THE GEOLOGICAL SURVEY OF WYOMING
Daniel N. Miller, Jr., State Geologist

REPORT OF INVESTIGATIONS No. 22

COALS AND COAL-BEARING ROCKS OF THE HANNA COAL FIELD, WYOMING

By Gary B. Glass and Jay T. Roberts

Portions of this report were developed through the use of funds provided by the Laramie Energy Technology Center, U.S. Department of Energy

LARAMIE, WYOMING

1980

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Front Cover: Typical strip mine in the Hanna coal field.

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INTRODUCTION

Although most of the Hanna Coal Field of southcentral Wyoming lies within Carbon County, a small portion extends eastward into Albany County as well (Figure 1). This coal-bearing area coincides with the Hanna and Carbon topographic and structural basins and is considered part of the U.S. Geological Survey's Rocky Mountain Coal Province. As defined, however, the coal field is limited to those portions of the basins that are underlain by rocks of the Mesaverde Group. With this convention, all other coal-bearing rocks of the Hanna Coal Field occur within the outcrop of the Mesaverde since they all overlie that group. The boundary between this field and the Rock Creek Coal Field to the east is usually drawn to coincide with the alluvial deposits associated with Rock Creek.

Based on past and present mining

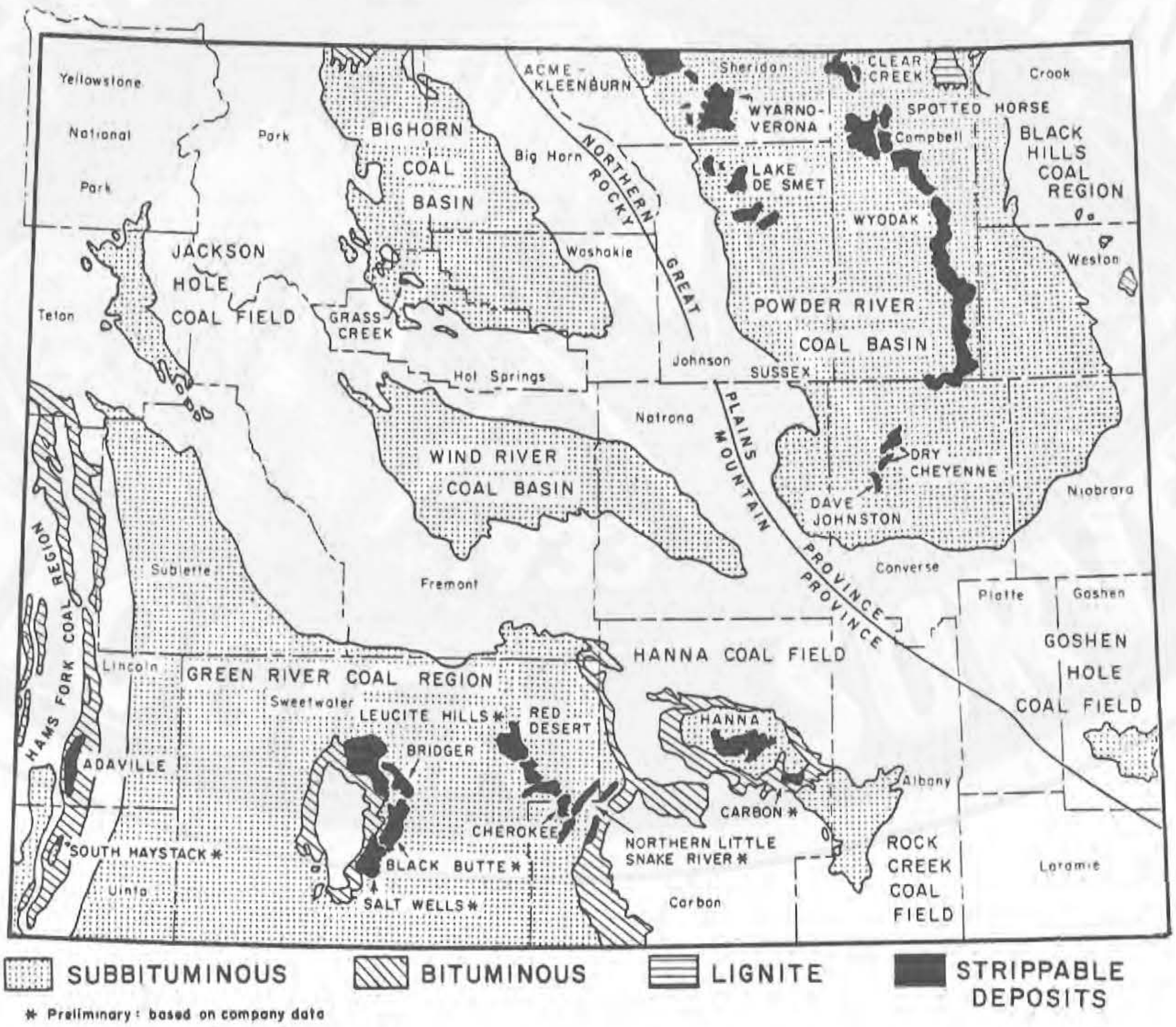


Figure 1. Wyoming coal-bearing areas.

activity, Glass and Roberts (1979) defined four mining districts within the field: the Hanna, Carbon, Seminoe, and Corral Creek districts. The boundaries of these districts are shown on Figure 2. Areas barren of near-surface coals serve to roughly delimit one district from another.

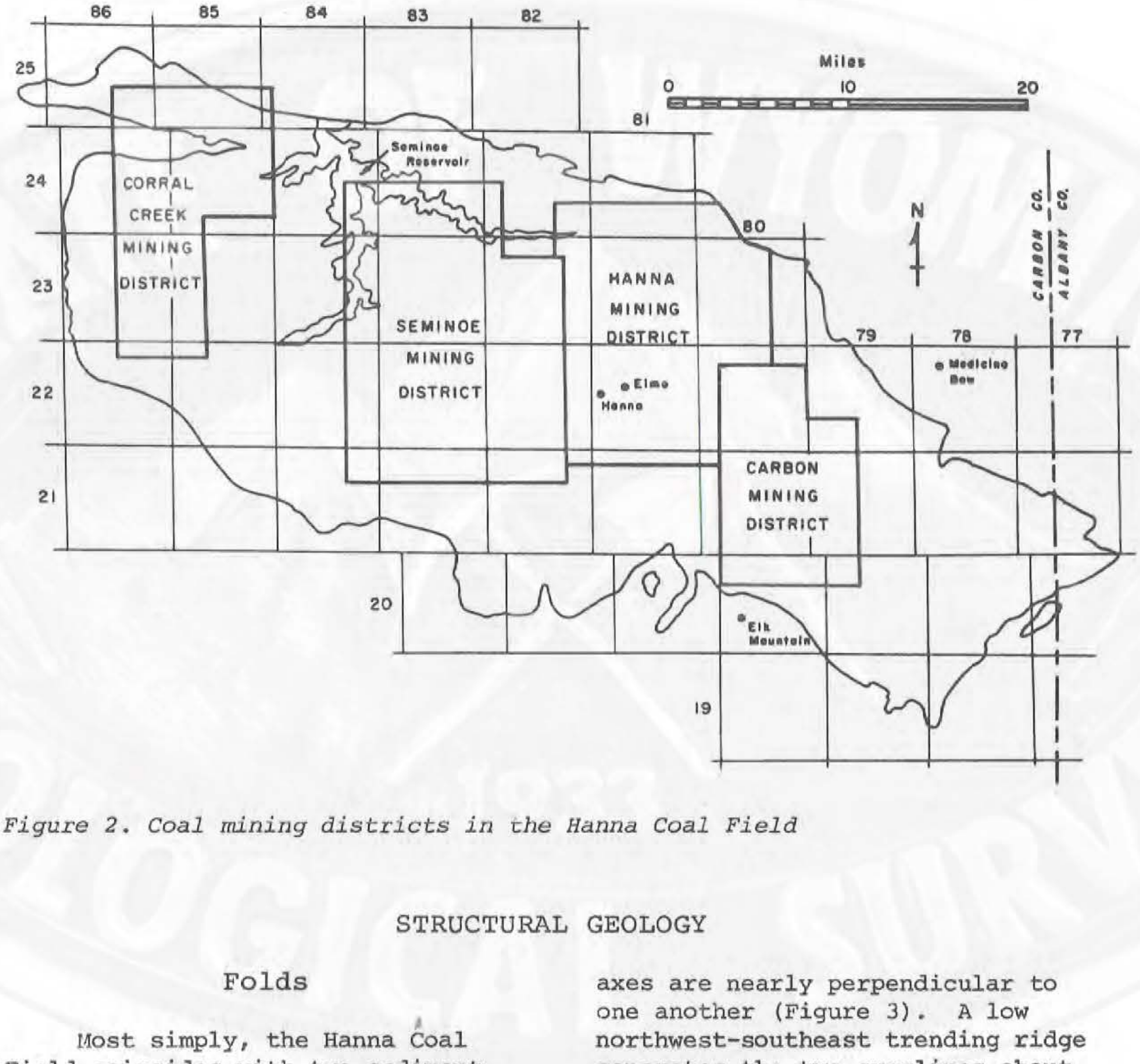


Figure 2. Coal mining districts in the Hanna Coal Field

STRUCTURAL GEOLOGY

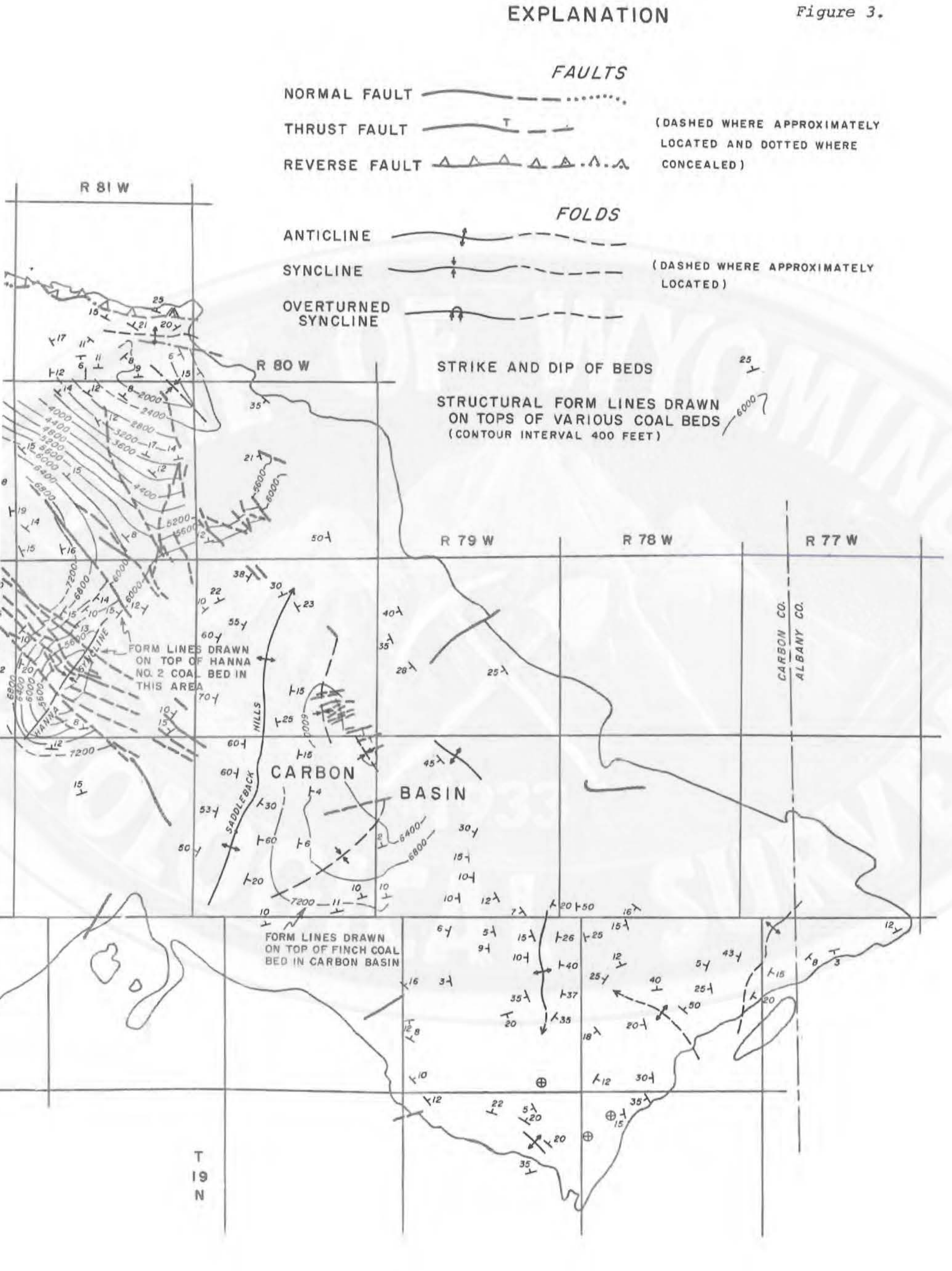
Folds

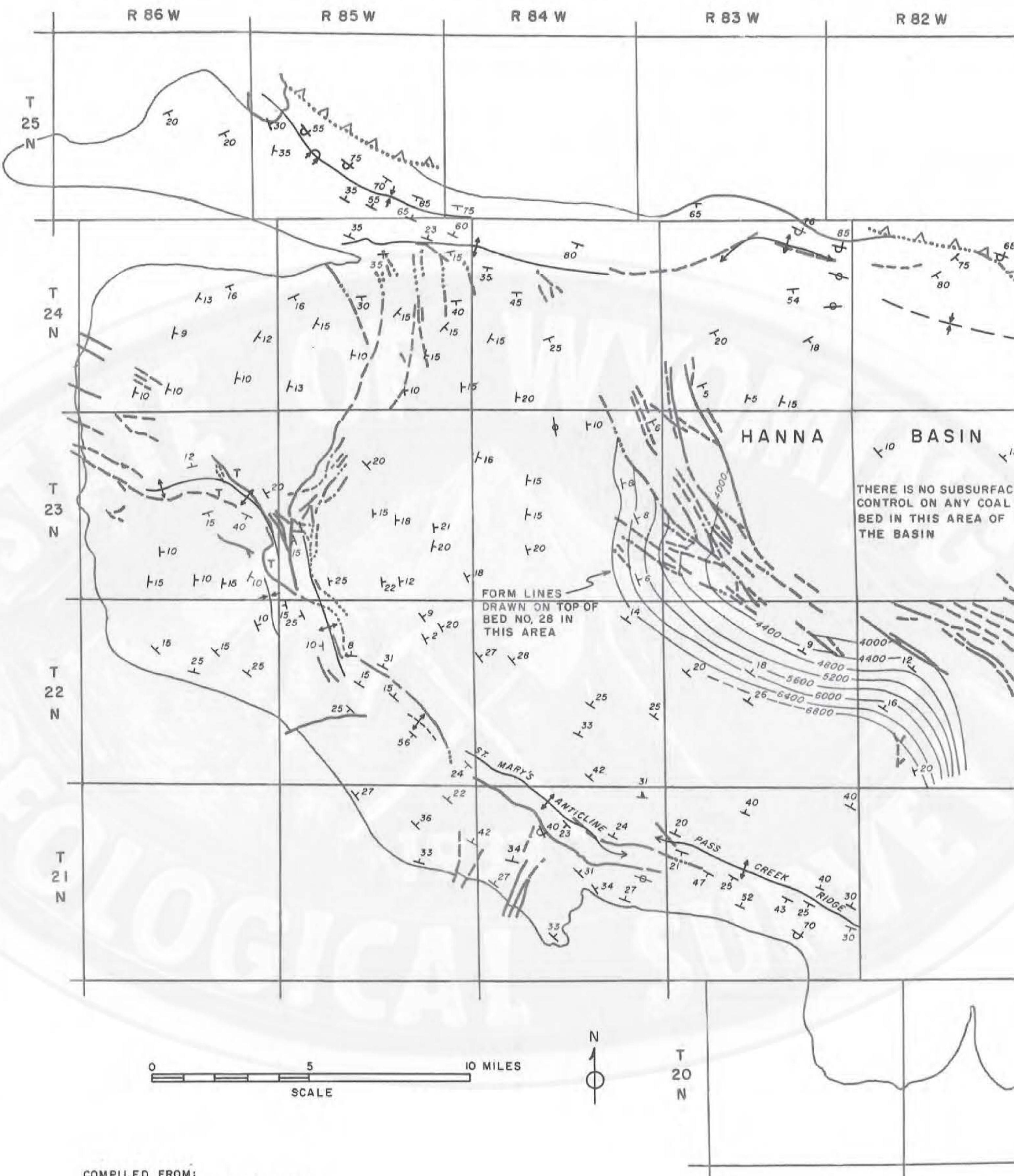
Most simply, the Hanna Coal Field coincides with two sediment-filled intermontane basins between uplifted areas. These basins are separated from one another by the Saddleback Hills Anticline with the Hanna Basin lying to the north and the Carbon Basin lying to the south. The Hanna Basin is itself separated into two synclines whose axes are nearly perpendicular to one another (Figure 3). A low northwest-southeast trending ridge separates the two synclines about three miles northeast of Hanna. The southernmost of these synclines is called the Hanna Syncline; the northernmost syncline is unnamed.

Like other intermontane basins of Wyoming, these depressions formed during the Laramide Orogeny, some

Figure 3. Generalized structural geology of the Hanna Coal Field, Wyoming.

Figure 3.


EXPLANATION
FAULTS
NORMAL FAULT
THRUST FAULT
REVERSE FAULT
(DASHED WHERE APPROXIMATELY LOCATED AND DOTTED WHERE CONCEALED)
FOLDS
ANTICLINE
SYNCLINE
OVERTURNED SYNCLINE
(DASHED WHERE APPROXIMATELY LOCATED)
STRIKE AND DIP OF BEDS
STRUCTURAL FORM LINES DRAWN ON TOPS OF VARIOUS COAL BEDS
(CONTOUR INTERVAL 400 FEET)
R 81 W
R 80 W
R 79 W
R 78 W
R 77 W
FORM LINES DRAWN ON TOP OF HANNA NO. 2 COAL BED IN THIS AREA
HANNA SYNCLINE
SADDLEBACK HILLS
CARBON BASIN
FORM LINES DRAWN ON TOP OF FINCH COAL BED IN CARBON BASIN
CARBON CO.
ALBANY CO.
T 19 N



COMPILED FROM:
DOBBIN AND OTHERS (1929)
KNIGHT (1951)
LOVE AND OTHERS (1955)
BAYLEY (1968)
MEREWETHER (1971), (1972) (1973)
LOWRY AND OTHERS (1973)
GLASS AND OTHERS (1979)

38-65 million years ago. The Hanna Basin, however, is rather atypical in that it is not only extremely deep for its size (Knight, 1951, estimated more than 30,000 feet of sedimentary rock overlie its crystalline basement), but a good portion of its sedimentary rocks are tightly folded and faulted. Even some younger coal-bearing rocks (Paleocene age) steepen to vertical dips or overturn on the northern flank

Figure 4. Normal fault with 40 feet of vertical displacement.

of the basin as they approach a major fault that separates the basin from the ranges to the north. Elsewhere in the coal field, rocks that crop out on the flanks of the basin are folded and steeply dipping (greater than 25 degree dip). In contrast, dips are much flatter in the central portions of the three major synclines, averaging 3-15 degrees (Figure 3).

Faults

Faulting is not limited to the major reverse fault that separates the basin from uplifted areas to the north or to the faulting that is common to the western and southwestern flanks of the basin (Figure 3). Normal faults occur within the more gently folded coal-bearing synclines as well. In these synclinal areas, the frequency of faulting shows a direct correlation with the intensity of coal mining. More faulting is mapped in the mined areas than the outlying areas. This observation suggests that many faults probably remain undetected until an area is mined.

At least in the Hanna and Seminoe mining districts, the predominant trend of normal faults is northwest at 306-317 degrees (N.54^{O}W. to N.43^{O}W.). Faults in the Seminoe District exhibit the slightly greater northerly trend (317 degrees). Cross-faulting between these major northwest-southeast trending faults is quite common. It is also not uncommon for these major faults to occur within 500 feet of one another.

Unlike the northwest-southeast trending faults of the Hanna and Seminoe districts, normal faults in the Carbon District trend more nearly east-west, averaging about 76 degrees (N.76^{O}E.). Elsewhere in the coal field, faults are more variable in orientation and type.

Typically, vertical displacements on the normal faults in the Hanna and Carbon basins are less than 200 feet although some greater displacements occur. Displacements

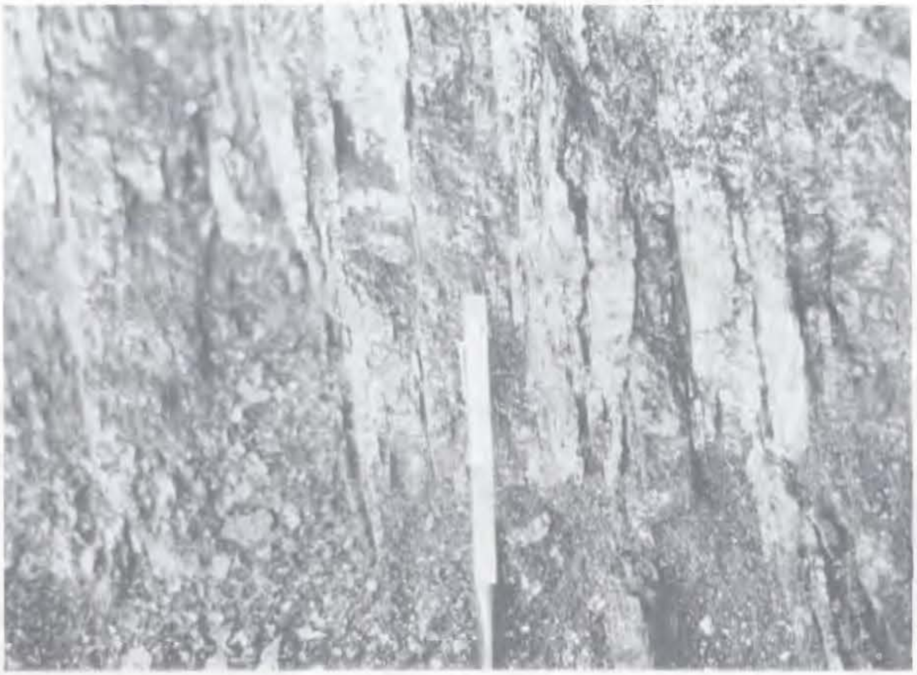


Figure 5. Closely spaced fracture zone immediately adjacent to a major fault (fractures strike parallel to the fault).

on the order of tens of feet are most common (Figure 4). To date, faults observed by the authors have only exhibited vertical slickensides. Dobbin, Bowen, and Hoots (1929), however, report seeing evidence of horizontal movement as well. Recent coal isopach maps, compiled by the authors, also strongly suggest that some faults have moved laterally as well as vertically. While fault breccia has not been observed in association with these normal faults, jointing and/or minor faulting parallel to the trends of major faults have been noted. Typically, these fractured zones extend no more than a few feet from the main fault (Figure 5).

Joints

Based on joint orientations taken at 32 different sites, four joint sets are recognized in the coals of the Hanna Basin portion of the Hanna Coal Field:

Set A	290-295°	(N.70-65°W.)
Set B	320-330°	(N.40-30°W.)
Set C	23-25°	(N.23-25°E.)
Set D	60-70°	(N.60-70°E.)

Figure 6 shows these joint measurements plotted on two rose diagrams. The left rose diagram shows the joint sets measured in the Ferris Formation coals. The right diagram is for Hanna Formation coals. Because of the geographic distribution of the sampling sites, all the Ferris readings were taken in the Seminoe Mining District or the western portion of the basin. All the Hanna Formation coal readings were taken in the Hanna Mining District or the eastern portion of the basin. As evidenced by the rose diagrams, all joint sets except Joint Set D are apparently rotated slightly clockwise in the western portion of the basin. Joint Set D, however, differs by 10 degrees in a counterclockwise direction.

Figure 6. Joint sets in the coals of the Hanna and Ferris formations.

Joint Set A (290-295°), which is well developed in the Ferris Formation coals, is almost unrecognizable in the Hanna coals to the east. This joint set and Joint Set C comprise one orthogonal joint system in this area as they are very nearly perpendicular to one another.

Joint Set B (320-330°), on the other hand, is most obvious in the Hanna Formation coals and poorly developed in Ferris coals to the west. In the Hanna District this joint set exhibits the same orientation as the predominant faulting in that area. Incidentally, this is the only joint set that parallels the direction of local faulting. It is unclear what significance this relationship might have. It may simply be coincidental. It is possible that Joint Set B and Joint Set D in the Ferris Formation coals comprise a second orthogonal joint system. Unfortunately, the existence of this second orthogonal system is less convincing in the Hanna Formation coals.

Joint Set C (23-25°) is the most often observed joint set of the four. Although it shows little difference in orientation in the two formations, its average orientation in the Ferris coals may be at least two degrees more eastward than in the Hanna coals. As mentioned earlier, this joint set and Joint Set A comprise an obvious orthogonal joint system.

Figure 7. Systematic joints in coal.

Joint Set D (60-70^{o}) is less commonly noted but nonetheless obvious in coals of both areas. Its orientation in the Ferris coals (60^{o}) is ten degrees north of the 70^{o} orientation typical of the Hanna Formation coals. Again, Joint Sets B and D may comprise a second orthogonal joint system, but less well developed than Joint Sets A and C.

There is a possibility that other joint sets are also present. But until more measurements are taken, the existence of more than four joint sets remains speculative. Because no joint orientations were measured in the Carbon Basin, nothing can be said about the joints in that area.

Because the vertical and lateral persistence of these various joint sets were not systematically noted, only a few general comments are possible. Some joint sets, most notably Joint Set C and to a lesser extent Joint Sets A and B, might best be termed systematic joints (Nickelsen and Hough, 1967). These systematic joints are vertically persistent; that is, they do not terminate at petrographically different zones in the coal (lithotypes) or at bedding planes within the coal. Instead, they persist for many inches to as much as several feet downward through the coal (Figure 7). They also do not terminate laterally against joints of other orientations. They cut through the other joint sets, exhibiting lateral extents on the order of many inches to several feet.

In contrast, the less well developed joint sets terminate against the more persistent and pronounced systematic joints and seldom cross differing coal lithotypes or bedding planes in the coal. These joints are likened to the nonsystematic joints of Nickelsen and Hough (1967).

Nickelsen and Hough (1967) felt that both the systematic and nonsystematic joints were extensional in origin. While their systematic joints were believed to form early, independent of folds and

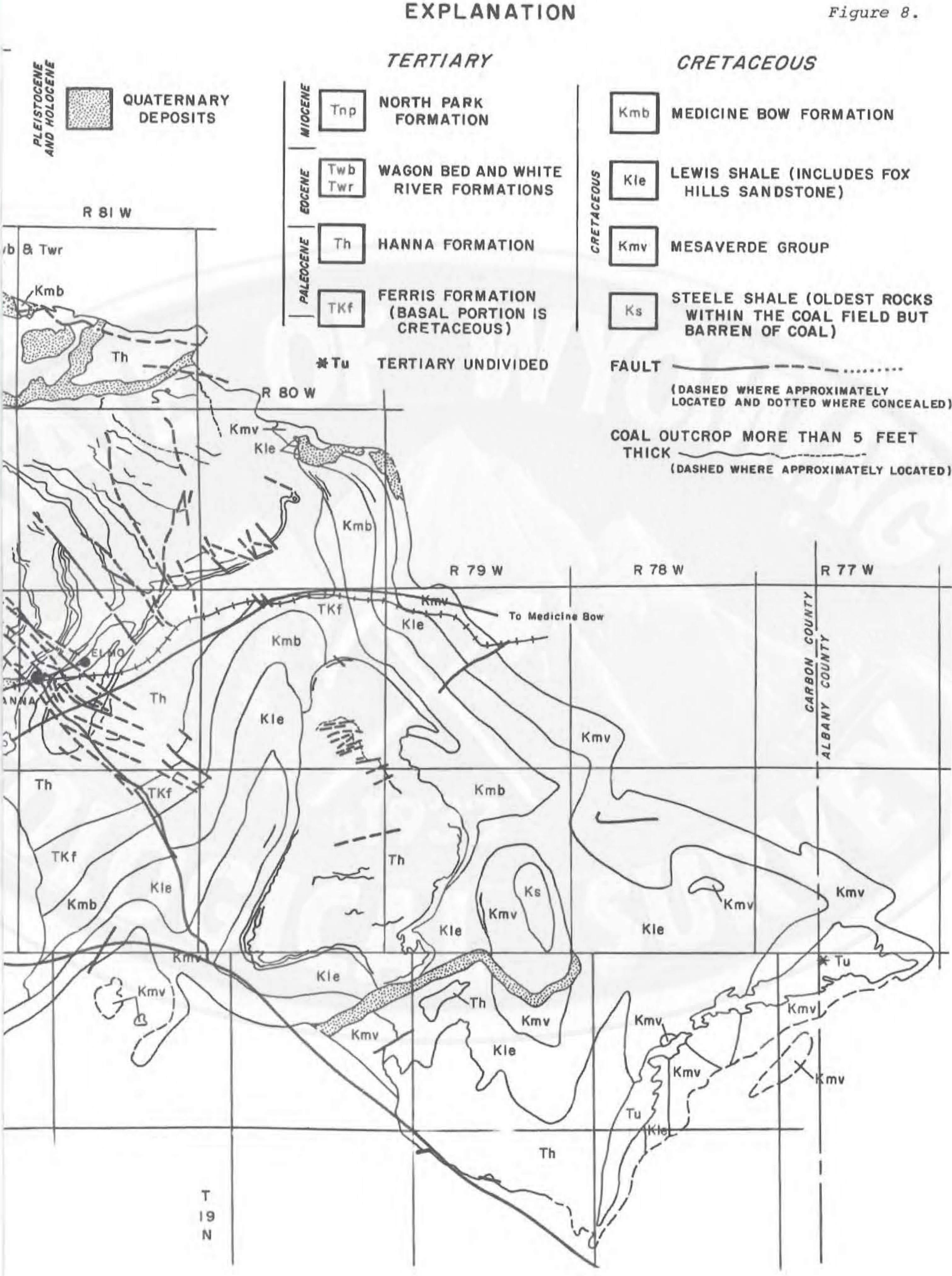
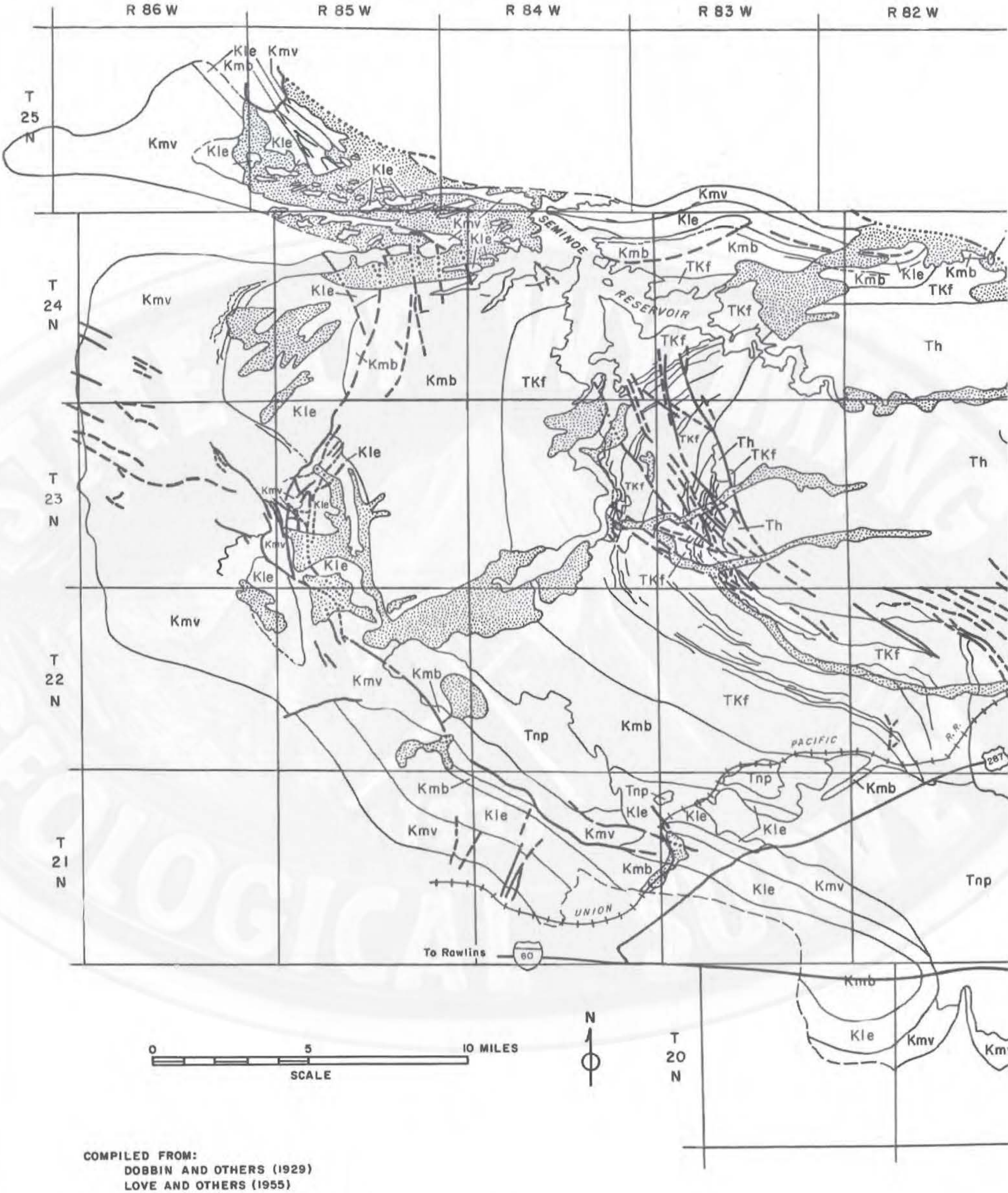

EXPLANATION
TERTIARY
CRETACEOUS
PLEISTOCENE AND HOLOCENE
QUATERNARY DEPOSITS
MIOCENE
Tnp NORTH PARK FORMATION
EOCENE
Twb Twr WAGON BED AND WHITE RIVER FORMATIONS
PALEOCENE
Th HANNA FORMATION
TKf FERRIS FORMATION (BASAL PORTION IS CRETACEOUS)
*Tu TERTIARY UNDIVIDED
Kmb MEDICINE BOW FORMATION
CRETACEOUS
Kle LEWIS SHALE (INCLUDES FOX HILLS SANDSTONE)
Kmv MESAVERDE GROUP
Ks STEELE SHALE (OLDEST ROCKS WITHIN THE COAL FIELD BUT BARREN OF COAL)
FAULT
(DASHED WHERE APPROXIMATELY LOCATED AND DOTTED WHERE CONCEALED)
COAL OUTCROP MORE THAN 5 FEET THICK
(DASHED WHERE APPROXIMATELY LOCATED)
R 81 W
R 80 W
R 79 W
R 78 W
R 77 W
b & Twr
To Medicine Bow
ELMO
HANNA
CARBON COUNTY
ALBANY COUNTY
T 19 N

Figure 8. Geologic map of the Hanna Coal Field, Wyoming.



COMPILED FROM:
DOBBIN AND OTHERS (1929)
LOVE AND OTHERS (1955)
BAYLEY (1968)
MEREWETHER (1971), (1972), (1973)
LOWRY AND OTHER (1973)
GLASS AND ROBERTS (1979)
HYDEN AND McANDREWS (1967)

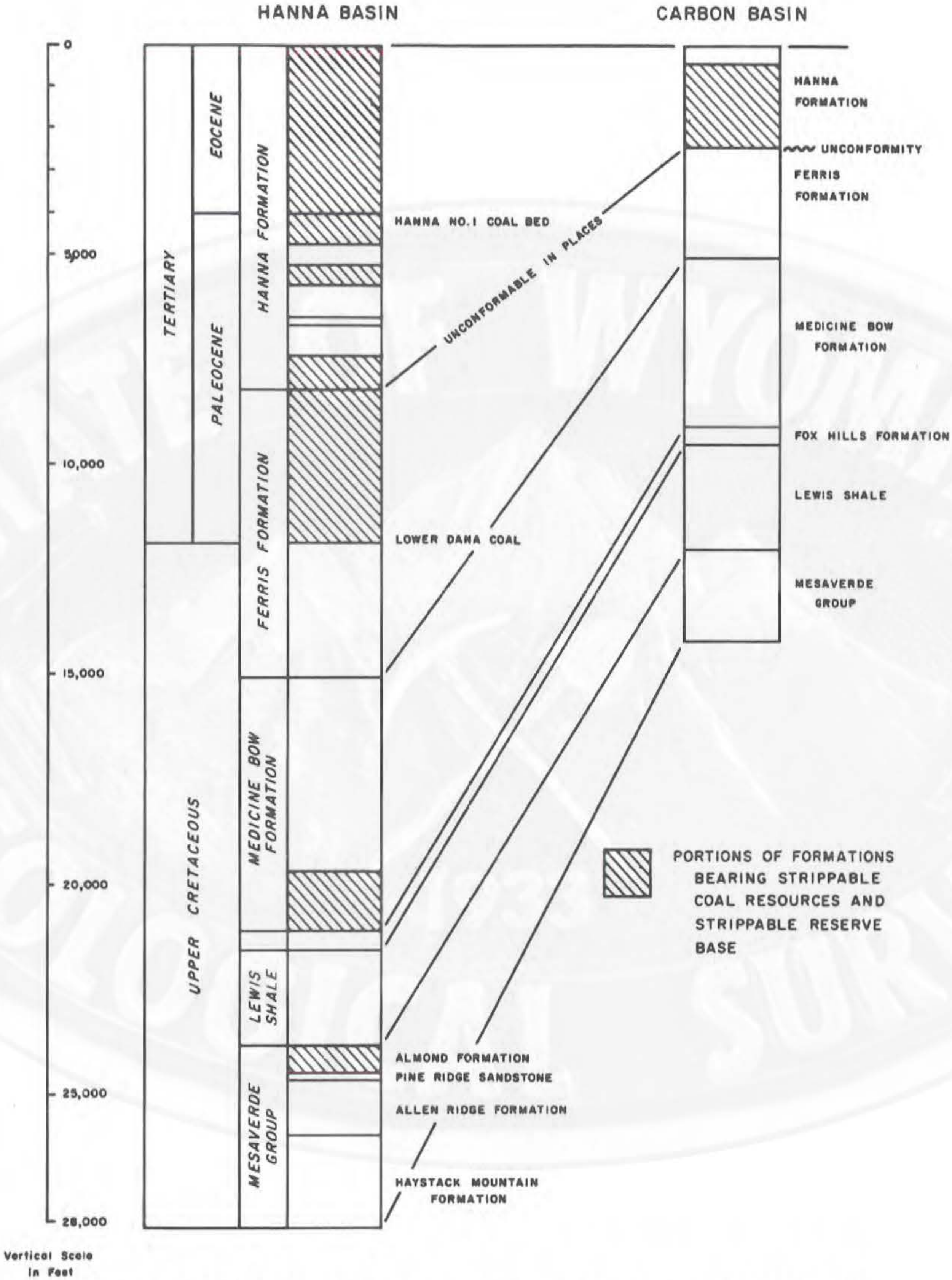


Figure 9. Generalized stratigraphic columns for the Hanna Coal Field of southcentral Wyoming.

faults, their nonsystematic or truncated joints were:

probably late release type fractures resulting from a combination of residual tectonic stress differences and surficial stress differences arising in blocks between successive systematic joints during erosion and unloading.

At this time, it is not clear whether these conclusions are equally appropriate to explain jointing in the Hanna Basin.

Lithologies also affect the orientation of joints. Although not enough measurements were taken for a true comparison, the strikes exhibited by most joint sets vary as they pass through different lithologies. Nickelsen and Hough (1967) and Glass (1972a) mention similar phenomena in the bituminous coal fields of Pennsylvania. They noted that even bright and dull bands within a coal bed behave as minute structural rock units, and therefore alter or deflect the strike of joints as they pass from one band to another. This phenomenon is much more pronounced when the joint orientations found in coals are compared with the orientations of the same joint sets in overlying sandstones and shales. Glass (1972a) observed as much as a 2.5^{o} shift in orientation as a joint passed from one lithology to another.

Joint spacing also varies considerably with lithology. Generally speaking, joints in sandstones are the most widely spaced, measured in terms of feet or yards apart. Joint spacing in shales is best thought of in feet or inches while spacing in coals is more on the order of inches or centimeters.

COAL-BEARING ROCKS AND COAL BEDS

General

Although coal beds occur in the Upper Cretaceous Mesaverde Group and the Medicine Bow Formation, the most significant beds are in the Ferris Formation of Upper Cretaceous and Paleocene age and in the Hanna Formation of Paleocene and Eocene age. In general the older Mesaverde and Medicine Bow formations crop out on the flanks of the coal field while the younger Ferris and Hanna formations occupy the more central portions of the coal field (Figure 8). Stratigraphic columns in Figure 9 show the approximate position of the more persistent coal beds in the Hanna and Carbon basins. Correlation of coal beds between the two basins is not yet possible.

Coal beds occur in a rock interval up to an estimated 24,000 feet thick. Coal, of course, accounts for only a minor portion of this great thickness of rock, probably less than 2 percent (Table 1). Coals are most numerous in the upper 12,000 feet of rock, which comprise the Hanna Formation and the upper portion of the Ferris Formation. These Tertiary age coals are the youngest in the field (38-65 million years old) and also the most exploited coals. Mining of Tertiary coals in the Hanna Coal Field, which dates back to the 1860's, is still occurring today. In fact, all the active mining in the coal field is on coals of the Hanna or Ferris formations.

Table 1. Estimated cumulative coal thicknesses in the Hanna Coal Field.[1]

Formation, District	Estimated # of coals > 5' thick	Range in cumulative thickness	Average cumulative thickness	Percent of formation thickness	Average interval between minable coals
Hanna Fm.					
Carbon Dist.	6	30-70 ft.	50 ft.	1-5%	300 ft.
Hanna Dist.	24	125-375 ft.	250 ft.	2-5%	330 ft.
Ferris Fm.					
Seminoe Dist.	30	135-305 ft.	200 ft.	2-4%	150 ft.
Medicine Bow Fm.					
Corral Creek Dist.	3	10-15 ft.	12 ft.	1%	465 ft.
Almond Fm.					
Corral Creek Dist.	5	10-40 ft.	25 ft.	1-6%	140 ft.

[1] Generally does not include coals less than 5 feet thick.

Lithologic Character of Coal-bearing Rocks

Rocks associated with the coals of the Hanna Coal Field are extremely variable, consisting of conglomerates, sandstones, siltstones, claystones, and shales. In the case of the Mesaverde Almond Formation, Gill and others (1970) describe the rocks as predominately very fine grained, thin bedded sandstones interbedded with shales. Darker, gray shales contain limestone concretions with marine fossils. Other more brownish colored shales, however, predominate. These shales contain abundant ironstone concretions and are frequently interbedded with sandstones and carbonaceous shales. Brackish-water fossils are common in these shales and sandstones.

Rocks of the Medicine Bow Formation are described as sandstones and carbonaceous shales (Dobbin and others, 1929). The lower portion of the formation, where most of the coals occur, is principally comprised of massive, cross-bedded brown sandstones. Above this basal sandstone and coal sequence are interbedded fine grained sandstones and dark shales. Dobbin and others (1929) report coarser sandstones at the top of the formation interbedded with thick, dark gray shale units, Both fresh- and brackish-water fossils are found in the Medicine Bow Formation.

Rocks associated with the Ferris and Hanna formation coals are perhaps the most variable in the coal field. Massive, cross-bedded, sometimes conglomeratic sandstone units are interpreted as fluvial in origin, deposited by meandering or braided streams. These units are lenticular in cross section and linear or sinuous in plan view. Although they frequently crop out as impressive cliffs, in reality they are not the dominant lithology of the coal-bearing rocks. By far, the finer grained siltstones, claystones, and shales predominate. These fine grained rocks are variously interpreted as overbank deposits laid down during flooding of the major fluvial channels or lacustrine in origin, indicating the existence of fresh-water lakes or ponds. Plant remains, fresh-water invertebrates, and rare vertebrate remains are the only fossils identified in these coal-bearing rocks.

Commonly, very dirty coals or

Figure 10. Cut-bank side of ancient river channel, now filled with sandstone (note abrupt erosional contact of channel at center of picture).

interbedded coal and shale units overlie some of the coals. These units, variously called coaly shale or carbonaceous shales, are extremely high in ash (greater than 30%) and not coals in a strict sense. Sometimes individual zones within these interbedded units are thick and clean enough to qualify as coal, but these zones are not persistent enough to be of much economical value in the conventional sense.

All these various lithologies may abut or grade laterally or vertically into one another over very short distances or vertical intervals. In the case of the sandstones, abrupt angular contacts with adjacent units are common (Figure 10) where sandstones now fill erosional channels cut by the major streams that flowed into the Hanna Basin from surrounding highland areas and then eastward out of the coal field (Ryan, 1977).

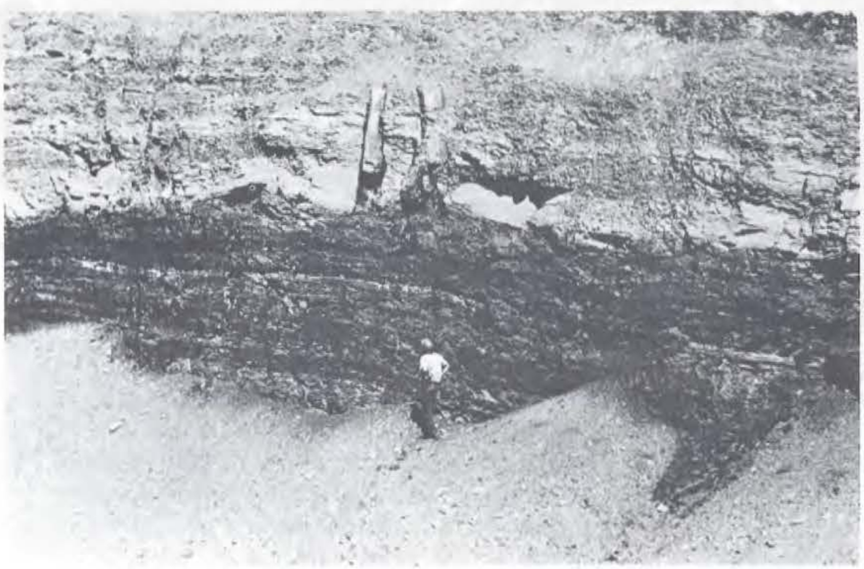


Figure 11. In situ tree trunks rooted in an interbedded coal and shale sequence overlying Bed No. 80.

The coals of the Hanna Coal Field are for the most part typical of autochthonous peat accumulations. They are generally underlain by rootworked, hackly siltstones or claystones. Soft, plastic clays, which commonly underlie Appalachian and Midcontinent coals are seldom observed, however. Upright or in situ tree trunks within the coal or rooted in the top of the coal or in shale or sandstone deposits just over the coal are particularly commonplace in the Tertiary coal deposits (Figure 11).

At least the Tertiary coals vary considerably in thickness, often quite irregularly. There is some indication that the more persistent coals may thicken toward the central areas of both the Hanna and Carbon basins, but not all coals exhibit this trend. The Tertiary coals appear to thin by one or a combination of three ways. In a few cases they are thinned by erosion resulting from nearly contemporaneous uplift. Most, however, either split into two or more benches that gradually thin or pinch out or they interfinger with other lithologies, generally dark shales. In this latter case, the coals split into numerous, gradually thinning lenses of coal separated by shaly interbeds. This change from coal to interbedded coal and shale to shale (coaly shale) is usually very gradual and occurs over distances of many hundreds of feet.

The variability of Mesaverde and Medicine Bow formation coals is not as well understood. There is some indication that these coals exhibit much smaller variations in thickness. No one has documented the manner in thich these Cretaceous coals thin, but reconnaissance work suggests that they split into benches which gradually thin or simply thin without splitting.

Hanna Formation Coal Beds

Although the 2,400 to 8,000 feet thick Hanna Formation apparently contains at least 32 coals greater than five feet thick, correlation problems could account for some duplication among the beds i.e., two names applied to the same coal in separated areas. In particular, Hanna Formation coals of the Carbon Mining District (Figure 12) have never been correlated with those in the Hanna District (Figure 13). For this reason, coals in the two districts are treated as separate beds. There is, however, some evidence that suggests there may not be any direct correlation of coals between the two basins (Ryan, 1977).

While the thicker coals of the Hanna Formation are 20-60 feet thick, most coals in this formation are much thinner, probably better characterized as 5 to 11 feet thick. At least on the basis of strippable coal resources, the weighted average thickness of Hanna Formation coals is 14.22 feet in the Hanna Mining District and 11.14 feet in the Carbon Mining District (Glass and Roberts, 1979).

Various of the Eocene and Paleocene coals of the Hanna Formation occur in three of the mining districts of the Hanna Coal Field: the Carbon, Hanna, and Seminoe districts. The stratigraphic position of fourteen mappable Hanna Formation coals in the Carbon Mining District is shown in Figure 12. This illustration uses the coal bed nomenclature of Glass (1978). Eight of these coal beds are greater than 5 feet thick although, as depicted on Figure 12, two of the coals are probably correlative with other coals in the district. The thickest coals in the district are the Johnson and Finch beds, which are up to 32.5 feet and 14.3 feet thick, respectively. A coal zone between the Johnson and Finch coal

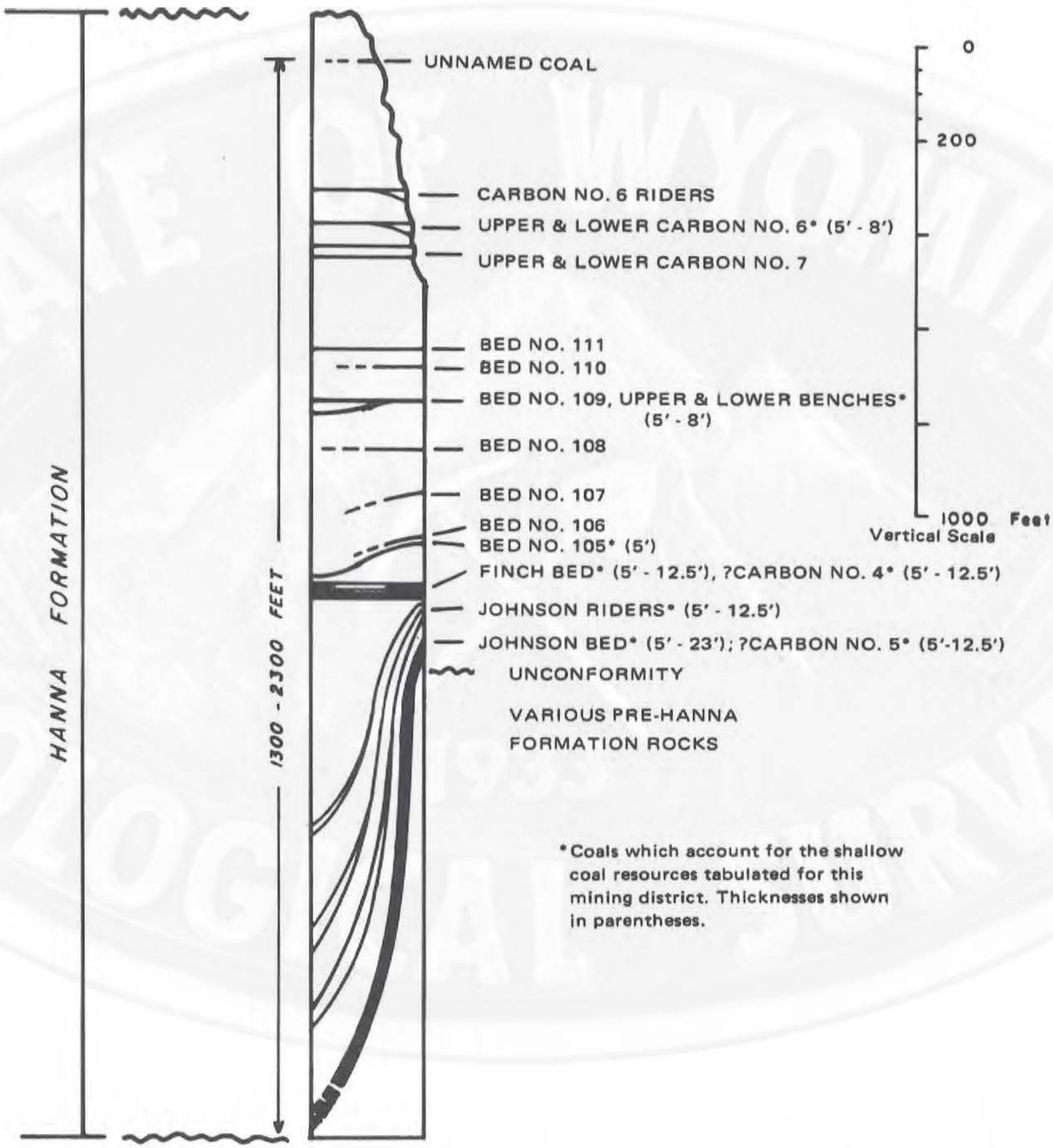


Figure 12. Coal nomenclature in the Carbon Mining District of the Hanna Coal Field.

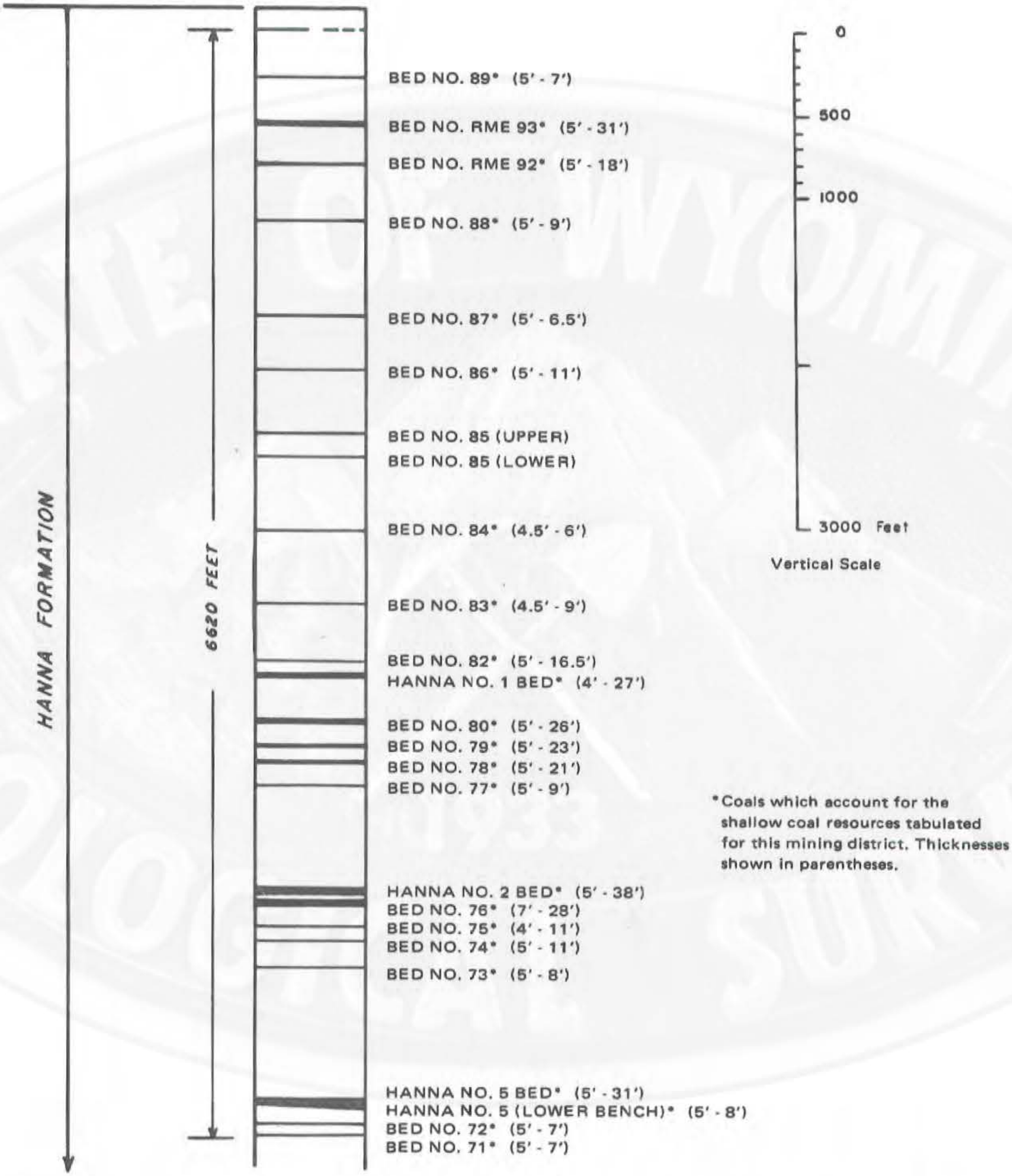


Figure 13. Coal nomenclature in the Hanna Mining District of the Hanna Coal Field.

beds, called the Johnson Rider bed, for simplicity, is locally characterized by up to 12.5 feet of coal.

Most of the Hanna Formation coals crop out in the Hanna Mining District. Twenty-three out of twenty-five persistent coals in that district at least locally equal or exceed 5 feet in thickness (Figure 13). Of these 23 coal beds, 8 exceed 20 feet in thickness (Bed No. RME 93, Hanna No. 1, Bed No. 80, Bed No. 79, Bed No. 78, Hanna No. 2, Bed No. 76, and Hanna No. 5) (Figure 14). The other coal beds are generally less than 12 feet thick. In places, the thickest coals, Bed No. RME 93, Hanna No. 2, and Hanna No. 5, all exceed 30 feet in thickness.

Although as many as five Hanna Formation coals occur in the Seminoe Mining District, only the Brooks coal bed is over five feet in thickness (Figure 15). The other four coals underlie the Brooks bed and apparently are all less than five feet thick.

Ferris Formation Coal Beds

Beneath the Hanna Formation, the upper part or Paleocene portion of the Ferris Formation contains at least 28 minable coal beds. Extensive faulting in the Seminoe Mining District, where these coals are mined, makes correlation difficult and accounts for more than one name being given to the same coal. Because of this duplication, more coals are identified than really exist. Figure 15 includes an attempt to show the approximate stratigraphic position of uncorrelated or isolated coal beds in the northwestern portion of the Seminoe Mining District. Because of these problems in correlation, there are as many as 45 coal beds mapped in the Seminoe Mining District. Correlation of Ferris coals beneath the Hanna Formation of the Hanna Mining District is not yet possible since these Ferris coals lie at great depths not yet penetrated by exploratory coal drilling.

Most minable coals in the Ferris

Figure 14. Bed No. 79 in the Seminoe No. 2 strip mine (20 feet thick).

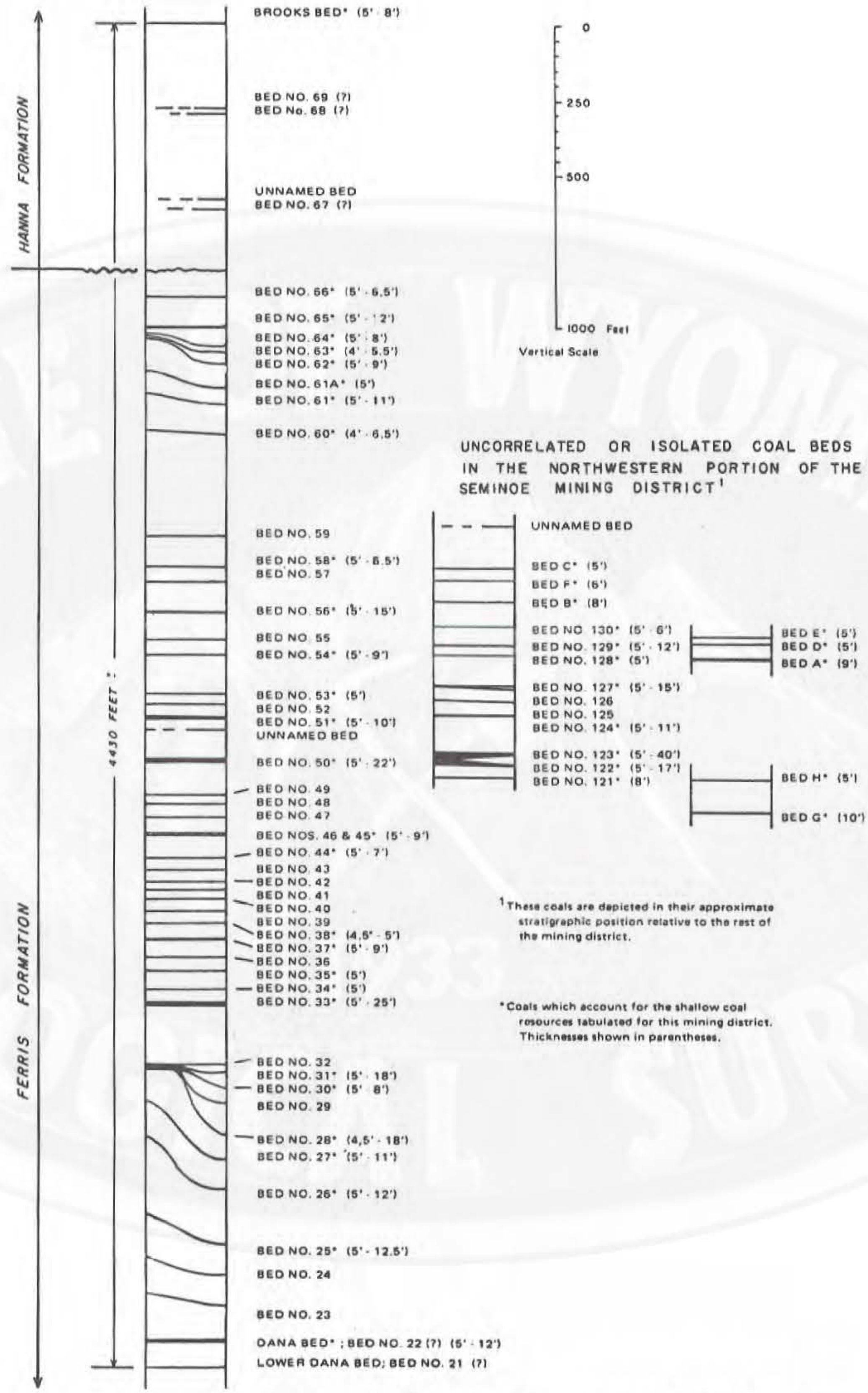


Figure 15. Coal nomenclature in the Seminoe Mining District of the Hanna Coal Field.

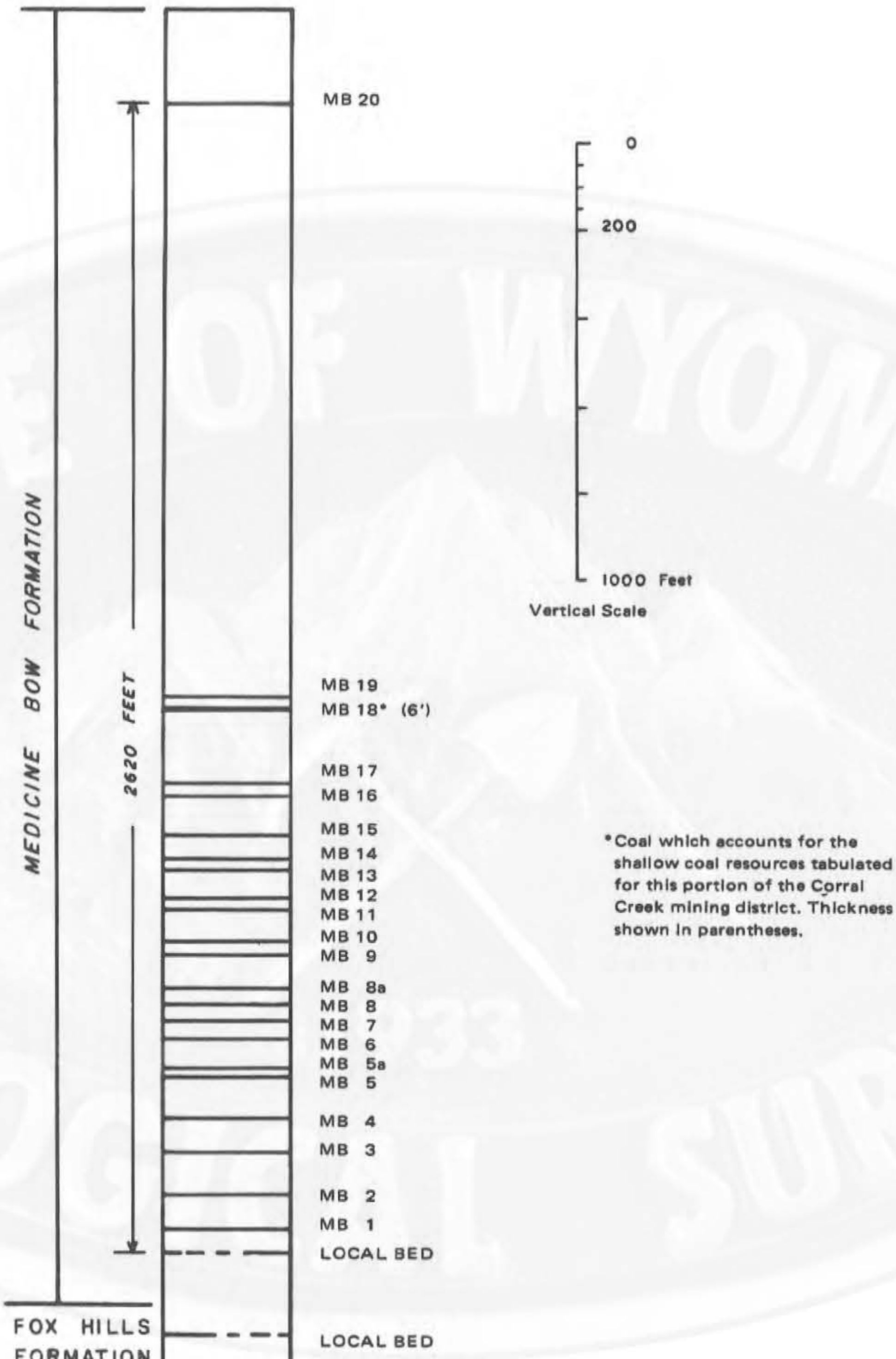


Figure 16. Coal nomenclature in the eastern portion of the Corral Creek Mining District of the Hanna Coal Field (modified from Texas Instruments, 1978p).

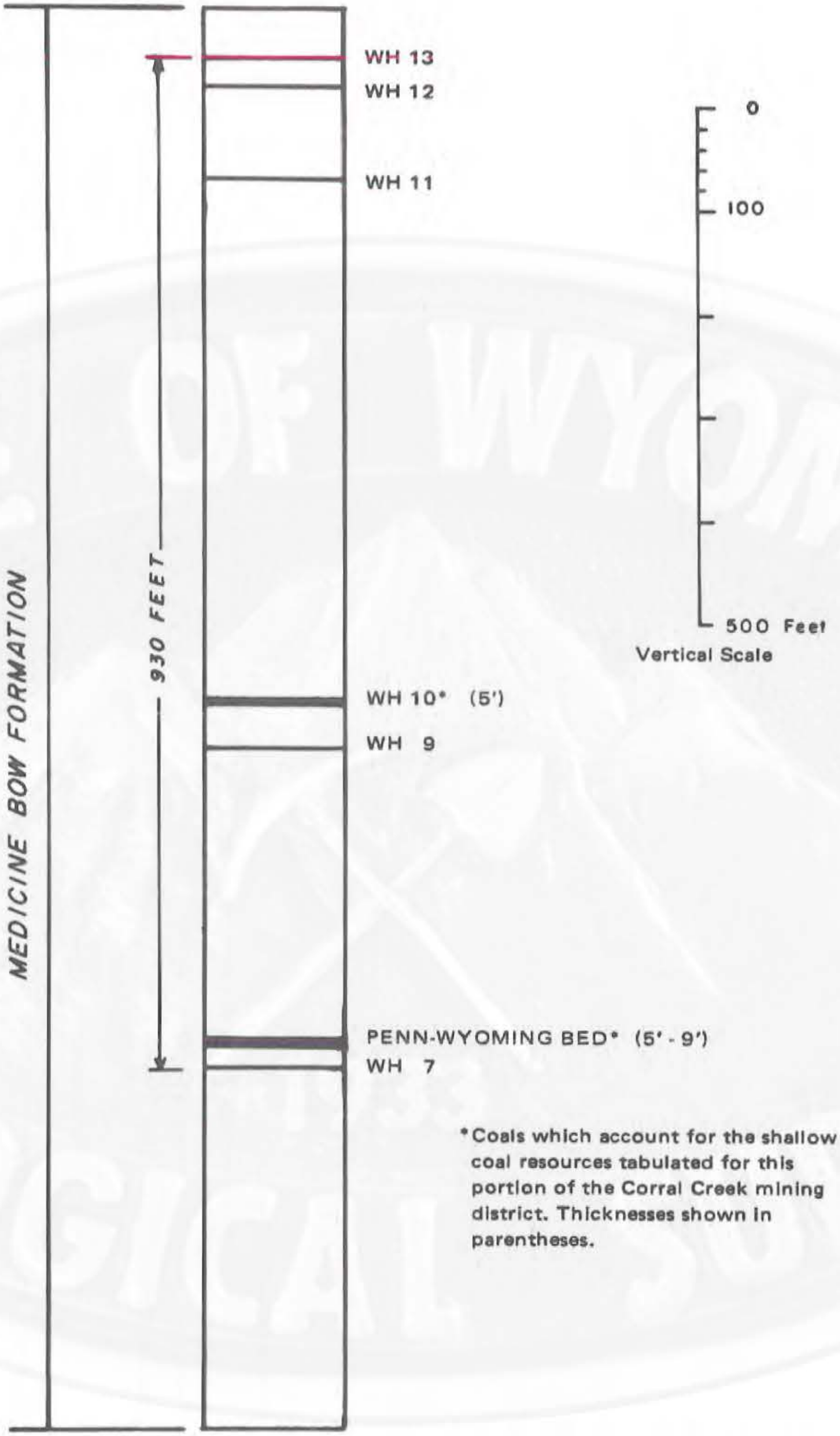


Figure 17. Coal nomenclature in the northern portion of the Corral Creek Mining District of the Hanna Coal Field (modified from Texas Instruments, 1978u).

Formation are thinner than those in the Hanna Formation. In fact, the majority of the coals in the Ferris Formation are only 5-10 feet thick. Based on strippable resources, Glass and Roberts (1979) report that the weighted average thickness of Ferris coals is 9.79 feet, compared to 11.14-14.22 feet for Hanna Formation coals. Thicker Ferris Formation coals are Bed No. 50, which is up to 22 feet thick, Bed No. 33, which is up to 25 feet thick, and Bed No. 123, which at least locally is over 40 feet thick (Blanchard and Pike, 1977). In the case of Bed No. 123, its thickest expression may coincide with an area where an underlying coal (Bed No. 122) has coalesced with it. According to a local mining company, as much as 60 feet of coal locally is found at this horizon. Other coals also coalesce and become quite thick in places. For example, Bed Nos. 28 through 32 apparently do this in the vicinity of the Seminoe No. 1 strip mine (T.22N., R.83W.)

Medicine Bow Formation Coal Beds

The next older coal-bearing unit below the Ferris Formation is the Upper Cretaceous Medicine Bow Formation (Figure 9). Persistent coals greater than five feet thick, however, are fewer in number than such coals of the Hanna and Ferris formations. Medicine Bow coal beds are usually limited to the lower 900-2,600 feet of that formation (Merewether, 1971, 1972, and 1973). Although as many as thirty Medicine Bow Formation coals are mapped in the Corral Creek Mining District, there are only three that are five feet or thicker (Figures 16 and 17). Because these coals occur in two isolated areas of the Corral Creek Mining District, correlation between the two areas is currently impossible. The thickest of the three coals is the Penn-Wyoming coal bed, which is up to nine feet thick (Figure 17). The other two coal beds are unnamed and only 5 to 6 feet thick. With one exception, the informal bed designations in Figures 16 and 17 are those of Texas Instruments (1978l and 1978u) and are not formal names. The Penn-Wyoming bed was formally given that name by Glass and Roberts (1979).

In the Corral Creek Mining District and other portions of the Hanna Coal Field, there are additional Medicine Bow Formation coals that at least locally exceed five feet in thickness. The Medicine Bow coals in these other areas, however, dip rather steeply, usually greater than 25 degrees. Little additional information is available on these more steeply dipping coal beds.

Mesaverde Group Coal Beds

The oldest coals in the Hanna Coal Field are found in the Upper Cretaceous rocks of the Mesaverde Group. Thicker, potentially minable coals, however, are only reported in the uppermost formation of that group, the Almond Formation (Gill, Merewether, and Cobban, 1970). The Almond Formation has as many as seven persistent coal beds that reach minable thickness (5 feet or greater). With the exception of the Almond coals in the Corral Creek Mining District, Almond Formation coals dip at very steep angles. In the Corral Creek Mining District, however, Almond Formation coal beds occur in two separated areas at shallow enough dips for strip mining (less than 25 degrees). In those areas, several unnamed Almond coals vary between 5-10 feet in thickness, averaging closer to 6 feet thick. Because the two

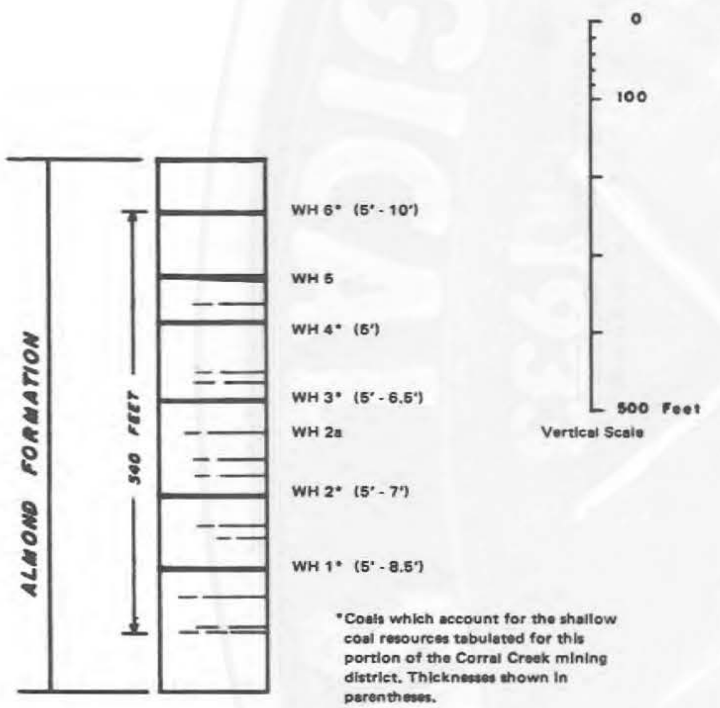


Figure 18. Coal nomenclature in the central portion of the Corral Creek Mining District of the Hanna Coal Field (modified from Texas Instruments, 1978u).

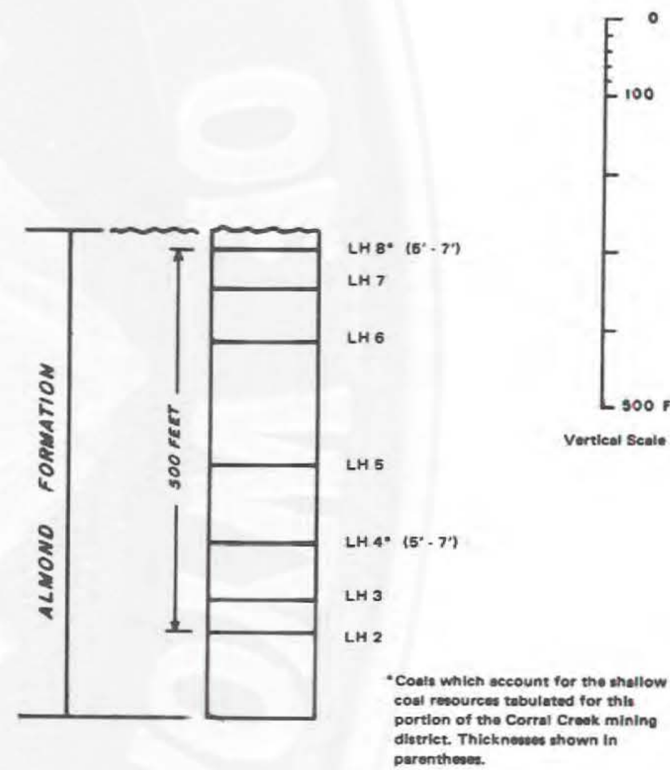


Figure 19. Coal nomenclature in the southern portion of the Corral Creek Mining District or the Hanna Coal Field (modified from Texas Instruments, 1978l).

areas are isolated from one another, correlation between them is impossible at this time. There is every likelihood, however, that some of the coal beds in these two areas are correlative with one another.

For discussion purposes, Almond Formation coals in the Corral Creek Mining District are given the informal designations shown in Figures 18 and 19. These designations are those of Texas Instruments (1978l and 1978u) and are not formal names at this time.

Like the Ferris Formation coals, coals in both the Medicine Bow and Almond formations cannot be correlated at any great depths in the Hanna Coal Field. Knowledge of the coals in these two formations is restricted to their outcrops or to very shallow drilling.

Some additional comments about the coal geology are necessary. Particularly because of extensive faulting, many coal bed correlations in other reports do not agree with recent mapping by the author (Glass and Roberts, 1979). For this reason, the coal bed nomenclature in this report does not necessarily agree with coal bed designations of some mining companies or some published reports. Every attempt, however, was made to adhere to the nomenclature set up by Dobbin, Bowen, and Hoots (1929). Pseudonymns for the various coal beds in this report are provided in Appendix A of Glass and Roberts (1979).

HISTORY OF COAL DEPOSITION

With the possible exception of all or part of the uppermost Medicine Bow Formation, Upper Cretaceous coals in the Hanna Coal Field are probably all derived from peat swamps that accumulated in close proximity to a sea some 70-130 million years ago. The coals of the Cretaceous Almond Formation, in particular, are probably the remnants of transgressive and regressive swamps that grew along the shoreline of a widespread Cretaceous seaway that periodically advanced and retreated across vast portions of Wyoming and adjacent states, including the area now occupied by the Hanna Coal Field.

The Upper Cretaceous Medicine Bow Formation was deposited during and after the final regression of the Cretaceous sea from the Western Interior. Although coals may have been paralic in origin at the base of the Medicine Bow Formation, the upper part of the Medicine Bow Formation became more continental in nature as the sea retreated beyond Wyoming's borders. The uppermost Medicine Bow Formation contains only a few coals, which are probably derived from swamps growing on a vast plain of low relief, characterized by meandering streams and even fresh-water lakes.

By Paleocene time, Wyoming was experiencing widespread erosion and orogenic activity that partitioned the state into various intermontane basins, one of which was the area now known as the Hanna Basin. The seaways of the Cretaceous were long gone and the Cretaceous rocks were being folded and faulted within the basins as mountains rose around them. Detrital Tertiary sediments were carried into the basins by rivers and deposited over these older rocks.

During this period, peat swamps frequently accumulated over large areas of the intermontane basins, including the Hanna Basin. It is these peats and their associated sediments that became the thick, Tertiary age, continental sequences of rock now called the Hanna and Ferris formations. Rocks observed in these formations indicate a depositional complex of alluvial fan and braided stream deposits, some lacustrine deposits, and flood-plain deposits (Ryan, 1977; Brooks, 1977; Glass, 1979). Although most of the Hanna and Ferris coals are apparently derived from peat swamps associated with the flood-plain deposits, others may be more closely allied with backswamps adjacent to braided streams and shorelines of fresh-water lakes.

COAL RANK, CHEMICAL COMPOSITION, PHYSICAL PROPERTIES, AND PETROGRAPHY

Rank

Based on standard calculations (ASTM, 1974), the apparent rank of the coals in the Hanna Coal Field varies from subbituminous A to high volatile C bituminous. This variation in rank, however, is not simply correlative with the age of the various coals. The Mesaverde Group coals, which are the oldest in the field, do exhibit the highest apparent ranks, high volatile C bituminous. On the other hand, published reports refer to the overlying Upper Cretaceous Medicine Bow Formation coals as subbituminous in rank (Dobbin, Bowen, and Hoots, 1929; Berryhill and others, 1950). But the limited number of analyses and the dubious quality of the coal samples that were analyzed leave even the apparent rank of the Medicine Bow Formation coals open to question. The rank of Medicine Bow coals must await adequate sampling and analysis.

Most surprisingly, recent analyses of Hanna Formation coals indicate an apparent rank of high volatile C bituminous (Glass and Roberts, 1979, Appendix A). This apparent rank contradicts the subbituminous rank reported in older publications (Dobbin, Bowen, and Hoots, 1929; Berryhill and others, 1950). In contrast, the apparent rank of Ferris Formation coals is usually subbituminous A, which is similar to that cited in the same older publications. These observations present an obvious enigma since the younger coals of the Hanna Formation are exhibiting a higher rank than older coals of the Ferris Formation.

This observation is best explained by noting the geographic location of the coal samples that were analyzed. All the analyzed samples of Ferris coals came from the Seminoe Mining District or western part of the field. All of the analyzed samples of the Hanna Formation coals came from the Hanna or Carbon mining districts in the eastern or central portions of the field. Spatial variations in rank, such as these, can be explained by variations in depth of burial or alternately by variable heat flow within the basin. In this case, variations in depth of burial are probably not the cause since some of the very shallowest coals are the highest in rank. There is no evidence to suggest that these particular coals were ever more deeply buried than older Ferris coals. More likely the variation in rank across the basin is the result of variations in heat flow within the basin. The heat flow could have been higher in the central and eastern portions of the basin or it may simply have been of longer duration. In either case, the rank of coals in all the coal-bearing formations most probably increases eastward. And indeed, the highest rank Hanna Formation coals occur in the Carbon Basin or the east side of the coal field (Figure 20).

Whatever the reasons, Hanna Formation coals in the Hanna Coal Field are best described as high volatile C bituminous in rank. Ferris Formation coals are subbituminous A in rank at least in the Seminoe Mining District. Their rank in the other mining districts is unknown since there are no analyzed samples from those areas. There is, however, no reason to suspect that the Ferris coals beneath the Hanna Mining District would not be high volatile C bituminous like the overlying Hanna Formation coals of that district.

There is also the intriguing possibility that the Medicine Bow and Mesaverde coals that underlie the central portions of the field or crop out on the eastern flanks of the field could be high volatile A or B bituminous coals. In fact, the Mesaverde coals that crop out on the flanks of the Saddleback Hills Anticline are very probably some of the highest rank coals that crop out in the field. At this time the lack of good analyses of coals east of the Carbon Basin prevents any extrapolation of rank eastward beyond that basin.

A few parting words of caution are warranted. Because of sampling methods, very few analyses from the Hanna Coal Field were collected in a manner that permits a true rank determination as prescribed by the American Society for Testing and Materials (ASTM, 1974). For this reason, the previous discussion of coal rank dealt with "apparent" coal ranks. An "apparent" coal rank,

Figure 20. Variation in apparent coal rank as indicated by moist, mineral-matter-free heat value.

Table 2. Summary table of ultimate and proximate analyses, heats of combustion, and major oxides of coal ash for coals of the Hanna Coal Field.

	Hanna Formation Hanna District		Hanna Formation Carbon District		Ferris Formation		Medicine Bow Formation		Mesaverde Formation	
	Mean	#Samples	Mean	#Samples	Mean	#Samples	Mean	#Samples	Mean	#Samples
Moisture (%)	12.76	155	10.00	50	12.58	139	13.49	29	12.07	2
Volatile Matter (%)	36.68	"	36.71	"	34.30	"	35.48	"	34.65	"
Fixed Carbon (%)	41.82	"	39.55	"	45.19	"	47.24	"	45.71	"
Ash (%)	8.75	"	13.74	"	7.93	"	3.81	"	7.57	"
Hydrogen (%)	5.70	34	4.84	14	5.31	33	5.51	7	5.45	2
Carbon (%)	60.44	"	46.84	"	59.29	"	60.55	"	52.65	"
Nitrogen (%)	1.14	"	0.97	"	1.05	"	1.52	"	1.15	"
Oxygen (%)	24.13	"	16.64	"	25.17	"	28.31	"	32.25	"
Sulfur (%)	0.76	"	2.72	"	0.49	"	0.54	"	0.50	"
Ash (%)	7.84	"	27.95	"	8.69	"	3.58	"	8.00	"
Heat Value (Btu/lb)	10,420	158	10,190	198	10,140	198	10,810	24	10,818	16
Sulfur (%)[1]	1.00	193	1.35	50	0.46	200	0:69	27	0:67	23

[1] Includes all available sulfur analyses

Table 2. Continued.

	Hanna Formation Hanna District		Hanna Formation Carbon District		Ferris Formation		Medicine Bow Formation		Mesaverde Formation	
	Mean	#Samples	Mean	#Samples	Mean	#Samples	Mean	#Samples	Mean	#Samples
Al_2O_3 (%)	16.9	33	16.5	13	16.4	40	No analyses available		23.0	3
CaO (%)	16.4	"	7.6	"	17.2	"			2.6	"
Fe_2O_3 (%)	8.9	"	14.2	"	6.5	"			4.9	"
K_2O (%)	0.8	"	1.9	"	1.0	"			0.3	"
MgO (%)	3.4	"	1.5	"	2.7	"			0.5	"
Na_2O (%)	1.0	"	0.2	"	0.4	"			0.1	"
P_2O_5 (%)	1.0	"	1.1	"	0.8	"			0.1	"
SiO_2 (%)	32.6	"	47.3	"	36.1	"			53.7	"
SO_3 (%)	13.1	"	5.5	"	10.1	"			4.2	"
TiO_2 (%)	0.8	"	0.8	"	0.6	"			0.8	"

Table 3. Concentrations of trace elements in coals of the Hanna Coal Field (in parts per million on a whole-coal basis).

Trace Element	Hanna Formation Hanna District			Hanna Formation Carbon District			Ferris Formation			Mesaverde Formation		
	Mean	Range	#Samples	Mean	Range	#Samples	Mean	Range	#Samples	Mean	Range	#Samples
Arsenic (As)	3.3L[1]	0.88 - 7.7	17	25	7 - 86	17	4.6	0.58 - 35	34	1	1	3
Boron (B)	30	10 - 100	17	30	20 - 70	18	30	10 - 76.3	34	20	10 - 50	3
Barium (Ba)	200	100 - 450	20	200	100 - 500	18	300	148.5 - 1000	36	150	70 - 300	3
Beryllium (Be)	0.3L	ND[2] - 0.5	19	1.0	ND - 1.5	18	0.5L	ND - 2.0	36	1.5	0.7 - 1.5	3
Cadmium (Cd)	0.171L	0.060 - 0.50	17	0.54L	0.15L - 1.4	18	0.176L	.08L - 0.50	35	0.30	0.12 - 0.50	3
Cerium (Ce)	10L	ND - 70	20	30	ND - 100	18	5L	ND - 52L	26	70L	50L - 100	3
Chlorine (Cl)	190L	50 - 1000	22	Not Determined			163L	10L - 800	35	Not Determined		
Cobalt (Co)	2L	0.5 - 3.53	22	3	0.5 - 10	18	1.5	0.3 - 2.72	40	5	3 - 7	3
Chromium Cr)	7	2.92 - 20	20	10	0.7 - 30	18	10	1.5 - 16.1	37	7	3 - 10	3
Copper (Cu)	10.0	2.6 - 20.1	20	29	10 - 55	18	11.6	3.3 - 41.3	37	12.4	9.3 - 16.0	3
Fluorine (F)	78	20 - 155	17	212	75 - 500	18	111L	20L - 460	34	68	60 - 80	3
Gallium (Ga)	1.5L	0.37 - 3.18	21	7	2 - 15	18	2L	0.5L - 5.97	25	3	3 - 5	3
Germanium (Ge)	0.7L	ND - 2	19	Not Determined			0.3L	ND - 2L	36	ND		3
Mercury (Hg)	0.08	0.02 - 0.15	17	0.20	0.10 - 0.36	18	0.08L	0.01L - 0.40	35	0.03	0.02 - 0.04	3
Lanthanum (La)	7	ND - 20	22	30	ND - 70	18	7L	ND - 50	39	15	15 - 20	3
Lithium (Li)	3.9	0.05 - 8.9	17	19.7	0.49 - 60	18	8.1	0.60 - 20.2	35	4.6	4.5 - 4.8	3
Manganese (Mn)	63L	11L - 165	19	192	58 - 410	18	59L	8L - 430	37	11	4.5 - 18	3
Molybdenum (Mo)	2	0.5 - 8.3	17	5	2 - 15	18	2	0.3 - 3.96	35	1.5	1 - 2	3

[1] L = less than   [2] ND - not detected

Table 3. Continued.

Trace Element	Hanna Formation Hanna District			Hanna Formation Carbon District			Ferris Formation			Mesaverde Formation		
	Mean	Range	#Samples	Mean	Range	#Samples	Mean	Range	#Samples	Mean	Range	#Samples
Niobium (Nb)	1.5L	ND - 4L	23	3	ND - 10	18	1.5L	ND - 6.1	39	3	3 - 5	3
Nickel (Ni)	7	2 - 15	20	15	7 - 70	18	5	1 - 15	36	10	7 - 10	3
Lead (Pb)	3.5L	0.04 - 12	23	11.1L	3.1 - 25	18	5.2L	1.5 - 21.5	40	8.1	5.8 - 9.3	3
Antimony (Sb)	0.6L	0.01L - 1.2	17	1.6	0.8 - 6.0	18	0.7	0.18 - 1.38	34	0.4	0.2 - 0.5	3
Scandium (Sc)	1.5	0.65 - 3	23	7	1.5 - 15	18	1.5L	0.2L - 7	38	1.5	1.5 - 2	3
Selenium (Se)	0.79	0.29 - 2.31	15	3.2	1.5 - 5.1	18	0.67L	0.01L - 1.28	34	2.6	2.4 - 2.9	3
Strontium (Sr)	150	30 - 470	20	150	30 - 500	18	150	30 - 500	36	100	20 - 200	3
Thorium (Th)	3.7	0.86 - 8.9	17	6.9	1.8 - 12.7	18	5.2L	2.0L - 15.3	33	4.1L	3L - 6.3	3
Uranium (U)	1.8	0.6 - 4.2	19	3.9	2.3 - 17	18	2.4	0.1 - 9.6	34	1.7	1.0 - 2.2	3
Vanadium (V)	15	7 - 30	20	70	10 - 150	18	20	3 - 100	37	15	7 - 15	3
Yttrium (Y)	7	2 - 15	23	20	7 - 50	18	5	1 - 20	39	15	7 - 20	3
Ytterbium (Yb)	0.5	0.11 - 1.4	22	2	1 - 5	17	0.7L	0.1 - 1.5	36	1.5	0.7 - 2	3
Zinc (Zn)	11.7	0.21 - 35.5	20	69	24 - 140	18	14.7L	0.3L - 97.2	37	22	17.4 - 30.9	3
Zirconium (Zr)	15	4.55 - 20	19	30	3 - 100	18	50	3 - 901	36	50	30 - 70	3

[1] L = less than [2] ND = not detected

however, is precise enough on a fresh coal sample to document the relative differences in rank exhibited by coals in the various formations and is probably very close to the true ASTM rank.

Another complication in any discussion of the rank of these coals, is the questionable reliability of ASTM procedures for the classification of lower rank coals. In the Hanna Coal Field, ranks based strictly on reflectance frequently do not agree with ASTM calculated ranks. It is premature to say that one of these methods of rank determination is better than the other, for indeed, neither may be wholly satisfactory for low rank coals. The resolution of this problem hopefully will come in the near future.

Chemical Composition

The older, Upper Cretaceous coals of the Hanna Coal Field now differ in quality from the younger coals partially because of their different depositional histories and partially because of their higher rank. The higher rank of the Upper Cretaceous coals accounts for their lower moisture contents and higher heat values. Dissimilar depositional histories as well as rank probably account for some differences in major, minor, and trace element concentrations between the two ages of coals. Unfortunately, there are too few major, minor, and trace element analyses of the Upper Cretaceous coals of the Hanna Coal Field on which to draw any real conclusions or comparisons.

Tables 2 and 3 summarize proximate and ultimate analyses, heat values, and concentrations of major, minor, and trace elements of coals on the basis of age and mining district. The analytical data summarized in these tables came from the Bureau of Land Management (1975), Dobbin, Bowen, and Hoots (1929), Glass (1975, 1978), Lord (1913), Texas Instruments (1978 a, c-h, j-m, o-s, u), and the U.S. Bureau of Mines (1931) as well as unpublished company records and government analyses on file at the Geological Survey of Wyoming. Glass and Roberts (1979) provide a comprehensive listing of coal analyses summarized on a bed by bed basis in Appendix A of their report.

Physical Properties

All the coals in the Hanna Coal Field are reportedly nonagglomerating and therefore exhibit no free-swelling indices. Although the specific gravity of the coals in the Hanna Field is reportedly 1.32 (1800 tons/acre foot) for the bituminous Upper Cretaceous coals and 1.30 (1770 tons/acre foot) for the younger Tertiary coals (Berryhill and others, 1950), the apparent ranks of various coals in this field suggest that these published specific gravities may be inaccurate. Company resource estimates also suggest that present information on the specific gravity of these coals warrants further investigation.

Glass (1975) summarized ash fusion temperatures for 12 Tertiary coals in the Hanna Coal Field (Table 4). From this data, no significant differences in fusion temperatures for ash of the Hanna and Ferris formation coals are evident. Data on the fusion temperature of Upper Cretaceous coal ash from the Hanna Coal Field, on the other hand, are so rare that meaningful comparisons are not possible at this time.

Coals in the Hanna Coal Field do not appreciably slake as they dry out. They are, however, highly prone to spontaneous combustion, particularly the Tertiary coals (Figure 21). This tendency to ignite apparently varies along the strike of a coal bed with some areas igniting rapidly and others rarely if ever catching fire. No sys-

Table 4. Fusibility of coal ash.

	Hanna Formation Coals[1]		Ferris Formation Coals[2]	
	Range	Average	Range	Average
Initial Deformation Temperature (°F)	2080-2230	2100	2080-2400	2190
Softening Temperature (°F)	2080-2280	2140	2120-2430	2230
Fluid Temperature (°F)	2130-2360	2200	2150-2460	2270

[1] 5 samples [2] 7 samples

Figure 21. Fires often start in the strip mines by spontaneous combustion.

tematic observations of the spontaneity of coals in this field have been made.

The Hardgrove Grindability Indices of the Tertiary coals in the Hanna Coal Field indicate that they are relatively hard to grind. Indices for these coals vary from 43 to 53, averaging 49.

Petrography

Limited petrographic analyses of coal beds from the Hanna Coal Field indicate that the vitrinite group of macerals accounts for well over 80% of the coal on a dry, mineral-matter-free volume basis. The most common macerals of the inertinite group are fusinite and semifusinite, which can account for over 9% of a coal. Sporinite is the most common exinite group maceral followed by resinite. Sclerotinite, alginite, and cutinite are generally absent. Because of the sparcity of petrographic data from the Hanna Coal Field, no firm generalizations about the petrographic composition of coals in this field are possible at this time.

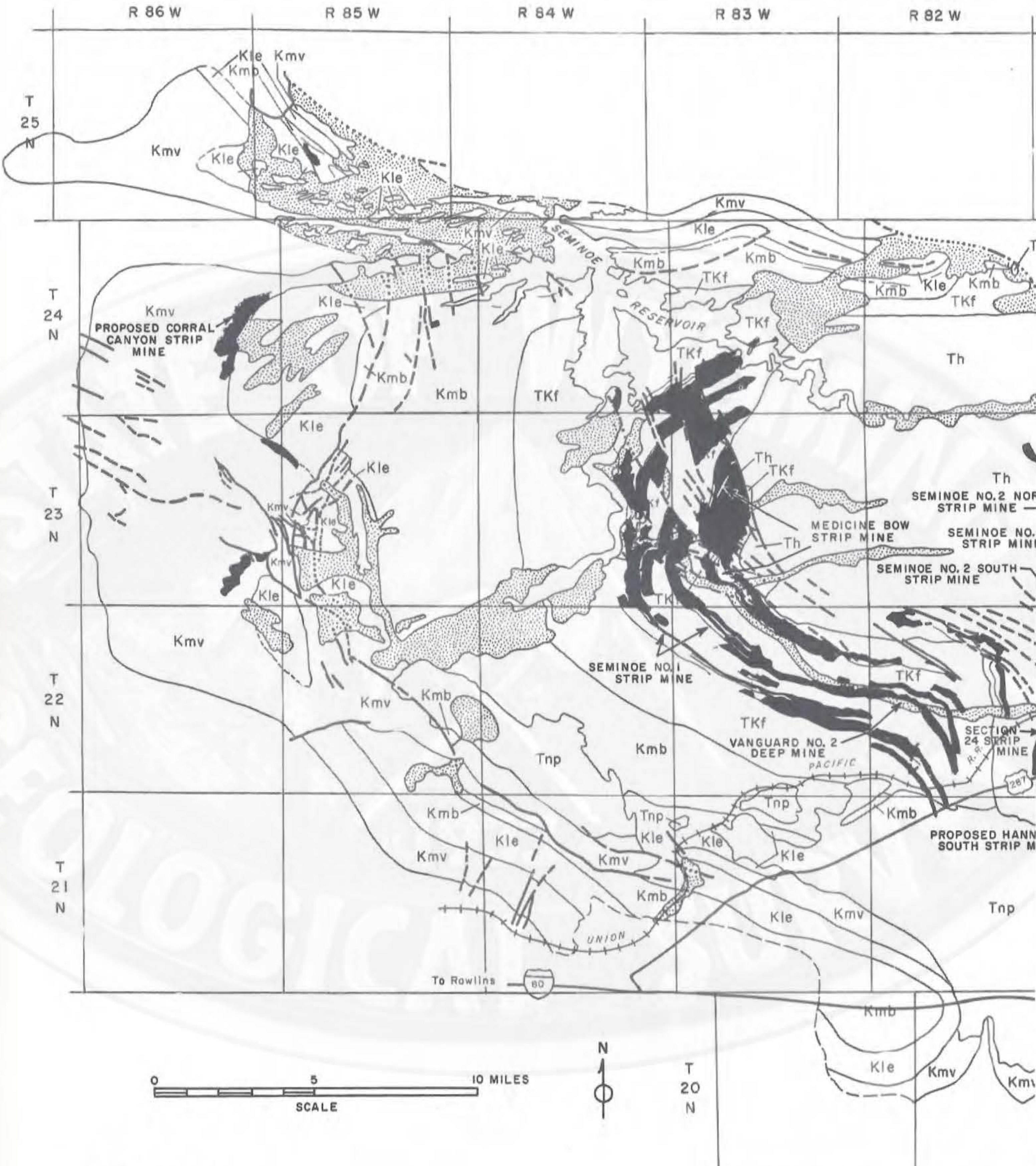
Macroscopically, the Cretaceous and Tertiary coals of the Hanna Coal Field are banded varieties with thin bands and/or thick lenses of vitrain in a bright to dull attritus. Most of the thicker vitrain lenses are obviously logs now partially compressed and coalified and still exhibiting annular rings and cellular structure. Fusain lenses and bands are also commonly visible, but seldom make up any appreciable portion of the beds. Resinite in the form of honey-yellow, amber-like spheres and globules up to ¼" in diameter also occur disseminated in the coal or concentrated in bands that may or may not coincide with bedding planes within the bed. Joints or other fractures in the coal are often cemented or filled with gypsum or calcite. The only observable pyrite in any of the Hanna Formation coals occurs as very thin films on joint surfaces.

MINING ACTIVITY

Of approximately 189.6 million tons of coal mined or lost as a result of mining in the Hanna Coal Field prior to January 1, 1979, at least 79.7 million tons were depleted by strip mining (this includes an estimated 15.5 million tons lost during mining). Another 109.9 million tons were removed or lost by underground mining.

Currently, six companies are mining in the Hanna Coal Field: Arch Mineral Corporation, Carbon County Coal Company, Energy Development Company, Medicine Bow Coal Company, Resource Exploration and Mining, Inc., and Rosebud Coal Sales Company. These companies are depleting coal reserves at the rate of 15 million tons per year (includes 20 percent mining losses for strip mining and mining losses equal to production for deep mining). Ninety-eight percent of this current production, however, is from strip mines (Figure 22). Additionally, the U.S. Department of Energy's Laramie Energy Technology Center is operating an experimental in situ

Figure 22. Arch Minerals' Seminoe No. 1 strip mine in the Ferris Formation.



COMPILED FROM:
DOBBIN AND OTHERS (1929)
LOVE AND OTHERS (1955)
BAYLEY (1968)
MEREWETHER (1971), (1972), (1973)
LOWRY AND OTHER (1973)
GLASS AND ROBERTS (1979)
HYDEN AND McANDREWS (1967)

coal gasification project just south of Hanna (Figure 23).

Edison Development, Arch Mineral, and Rocky Mountain Energy companies have proposed additional mines in the field. Even with the opening of some new mines, annual production is not expected to exceed 17 million tons per year by 1985. Coupled with mining losses, the annual depletion of coal reserves might approach 20 million tons by that same year (Table 5).

Although the older, now abandoned, underground coal mines of the early 1900's through the 1950's went to depths in excess of 1,500 feet, more recent deep mining has seldom exceeded depths of 400 feet (Figure 24). Some of the proposed or active coal mines, however, may go deeper in the future. Strip mining, on the other hand, has gone as deep as 250 feet after a 30 feet thick coal although the average highwall is probably closer to 120 feet high. A highwall 300 feet high has already been proposed where a coal exceeds 50 feet in thickness. Current mining ratios for strip mines in the Hanna Coal Field, which have been as high as 28:1, average less than 15:1.

COAL RESOURCES AND RESERVE BASE

Dobbin, Bowen, and Hoots (1929) were the first to report detailed information on the coal resources of the Hanna Coal Field. They estimated that the field contained 4.2 billion tons of coal at depths up to 3,000 feet and that perhaps another 4 billion tons occurred at greater depths. Their estimates, however, provided no breakdown by coal thickness or reliability. In particular, they made no attempt to break their estimates down any further than 3,000 feet of cover.

Twenty-two years later, Berryhill and others (1950) reexamined the coal resources of the Hanna Coal Field, relying heavily on the earlier report by Dobbin, Bowen,

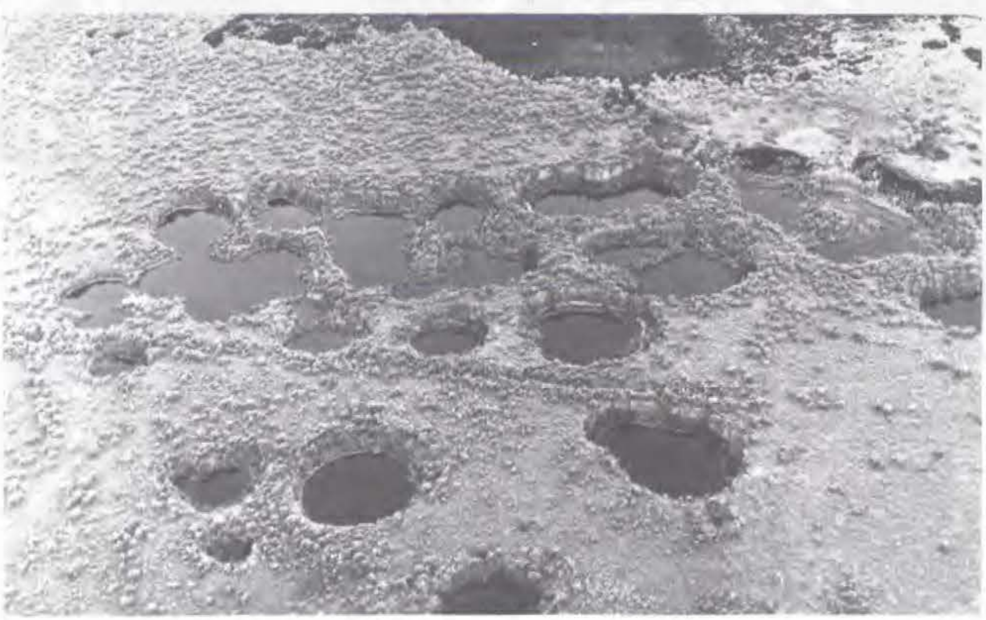
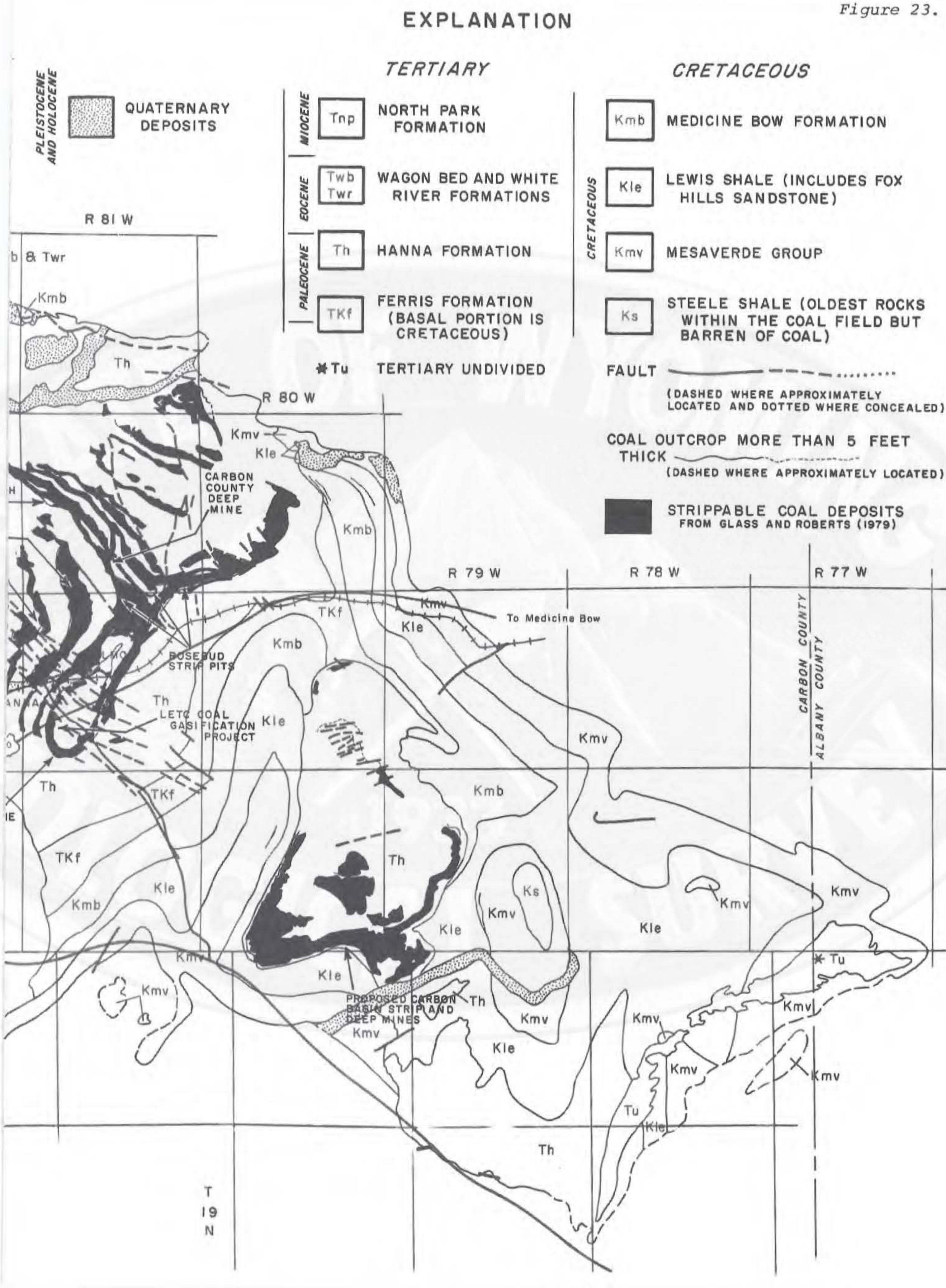


Figure 24. Mine subsidence often provides stark evidence of underground mining (abandoned Hanna No. 3 mine area in Big Ditch).

Figure 23.



EXPLANATION
TERTIARY
CRETACEOUS
PLEISTOCENE AND HOLOCENE
QUATERNARY DEPOSITS
MIOCENE
Tnp
NORTH PARK FORMATION
EOCENE
Twb Twr
WAGON BED AND WHITE RIVER FORMATIONS
PALEOCENE
Th
HANNA FORMATION
TKf
FERRIS FORMATION (BASAL PORTION IS CRETACEOUS)
*Tu
TERTIARY UNDIVIDED
Kmb
MEDICINE BOW FORMATION
CRETACEOUS
Kle
LEWIS SHALE (INCLUDES FOX HILLS SANDSTONE)
Kmv
MESAVERDE GROUP
Ks
STEELE SHALE (OLDEST ROCKS WITHIN THE COAL FIELD BUT BARREN OF COAL)
FAULT
(DASHED WHERE APPROXIMATELY LOCATED AND DOTTED WHERE CONCEALED)
COAL OUTCROP MORE THAN 5 FEET THICK
(DASHED WHERE APPROXIMATELY LOCATED)
STRIPPABLE COAL DEPOSITS FROM GLASS AND ROBERTS (1979)
R 81 W
R 80 W
R 79 W
R 78 W
R 77 W
& Twr
CARBON COUNTY DEEP MINE
ROSEBUD STRIP PITS
LETC COAL GASIFICATION PROJECT
To Medicine Bow
CARBON COUNTY
ALBANY COUNTY
PROPOSED CARBON BASIN STRIP AND DEEP MINES
T 19 N

Figure 23. Strippable coal deposits and mining activity in the Hanna Coal Field.

Table 5. *Current and proposed coal mining activities in the Hanna Coal Field.*

COMPANY NAME	MINE NAME	MINE TYPE	MINING DISTRICT	PRODUCTION 1978, [1,2]	DESIGN CAPACITY[2]	ESTIMATED 1985 PRODUCTION [2]	MINED COAL BEDS
Arch Mineral Corp.	Seminoe No. 1	Strip	Seminoe	2.50	3.0	3.0	65, 64*, 53*, 52, 51, 50* 37, 35*, 34, 33, 31, 30, 28, 26, 25, Dana*
Arch Mineral Corp.	Seminoe No. 2	Strip	Hanna	2.83	3.0	3.0	83*, 82*, 80*, 79, Hanna No. 2, 76, 75, 74, Hanna No. 5, 72*
Arch Mineral Corp.	Hanna South	Strip	Hanna	Proposed	0.8	0.8	Hanna No. 1*, 80*, 79?*, 78*, 77*
Carbon County Coal Co.	Carbon County	Deep	Hanna	Opened 1979	1.5	0.8	82*, 80*, 79*, Hanna No. 2*
Department of Energy, Laramie Energy Technology Center	Hanna In Situ Gasification Project	-	Hanna	-	-	-	Hanna No. 1
Edison Development Co.	Carbon Basin	Strip and Deep	Carbon	Proposed	5.0	2.0	Finch*, Johnson Rider*, Johnson*
Energy Development Co.	Vanguard No. 2	Deep	Seminoe	0.41	1.0	0.5	50
Medicine Bow Coal Co.	Medicine Bow	Strip	Seminoe	3.13	3.0	3.0	65, 64, 63, 62, 61, 60, C*, F*, 129*, 127*, 124*, 51*, 123*, 122*, 46*, 44*, 34*, 33*, 31*, 25*
Resource Exploration and Mining, Inc.	Section 24 Pit	Strip	Seminoe	0.80	0.70	0.7	Hanna No. 5, ?50*
Rocky Mountain Energy Co.	Corral Canyon	Strip	Corral Creek	Proposed	?0.5	0.5	?(WH6*, WH4*, WH3*, WH2*, WH1*)
Rosebud Coal Sales Co.	Rosebud Pit Nos. 4, 5, 6, 7, 8, 9	Strip	Hanna	2.92	2.5	2.5	83*, 82, 80, 79
			TOTALS	12.59	21.0	16.8	

[1] Preliminary figures from the Wyoming State Inspector of Mines [2] Millions of tons * Coals that will be mined

and Hoots (1929). In this case, however, they tabulate original resources on the bases of coal thickness, various depths of cover up to 3,000 feet, and various reliability categories. Their grand total was 3.9 billion tons or slightly less than the earlier estimate.

With the growing dominance of strip mining, the demand for estimates of shallow (0-200 feet) resources grew. In 1971, the U.S. Bureau of Mines made the first estimate of "strippable coal reserves" in the Hanna Coal Field (U.S. Bureau of Mines, 1971). From a study of eight coal beds of the Hanna Formation, they identified 10 million tons of strippable resources. Applying an 80 percent recovery factor, they reported that eight million tons of that resource were strippable reserves. The estimate was so conservative that it provided no insight into the total strippable coal resources of the field.

Glass (1972b) made a second approximation of the strippable coal resources of the coal field. That estimate, however, was derived from a simple manipulation of the earlier resource figures provided by Berryhill and others (1950). Glass (1972b) estimated that strippable resources were equal to two-tenths of the remaining original resources for bituminous coals over 42 inches thick and under less than 1,000 feet of cover plus two-tenths of the resources for subbituminous coals over five feet thick and under less than 1,000 of cover. This crude approximation suggested that there were 312.98 million tons of strippable resources in the Hanna Coal Field. Since resource reliability categories were ignored, Glass' (1972b) estimate was at best a strippable coal resource rather than strippable reserve base.

In 1975, a U.S. Department of Interior study near Seminoe Reservoir in the Seminoe Mining District identified 41.21 million tons of "strippable resources" in a 9.6 square mile area (Bureau of Land Management, 1975). All these resources were between 0 and 200 feet of cover. The report did not identify the individual coal beds or the number of coal beds included in the study, but they were all Ferris Formation coals. For comparison, Glass and Roberts (1979) show 173.01 million tons of strippable resources underlying the townships included in the Department of Interior study. It must be remembered, however, that the earlier estimate only applied to a 9.6 square mile portion of the four townships.

A series of U.S. Geological Survey open-file reports, prepared by Texas Instruments, might have provided the most recent estimates of coal resources in the Hanna Coal Field, but contract requirements forbade calculation of any resources or reserves for any lands other than unleased Federal mineral lands (Texas Instruments, 1978 a-u). Because of this stipulation, and numerous other stipulations, the resource and reserve estimates in these open-file reports provide little insight into the total coal resources of the Hanna Coal Field.

Glass and Roberts (1979) provide the most recent and most comprehensive coal resource estimate for the Hanna Coal Field, but they only estimated strippable resources and reserve base. As of January 1, 1978, they estimated that 674.31 million tons of strippable coal resources remained in the Hanna Coal Field in southcentral Wyoming (Table 6). Of these strippable resources, 46 percent or 309.97 million tons lie between 0 and 100 feet of cover while the other 54 percent or 364.34 million tons

Table 6. Remaining strippable coal resources and strippable reserve base of the Hanna Coal Field by mining district, January 1, 1978 (all figures in millions of tons).

MINING DISTRICT	MEASURED RESERVE BASE Overburden thickness (feet):			INDICATED RESERVE BASE Overburden thickness (feet):			TOTAL RESERVE BASE Overburden thickness (feet):			INFERRED RESOURCES Overburden thickness (feet):			GRAND TOTAL Overburden thickness (feet):		
	0-100	100-200	0-200	0-100	100-200	0-200	0-100	100-200	0-200	0-100	100-200	0-200	0-100	100-200	0-200
CARBON MINING DISTRICT (11.14 feet)[1]	29.05	20.53	49.58	13.60	55.68	69.28	42.65	76.21	118.86	0.35	2.34	2.69	43.00	78.55	121.55
HANNA MINING DISTRICT (14.22 feet)[1]	86.18	85.67	171.85	43.87	58.16	102.03	130.05	143.83	273.88	2.44	2.36	4.80	132.49	146.19	278.68
SEMINOE MINING DISTRICT (9.79 feet)[1]	76.15	64.94	141.09	38.25	59.13	97.38	114.40	124.07	238.47	10.06	8.47	18.53	124.46	132.54	257.00
CORRAL CREEK MINING DISTRICT (5.9 feet)[1]	7.44	4.51	11.95	2.58	2.55	5.13	10.02	7.06	17.08	--	--	--	10.02	7.06	17.08
GRAND TOTAL FOR ALL MINING DISTRICTS (11.77 feet)[1]	198.82	175.65	374.47	98.30	175.52	273.82	297.12	351.17	648.29	12.85	13.17	26.02	309.97	364.34	674.31

[1] (Weighted average thickness of coal)

lie between 100 and 200 feet of cover. Table 6 shows that most of these remaining strippable coal resources (79%) occur in the Hanna and Seminoe mining districts. These strippable resources include 26.02 million tons of coal in an inferred category of reliability, which is usually not considered part of the strippable reserve base (U.S. Bureau of Mines and U.S. Geological Survey, 1976).

For this reason, the remaining strippable reserve base or that part of the strippable resources from which strippable reserves are derived is reduced to 648.29 million tons (96 percent of the strippable resources). Forty-six percent or 297.12 million tons of the reserve base occur under less than 100 feet of cover while the remaining 351.17 million tons occur under thicker cover (100-200 feet thick).

Although strippable reserves *per se* (recoverable reserves) were not estimated, a fair approximation is that strippable reserves equal at least 80 percent of the reserve base between 0 and 100 feet deep or 237.7 million tons. Although some percentage of the reserve base between 100 and 200 feet deep is also recoverable, the percentage is harder to estimate. Applying the same rule of thumb that strippable reserves may equal 30 percent of that tonnage as well, another 280.94 million tons of reserves are identified for a total of 518.64 million tons of strippable reserves in the Hanna Coal Field.

A more conservative appraisal of strippable reserves in the 100-200 feet depth range is half the reserve base or 175.59 million tons, thus reducing the remaining reserves to 413.29 million tons. Unfortunately, accurate estimation of strippable reserves is highly subjective since it is based on criteria that vary from mining company to mining company.

Glass and Roberts (1979) also point out that a portion of the inferred strippable resources will also become part of the reserve base as drilling and mapping substantiate its existence. Again, the percentage of the inferred resources that will ultimately become strippable reserve base is speculative at this time.

It is also noteworthy that although the four mining districts in Figure 2 contain all the known strippable coal resources of the Hanna Coal Field that dip at 25 degrees or less, they also contain some coals that dip more steeply. Coals outside the four mining districts are either too thin to mine or dip more than 25 degrees.

Choate and Lent (1977) estimate that the steeply dipping coals of the Hanna Coal Field account for 240 million tons of coal. Their steeply dipping resource includes coals between 5 and 30 feet thick with dips in excess of 20 degrees. This estimate, however, is nothing but an approximation derived from the resource estimates of Berryhill and others (1950). The estimate is apparently no more than a percentage of the total coal resources weighted to the areal extent of steeply dipping coals in the coal field. Choate and Lent (1977) also provide no depth cutoff for their estimated resource.

Significant underground coal resources also underlie all four mining districts as well as some other areas of the coal field. As of January 1, 1979, the remaining underground reserve base for the Hanna Coal Field conservatively approximates 768 million tons. This estimate was derived from Berryhill and others (1950) using the following procedure. The identified coal resources under less than 1,000 feet of cover were calculated by adding Berryhill and others' (1950) estimates of the measured and indicated bituminous coal resources for coals greater than 42 inches thick to the measured and indicated resources for subbituminous coals greater than 5 feet thick in the 0-1,000 feet of cover category. The cumulative production and mining losses for the Hanna Coal Field were then subtracted from this total to get the remaining reserve base between 0 and 1,000 feet of cover. From this, the remaining strippable reserve base of Glass and Roberts (1979) was subtracted, leaving a remaining underground reserve base of 768 million tons. Obviously, this simplistic approach only provides a rough approximation of the underground reserve base.

Because this estimated underground reserve base, which only refers to coals between 200 and 1,000 feet deep, is not much larger than the remaining strippable reserve base of 633.67 million tons, which only includes coals less than 200 feet deep, there is a very good chance that the preceding estimate of underground reserve base could easily be 3 to 4 times too small. Only a more conventional reserve estimation, however, will improve on the earlier methodology or prove that the previous estimate was inaccurate.

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