UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

SECTIONS OF DRILL HOLES ON MINNESOTA CREEK, AND IN NORTH FORK MINING AREA ALONG LINE A-A′

SECTIONS OF DRILL HOLES ON COAL, ANTHRACITE, AND MUDDY CREEKS ALONG LINE B-B′

SECTIONS OF DRILL HOLES ON SNOWSHOE CREEK AND NORTH FORK ALONG LINE C-C′

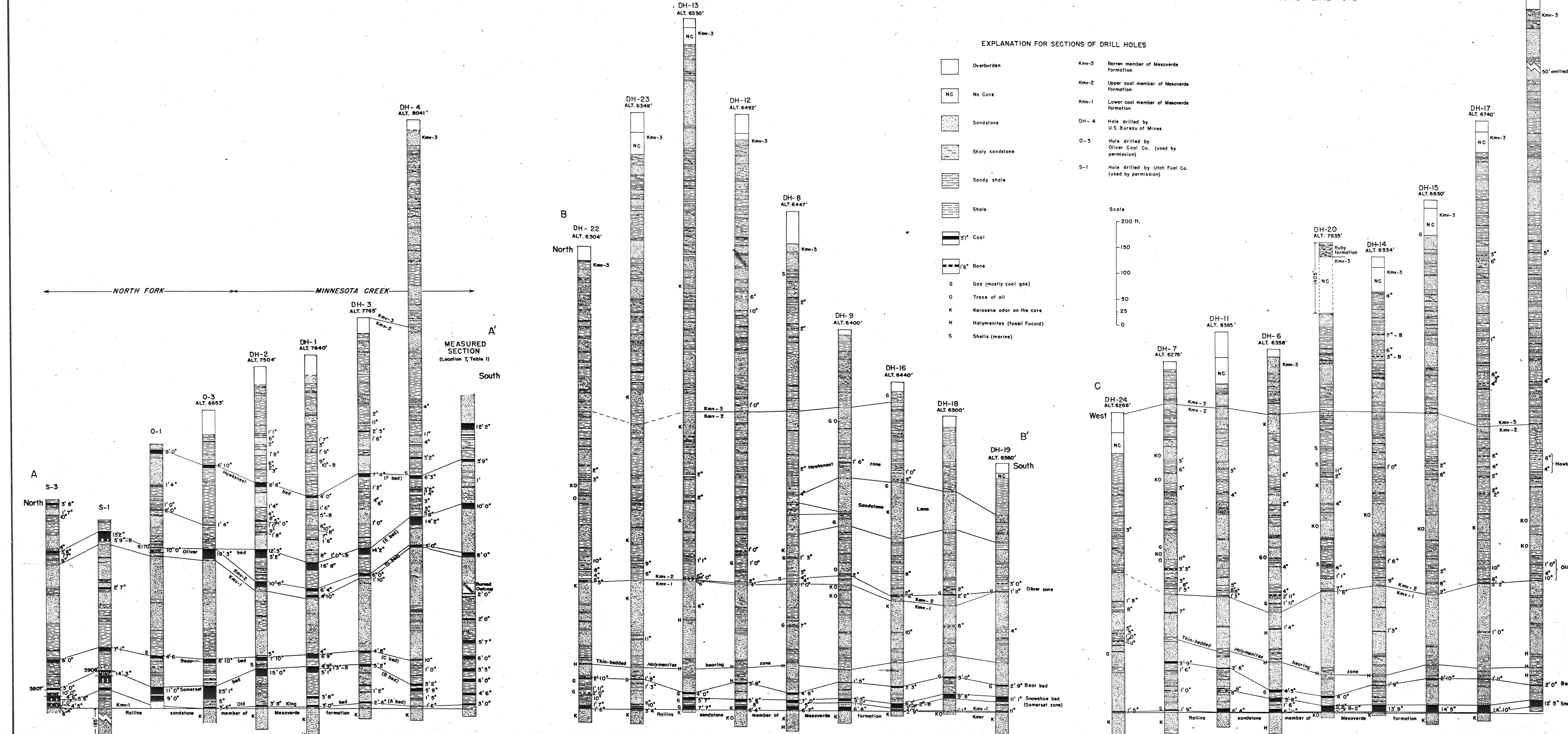


TABLE 1.—DATA ON MINES, PROSPECTS, AND COAL EXPOSURES IN MINNESOTA CREEK, NORTH FORK, AND COAL CREEK DISTRICTS — LOCALITIES INDICATED BY UNDERLINED NUMBERS ON MAP

District	No. on map	Township (S)	Range (W)	Section	Fraction section	Name	Type of exposure (1)	Formation member (2)	Coal bed	Total thickness of coal Ft.	in.	Clean coal thickness Ft.	in.	Benches of coal	Ref. No. U.S.G.S. Bull. 510	Daily production 1946 (tons)	Altitude (feet)	Feet above Rollins sandstone	Dip	Character of roof	Comments
Minnesota Creek	1	14	90	22	SW¼SE¼	Simonton	C	L	A	1		1		1	48		8,400	21	35°NE	Shale	Coal exposed in landslide scar on east side of East Fork, Minnesota Creek, 200 ft. above stream. Top of coal is covered by soil mantle. Six ft. of shale between coal beds.
									B	25	2	23	2	2	48		8,400	36	35°NE	Shale	
									C(3)	18	4	17	1	3	48		8,400	67	35°NE	Sandy shale	
	2	14	90	21	SW¼NE¼	Watermeter	C	U	F	8		6		2			8,000		12°NE	Sandy shale	Outcrop exposed 10 ft. above stream near a stream-gauging station. Lower portion is dirty coal.
	3	14	90	16	SW¼SE¼	Beckman	P	U	E	14		13	6	2			7,800		11°ENE	Sandstone	Adit 8 ft. high by 200 ft. long, in ledges 80 ft. above stream. Thick sandstone 2-3 ft. below coal.
							P	U	F	6		5		2			7,900		11°ENE	Sandy shale	Caved adit 100-200 ft. above lower adit.
	4	14	90	16	NW¼NE¼	?	C	L	B	5							7,400	50	ENE	Shale	West side of Minnesota Creek, opposite mouth of South Prong. No solid sections.
	5	14	90	16	NW¼NE¼	?	C	L	A	3							7,360	10-15		Shale	Outcrops on Rollins sandstone along ledges north of No. 4.
	6	14	90	9	NE¼SW¼	Lick Creek	P	L	A	4		4		1			7,340	10		Shale	Small adit north of mouth of Lick Creek. Adit caved but shows 4 ft. of coal 10 ft. above Rollins sandstone.
	7	14	90	5	S½	Johnson	CP	UL	(4)	See graphic log					47						Measured section (W. T. Lee, U.S.G.S. Bull. 510, p. 108). See graphic log.
	8	13	90	32	SW¼NW¼	Shoecroft	P	L	B	5	6	5	6	1	46		6,950	50	NE	Shale	Tunnel through 40 ft. of rubble. Lee reports 7 ft. of coal. Opening referred to by Lee may be caved adit 100 yds. west.
North Fork	9	13	91	23	NW¼SE¼	Whitelaw	P	L	B	18-20		18-20		1?	41		6,911	50	NE	Shale	900-ft. adit and accompanying manway caved. Statements by Lee are orally confirmed by A. Bowie.
	10	13	91	19	SE¼NW¼	Dorrance	MA	L	A & B	3-4		3		1			7,000	30	3-5°NNE	Sandy shale	Several caved adits. Max. of 37 in. of clean coal. Several small and dirty beds in short vertical interval. About 30-40 ft. above Rollins sandstone. Also thin bed on Rollins sandstone.
	11	13	91	17	SW¼SW¼	Farmers	M	L	C	6-8		6-8		1	36	50-100	7,040	180	3°NNE	Sandstone	Correlated with Bear coal bed because of massive sandstone bed above.
	12	13	91	16	SE¼NE¼	Gelwick	MA	L	A	5	6	4	4	1			6,609	15	5°N	Shale	Abundant marine mollusks in roof. Adit about 100 yds. long.
							P	L	B	8		8		1?			6,750	56	5°N	White shale	Caved adit 60 ft. long; accessible. Outcrop burned, coal partly coked. Roof irregular, undulating, and burned.
	13	13	91	15	NE¼NW¼	Old King	MA	L	A	5		4		1	37		6,519	10		Sandstone shale, bone	Original workings abandoned in favor of mine on B bed. Adit 800 ft. long.
	14	13	91	15	NE¼NE¼	Bowie (New King)	M	L	B	30	10	20	6	4-7	38	250-400	6,571	80	4°NNE	Shale	Juanita Coal Co., operated by Bowie Bros.
	15	13	91	11	SW¼SW¼	Bowie	P	L	B	14				1?			6,465	75		Shale	Prospect in gulch east of Bowie mine. Adit less than 30 ft. long. Coal thickness reported orally by A. Bowie.
	16	13	91	11	SW¼SE¼	Blackburn	MA	L	A	4-5							6,374	15		Shale	500-ft. adit abandoned because of burned bed.
				11	SW¼SE¼	Blackburn	P	L	B								6,443	85		Shale	Prospect opening on B bed. Burning coal below has partly coked the coal in this adit. Caved adit 100 yds. east of old mine, may have been manway.
				14	NW¼NE¼	Blackburn	P	L	A								6,346	15		Shale	
	17	13	91	12	SW¼SW¼	Mallott	P	L	B	12		12		1	39		6,300	60		Shale	Prospect by Mr. Mallott, opened to measure coal. Workings no longer visible.
	18	13	91	2	NE¼SE¼	Hubbard Creek	P	L	C	4		4		1			6,200	100±		Sandstone	Small caved prospect in Bear bed about 5 ft. above creek.
	19	13	90	18	SE¼SE¼	Lone Pine Mallet opening	P	L	B	16	4	16	2	2	40?		6,500	30		Shale	Caved adit indicates length of more than 250 ft. No coal now exposed. Measurement by W. T. Lee, U.S.G.S. Bull. 510, p. 105.
	20	13	90	8	SW¼SE¼	Somerset	M	L	B	17-24		10-15		1-3	42	700-1000	6,115	45	3-5°NNE	Shale & sandy shale	Mining in sections 4, 5, 6, 7, 8, and 9.
						do. (upper)	M	L	C	7-11	9	6-11		1-2	42		6,215	100	3-5°NNE	Shale & sandstone	This bed re-opened by "rock-tunnel-raise" in NW¼ sec. 7.
	21	13	90	17	NE¼NE¼	Clark	M	L	B	17-18		10		1-3		200-450	6,080	40	3-5°NNE	Shale	Formerly known as the Edwards mine.
							P	L	C	7?				1			6,130	90	3-5°NNE	Sandstone	Exposed by open cut in 1946. Not solid.
	22	13	90	9	SE¼SW¼	Tony Bear	M	L	C	6-8		7	6	2		100-200	6,060	110	3-4°N	Sandstone	Old portal.
										New opening							6,075	110		Sandstone	New portal opened to facilitate mining.
	23	13	90	9	SE¼SE¼	Bear Prospect	P	U	D	6		6		1			6,230	270		Sandstone	In ledges above Bear mine. Coal replaced by gravel 30 ft. in from portal. Lower split of Oliver bed.
	24	13	90	16	SE¼SE¼	Gallob Prospect	P	U	F	6	10	6	10	1			6,625	465		Shale & sandstone	100-foot opening for farm consumption. Shale roof 15-28 in. thick capped by 30 ft. of massive sandstone.
	25	13	90	10	SW¼SE¼	Oliver No. 1	MA	U	DE	10-15		6-10		1-4			6,100	290	3-5°NNE	Shale & sandstone	Sandstone partings thicken at expense of coal. Mined to limit of economical mining thickness.
	26	13	90	10	SW¼SE¼	Oliver No. 2	M	U	DE	19		9-19		1-4		300-500	6,108	290	3-5°NNE	Shale & sandstone	New opening, 1944. Local partings of sandstone, shale, and bone. 19-ft. coal bed indicated by advance drilling.
	27	13	90	10	NW¼SE¼	Oliver Prospect	P	U	F	4	6	4	6	1			6,285	460		Shale & sandstone	500-ft. adit to prospect the Hawksnest bed.
	28	13	90	11	NW¼SW¼	Highway Prospect	P	U	F	4		4		1			6,200	460		Sandy shale	Outcrop burned; exposed coal is partly coked.
	29	13	90	11	SW¼NE¼	Hawksnest No. 2	M	U	F	8		8		1	45	100-250	6,220	490	3-5°N	Sandstone	Portal 30 ft. above coal bed. New opening to facilitate mining sandstone roof area.
	30	13	90	11	NE¼SE¼	Hawksnest No. 1	M	U	F	8		6½-8		1-2		100-200	6,180	460	3-5°N	Shale & sandy shale	Eastern (old) part of mine showed thinning coals and bad roof.
Coal Creek	31	13	89	34	SW¼SW¼	Thomas	P	U?	D?	5		5		1	49?		6,740	230?		Sandstone	Outcrop exposed in stream bed.
	32	13	89	33	NE¼SE¼	?	C								49?		6,720		15°SW	Shale	Not in place. Reversed dip indicates sliding.
	33	14	89	3	SW¼SE¼		C			8		8		1	50		7,300			Shale	Data from U.S.G.S. Bull. 510, p. 120.
	34	14	89	10	SW¼SE¼	Mosley No. 1	P	L	C?	10		10		1	52		7,150±				Do.
	35	14	89	10	NW¼SE¼	Mosley No. 2	P	U?	D?	7	8	7	8	1	51		7,250±				Do.
	36	14	89	10	SE¼SE¼	Davenport No. 1	P			6-6½		6		1			7,100±		2°N?	Shale	Short adit driven for local consumption.
	37	14	89	11	NW¼SW¼	Davenport No. 2	P			3	11	2	6	2			7,190±		2°N	Shale	Prospect opening. Two thin coal beds have 17 in. shale parting.

(1) Type of exposure: C-Outcrop, P-Prospect, M-Mine, MA-abandoned mine. (2) coal member: U-upper, or L-lower.
(3) Correlation based on assumption that all three beds of lower coal member are present. (4) Measured section by Lee and Porter, U. S. Geol. Survey Bull. 510, p. 98, location 47.

GEOLOGY OF THE PAONIA COAL FIELD, DELTA AND GUNNISON COUNTIES, COLORADO

By Vard H. Johnson

The Paonia coal field lies east of Paonia and south of Grand Mesa in Delta and Gunnison Counties, Colorado. The North Fork of Gunnison River has cut a deep canyon across the northern part of the field. This canyon separates the tableland south of the river from Grand Mesa. This southern tableland, 2,000 feet or more above the valley around Paonia, is deeply dissected by tributary streams of North Fork, and is bounded on the south and east by an arc of intrusions of porphyritic igneous rock which forms Mount Lamborne, Coal Mountain, Mount Gunnison, Mount Beckwith, Mount Marcellina, and Ragged Mountain.

The Paonia coal field is described in W. T. Lee's report on the coal fields of Grand Mesa and the West Elk Mountains, Colorado.1/ The present geologic study was undertaken as part of a cooperative program of the U. S. Bureau of Mines and the U. S. Geological Survey for the purpose of locating additional deposits of coking coal in the Western States. The geologic work, which was in conjunction with the drilling of prospect holes by the Bureau of Mines, was done by D. A. Andrews, assisted by R. C. Robeck, in the autumn of 1943, and by the writer during the summer of 1944, and from September 1945 to November 1946. The cooperation of Mr. George H. Horn, of the Conservation Branch of the Geological Survey, is gratefully acknowledged, as are also the information and assistance provided by Mr. Ronald C. Oliver, of the Oliver Coal Company, Mr. Claude P. Heiner, of the Utah Fuel Company; Messrs. Alex and Wallace Bowie, of the Juanita Coal and Coke Co.; and by other mine operators in the area.

STRATIGRAPHY

The rocks exposed in the Paonia coal field consist of the Mancos shale and the coal-bearing Mesaverde formation of Upper Cretaceous age, the Ohio Creek conglomerate and the Wasatch ("Ruby") formation of early Tertiary age, and quartz monzonite porphyry of Tertiary age.

Mancos shale

The Mancos shale, the oldest formation exposed in the Paonia area, comprises a sequence of dark-gray to drab, locally buff marine shale, 2,000 to 3,000 feet thick. The shale weathers to a drab color and is characterized by rolling badlands and terraces. Only the upper part of the formation is here exposed.

Mesaverde formation

The Mesaverde formation, which overlies the Mancos shale, is divided into four members, which are, in ascending order: Rollins sandstone member, lower coal member, upper coal member, and barren member.

Rollins sandstone member.--The Rollins sandstone member is a conspicuous cliff-forming white to buff sandstone, 150 to 200 feet thick, characterized by an abundance of the fossil fucoid, Halymenites major (Lesquereux). The lower part of the member consists of thin-bedded sandstone which grades downward into the Mancos shale and upward into massive sandstone. Cross bedding is common but is not conspicuous in the massive portion.

Lower coal member.--Lee 2/ divided the coal-bearing beds of the Mesaverde into the underlying Bowie shale member of marine and brackish-water origin, and the overlying Paonia shale member of fresh-water origin. This separation was based on paleontological evidence, and the coal beds were correlated by the same means. During the course of the present study, it was found that interfingering of the beds of marine and non-marine origin is too extensive to permit mapping on the basis of fossils alone. Dinosaur tracks were noted, for example, above a coal bed in the generally marine Bowie shale, and oyster shells and other marine fossils were found in the generally nonmarine Paonia shale. The lower coal member of this report, however, is nearly the same unit as Lee's Bowie shale member, and the upper coal member is nearly the same as his Paonia shale member.

The lower coal member comprises in its lower part a sequence of interbedded shale and sandstone, 50 to 180 feet thick, and in its upper part an irregular sandstone bed 75 to 225 feet thick, the top of which is taken as the top of the lower coal member. The shaly lower portion of this member contains two to four workable coal beds, two of which are very persistent and uniformly workable over wide areas. In general, the shaly part of the member thins eastward from a maximum of 180 feet near the Farmers mine, to about 50 feet at the eastern limit of the map. Lenses and beds of sandstone are irregularly interbedded with the shale. The proportion of sandstone to shale is highly variable. The upper sandstone part of the member is most conspicuous east of Bowie, where it is readily recognized in both drill core and outcrop. West of Bowie it is more lenticular, and forms discontinuous cliffs. Locally the upper part of this member resembles the Rollins sandstone member, except that the Halymenites in it are smaller, less abundant, and generally limited to a zone of thin interbedded sandstone and shale in the lower portion. In the Coal Creek area, this zone was encountered in most of the wells drilled. It lies a short distance above the Bear bed and aids greatly in the identification of this bed.

The coal beds in the lower coal member of the Mesaverde formation are different in both character and grouping in the western and eastern parts of the Paonia field (see graphic sections). The division between the two parts of the field lies approximately along the township line between Ranges 89 and 90 West. The part of the field west of this line is termed the North Fork-Minnesota Creek area, and that east of the line the Coal Creek area.

In the North Fork-Minnesota Creek area there are three, and locally four, coal beds more than 3 feet thick. The lowest, Old King, or A, bed is immediately above the Rollins sandstone member. In some places the bed rests directly on the Rollins; at others there is as much as 15 feet of intervening shale. In outcrops in North Fork canyon this bed is thin and dirty, and consists in places of two bands of dirty coal separated by 5 to 10 feet of carbonaceous shale. The maximum observed thickness of the bed is near the Minnesota Creek reservoir where it is a single bed 3 feet 8 inches thick, but drilling indicates that from this point south and east it splits into two beds, each ranging in thickness from 1 to 3½ feet.

The second coal bed, here designated the Somerset, or B, bed, is mined extensively at Somerset and is the most important bed of the area. It is thickest along the walls of North Fork canyon where it has an observed maximum thickness of 25 feet 9 inches. The Somerset, Clark, and Bowie mines all produce from this bed, and account for more than half of the production of the Paonia field. Southward, in Minnesota Creek, this bed ranges in thickness between 5 feet 2 inches, and 15 feet, and is of commercial grade and thickness at all points observed.

The next higher bed, which is called the Bear, or C, bed, after the largest mine obtaining coal from it, lies above the Somerset bed, and beneath the large sandstone that caps the lower coal member. It ranges in thickness from 4½ to 8½ feet over a wide area. The Farmers mine, 5 miles north of Paonia, is also believed to be producing from the Bear bed.

In the Coal Creek area there are two principal beds in the lower coal member. The lower, here termed the Snowshoe bed, because it attains its maximum thickness under Snowshoe Creek, lies just above the Rollins sandstone member in many places, and is separated from it by only a thin carbonaceous sandstone. In this respect it conforms to the stratigraphic position of the Old King bed described above. This bed is 9 to 15 feet thick in drill holes along Snowshoe and Coal Creeks, but northward and westward it splits and thins out. Where the bed is split, the lower split conforms to the position of the Old King bed and the upper split to that of the Somerset bed of the North Fork-Minnesota Creek area.

The upper bed in the lower coal member of the Coal Creek area conforms to the position of the Bear bed in that it lies immediately below a massive sandstone. It is, therefore, termed the Bear bed in this area also, though the interval above the top of the Rollins sandstone member is appreciably less than in the North Fork-Minnesota Creek area. It is a persistent bed which is locally minable but is less than 3 feet thick in most of the Coal Creek area. The presence of unusually large amounts of sandstone in the lower coal member shale zone in drill holes 22, 23, 24, and 7, in the Coal Creek area, and in drill hole 4 in the North Fork-Minnesota Creek area (sec. 10, T. 14 S., R. 90 W.), suggests the possibility that a northeasterly flowing stream separated the two areas of coal deposition and deposited a sand barrier between them.

Upper coal member.—The upper coal member of the Mesaverde formation comprises a sequence of interbedded sandstone and shale similar to that in the lower coal member except that the beds are more lenticular. This member ranges from 400 to 600 feet in thickness and is capped by thick sandstone. The lenticular nature of this upper sandstone makes it difficult to identify or map the upper limit of this member in some places.

The upper coal member contains four workable beds, but the thick coal beds are more restricted in area than those of the lower coal member. Drilling on Minnesota Creek disclosed three, and locally four, commercial beds, some of which are unusually thick. Exposures and drill holes on North Fork show two, and locally three, minable beds. In the Coal Creek area, however, the coal beds in this member are thin, and the best showing of coal encountered was in drill holes 18 and 19 where the coal is 26 and 23 inches thick respectively. North of drill holes 18 and 19, in the northern half of T. 13 S., R. 89 W., the coal beds are represented by bone and thin erratic seams of coal commonly less than 1 foot thick.

In the Minnesota Creek area the upper coal member contains three workable coal beds. The lowest of these is designated the D bed. It ranges in thickness from 3 feet 2 inches in the vicinity of drill hole 4, to 10 feet 8 inches in drill hole 2. It rests on the massive sandstone that marks the top of the lower coal member. Correlation of this bed with known beds in the North Fork area 2½ miles distant is difficult because of the stratigraphic differences between the two areas. This bed may represent a lower split of the Oliver bed such as occurs in the western workings of the Oliver mine, in surface exposures near the Bear mine, and in a drill hole near the west quarter corner of sec. 16, or it may not extend into the North Fork area. The writer prefers to correlate it with the lower split of the Oliver bed.

The E bed in the Minnesota Creek area is near the middle of the shaly portion of the upper coal member. This bed is consistently 14 to 16 feet thick in all exposures and drill holes on Minnesota Creek. Based on vertical intevals, stratigraphy, general uniformity of thickness, and continuity, as shown by drilling, it is the bed most logically correlated with the coal bed being mined at the Oliver mine; it is so shown on the correlation charts.

The Oliver bed, so called after the Oliver mine, is the lowest bed of the upper coal member exposed in North Fork. It ranges from 9 to 19½ feet thick. Evidence from drill holes, mines, and outcrops indicates that the bed splits into two distinct beds near the western limits of the Oliver mine. It is believed, as stated above, that the lower split should be correlated with the D bed in the Minnesota Creek area. As mining advanced north and east of the portal, the workings of the mine encountered a wedge of sandstone which thickened at the expense of the coal. This fact, combined with the drilling data, suggests that a former shoreline limited the basin of deposition in a northeasterly direction, and that a minable thickness of coal in the Oliver bed does not extend far beyond the limits of the present mine in that direction.

The Hawksnest, or F, bed, named after the Hawksnest mine, lies 120 to 200 feet above the Oliver bed and is separated from it by varying proportions of shale and sandstone. In general, the greater separation between the two beds is accompanied by an increase in the proportion of sandstone. The bed has a thickness of 4 to 9 feet, and is correlated with minable seams in Sylvester gulch and Minnesota Creek. North and east of the portal of the Hawksnest mine, the bed splits and becomes thinner. This condition and the absence of a recognizable bed in drill hole 24, approximately 2 miles to the east, suggest that the minable thickness of coal is limited to a short distance east of the mine. Throughout the Coal Creek, Snowshoe Creek, and Anthracite Creek area in Tps. 13 and 14 S., R. 89 W., the position of the Hawksnest coal is marked only by stringers and thin beds, which are grouped as the Hawksnest coal zone.

The Hawksnest coal zone is overlain by a sedimentary sequence about 100 to 200 feet thick composed dominantly of sandstone, which crops out prominently. The top of this unit has been selected as the boundry between the upper coal member and the overlying barren member.

A study of the graphic logs shows that the vertical interval separating the coal beds within each of the coal members varies considerably. Where the interval between coal beds is great a larger proportion of sandstone is present between the coals. This relation may be explained either by the more rapid rate of deposition of sand as compared with clay, or by the lower compaction ratio of sand. Either factor would cause a greater separation of the coal beds by sandstone than by shale.

Table 1 and the graphic drill logs give specific information on exposures, mines, coal thickness, and correlation of the seams.

Barren member.—The upper part of the Mesaverde formation lying above the thick sandstone that overlies the Hawksnest coal horizon, is here referred to as the barren member. It consists of interbedded and interlensed sandstone and shale of varying thicknesses. The general character of these barren upper beds is the same as in the coal-bearing members except that the sandstone beds are more lenticular and the shale zones are essentially barren of coal. The thickness of the barren member varies greatly owing to post-Mesaverde erosion, but was originally much in excess of 1,500 feet. Field evidence suggests a southward truncation of the entire Mesaverde formation by post-Cretaceous tilting and subsequent erosion. This erosional period is tentatively correlated by Lee 3/ with the deposition of the Lewis shale and "Laramie beds" of the San Juan Basin area.

Ohio Creek conglomerate

The Ohio Creek conglomerate of Tertiary age rests on the Mesaverde formation and is separated from it by an irregular unconformity which indicates some channeling. The formation consists of light-colored sandstone, locally containing abundant pebbles of chert, jasperoid quartz, and several kinds of igneous rocks. The sand of the matrix was largely derived from the Mesaverde formation, from which it was eroded by early Tertiary streams, and deposited chiefly in and around the channels of those streams. The Ohio Creek conglomerate is erratic and locally absent, though in places it is as much as 200 feet thick. Where the pebbles are scattered or lacking the Ohio Creek conglomerate is difficult to separate from the underlying Mesaverde formation.

Wasatch ("Ruby") formation

The Wasatch ("Ruby") formation lies unconformably on the Ohio Creek conglomerate or, where the Ohio Creek conglomerate is lacking, on sandstone and shale of the Mesaverde formation. It is composed principally of coarse red conglomeratic sandstone and dark-red to maroon sandy shale. Locally, an abundance of epidote and other ferrous silicates produces a greenish color. The strong coloring of the Wasatch ("Ruby") formation contrasts sharply with that of the light-colored Ohio Creek conglomerate and with the sandstone of the Mesaverde formation. Conglomerate and sandstone predominate in the lower 100 feet of the Wasatch ("Ruby") formation. Several boulders of scoriaceous basalt as much as 2½ feet in diameter are present, and smaller pebbles of chert, jasperoid quartz, and a variety of igneous and metamorphic rocks are widely distributed. Above the conglomerate and sandstone zone, red and green shale and silt predominate.

IGNEOUS ROCKS

The igneous masses in the southeast part of the mapped area are composed of quartz monzonite porphyry and kindred varieties of intrusive rocks of Tertiary age. Mt. Gunnison is a laccolithic intrusion, which invaded the Mancos shale and arched the Mesaverde formation around its base. Locally, it cut across the Mesaverde formation, and on the north flank is in apparent contact with the Wasatch ("Ruby") formation. At this place, however, the contact is obscured by heavy talus, and the relations are inferred by the strike and dip of the beds outside the talus zone. All the observed contacts of the intrusion are with the Mancos shale or the Mesaverde formation. Contact metamorphism commonly is limited to a zone a few feet wide.

"The Cliff" along Cliff Creek, a tributary of Coal Creek, is a sill which probably connects underground with the Stormridge and Mount Beckwith with bodies of porphyry southeast of the map area. The sill spreads out in the Mesaverde formation, near the top of the upper coal member, and ranges in thickness from a few feet, near the Davenport ranch close to the mouth of Cliff Creek, to about 1,000 feet in Mosely Ridge. Metamorphism resulting from this intrusion also affected only a narrow zone but was sufficient to alter some of the underlying coal to semianthracite.

Mount Beckwith is formed by a laccolithic intrusion which spreads out near the base of the Tertiary strata and overlaps the Cliff sill. Mount Marcellina is a tongue or stock of porphyry south of Anthracite Creek and just east of the area covered by the map. On the north and east flanks the porphyry has arched the Mesaverde strata, but on the south it appears to have cut across the Wasatch ("Ruby") formation. Evidence of contact metamorphism is slight.

COKING COAL

Analyses of coal samples obtained in drill holes 6 to 24 inclusive, and the results of carbonization tests on cores obtained from hole 10, are contained in a report by the Bureau of Mines.4/ The results of the coking tests show that coal from the Bear bed and the lower split of the Snowshoe bed will yield coke stronger than that made at Sunnyside, Utah, whereas the coal from the upper split of the Snowshoe bed in hole 10, produces coke somewhat inferior to Sunnyside coke. From a comparison of the analyses and properties of the coking coal in hole 10 with that found in the surrounding holes, it is apparent that large areas of coal east of the confluence of Coal Creek and Anthracite Creek have the same coking qualities.

Similar comparisons of the analyses and properties of the coking coal from drill hole 10 with analyses and properties of coal from drill holes 3 and 5 in Minnesota Creek,5/ and with numerous analyses of samples from mines along North Fork 6/ suggest that the coals in these areas would not produce metallurgical coke.

RELATION OF GEOLOGY TO COKING QUALITY

A study of the analyses of drill samples suggests that two geological factors have influenced the present distribtuion of coking coal in the Paonia coal field. These factors are (1) heat from nearby intrusions and (2) circulating ground water and its relation to the regional water table. The available evidence indicates that little, if any, marked metamorphism took place beyond the immediate contacts of the intrusive bodies, but the total effect of all of the intrusions was to raise the temperature of the rocks over a wide area. Marked alteration of the coal is limited to the immediate area of the intrusive contacts and to a few hundred feet stratigraphically, but the general increase in temperature was sufficient to hasten the coal-forming processes and to raise the percentage of fixed carbon higher than it would otherwise have been. The beneficial effect of this heat is most pronounced close to the intrusion. After poor results were obtained by drilling in the Minnesota Creek area, the decision to drill at the mouth of Coal Creek was based on this line of reasoning. With the possible exception of the Beckwith and Cliff intrusions, however, the influence of the individual intrusions on the percentage of fixed carbon in the coal has been insufficient to be represented by means of contour lines showing changes in the fixed carbon-volatile matter ratio in the holes drilled up to the end of 1946.

Western coals containing more than 11 percent oxygen,7/ as computed for moisture and ash-free coals, are considered to be "non-coking". Most of the coal samples taken from the Paonia field prior to 1944 possessed marginal coking qualities. Some of the samples formed a poor quality of coke but others would not coke. In the Paonia coal field, samples of fresh, unweathered coal from above the water table contain 10 to 15 percent oxygen, whereas those taken from beds well below the water table in the Coal Creek area all contain less than 10 percent oxygen. A representation of the oxygen content by lines of equal percentage of oxygen (iso-oxygen lines), as shown by study of drill samples of the Snowshoe bed, shows a strong tendency for the trend of the iso-oxygen lines to parallel the structure contours. A slight divergence of these lines toward the west, however, conforms to the direction of regional groundwater drainage. The trend of the iso-oxygen lines, therefore, is more nearly parallel to the water table than to the structure contours. Near parallelism also exists between the structure contours and watertable on the one hand and such indicators of coking quality as hydrogen-oxygen ratio, fuel value (B.t.u.), and agglutinating index on the other hand.

The above relationships seem to indicate that oxygen carried by circulating ground water in the zone of aeration has been added to the coal, thus increasing its oxygen content to the extent that coal which once would coke is rendered non-coking. These relationships may be local and fortuitous, but it is the writer's belief, based on the observations cited above, that the hypothesis is sufficiently well demonstrated to warrant further testing.

FUTURE PROSPECTING

Drilling in connection with the current project has tested only a portion of the favorable area near Snowshoe and Anthracite Creeks. Geological conditions are favorable for the presence of coking coal in an area of 12 to 16 sections in which the coal lies beneath a maximum overburden of 2,500 feet. This area lies east and southeast of the area that has been drilled.

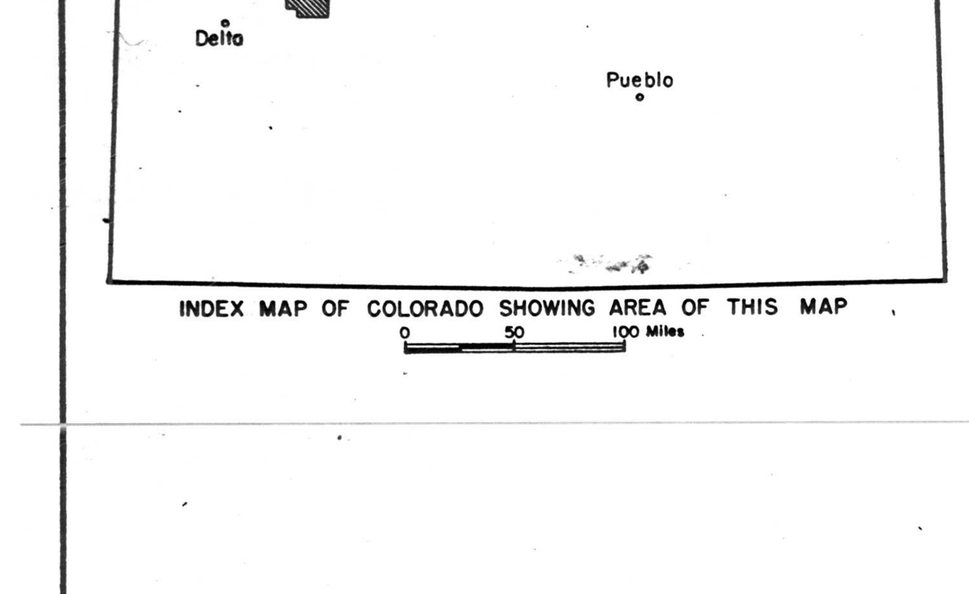
1/ Lee, W. T., Coal fields of Grand Mesa and the West Elk Mountains, Colorado: U. S. Geol. Survey Bull. 510, 1912.
2/ Lee, W. T., op. cit., p. 32.
3/ Lee, W. T., op. cit., p. 48.
4/ Toenges, A. L., Turnbull, L. A., Davis, J. D., and Reynolds, D. A., Investigation of coal deposits in the Coal Creek District, Gunnison County, Colorado, Progress Report 1: U. S. Bur. Mines Rept. Inv. 4104, April 1947.
5/ Reynolds, D. A., and others, Carbonizing properties of western coals: U. S. Bur. Mines Tech. Paper 692, pp. 4-7, 1946.
6/ Analyses of Colorado coals: U. S. Bur. Mines Tech. Paper 574, pp. 56-59, and 74-77, 1937.
7/ Parry, V. F., Coals of the Rocky Mountain and Great Plain regions: Industrial West Foundation, Washington, D. C., 1939; Trends in the use of energy in the Western States with particular reference to coal: U. S. Bur. Mines Rept. Inv. 3,680, p. 31, 1943.

TABLE 2.—ESTIMATED RESERVES OF COAL IN BEDS MORE THAN 30 INCHES THICK

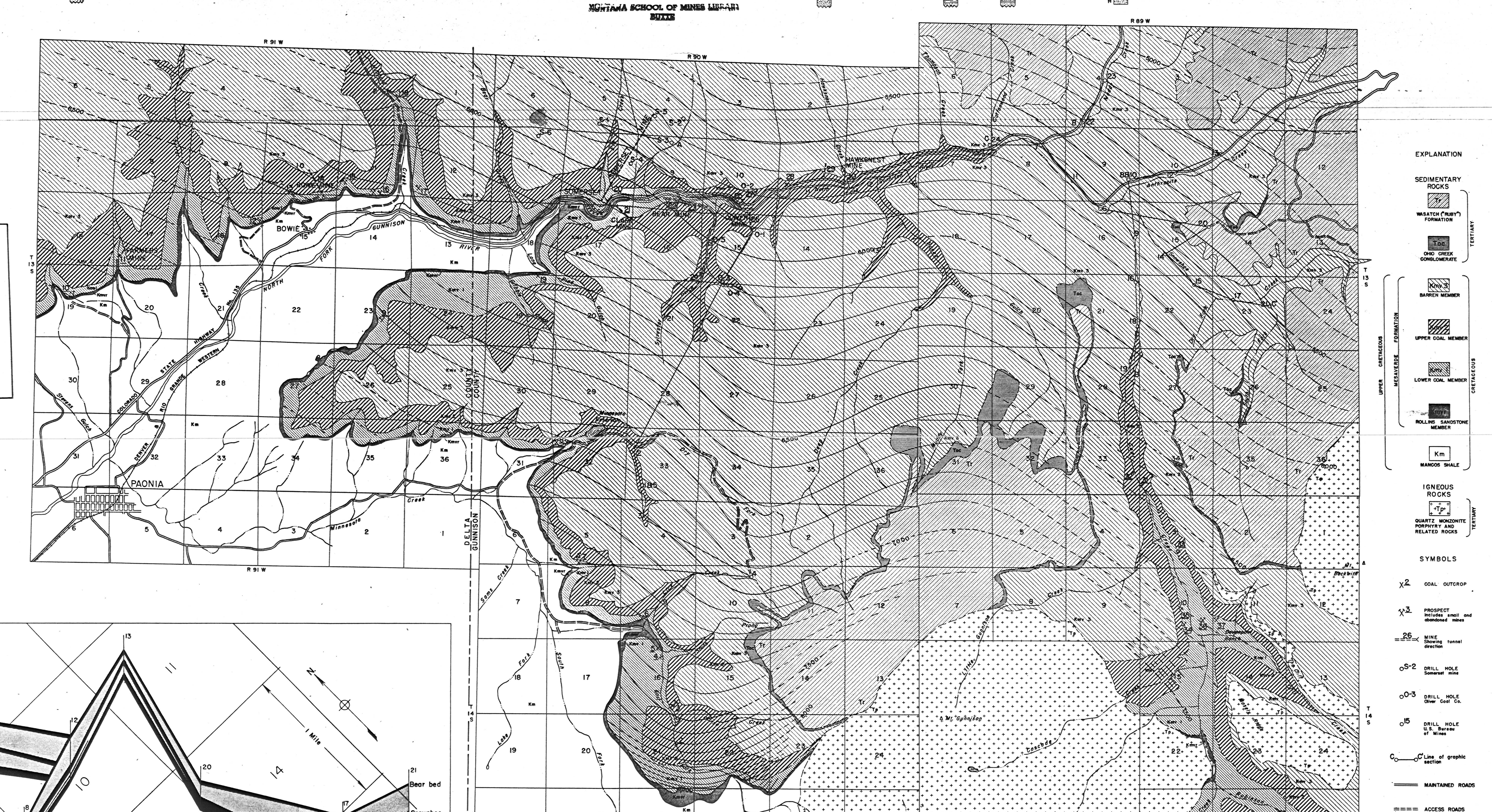
In the second column, the coal beds are identified as follows: A - Old King bed, B - Somerset bed, AB - Snowshoe bed (where split it conforms to the A and B beds near Somerset), C - Bear bed, D - lower coal bed of upper coal member, E - middle bed of upper coal member, DE - Oliver bed, F - Hawksnest bed.
Tonnage is calculated by the formula H x A x 1.13 = millions of tons, where H = thickness in feet, A = area in square miles, and 1.13 factor for conversion into millions of tons. Specific gravity of the coal is assumed to be 1.31.
In general, the reliability of the estimates is proportional to the number of observations.

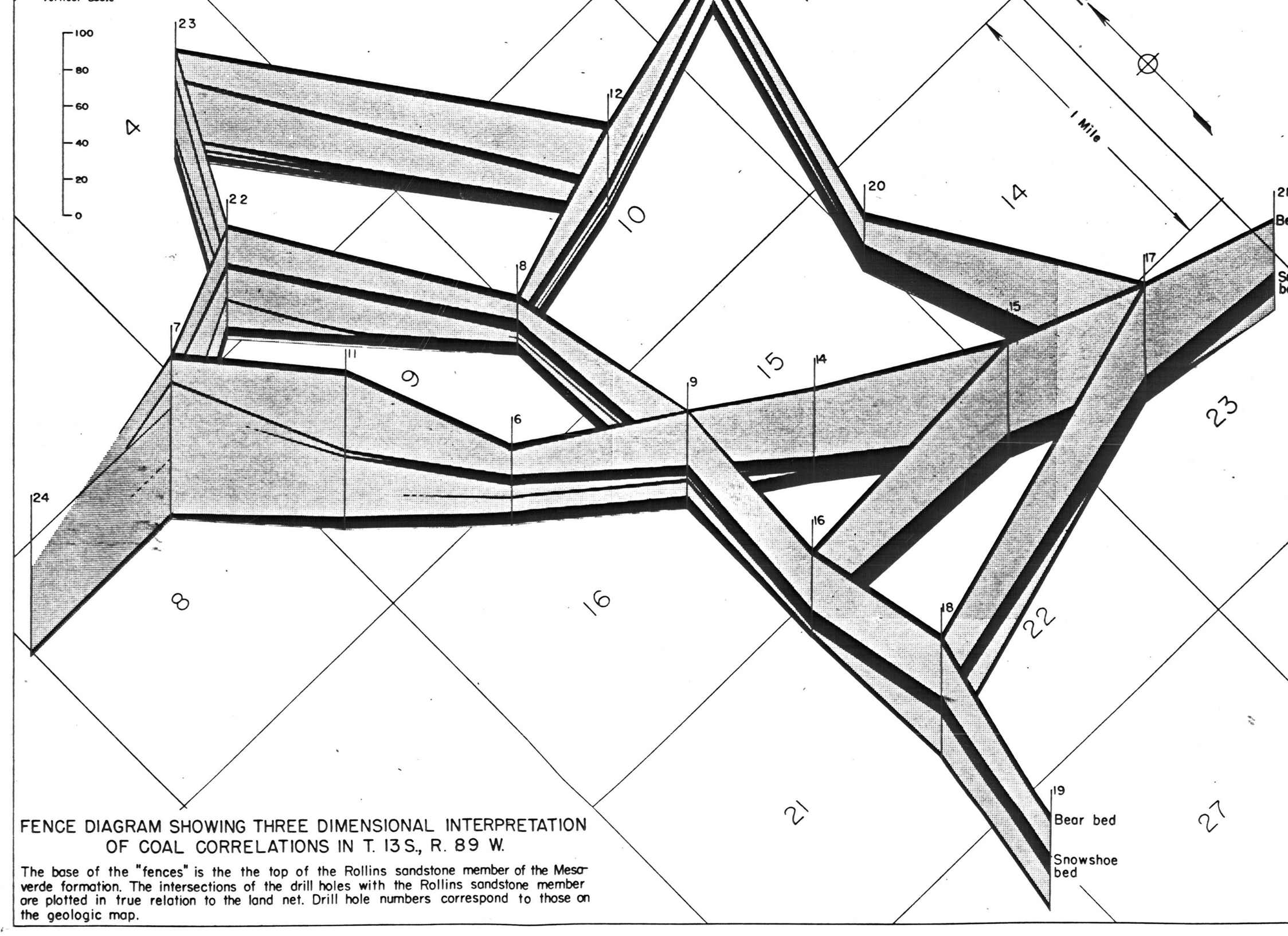
Township and Range	Group or bed	Number of observations	Average thickness of coal (feet) (1)	Area underlain by coal (sq. mi.) (2)	Reserves (millions of tons) (3)	Township totals (millions of tons) (3)
T. 13 S. R. 91 W.	A	4	3.9	19 (4)	83.4	
	B	5	15.5	18½(4)	325.0	
	C	2	5.5	18 (4)	112.0	
	Lower coal member		24.9		520.4	
	Upper coal member	(6)	15.	16	270.0	
						790.4
T. 13 S. R. 90 W.	A	3	3.6	35	142.5	
	B	13	15.6	32½ (5)	578.0	
	C	10	7.4	34½ (5)	288.8	
	Lower coal member		26.6		1009.3	
	DE	13	11.5	29½ (5)	383.3	
	F	8	6.2	29½ (5)	206.7	
	Upper coal member		17.7		590.0	
						1599.3
T. 13 S. R. 89 W.	AB	16	10.9	33	408.0	
	C	12	3.5	24	95.0	
	Lower coal member		14.4		503.0	
	Upper coal member D	2	3.6	12	47.6	
						550.6
T. 14 S. R. 90 W.	A	5	3.3	6	22.4	
	B	7	9.1	14	144.0	
	C	6	5.6	14	88.6	
	Lower coal member		18.0		255.0	
	D	5	5.0	13	73.5	
	E	6	14.0	13	205.8	
	F	6	5.7	12	77.3	
	Upper coal member		24.7		356.6	
						611.6
T. 14 S. R. 89 W.	Lower coal member	2	8.3	11	103.2	
	Upper coal member	2	7.8	10	88.2	
						191.4
Total reserves in beds more than 30 inches thick						3743.3
Reserves in beds 14 to 30 inches thick						420.0
Grand total						4163.3

(1) Average of observations shown in previous column.
(2) Corrected for burned outcrops and mining depletion.
(3) Total tonnage not necessarily recoverable.
(4) Estimates corrected for burned outcrop.
(5) Estimates corrected for coal mined.
(6) Thickness projected from R. 90 W.



INDEX MAP OF COLORADO SHOWING AREA OF THIS MAP

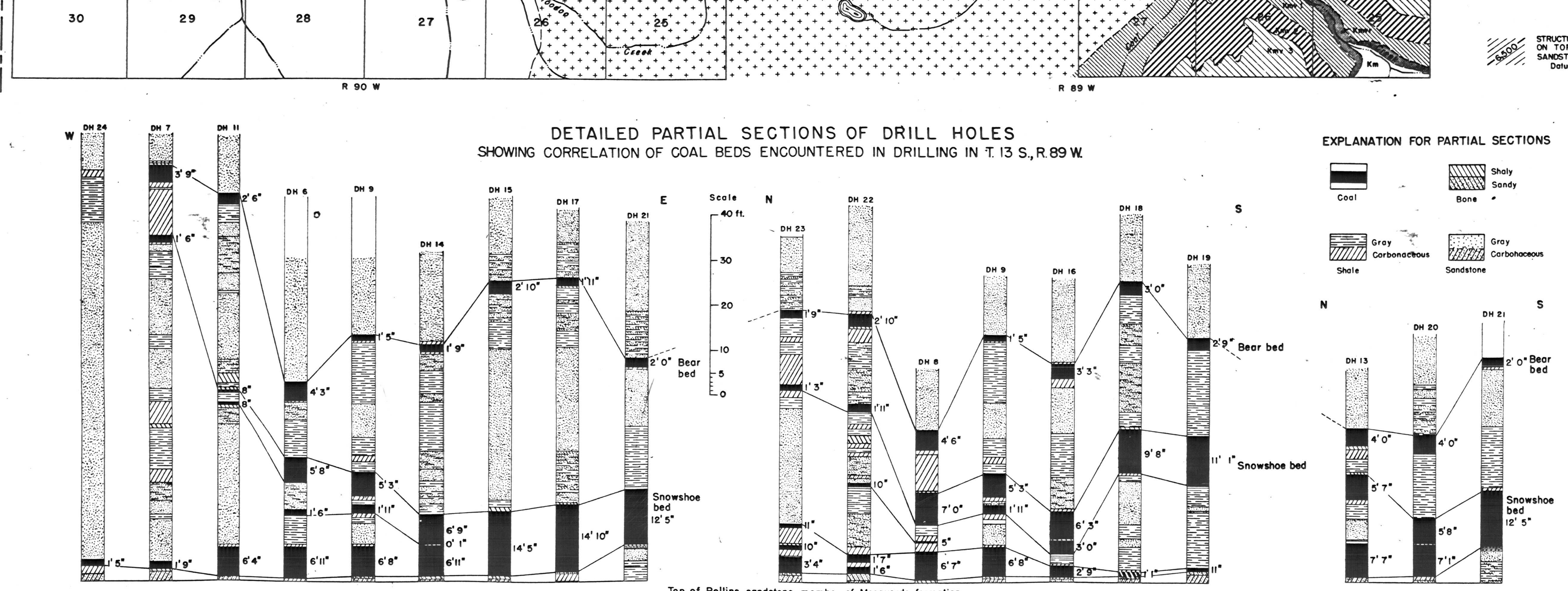




FENCE DIAGRAM SHOWING THREE DIMENSIONAL INTERPRETATION OF COAL CORRELATIONS IN T. 13 S., R. 89 W.

The base of the "fences" is the the top of the Rollins sandstone member of the Mesaverde formation. The intersections of the drill holes with the Rollins sandstone member are plotted in true relation to the land net. Drill hole numbers correspond to those on the geologic map.

DETAILED PARTIAL SECTIONS OF DRILL HOLES
SHOWING CORRELATION OF COAL BEDS ENCOUNTERED IN DRILLING IN T. 13 S., R. 89 W.



GEOLOGY OF THE PAONIA COAL FIELD, DELTA AND GUNNISON COUNTIES, COLORADO

By Vard H. Johnson

2,000 0 2,000 4,000 6,000 10,000 15,000 Feet
1 ½ 0 1 2 3 Miles

1948