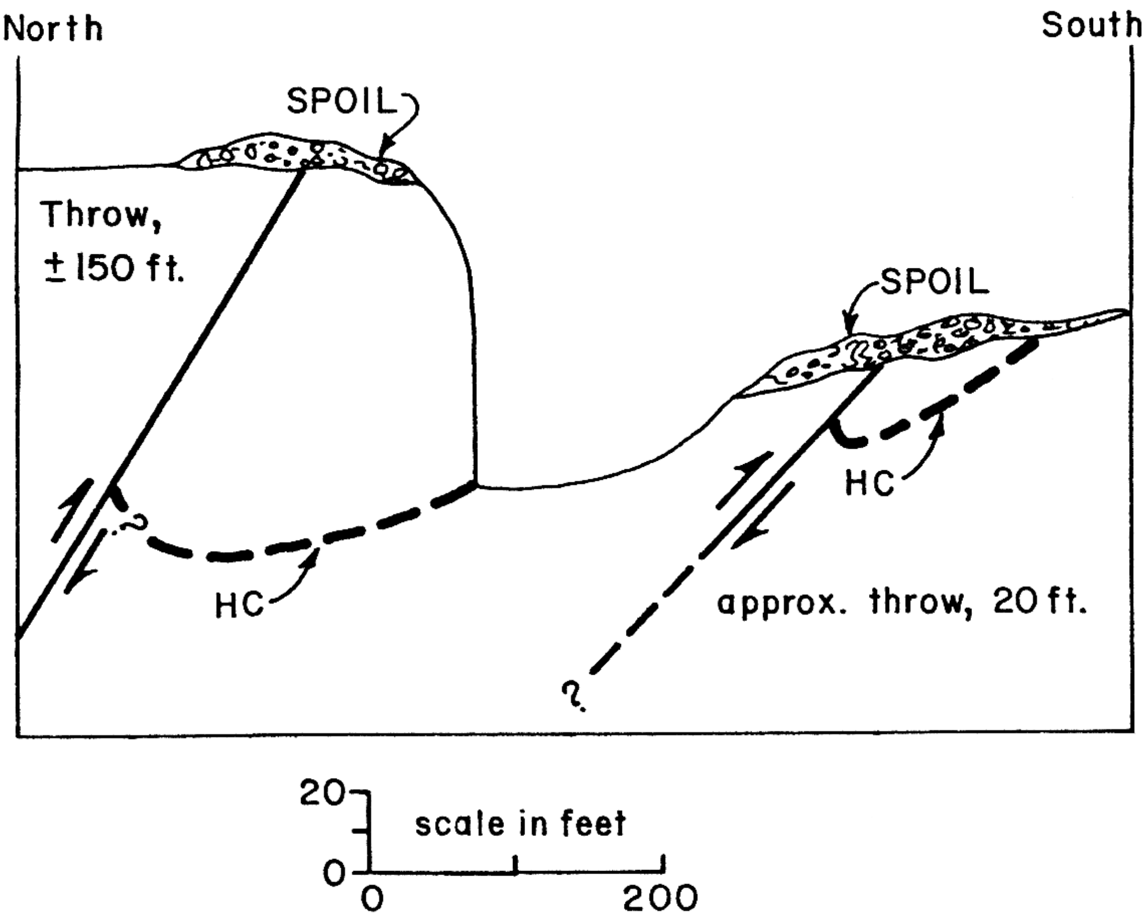


Figure 19. Cross section showing two faults and the Hartshorne coal in the west end of the Karsh pit, McCurtain No. 2 mine.

Interval (miles)	Cumulative (miles)	Leave McCurtain No. 2 mine, Great National Corporation. Left turn on county road.
0.8	289.0	Intersection of county road and State Highway 26. Turn left (south).
0.4	289.4	Railroad-spur crossing.
0.3	289.7	McCurtain
0.3	290.0	Junction of State Highways 26 and 31. Turn left (east) onto S.H. 31
1.4	291.4	Leave McCurtain
10.3	301.7	Bokoshe

0.6	302.3	Right (south) turn at last street before railroad tracks. Cross railroad spur (rough!); turn right at Y in road.
1.3	303.6	Left (east) turn at north end of strip mine. Right (south) turn and right again to main haulage road. Proceed carefully southward. Watch out for coal trucks and scraper. Stop at office. This is a HARD HAT AREA.

STOP 8

Bokoshe No. 10 strip mine of Garland Coal & Mining Company (Fig. 20) has been producing from the Upper and Lower Hartshorne coals since 1975. Thin clay and shale partings and pyrite require special preparation of these coals. The plant contains heavy media separators, Deister vibrating tables, and froth flotation units. The cleaned product contains ≤1.0% sulfur and ≤8% ash, and it is shipped by rail to Pueblo, Colorado, where it is made into blast-furnace coke by Colorado Fuel & Iron Corp. (CF&I). Chemical analyses of channel samples of the Hartshorne coals collected at this mine were performed by OGS chemist David Foster, as follows.(Proximate analyses are in percent by weight.)

Upper Hartshorne	Proximate					
Coal, 3.3 ft	Moisture	Volatile Matter	Ash	Fixed Carbon	S.	Btu
75X30,31,32	4.9	20.7	11.6	62.8	1.9	12,590
Lower Hartshorne Coal						
75X52,53	3.5	18.1	8.3	70.1	1.1	13,400

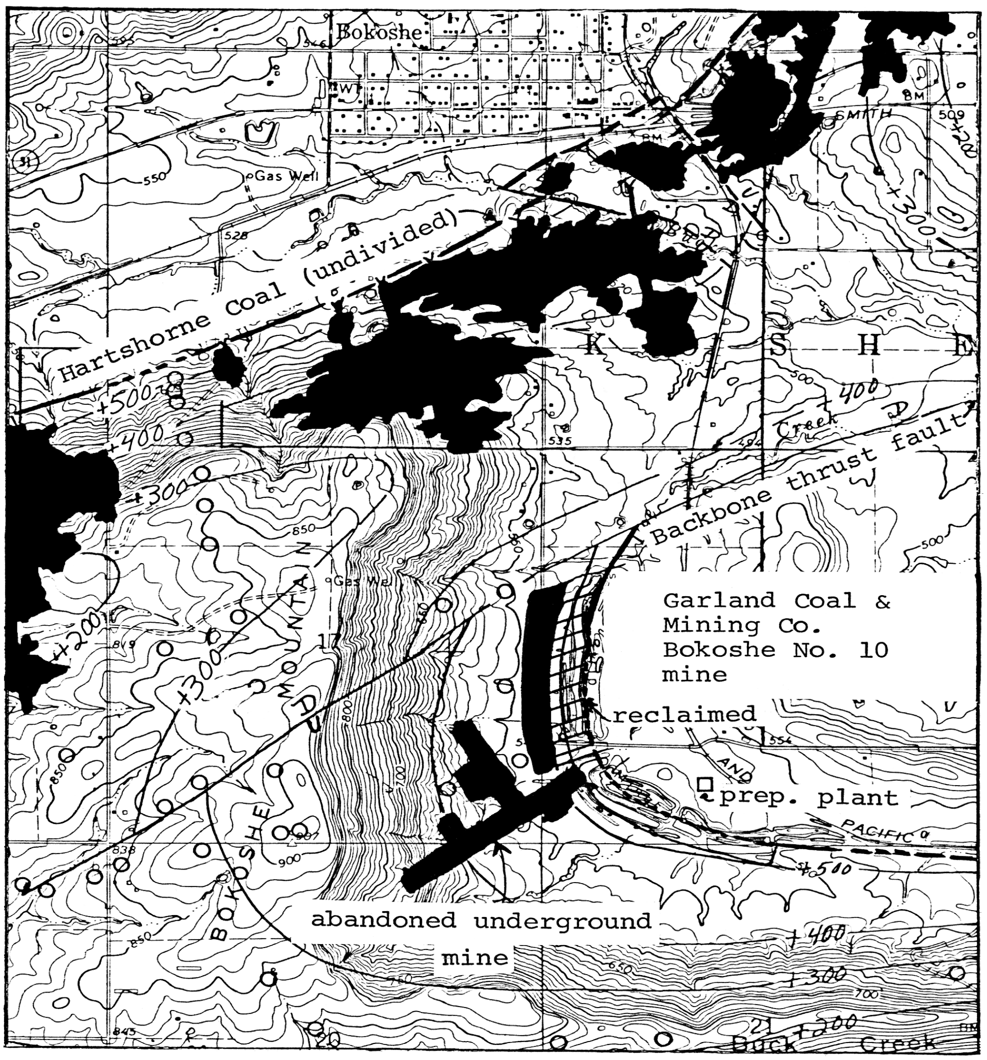
These analyses are typical of the first year's production, but the sulfur and ash were somewhat lower during 1976 and 1977. Coal production at this mine was 137,000 tons in 1976, and 135,000 in 1977. This coal was produced from the faulted, north flank of Backbone anticline (Fig. 20). The mine was begun at the surface in the Upper Hartshorne coal, and then deepened 30 ft to the Lower Hartshorne coal. The abandoned, older strip mine east of the Bokoshe No. 10 mine, was 30 ft deep, contained water that required draining, and has been reclaimed by Garland Coal & Mining Co.

Mining has progressed westward to the foot of Bokoshe Mountain, where the top of the Lower Hartshorne coal, which is 117 ft deep and 3.5 ft thick. The shale interval between the Upper and Lower Hartshorne coals increases westward from 30 ft in 1975 to 38 ft at the present location. The Upper Hartshorne coal also is 3

1/2 ft thick. Mining is interrupted at the Backbone thrust fault at the north end of the pit (Fig. 20), and by the abandoned underground Bokoshe No. 1 mine at the south end, on the axis of the anticline. Immediately south of Bokoshe, abandoned underground mines are present that were developed in 1904-1949, in an area where the shale split was only a 1- to 11-inch parting, or a 2-8-foot thick shale and sandstone split(Knechtel, 1949, pl. III). Thus the Hartshorne coal bed is split into the Upper Hartshorne coal and the Lower Hartshorne coal in this area. Shale and/or sandstone are present in the interval between the coal beds. This interval increases southwards.

R.24 E.

T. 8 N.



o coal-test borehole

Figure 20. Map showing Bokoshe No. 10 strip mine at the western end of the Backbone anticline. Closed (abandoned) underground coal mines and structural contours (at 100-ft intervals) on the top of the Lower Hartshorne coal also are shown. The base map is part of the U.S.G.S. Bokoshe 7.5′ Topographic Quadrangle map.

Interval (miles)	Cumulative (miles)	
		Leave Bokoshe No. 10 strip mine, by using haul road towards the north. Turn left at angular junction with county road; follow county road westward, then northward to Y junction and turn left (northward), crossing rough railroad spur.
1.3	304.9	Junction of county road and State Highway 31. Turn right (east).
3.2	308.1	Leave Bokoshe 7.5' Quadrangle and enter Panama 7.5' Quadrangle.

Under the guidance of the present writer, Dana L. Craney* has almost completed his Master's thesis on the "Distribution, structure, origin, and resources of the Hartshorne coals in the Panama Quadrangle, Le Flore County, Oklahoma". Craney's preliminary abstract follows.

"The Hartshorne coals were studied in the Panama 7.5 minute topographic quadrangle map area in Le Flore County, Oklahoma to determine the distribution, structure, origin and resources of the Hartshorne coals. The area is in the Arkoma basin which was on the continental margin north of the Ouachita geosyncline during Paleozoic time. The Hartshorne sandstone deltaic system (Desmoinesian) prograded southwestward into the basin and provided an environment on which a forested peat-forming swamp flourished. Brackish conditions added sulfide minerals to the peat. An isochore map of the clastic interval between the Upper and Lower Hartshorne coals suggests that possible late slippage along an Atokan growth fault caused a small split-forming transgression. The interruption in the deposition of the Hartshorne peat formed the Upper and Lower Hartshorne coals which are the lateral equivalent of the upper and lower benches of the Hartshorne coal (undivided) to the north. Isocarb maps show that burial of the peat and a persistant heat source to the east raised the Upper, Lower, and undivided Hartshorne coals to low- to medium-volatile bituminous rank before deformation of the Arkoma basin. All contacts in the Savanna, McAlester, Hartshorne, and Atoka Formations in the Panama Quadrangle are conformable as shown by 9 cross sections. The Hartshorne Formation is 130 to 250 feet thick. The Hartshorne coals are 1.7 to 6.9 feet thick and contain 0.6 to 2.7 percent sulfur. Remaining resources of 13,711,000 tons (strippable) and 230,696,000 tons (non-strippable) are present in 42 square miles of the Panama Quadrangle."

6.2	314.3	T Junction with State Highway 59. Turn right (south)
1.2	315.5	Panama
3.0	318.5	Shady Point
4.7	323.2	Poteau

*Geology Graduate Student, The University of Oklahoma

4.0	327.2	Y Junction. Turn left (SSE) to stay on S.H. 59 to Howe & Heavener as U.S. 271 goes straight SW to Wister.
		Enter the Heavener 15'Quadrangle at the Poteau River valley.

Under the guidance of the present writer, David R. Donica* has almost completed his Master's Thesis, "The geology of the Hartshorne coals (Desmoinesian) in parts of the Heavener 15' Quadrangle, Le Flore County, Oklahoma". Donica's preliminary abstract follows.

"An 119-square-mile area within the Heavener 15' Quadrangle, Le Flore County, in the eastern part of the Arkoma basin, Oklahoma, was investigated to determine the geology of the coals in the Hartshorne Formation (Desmoinesian). The Lower Hartshorne coal lies about 60 feet above the base of the Hartshorne Formation, and is low- to medium-volatile bituminous in rank (75-84% fixed-carbon, mmf). It is low in sulfur (0.5-3.0%) and ash (8.6-14.2%), is 1.5 to 6 feet thick, and has a calorific value of about 14,000 Btu. A free-swelling index of 9 indicates that the coal makes a strong blast-furnace coke. Approximately 13,356,000 short tons of coal has been mined and lost-in-mining, leaving an estimated 313,478,000 tons in the remaining-resources category.

"The northeastward increase in rank of the Lower Hartshorne coal was probably caused by a deep-seated heat source in eastern Arkansas. In the Arkoma Basin, folding induced by the Ouachita orogeny apparently did not affect the rank of the coal.

"The Upper Hartshorne coal lies between 60 and 120 feet stratigraphically above the Lower Hartshorne coal. The coal is low- to medium-volatile bituminous in rank, is 1 1/2 to 3 feet thick, contains 0.8-2.6% sulfur and 126,161,000 tons of coal in the remaining-resources category.

"The sediments which formed the Hartshorne Formation were deposited within a prograding deltaic plain environment. Hundreds of fossil tree trunks, stems, and leaves are evidence for deposition within a crevasse splay environment. A southwestward flowing distributary channel was active during the deposition of the upper Hartshorne Formation. The Upper Hartshorne coal is thin where it overlies a channel-fill sandstone in the distributary; the coal is thicker in areas adjacent to the channel because of greater subsidence."

9.6	336.8	Heavener
2.5	339.3	Road cut along new U.S. Highway 59. Exposures of Atoka and Hartshorne Formations. Pull completely off the paved highway at once. Traffic approaching hill top is hazardous to your health; avoid walking on pavement.

*Geology Graduate Student, The University of Oklahoma

Hendricks (1939, p. 266, pl. 29) noted the occurrence of a channel-fill sandstone and upright fossil tree trunks [*Calamites* and *Cordaites*] in an abandoned strip mine on Pine Mountain, southwest of Heavener (Fig. 21). He assigned the strata to the upper part of the Hartshorne sandstone. These plants are preserved as casts and molds in the sandstone and shale of the Upper Hartshorne member (of McDaniel, 1961, p. 70).

The present writer has observed upright casts and molds of parts of *Lepidodendron* trees, 8 inches in diameter and 3 feet long, some 25-35 ft above the Lower Hartshorne coal in the highwall of the Heavener pit, formerly operated by Paul Rees Coal Company (Fig. 21). The total thickness of the sandstone is not present because of Quaternary erosion, but 30 ft of the sandstone is present at places in the Pine Mountain strip mine. Also at least 20 feet of the sandstone is present in the Heavener pit. The sandstone is exposed also in the Petros railroad cut, a few hundred feet west of the Petros pit, and in the road cut of new U.S. Highway 59 (Stop 9 of this field trip). No one yet has observed upright trees in the Petros railroad cut or in the abandoned Petros pit. To date *Calamites*, [*Lepidodendron*, *Eusigillaria*], and small branches of woody trees have been observed in the large roadcut along U.S. Highway 59. Thus it is tentatively concluded that a crevasse splay was a sub-environment of deposition on the upper deltaic plain in which the once tall trees were buried upright. The thickness of the Upper Hartshorne sandstone decreases eastward from the Heavener pit and the roadcut, to the Petros railroad cut and the Petros pit. Probably the crevasse splay environment terminates about 3/4 mile east of U.S. Highway 59.

STOP 9

Measured stratigraphic section of the west side of the roadcut along U.S. Highway 59, approximately 1.5 miles south of Heavener, Ok (uppermost 20 ft not included). By David R. Donica, August, 1977.

measured from	in feet to	thickness	description
Hartshorne Formation:			
175.5	177.5	2.0	Sandstone, gray, weathers buff (top of section).
161.5	175.5	14.0	Shale, interlaminated gray and brown, containing siderite nodules and upright *Calamites*
152.5	161.5	9.0	Sandstone, gray, fine-grained, containing upright *Calamites*
145.7	152.5	6.8	Shale, gray, interbedded with cross-bedded sandstone
138.9	145.7	6.8	Shale, gray, thinly laminated, containing siderite nodules
137.7	138.9	1.2	Shale, black, carbonaceous

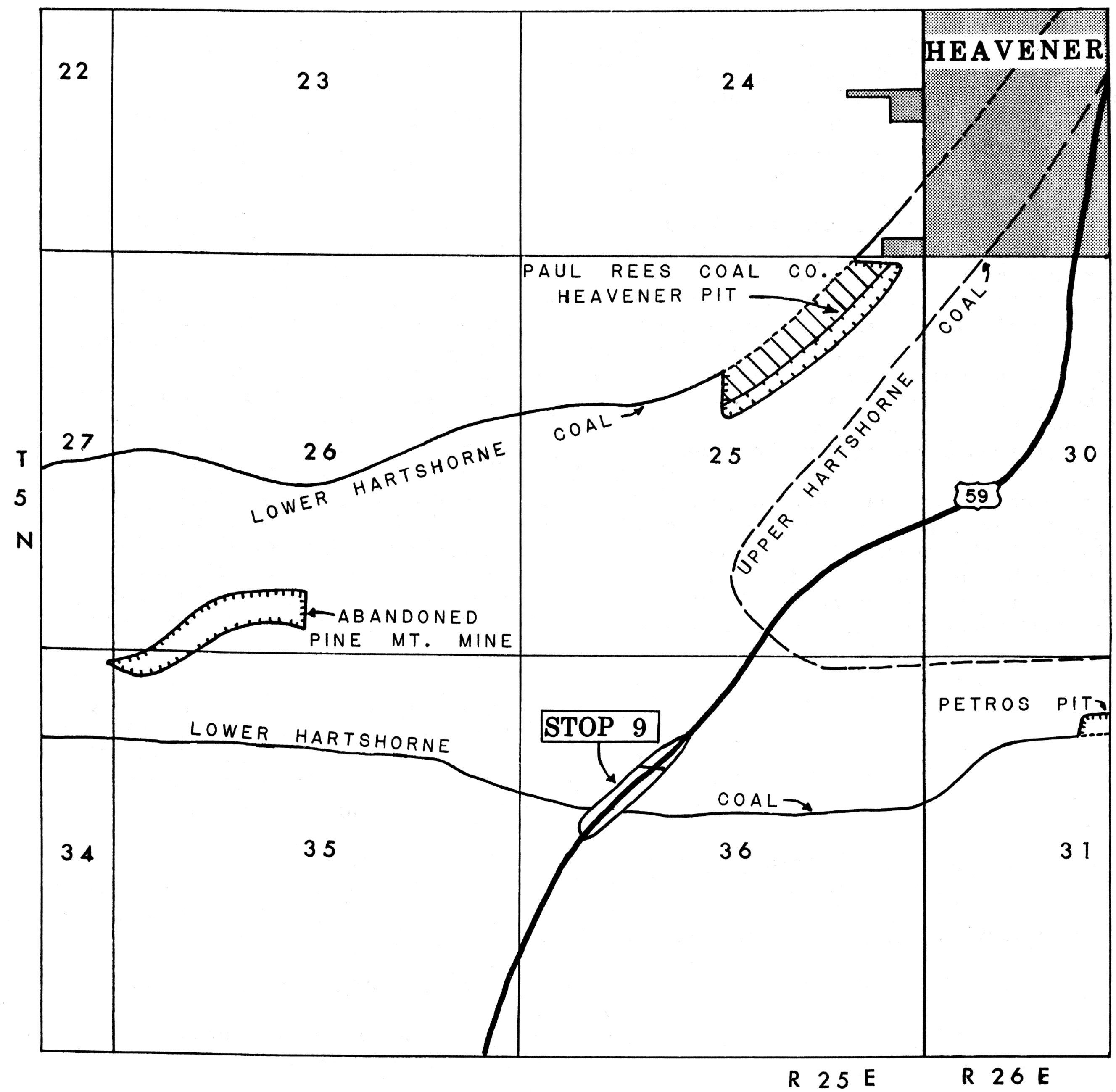


Figure 21. Map showing location of Heavener , Le Flore Co., the Heavener pit of Paul Rees Coal Co., and a large exposure of parts of the Hartshorne and Atoka Formations along a new section of U.S. Highway 59, which was dug in trespass (without a proper Federal permit) on a Federal coal lease. It is believed that a good part of the coal and other strata that were removed were used to build the road bed.

135.8	137.7	1.9	Coal (Lower Hartshorne)
135.3	135.8	0.5	Underclay, rooted
125.9	135.3	9.4	Shale, gray, fissile, containing siderite nodules and streaks of coal
113.1	125.9	12.8	Sandstone, gray, cross-bedded containing upright *Calamites,* interbedded with gray shale containing siderite nodules
107.3	113.1	5.8	Shale, gray, containing siderite nodules
105.6	107.3	1.7	Sandstone, gray, fine-grained, containing upright *Calamites,* one of which is 1.8 feet tall. The sandstone is variable in thickness.
101.4	105.6	4.2	Shale, gray, finely laminated, with siderite nodules which contain plant impressions
99.5	101.4	1.9	Sandstone, gray, fine-grained, cross-bedded
97.9	99.5	1.6	Shale, gray, thinly laminated, containing siderite nodules
97.4	97.9	0.5	Sandstone, gray, very fine-grained, cross-bedded
94.9	97.4	2.5	Shale, gray, thinly laminated, containing siderite nodules
89.7	94.9	5.2	Sandstone, gray, very fine-grained, containing upright *Calamites*
84.0	89.7	5.7	Shale, gray, finely laminated, with siderite nodules which contain numerous leaf impressions
76.5	84.0	7.5	Sandstone, gray, fine-grained containing *Calamites*
Atoka Formation			
70.8	76.5	5.7	Shale, gray, thinly laminated, containing siderite nodules
67.1	70.8	3.7	Shale, carbonaceous, containing thin coal streaks and siderite nodules
66.6	67.1	0.5	Coal
55.3	66.6	11.3	Shale, black, carbonaceous, with numerous coal streaks
48.8	55.3	6.5	Shale, gray, containing siderite nodules
37.3	48.8	11.5	Shale, gray
37.2	37.3	0.1	Shale, sideritic
36.1	37.2	1.1	Shale, black, carbonaceous, containing thin coal streaks and numerous plant impressions
35.6	36.1	0.5	Coal
34.7	35.6	0.9	Shale, black, with coal streaks
33.8	34.7	0.9	Shale, black, containing siderite nodules
31.8	33.8	2.0	Shale, gray, containing siderite nodules
0	31.8	31.8	Shale, gray, thinly laminated, with interbedded sideritic shale (base of section)

The Atoka-Hartshorne contact is believed to be exposed at the south end of the large road cut (Fig. 22a). The (0-76.5-ft) interval in the stratigraphic description (p. 50) contains dark-gray shale of the Atoka Formation, which is overlain by the Lower Hartshorne sandstone. This shale unit also contains two thin (0.7 ft) coals (Fig. 23) that should be included in the Atoka Formation. Other workers have placed the formational boundary in another position. Hendricks, (1939, p. 267) included these thin coals in the Hartshorne Formation, placing the formational boundry about 2 feet below the lower of the 2 thin coals (Fig. 23). Briggs and Roeder (1975, p. 93) apparently included the entire south end of the exposure (dark-gray shale, thin coals, etc.) in the Hartshorne Formation. The depositional environments represented in the road cut were summarized by Briggs and Roeder (1975, p. 93) as part of a lower delta plain. Sub-environments interpreted by these authors are an interdistributary bay that contained dark gray, laminated, silty shale, and light gray cross-bedded siltstone, and splay and overbank deposits that overlie the gray shales and siltstones, indicating a coarsening upwards sequence.

McDaniel (1968, p. 1,696) indicates a distributary channel in a [lower deltaic] paludal environment overlain by an alluvial environment, all in the Lower Hartshorne sandstone, in a general area that includes the area shown on Fig. 21 and the large roadcut.

The present writer agrees that an interdistributary bay could have been present during the deposition of the peat swamps that produced the upper Atoka coals and associated shales and underclays. He also believes that the Hartshorne siltstones and sandstones, which were deposited in crevasse splay sub-environments, must have required an upper deltaic plain-lower alluvial plain environment to have buried upright the *Calamites*, *Lepidodendron*, *Eusigillaria*, and *Cordaites* trees.

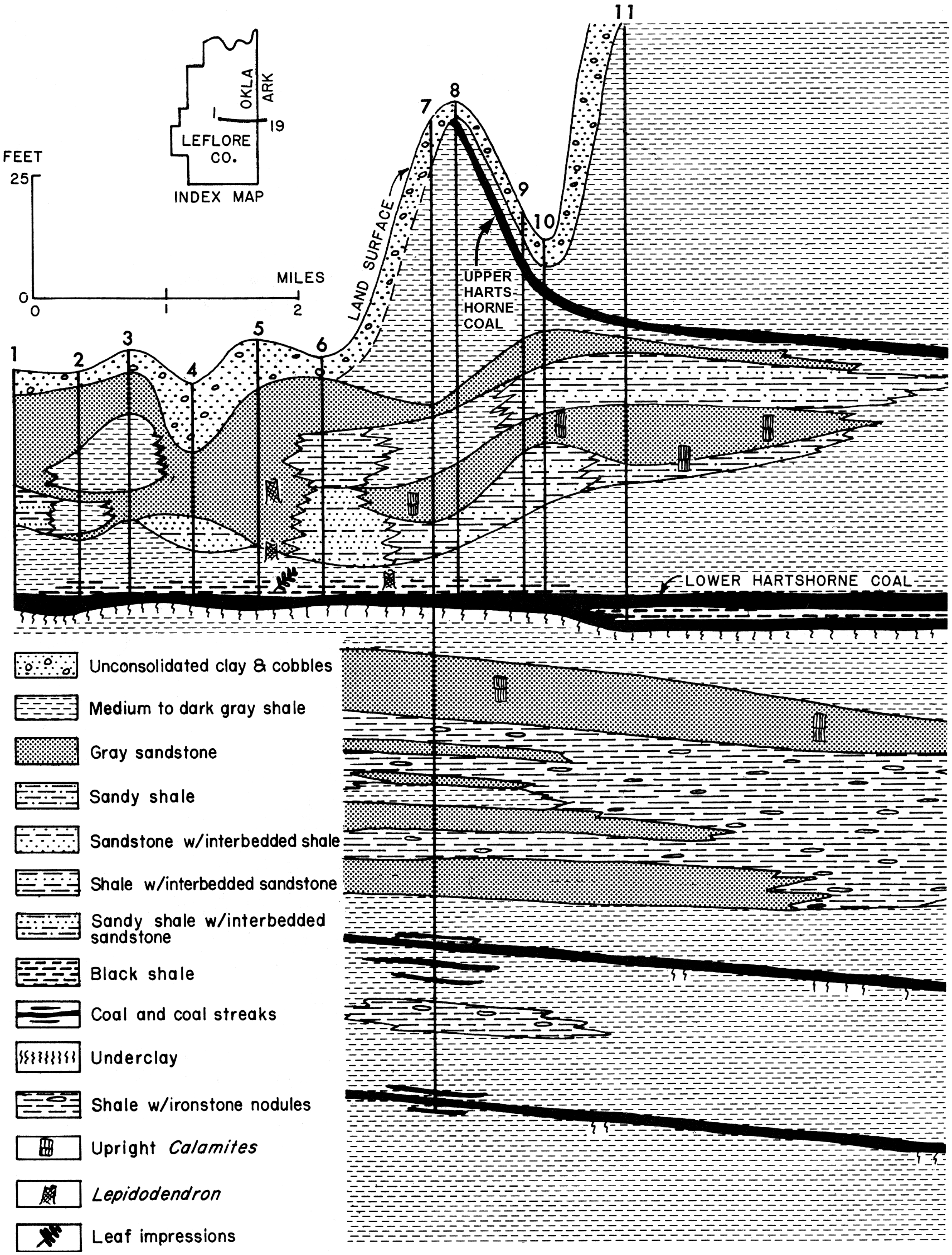
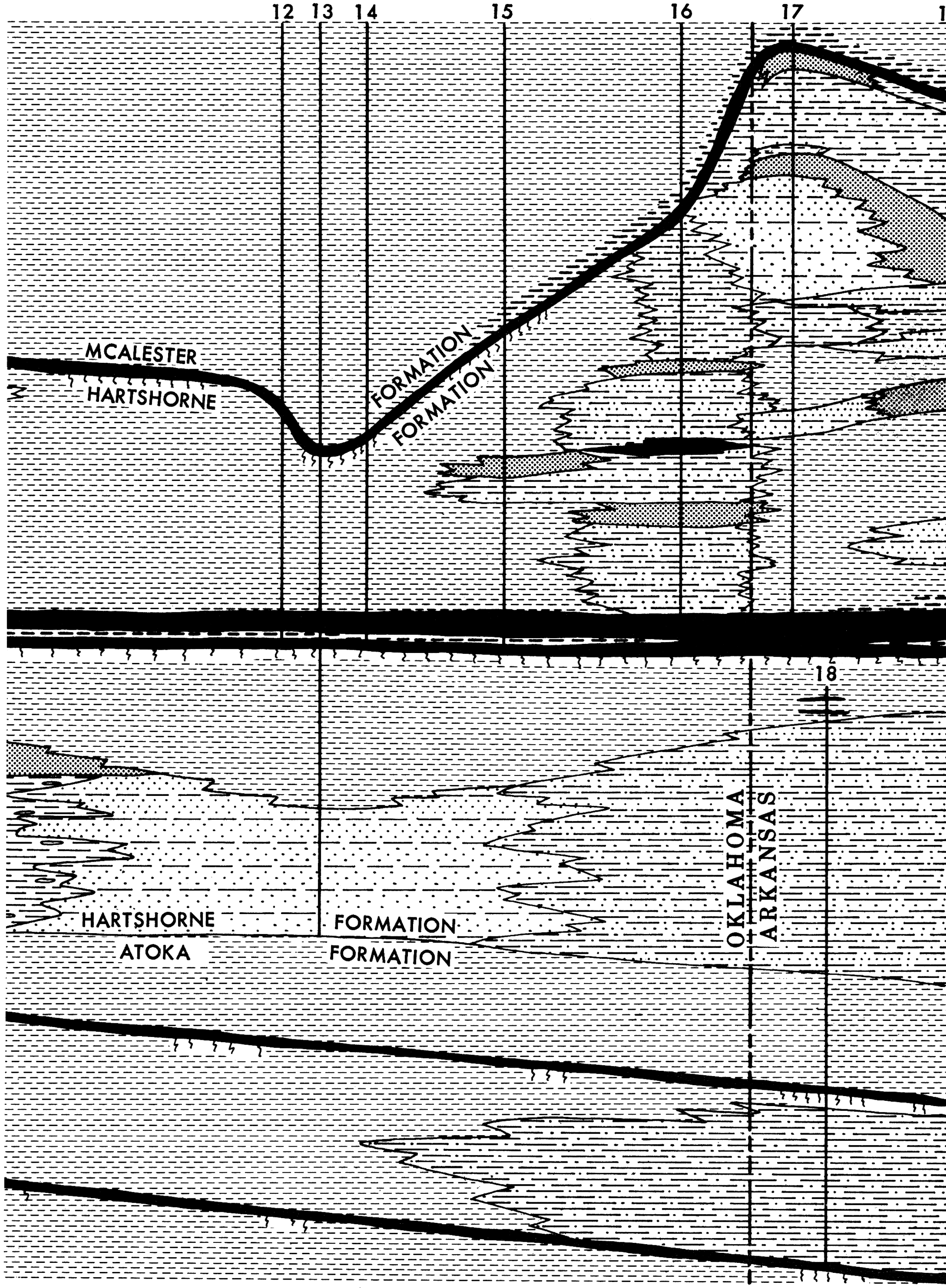


Figure 23. Cross section showing detailed stratigraphy of the upper part of the Atoka Formation, the Hartshorne Formation, and the lower part of the McAlester Formation, from exposures and coal-test boreholes from central Le Flore Co., Oklahoma, into Scott Co., Arkansas.



Upright fossil tree trunks of Calamites and Lepidodendron occur mostly in sandstone exposed in strip mines and in road cuts between the lower and upper Hartshorne coals in Oklahoma. Two thin coals occur in the upper part of the Atoka Formation.

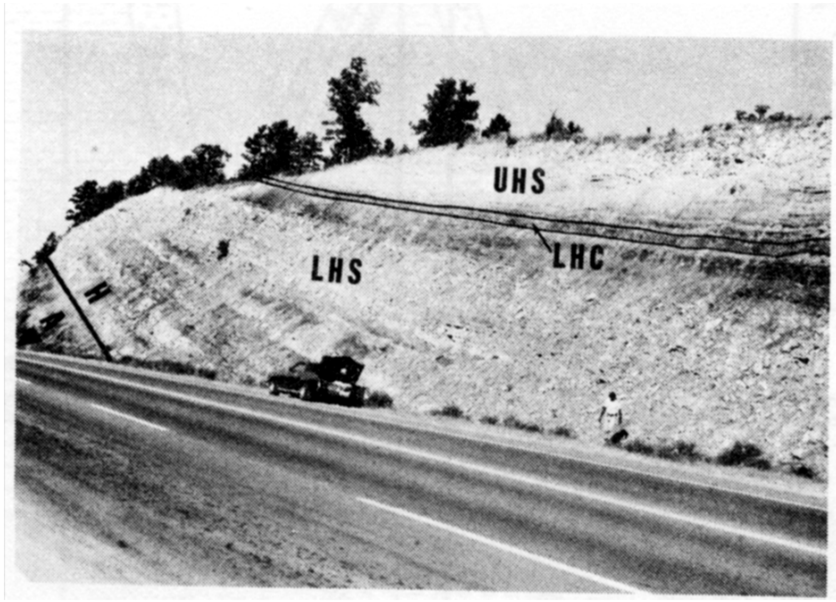


Figure 22a. Photograph (at Stop 9) of northwest side of road cut along new U. S. Highway 59, showing upper Hartshorne sandstone (UHS), Lower Hartshorne coal (LHC), lower Hartshorne sandstone (LHS), and the contact between the Hartshorne (H) and the Atoka (A) Formations. (Photo by D. R. Donica.)

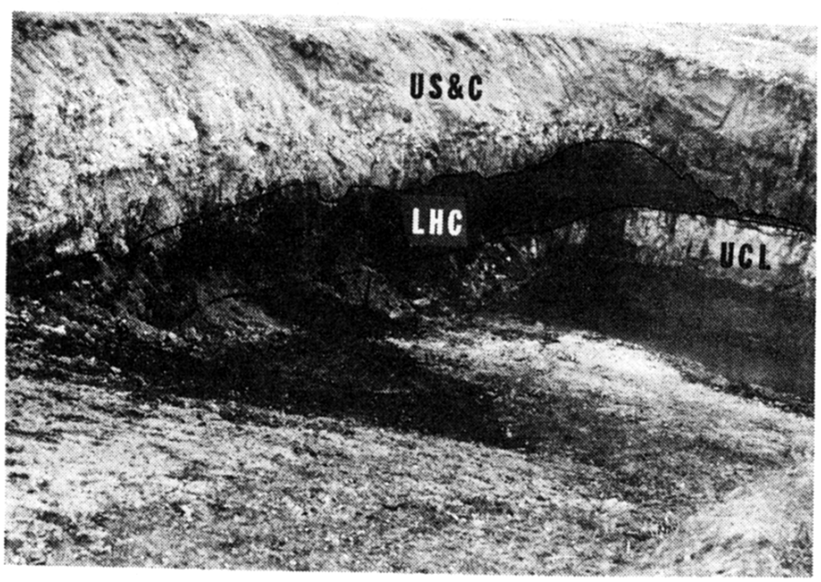


Figure 22b. Photograph of an excavation for a water hole in the NE1/4NW1/4 Sec. 18 T. 5 N., R. 26 E., that exposes the Lower Hartshorne coal (LHC) overlain by unconsolidated clay and soil (UC&S); UCL is underclay. (Photo by D. R. Donica.)

Interval (miles)	Cumulative (miles)	
16.0	355.3	Return to the Myriad Convention Center, from the U.S. Highway 59 road cut. Retrace route via U.S. Highway 59 to Heavener, Poteau, Panama, and turn left (west) at T junction with State Highway 9.
5.0	360.3	Right (north) turn onto U.S. Highway 59 (north).
9.0	369.3	Cross Arkansas River below Robert S. Kerr Lake and lock. T junction of U.S.59 North.
4.5	373.8	Junction with I-40. Take I-40 West.
21.0	394.8	Toll road to Muskogee.
11.0	405.8	Warner exit.
13.0	418.8	Checotah exit (U.S. Highway 69).
24.0	442.8	Henryetta. U.S. Highway 62, north. Indian Nation Turnpike, south. Rest stop planned in this vicinity, if we are not running late. ETA the Myriad, 1 1/2 hours.
24.0	466.8	North Canadian River
53.0	519.8	I-240 (short route to Norman)
12.0	531.8	I-35 north
2.5	534.3	Take Robinson Street exit. Leave I-40; right (north) turn to Convention Center and downtown Oklahoma City.

END OF FIELD TRIP.

COAL RESOURCES

The coal resources of Oklahoma have been described and tabulated by Trumbull (1957) and Friedman (1974). The following table was derived from Friedman (1974), and represents the identified, remaining, strippable coal resources in the coal beds studied in the counties visited on this field trip. In 1974, coal beds that were at least 1 foot thick and 0-100 feet deep were considered strippable. It is believed that present economic and technologic conditions are such that coking coals only 18 inches thick and up to 150 feet deep could be mined at a profit. Thus the summary table of resources is conservative. The 103 million tons of selected remaining resources is only 1.4% of the State total of 7,200 million (Friedman, 1974).

Table 1. Strippable Coal Resources in Selected Counties of Oklahoma

Haskell County	Acres	Short Tons (thousands)
Stigler coal	11,534	35,181
Hartshorne coals	662	4,138
Le Flore County		
Hartshorne coals	8,032	13,491
McIntosh County		
Secor coal	3,736	17,893
Muskogee County		
Stigler coal	3,181	9,444
Okmulgee County		
Croweburg coal	5,990	23,037
Total	33,135	103,184

COAL PRODUCTION

The strip mines scheduled to be visited on this trip produced about 598,000 short tons, which is 11% of the State total of 5.3 million. This total surpassed the previous State high production of 4.85 million tons in 1920 (Fig. 24). At present coal production in Oklahoma is from approximately 40 strip mines. Table 2 lists the production from each coal bed in Oklahoma in 1976. Preliminary estimates show that Croweburg coal production increased more in 1977 than did the other coals, because more new mines were developed in this coal bed in places where it contains 0.5%-2.5% sulfur. Table 3 answers many inquiries directed at the Oklahoma

Geological Survey concerning the uses of the State's coal production.

The major use is in steam-electricity generating plants in the Kansas City metroplex. Coking-coal production decreased, and use in cement kilns was the second major use of Oklahoma's coal production in 1977.

Table 2. Oklahoma Coal Production by Coal Bed, 1976

Name of coal	Short tons	Percentage of total
1. Iron Post	1,719,596	49
2. Croweburg	665,899	19
3. Mineral	450,441	13
4. Stigler	239,601	7
5. Upper Hartshorne Lower Hartshorne	228,159	6
6. Secor and Secor rider	95,843	3
7. Weir-Pittsburg	58,233	2
8. Rowe	27,970	1
9. Cavanal	19,447	1
10. McAlester	12,541	<1
TOTAL	3,517,730	100

Table 3. Estimate of Principal Uses of Oklahoma Coal Produced, 1972-1976

Year	Coking Coal Production (short tons)	Percent of total	Steam and Other Coal Production (short tons)
1972	680,000	27	1,850,211
1973	606,828	28	1,587,842
1974	582,455	25	1,792,230
1975	910,004	32	1,940,423
1976	665,924	18	2,960,757

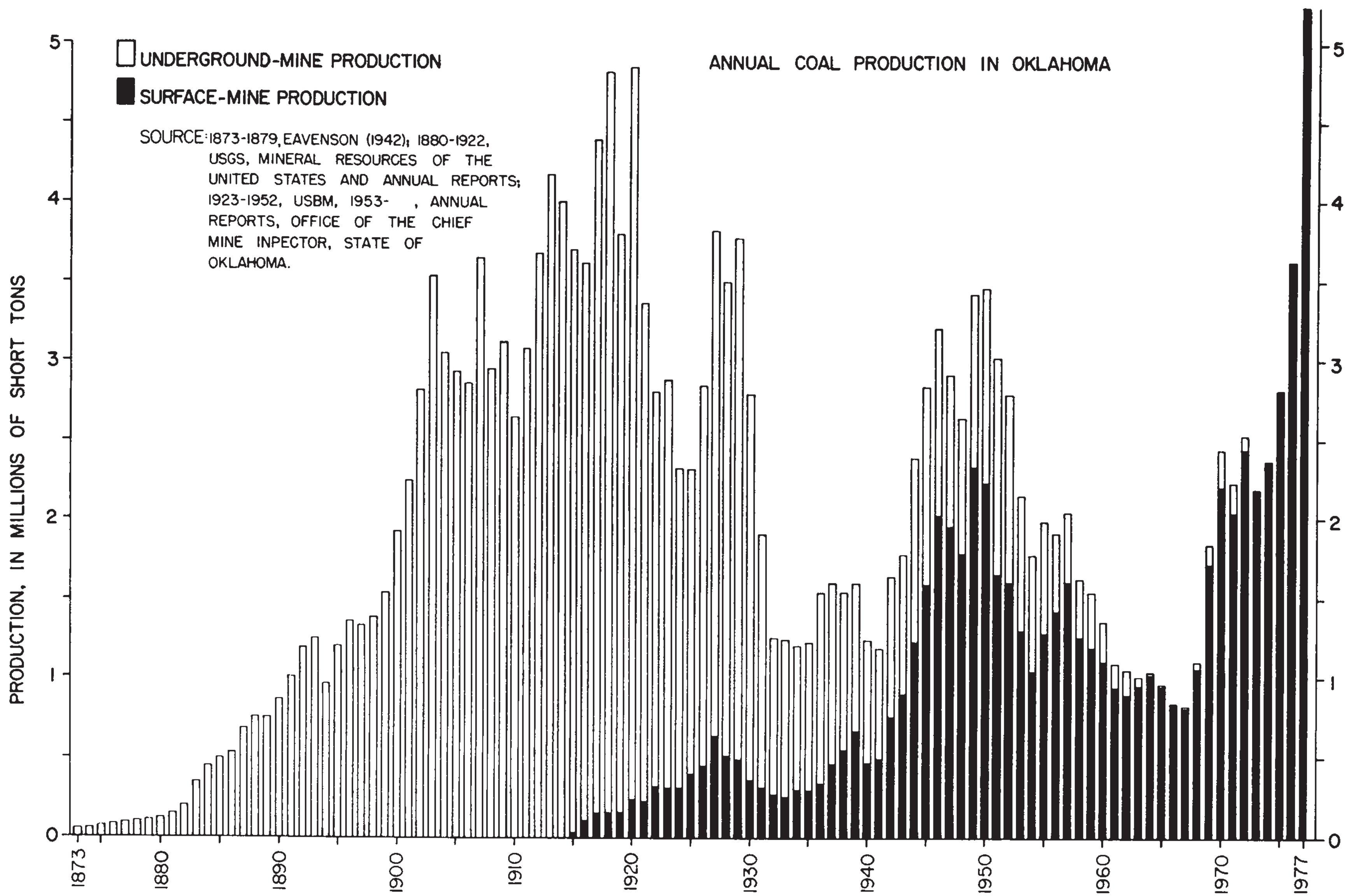


Figure 24. Bar graph showing annual underground and surface coal production in Oklahoma,1873-1977.

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Neal Crutchfield, (left) dragline operator, and Samuel A. Friedman, O.G.S. senior coal geologist, at Garland No. 9 strip mine, north of Stigler, Oklahoma, 1978. (Gob from McAlester Formation is in the background).

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