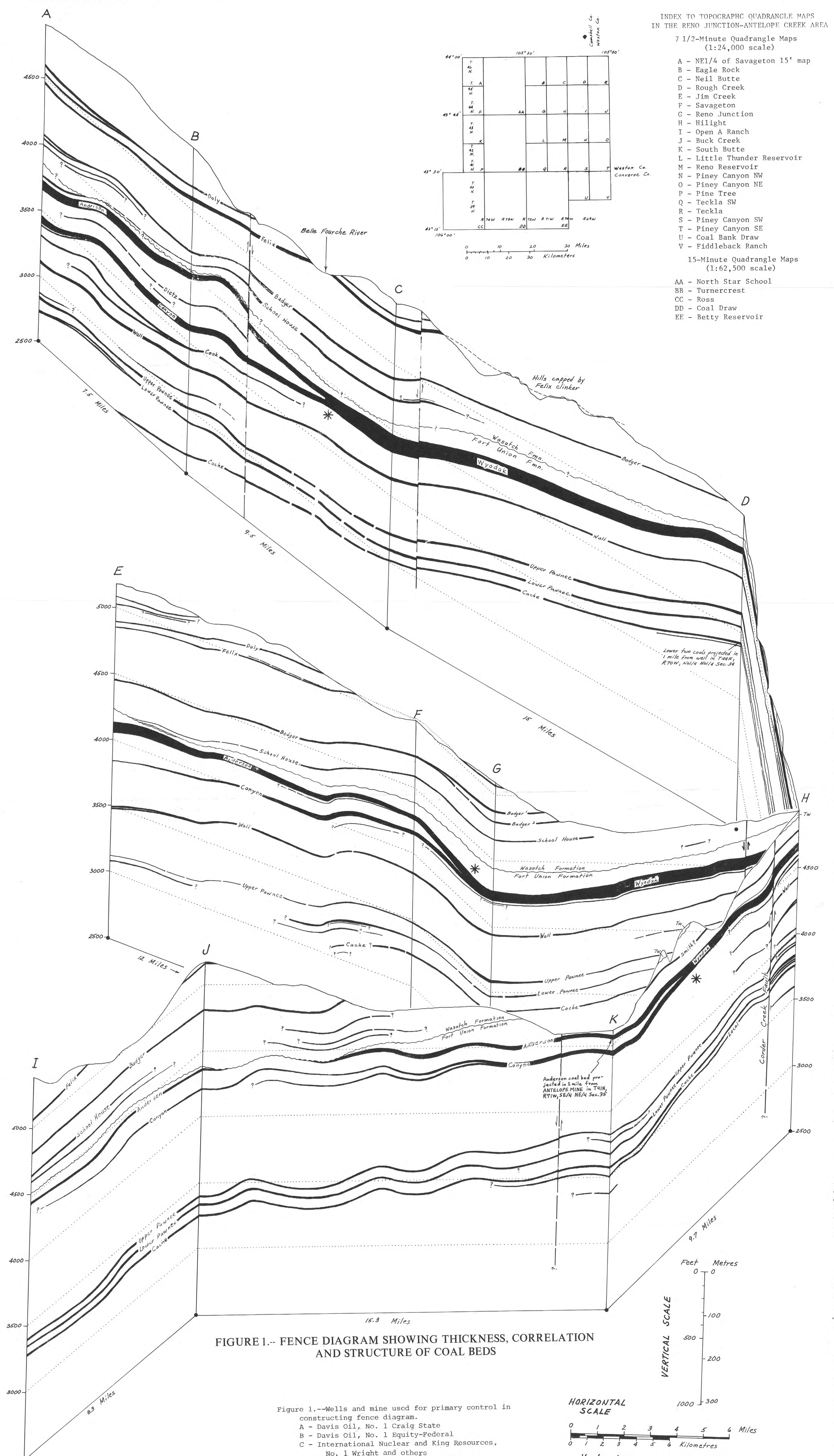


FIGURE 1.-- FENCE DIAGRAM SHOWING THICKNESS, CORRELATION AND STRUCTURE OF COAL BEDS

Figure 1.--Wells and mine used for primary control in constructing fence diagram.

A - Davis Oil, No. 1 Craig State
B - Davis Oil, No. 1 Equity-Federal
C - International Nuclear and King Resources, No. 1 Wright and others
D - Anderson Oil, No. 5 Homan-Federal (lower two coal beds projected 1 mi from Husky Oil, 4-34 Federal Jacobs)
E - Inexco Oil, 1 USA-29-PRE
F - Properties Inc., No. 1 Burt Reno
G - Inexco Oil, USA No. 6 PRE
H - Champlin Petroleum, American Quasar Nos. 32-26 Janzen-Federal
I - Anadarko Production, North Fox Federal No. A-1
J - Woods Petroleum, No. 1 Anderson-Federal
K - Phillips Petroleum, Antelope Creek "A" No. 1 (Anderson coal projected 1 mi from Antelope Mine)

INDEX TO TOPOGRAPHIC QUADRANGLE MAPS IN THE RENO JUNCTION-ANTELOPE CREEK AREA

7 1/2-Minute Quadrangle Maps (1:24,000 scale)

A - NE1/4 of Savageton 15' map
B - Eagle Rock
C - Neil Butte
D - Rough Creek
E - Jim Creek
F - Savageton
G - Reno Junction
H - Hilight
I - Open A Ranch
J - Buck Creek
K - South Butte
L - Little Thunder Reservoir
M - Reno Reservoir
N - Piney Canyon NW
O - Piney Canyon NE
P - Pine Tree
Q - Teckla SW
R - Teckla
S - Piney Canyon SW
T - Piney Canyon SE
U - Coal Bank Draw
V - Fiddleback Ranch

15-Minute Quadrangle Maps (1:62,500 scale)

AA - North Star School
BB - Turnercrest
CC - Ross
DD - Coal Draw
EE - Betty Reservoir

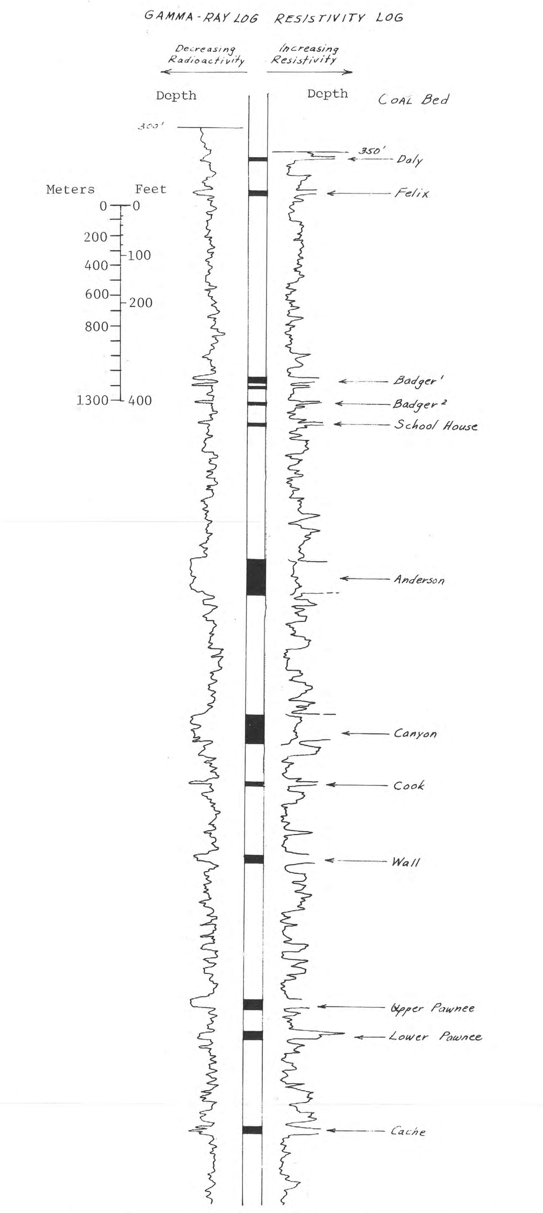


Figure 2.--Sample gamma-ray and resistivity well logs showing coal beds

EXPLANATION

HIGH-ANGLE FAULT INFERRED FROM ABRUPT SUBSURFACE CHANGE IN DISTRIBUTION, STRUCTURAL CONFIGURATION, OR THICKNESS OF COAL--Dashed where approximately located; bar and ball on downthrown side where separation known, or on side with contoured datum horizon predominantly down where apparent reversals in sense of separation occurred. Dips uncertain but probably steep judging from linearity of fault traces. Movement on some faults is interpreted to have occurred intermittently during sedimentation. Inferred faults generally coincide with surface lineaments having little or no displacement, but subsurface data suggest that greater movement occurred on some faults prior to deposition of the Wasatch Formation

HIGH-ANGLE FAULT--Inferred from configuration of structure contours on the base of the Wyodak-Anderson coal bed only (Denson and others (1978). Bar and ball on downthrown side as inferred from separation of contoured datum horizon

TOPOGRAPHIC LINEAMENT--Represents linear stream course or alined topographic features

UNCONFORMABLE CONTACT BETWEEN WASATCH FORMATION AND FORT UNION FORMATION--Formation and member names of rock-stratigraphic units labeled on map

135 DRILL HOLE USED FOR MAP CONTROL--Total coal thickness shown in feet; ± indicates estimated thickness based on log that is incomplete or ambiguous; + indicates minimum thickness. Subsurface data from electrical and radiometric logs as of Sept. 1, 1977

A DRILL HOLE USED IN CONSTRUCTING FENCE DIAGRAM A-K

DRILL HOLE IN WHICH NO COAL IDENTIFIED ON LOGS

SAMPLE FOR WHICH HEAVY MINERAL ANALYSIS AVAILABLE (TABLE 1)

4 LOCALITY FOR WHICH HEAVY MINERAL ANALYSIS OF TWO OR MORE SAMPLES ARE COMPARED (TABLE 2)--Sample numbers shown are those listed in Table 2

COAL MINE

150 ISOPACH LINE--Shows total coal thickness in feet; separates categories of total coal thickness; dashed where approximately located

DISCUSSION

The Powder River Basin of Wyoming and Montana contains some of the world's most extensive deposits of low sulfur subbituminous coal. The major coal beds occur in the upper part of the Fort Union and lower part of the Wasatch Formations of early Tertiary age (deposited about 60 to 50 million years ago) Most of the coal beds have been given informal names by local workers; names used in the Reno Junction-Antelope Creek area are shown on the fence diagram and on the sample well logs (fig. 1). Conditions leading to the formation of these coal deposits in the geologic past are discussed by R. W. Brown (1958, 1962).

COAL THICKNESS MAP

The coal thickness map shows the total thickness of all coal between the Cache coal bed in the Fort Union Formation of Paleocene age (oldest) and the Daly coal bed in the Wasatch Formation of Eocene age (youngest) in the Reno Junction-Antelope Creek area. The Wasatch-Fort Union contact (heavy line) is mapped on the basis of observed physical characteristics, supported by the distribution of distinctive heavy mineral suites in the two formations. In the Reno Junction-Antelope Creek area, the Fort Union Formation comprises the Tullock and overlying Lebo Members.[1] The Lebo Member contains all the Fort Union coal beds down to and including the Cache bed, and all but a few thin coals that occur below the Cache. Coals in the lower part of the overlying Wasatch Formation generally contribute less than 20 percent of the total coal thickness.

[1]The Lebo Member of the Reno Junction-Antelope Creek area is equivalent to the Lebo and overlying Tongue River Members of the Fort Union Formation in the northern part of the Powder River Basin.

Subsurface map control is based on geophysical logs from 315 wells, drilled at locations indicated by black dots and open circles. Total coal thickness, as interpreted from the logs of each drill hole, is given in feet;[2] a note on how coal beds are identified and correlate from well logs is included. Isopachs depict the areal distribution of total coal thickness. A wide isopach interval is used because available data are limited; additional drilling will no doubt lead to refinements in the map.

[2]To convert to meters, multiply by 0.3048.

Faults and lineaments shown on the map are largely interpretive. Most of the faults shown in heavy lines are inferred from the abruptness of differences in the distribution, sequence, thicknesses, or elevations of coal beds and intervening sediments as interpreted from close-spaced wells. Topographic lineaments represent linear stream courses or alined topographic depressions, linear scarps, and so forth.

FENCE DIAGRAM

The fence diagram shows the positions, approximate thicknesses, correlation, and structural configuration of coal beds in the Reno Junction-Antelope Creek area. Primary control for the diagram is from 11 oil and gas test wells and one mine (fence posts A-K, figure 1); also included is information on coal depth and thickness from numerous other wells lying near the section lines. Data on surface exposures of coal and clinker (residue of burned coal and overlying baked rocks) were taken from published maps (Dobbin and Barnett, 1927; Wegemann and others, 1928) and recent field data of N. M. Denson are also shown on the diagram. Coal beds are illustrated mainly between the Cache and Daly coal beds, but a few other thin coals above the Daly or below the Cache are shown where present. Solid lines mark coal beds with known or probable continuity; dashed lines indicate interpretation of coal bed correlation where information is inconclusive. Question marks are used where available data are insufficient for interpretation. Also shown on the fence diagram is the Wasatch-Fort Union contact, tentatively interpreted as an unconformity from evidence to be discussed below, and the traces of faults and lineaments, plotted as vertical features in the absence of dip information.

The profiles forming the top lines of the fence diagram represent the land surface between posts. Thus the vertical distance between the ground surface and a given coal bed at any point along a fence segment is the approximate depth to that bed. Both surface topography and bedding dips are much exaggerated on the fence diagram because of the expanded vertical scale.

GEOLOGIC INTERPRETATION

Although most coal beds are remarkably persistent over the Reno Junction-Antelope Creek area, local variations in coal thickness are common, and some beds split, converge, or pinch out. Most thickness variations appear to be related to local structures. For example, the Wyodak coal bed is thickest in the syncline at well C on the fence diagram, and the Upper Pawnee coal is relatively thick in the broad syncline of fence segment F-G-H. Conversely, the Anderson coal bed is anomalously thin on the anticlines near wells B and F, and is thin or absent on the crests of two small anticlines in fence segment J-K. A similar relationship is shown by the Canyon coal bed in fence segment A-B. Variations in the continuity of individual beds may also be structurally controlled. Zones where coal beds split or converge commonly coincide with the flanks of broad folds. Examples are the zone of convergence of the Anderson and Canyon coal beds to form the Wyodak, marked by an asterisk in all three legs of the fence diagram, and splits or convergences involving the Badger, Cook, Canyon, and other coal beds in the area. Furthermore, most (but not all) of the pinchouts are over anticlines or toward structrual highs, as illustrated by the School House and Cook coal beds in fence segment A-B-C-D, and several of the upper coal beds in segment I-J-K.

Faults, as well as folds, apparently control some stratigraphic changes. The unnamed fault cutting fence segment B-C is an example that seems to indicate complex fault movement prior to deposition of the Wasatch Formation, to account for an abrupt change in the thickness of sediments in the interval between the Anderson and Canyon coal beds. Similar relations are illustrated and discussed for the House Creek and Neil Butte faults in Denson and others (1978, figs. 1 and 2). Lineaments define a pronounced NW-SE rectangular drainage pattern for which fracture control is inferred. The lineaments are shown on the map because (1) their most prominent orientation coincides with the principal trend of inferred faults, and (2) their common occurrence along the margins of broad warps and folds introduces the possibility that much of the folding may be genetically related to small differential movements between fault-bounded blocks.

Total coal thickness and depth to individual coal beds generally increase toward the interior of the Powder River Basin (northwestward in this area) because the center of the basin was relatively more depressed and received thicker coal and intercoal sediments than did its margins (Denson and others, 1973). However, data for the Reno Junction-Antelope Creek area show that both total coal thickness and depth to beds exhibit marked local differences coincident with the same structural features that influenced variations in the thickness and continuity of individual beds.

As a general rule, a systematic relation between sedimentary facies or stratigraphic thickness and structure indicates deformation during or soon after deposition. In the vicinity of fence segments B-C and J-K, either relatively thin Anderson coal was deposited over the crests of upwarps forming during deposition, or the Anderson was thinned or removed by erosion on the crests of anticlines that formed after a full thickness of Anderson was deposited, but before Wasatch deposition. It is possible that both of these occurred as parts of a continuous process, but if so, folding and erosion prior to Wasatch deposition was comparatively accelerated, judging from the amount of post-Anderson section missing from below the School House coal bed of the Wasatch Formation at these places. This interpretation is compatible with the occurrence, in places, of gentle folds in Wasatch strata having axes coincident with somewhat tighter pre-Wasatch folds in the Fort Union, indicating that differential compaction or continued weak folding during or after deposition of the lower part of the Wasatch was controlled by the earlier folding (see fence leg A-B-C). The concept of accelerated pre-Wasatch deformation is also consistent with inferred fault movements in fence segment B-C and for the House Creek and Neil Butte faults (Denson and others, 1978, figs. 1 and 2).

The unconformity we propose to mark the Wasatch-Fort Union contact throughout the Reno Junction-Antelope Creek area has been mapped by Denson near fence posts D, H, and K (see map). Samples taken randomly across the contact have two distinct heavy mineral assemblages, as summarized in Table 1. Heavy minerals from rocks mapped as Fort Union contain abundant zircon and tourmaline; rocks assigned to the Wasatch are rich in garnet, epidote, and biotite. Table 2 illustrates the striking difference in heavy mineral suites for five groups of samples that cross the same contact (localities 1 to 5 on the map). Denson's mapping shows that the contact between these two groups of rocks, each with its own diagnostic heavy mineral signature, changes stratigraphic position across the area more abruptly than can be explained readily by assumed facies changes. The position of this contact lies on or close to the top of the Wyodak coal bed along much of fence segments B-C, D-H, and I-J, but climbs to at least 200 feet above the Wyodak and Anderson on leg K-H.

Age	Formation	No. of samples analyzed	Heavy minerals in very fine-grained sand fraction (in percent of total minerals)	Heavy mineral (In percent of total non-opaque minerals): Dominantly Metamorphic: Brown Hnbd.	Blue-green Hnbd.	Garnet	Epidote	Biotite	Chloritoid	Kyanite	Staurolite	Andalusite	Sub-Total	Dominantly Igneous: Zircon	Sphene	Tourmaline	Rutile	Apatite	Sub-Total
Early Eocene	Wasatch	43	1.44	1	4	43	23	3	1	tr	1	tr	76	6	10	5	2	1	24
Paleocene	Fort Union Lebo Member	25	0.45	--	--	16	4	1	2	1	4	--	28	29	6	32	5	--	72

[Mineral identifications by W. A. Chisholm. Leaders (--) no data; tr, trace]

Table 1.--Average percentages of non-opague heavy minerals in samples from the Wasatch and Fort Union Formations, Reno Junction-Antelope Creek area, Wyoming

Map Locality	Sample Number	Age and Formation	Non-opaque heavy minerals (Percent of total): Dominantly Metamorphic: Andalusite	Kyanite	Chloritoid	Garnet	Epidote	Biotite	Staurolite	Chlorite	Sub-Total	Dom. Igneous: Zircon	Tourmaline	Rutile	Sphene	Apatite	Sub-Total
1	7	Tw	--	--	--	63	--	6	1	--	70	7	8	1	11	3	30
	6	Tfu	--	--	1	8	--	--	9	1	19	14	62	5	--	--	81
2	36	Tw	--	--	--	68	2	--	--	2	72	14	2	2	6	4	28
	35	Tfu	--	--	--	2	2	--	6	--	10	44	40	6	--	--	90
3	9	Tw	--	--	--	36	15	21	1	--	73	7	3	2	15	--	27
	8	Tfu	--	--	1	3	2	3	5	--	14	60	20	6	--	--	86
4	47	Tw	--	--	--	25	42	14	--	--	81	2	6	--	11	--	19
	48		--	--	--	49	32	--	--	--	81	4	3	--	12	--	19
	15	Tfu	1	--	2	23	4	1	5	--	36	24	17	5	18	--	64
5	205	Tw	--	--	3	60	20	1	--	--	84	2	11	3	--	--	16
	211	Tfu	--	1	2	16	1	1	2	--	23	61	10	5	1	--	77
	212		--	1	--	2	--	--	4	--	7	76	13	3	1	--	93

[Mineral identifications by W. A. Chisholm. Leaders (--) no data]

Table 2.--Percentages of non-opague heavy minerals in samples collected at random across from the Wasatch-Fort Union contact at five localities in the Reno Junction-Antelope Creek area, Wyoming

IDENTIFICATION AND CORRELATION OF COAL BEDS IN WELLS

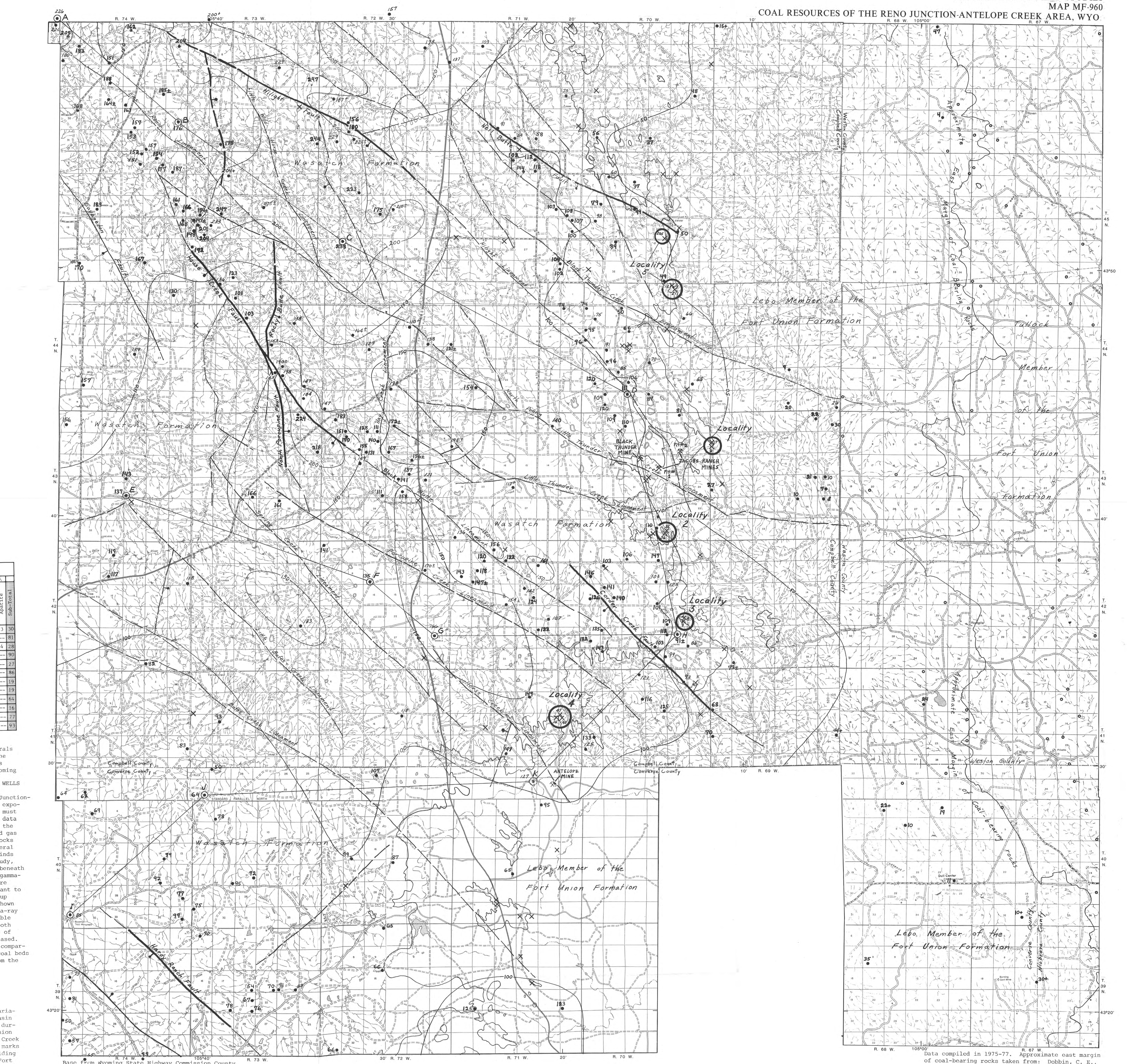
Because only a few coal beds in the Reno Junction-Antelope Creek area can be observed in surface exposures, much of the information concerning them must come from drill holes. Cores provide the best data on coals penetrated by wells; however, most of the wells in the area have been drilled for oil and gas and relatively few cores of the coal-bearing rocks were taken. Where no cores are available, several types of well logs are used to interpret the kinds of rocks encountered in the wells. In this study, the primary method for detection of coal beds beneath the ground surface is based on examination of gamma-ray and resistivity logs. Because the coals are virtually nonradioactive and are highly resistant to the passage of electrical currents, they show up conspicuously on these two types of logs, as shown on the sample logs (fig. 2). Of the two, gamma-ray logs are generally considered to be most reliable for identifying individual coal beds, but if both logs are available for a given well the degree of accuracy and confidence is substantially increased. Coal beds are correlated from well to well by comparing the thickness, position, and sequence of coal beds and intervening rock units, as interpreted from the logs of individual wells.

CONCLUSIONS

Most facies changes and coal thickness variations along the margins of the Powder River Basin are attributed to structural development both during and after deposition. The Wasatch-Fort Union contact throughout the Reno Junction-Antelope Creek area is considered to be an unconformity that marks a culmination of growth faulting and broad folding that recurred intermittently through much of Fort Union deposition, but continued only weakly during or after Wasatch time. Recognition of local deformational patterns and associated unconformities, and the question of whether an unconformity at the Wasatch-Fort Union contact has regional significance, are problems critical to the commercial development and reclamation of the strippable coal reserves of the eastern Powder River Basin. Additional drilling may clarify the depositional framework of these coal-bearing strata.

REFERENCES CITED

Brown, R. W., 1958, Fort Union Formation in the Powder River Basin, Wyoming, in Wyoming Geological Association Guidebook 13th Annual Field Conference, Powder River Basin, Wyoming, 1958, p. 111-113.
____1962, Paleocene flora of the Rocky Mountains and Great Plains: U.S. Geological Survey Professional Paper 375, 119 p.
Denson, N. M., Hover, J. H., and Osmonson, L. M., 1978, Structure contour and isopach maps of the Wyodak-Anderson coal bed in the Reno Junction-Antelope Creek area, Campbell and Converse Counties, Wyoming: U.S. Geological Survey Miscellaneous Field Studies Map MF-961, scale 1:125,000.
Denson, N. M., and Keefer, W. R., 1974, Map of the Wyodak-Anderson coal bed in the Gillette area, Campbell County, Wyoming: U.S. Geological Survey Miscellaneous Investigations Map I-848-D, scale 1:125,000.
Denson, N. M., and Keefer, W. R., and Horn, C. H., 1973, Coal resources of the Gillette area, Campbell County, Wyoming: U.S. Geological Survey Miscellaneous Map I-848-C, scale 1:125,000.
Dobbin, C. E., and Barnett, V. H., 1927, The Gillette coal field, northeastern Wyoming: U.S. Geological Survey Bulletin 796, p. 1-50.
Dobbin, C. E., Kramer, W. B., and Horn, G. H., 1957 Geologic and structure map of the southeastern part of the Powder River Basin, Wyoming: U.S. Geological Survey Oil and Gas Investigations Map OM-185.
Wegeman, C. H., Howell, R. W., and Dobbin, C. E., 1928, The Pumpkin Buttes coal field, Wyoming: U.S. Geological Survey Bulletin, 806, p. 1-14.



Base from Wyoming State Highway Commission County Map Series, 1956, with main highway system updated to 1969. Land grid and roads in T. 39-40 N. and R. 70 W. through center of R. 72 W. revised to conform with U.S. Geological Survey Betty Reservoir 15-minute quadrangle (1:62,500)

Data compiled in 1975-77. Approximate east margin of coal-bearing rocks taken from: Dobbin, C. E., Kramer, W. B., and Horn, G. H., 1957.

SCALE 1:250 000

LOWER TERTIARY COAL BED DISTRIBUTION AND COAL RESOURCES OF THE RENO JUNCTION-ANTELOPE CREEK AREA, CAMPBELL, CONVERSE, NIOBRARA, AND WESTON COUNTIES, WYOMING

By

N. M. Denson, J. H. Dover, and L. M. Osmonson

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