INTRODUCTION

Four quadrangles—from west to east, Pleasantdale, Scaper Reservoir, The Gap SW, and Saddle Horse Butte (formerly Kicken Creek)—have been mapped by the U.S. Geological Survey as part of a project to classify and evaluate Federal lands withdrawn for coal along the eastern edge of the Powder River Basin in Campbell County, Wyo. For convenience, the area is referred to herein as the Caballo Creek area. The text, tables 1–4, and figure 1 apply to the entire Caballo Creek area and are identical for all four maps.

Rocks exposed in the Caballo Creek area are the Fort Union Formation of Paleocene age and the Wasatch Formation of Eocene age. Quaternary deposits are terrace gravel of Pleistocene(?) age, and alluvium, landslide, and lag deposits of Holocene age.

FORT UNION FORMATION

About 400 feet (122 m) of the Fort Union Formation is exposed in the escarpment and the surrounding lowlands in the Saddle Horse Butte quadrangle. The escarpment is capped by rock baked and fused by the burning of the Wyodak coal and a badlands topography has developed on the underlying nonresistant Fort Union Formation. The total thickness of the formation is about 2,100 feet (640 m) in the Saddle Horse Butte quadrangle, but the thickness increases westward to about 2,700 feet (823 m) in the Pleasantdale quadrangle. Greater thickening of the Fort Union Formation occurs farther west toward the basin center where the formation reaches a maximum thickness of 5,215 feet (1,590 m) (Curry, 1971, p. 52–56).

Exposed rocks of the Fort Union Formation lack lithologically distinct units and, consequently, the formation was not subdivided. The only bed sufficiently distinct and continuous to serve as a marker is the Wyodak coal bed, the top of which is the top of the formation. Exposed rocks below this coal bed are characterized by their light color, fine-grain size, and poor consolidation; but thin, discontinuous, dark, well-indurated interbeds and coaly carbonaceous shale zones occur. The lighter colored rocks, which range from claystone through siltstone to fine-grained sandstone, are soft and poorly exposed. The dark, well-indurated beds consist of siltstone, fine- to medium-grained sandstone, and zones of discontinuous ironstone concretions. The concretions weather reddish brown and contain fractures commonly filled with yellow calcite. The numerous coaly or carbonaceous zones are generally thin and poorly exposed; an exception is the W_3 group of coal beds, which is a subzone of the Wyodak coal bed. This subzone reaches a thickness of about 45 feet (13.7 m). The principal lithology is dark-gray carbonaceous shale, but several coal beds commonly occur in the subzone.

The lack of lithologically distinct marker beds or stratigraphic intervals makes correlation difficult. The weak induration of the lighter colored rocks results in poor exposures. The poor exposures, together with numerous facies changes, present great difficulty in attempting to correlate the light-colored rocks over any distance. Similar problems occur in correlating the thinner, coaly, carbonaceous shale beds although the W_3 coal subzone can be traced throughout its outcrop area in the Saddle Horse Butte quadrangle with some certainty. The well-indurated siltstone and sandstone are easier to trace, but their use as marker beds is limited owing to variations in the degree of induration of a particular bed. Furthermore, several such beds, each varying in degree of induration along the outcrop, may occur within a thin stratigraphic interval.

Early workers in the Powder River Basin (Dobbin and Barnett, 1928), whose work preceded acceptance of the Paleocene Series by the U.S. Geological Survey, assigned the Fort Union Formation to the Eocene. Since 1936, the formation has been considered to be Paleocene in age in this area (Olive, 1957, p. 10). Recent work by R. H. Tschudy (written commun., 1973) demonstrates that on the basis of palynology the Wyodak coal bed is of Paleocene age. Tschudy's palynological study also indicates that several hundred feet of rock above the Wyodak, but below the Felix coal bed (fig. 1), may be of Paleocene age. Additional work will be necessary to properly select the Paleocene-Eocene boundary in this area (R. H. Tschudy, written commun., 1973).

WASATCH FORMATION

The Wasatch Formation was originally recognized in the Powder River Basin by Wegemann (1917) and the name was extended into the map area by Dobbin and Barnett (1928, p. 11).

The Wasatch Formation, in the Caballo Creek area, reaches a maximum thickness of about 1,800 feet (549 m) in the Pleasantdale quadrangle. The formation varies substantially in thickness, mainly as a result of Quaternary and, possibly, late Tertiary erosion, but subsurface data also show substantial thinning eastward during deposition of both the Wasatch and Fort Union Formations. This thinning indicates that the basin center was west of the Caballo Creek area and that sediment accumulation decreased toward the eastern edge of the basin.

Rocks of the Wasatch Formation are shades of gray, yellow, and brown and it is primarily this characteristic which distinguishes the Wasatch from the underlying, lighter colored Fort Union Formation. Wasatch rocks consist mostly of yellow to yellowish-orange siltstone and sandstone, gray shale, brown carbonaceous shale, and three major coal zones (fig. 1).

Coarse-grained friable sandstone, containing pebbles of granite, chert, and quartzite as large as several centimeters in diameter, occurs in the Wasatch Formation. Sandstone that contains pebbles can be found within 40 feet (12.2 m) of the base of the formation in sec. 29 and 30, T. 48 N., R. 70 W., and secs. 18 and 19, T. 47 N., R. 70 W., in the Saddle Horse Butte quadrangle. Coarsening of sandstone, therefore, sporadically accompanies the general color change which characterizes the boundary between the Wasatch and Fort Union Formations.

An extensive colluvial cover (not shown on the maps) consists mainly of fine- to coarse-grained sand that contains pebbles of granite, chert, and quartzite that is most apparent in The Gap SW quadrangle between the Wyodak and Felix coal beds. This colluvial cover gives the impression that the underlying bedrock is sandstone of the Wasatch Formation, but the predominance of claystone in drill cuttings from USGS coal test holes in the Caballo Creek area does not support this impression.

The source of the detritus in lower Tertiary rocks in the Caballo Creek area is problematical. The total sandstone percentage of both the Wasatch and Fort Union Formations seemingly increases eastward, which suggests an eastward source, but evidence is insufficient to warrant a firm conclusion. Field observations do, however, indicate that sandstone is coarser grained in stratigraphically higher beds. This is interpreted as evidence that stratigraphically higher sandstone units extend farther basinward than lower sandstone units and suggests that the basin became more restricted as sedimentation continued.

Ironstone concretions, commonly found in the Fort Union Formation, occur in the Wasatch Formation only at some places near its base. Well-indurated strata between the Wyodak and Felix coal beds are rare and, consequently, the topography developed on these rocks is gentle. Above the Felix, well-indurated, dusty-yellow siltstone beds occur and these commonly cap generally north-trending ridges separated by shallow, gently sloping valleys.

Correlation of clastic units in both the Wasatch and Fort Union Formations is hampered by similar problems. Exposures are poor; the rocks are commonly poorly indurated and covered by colluvium. Beds that are well indurated and, therefore, tend to cap ridges vary in degree of induration along the outcrop and, as with other clastic rocks in the Caballo Creek area, commonly change facies.

The coal beds tend to be laterally persistent and provide good marker beds. Exposures of the coal beds are generally poor, but there are sufficient outcrops and drilling data to correlate these beds throughout most of the Caballo Creek area.

The base of the Wasatch Formation is here chosen at the top of the Wyodak coal bed following the precedent set by Dobbin and Barnett (1928, p. 14–15), who called this coal bed D. Although this choice of contact is arbitrary, it is a mappable horizon near a general lithologic change and, furthermore, there is no compelling reason not to follow the precedent set by Dobbin and Barnett (1928). In the Caballo Creek area, the contact here chosen lies near a change in heavy-mineral suites (N. M. Denson, written commun., 1974). This change may indicate a significant event in the geologic history of the area (Denson and Chisholm, 1971, p. C123–C124). Where the Wyodak coal bed splits, the top of the uppermost mappable split is chosen as the base of the formation and, where burned, the base of the baked and fused rock is arbitrarily picked as the contact. The Wyodak coal bed, as well as the uppermost mappable split, the W_2 coal subzone in the Saddle Horse Butte quadrangle, is locally absent and there the contact is inferred to be at the stratigraphic horizon of the missing coal bed.

The top of the Wasatch Formation is not exposed in the Caballo Creek area. Lag deposits of the overlying White River Formation occur, but the underlying Wasatch Formation has been partially eroded.

WHITE RIVER FORMATION

The White River Formation of Oligocene age at one time extended over at least part of the Caballo Creek area. Sandstone blocks, tentatively identified as remnants of the White River Formation on the basis of comparisons with Oligocene sandstone in the Pumpkin Buttes area (E. M. Schell and W. L. Rohrer, oral commun., 1973), occur as lag deposits of Holocene age in the Pleasantdale quadrangle. In some areas in the Pleasantdale quadrangle the deposits form a partial to complete surface covering that consists of medium- to coarse-grained sandstone blocks as much as 10 feet (3.0 m) in diameter. They are well indurated, crossbedded, and very dusky red due to iron staining; as indicated by cavities, they may have contained pebbles as much as 3 inches (7.6 cm) in diameter. Cobbles and pebbles of this rock also constitute a large proportion of terrace gravels.

Reconnaissance of the area between the Pleasantdale quadrangle and the Pumpkin Buttes to the south reveals several deposits similar to the sandstone block deposits. Probably the White River deposits once blanketed much of the basin, but preservation was dependent upon a high degree of induration, which occurred only locally.

TERRACE DEPOSITS

These deposits consist mostly of a thin layer of sand and gravel capping indistinct terraces and a few scattered, distinct terraces. It is commonly difficult to differentiate the indistinct terraces from lag gravels which may or may not represent former terraces. Criteria used to distinguish terrace from lag deposits included topographic expression, amount of allogenic gravels, geographic location, and distinguishable boundaries of the deposits. The terrace deposits occur only along the main drainages—the Belle Fourche River, Caballo, Horse, and Hoe Creeks, and one unnamed creek.

The deposits consist of interstitial sand and pebbles, cobbles, and locally boulders as much as 1 foot (0.3 m) in diameter of quartzite, chert, granite, and well-indurated sandstone. Thicknesses may be as much as 20 feet (6.1 m) but are generally less than 5 feet (1.5 m). Probably most of these clastics are reworked from the Wasatch and White River Formations, but some of those along the Belle Fourche River may have been derived directly from the Bighorn Mountains when the ancestral Belle Fourche had its headwaters there (Wegemann and others, 1928, p. 3).

Dobbin and Barnett (1928, p. 11) recognized similar deposits and, on the basis of topographic position, regarded the highest ones as doubtfully of Tertiary age. In this report all these deposits are considered to be of Quaternary age. Although downcutting was probably continuous throughout the Quaternary, the terraces represent a period of greater stream capacity than today and are, therefore, assigned a Pleistocene(?) age.

LANDSLIDE DEPOSITS

Most of the mappable landslide deposits are slump blocks. Typically, a clinker, or a well-indurated siltstone or sandstone, forms a highly resistant caprock over soft sediments; consequently, undercutting and slumping have occurred. A rockfall is present in sec. 32, T. 48 N., R. 70 W., in the Saddle Horse Butte quadrangle.

ALLUVIUM AND COLLUVIUM

Alluvium, which occurs along the major drainages, is most readily distinguished from the more extensive colluvium by use of color aerial photographs. Sediment color, stream meander belts, and vegetation patterns serve as criteria in distinguishing between the two. The alluvium consists primarily of clay, silt, and fine sand. Pebbles and cobbles occur, but except during flash floods and possibly spring runoff, it is doubtful that any streams in the area can transport coarse detritus. The colluvium, derived from creep, sheetwash, and related processes, covers a major part of the area.

STRUCTURE

Tertiary beds in the Caballo Creek area have a westward regional dip of about 1°–3°. Subsurface information and field observations reveal numerous anticlines and synclines. For the most part, these folds are very small and probably originated from primary dip, differential compaction, mass wasting, and the burning of underlying coal beds. One fold—in T. 47 N., R. 74 W., in the Pleasantdale quadrangle—can be inferred from surface mapping, and others, plunging west to northwest, can be identified from subsurface data. The fold observed in surface mapping is best seen west of the Caballo Creek area (Wegemann and others, 1928, p. 6). None of the folds has structural relief exceeding 100 feet (30.5 m).

A small fault zone occurs in the Saddle Horse Butte quadrangle in sec. 20, T. 47 N., R. 70 W. The fault trends about N. 45° W., and the downthrown side is to the southwest. The fault zone cannot be traced across the Belle Fourche River to the northwest and, apparently, terminates along a monocline to the southeast. About 50 feet (15.2 m) of displacement can be seen.

ECONOMIC GEOLOGY

COAL

Four zones containing coal beds more than 2.5 feet (0.8 m) thick crop out in the Caballo Creek area. Thickest and currently of most economic importance is the Wyodak coal bed, and its splits or subzones, in the Fort Union Formation. The Fort Union Formation also contains seven thick coal beds in the subsurface at depths less than 1,000 feet (305 m) and three more at greater depth. Several thin coal beds crop out but were not mapped, and several others occur locally in the subsurface. Other coal intervals are the lower, middle, and upper zones of the Wasatch Formation. The lower zone in the Wasatch contains the C, C′, and C″ coal beds in an interval usually about 200 feet (61 m) thick. The middle zone, consisting of the Felix coal bed and its splits or subzones (F_1, F_2), reaches a maximum thickness of about 100 feet (30.5 m). The A, Lower Ulm, and Scott coal beds are in the upper zone, which is generally about 150 feet (46) thick.

Names and letter designations used by previous workers have been given to those coals that crop out in the Caballo Creek area. Correlations of some coal beds from the Caballo Creek area to their suspected type areas, particularly the Spotted Horse field, are not certain; but, in the interest of conformity to common usage, some names from that area are used. Arbitrary letter designations not corresponding to those used by earlier workers are herein given to the subsurface coal beds.

The stratigraphic succession of coal beds in the area is shown in figure 1. Subsurface correlations are based on all available mechanical logs from drill holes in, or from within about a mile (1.6 km) of, the Caballo Creek area. Parts of the Saddle Horse Butte quadrangle have small oil fields with numerous, closely spaced drill holes; in those areas, only the more informative drill-hole logs were selected for use in this report.

Resource estimates made for coal beds exceeding 2.5 feet (0.8 m) in thickness are listed in table 1. Isopach maps were drawn and division into measured, indicated, and inferred categories of coal resources was made according to the method proposed by Averitt (1969, p. 25–26). The resources were further subdivided into the following thickness-of-overburden categories: 0–50, 50–100, 100–200, 200–1,000, and more than 1,000 feet (0–15.2, 15.2–30.5, 30.5–61.0, 61.0–305, and more than 305 m).

Samples of the Wyodak coal from the Amax Belle Ayr mine in sec. 34, T. 48 N., R. 71 W., were analyzed (table 2) and the results were compiled by V. E. Swanson of the U.S. Geological Survey (written commun., 1973). In addition, core samples from USGS test holes were analyzed by U.S. Geological Survey and Montana Bureau of Mines and Geology personnel (1974); these analyses are summarized in tables 3 and 4. Of the test holes drilled, no core samples were taken from hole 7313 in The Gap SW quadrangle, hole 7317 in the Pleasantdale quadrangle, and holes 7318 and 7319 in the Scaper Reservoir quadrangle.

The coal beds are the most laterally persistent strata in the Caballo Creek area, but attempts to correlate the coal beds, in some instances, are difficult. Correlation of the Wyodak coal bed and its subzones is complex and considerably more subsurface data are needed to determine their relationships. The W_3 coal subzone, for example, contains several thin coal beds whose thickness reaches a maximum of 4.2 feet (1.3 m) but commonly totals less than 2.5 feet (0.8 m). Although the W_3 subzone seems continuous and can be correlated over many miles, individual beds within it tend to be lenticular. Other workers have recognized the lenticularity of the coal beds. Wegemann, in his report on the Barber coal field (1913, p. 272), stated: "The coal beds are the most persistent strata of the formation, yet even they show considerable irregularity.*** It is not at all unusual to find that a coal bed at one point several feet in thickness dwindles to a few inches in half a mile or perhaps disappears altogether. In many places as one bed thins another bed comes in above or below it, the deposits being lenticular in form and the ends overlapping."

Thick coal beds may be more lenticular than thin beds. Drill-hole data reveal several areas of abrupt lateral thinning of the Wyodak coal bed and in some places, particularly in the Saddle Horse Butte quadrangle, more than 60 feet (18.3 m) of coal thins to 0 within a few hundred yards. (Note the apparent facies change of the Wyodak coal bed to shale in Macpet 43–14 Federal and Macpet-Stroock-Federal 21–24 drill holes in secs. 14 and 24, T. 47 N., R. 71 W., in the Saddle Horse Butte quadrangle.) These abrupt changes can also be seen in the field. For example, numerous unburned areas separate outcrops of baked and fused rock. Commonly, a black, very lignitic shale occurs at such locations (for example, on the western side of the county road in the SW¼ sec. 24, T. 47 N., R. 71 W., in the Saddle Horse Butte quadrangle) and apparently the lateral extent of the burned area is controlled in these locations by the facies change of coal to black shale. The abrupt facies changes and lithologic characteristics of the shale probably reflect the filling of contemporaneous channels, backwaters, and ponds with sediment rich in organic matter.

In my opinion, the abrupt thickness variations of the coal beds are generally not due to erosional processes after coal-bed deposition. Throughout the Caballo Creek area, bedding generally is conformable and channeling, though present, seems to be insignificant; but note the excellent example of minor channeling in a roadcut along the 4–J road (not shown on the map) in the Pleasantdale quadrangle in the NW¼ sec. 26, T. 47 N., R. 74 W., where a coarse-grained sandstone fills a channel cut into the Scott coal bed.

COAL BEDS

Subsurface coal beds. – The X, V, U, T, S, R, Q, P, N, M, their splits, and three local beds occur only in the subsurface. Figure 1 and the well-log information depicted in the coal correlations supply pertinent information concerning stratigraphic relationships, occurrence, and ranges in thickness and overburden.

Wyodak coal bed and its subzones. – The Wyodak coal bed occurs from about 135 to 415 feet (41.4 to 126 m) below the C bed. This interval, which thickens from east to west, fluctuates markedly in the Pleasantdale quadrangle. The coal ranges in thickness from 0 to about 100 feet (0 to 30.5 m), but thicknesses of 60–70 feet (18.3–21.3 m) occur consistently. Generally the Wyodak has less than 200 feet (61.0 m) of overburden, but locally it does lie at depths as great as 1,800 feet (549 m). Near its outcrop in the Saddle Horse Butte quadrangle, the Wyodak coal bed is extensively mined at the Amax Coal Co. Belle Ayr mine.

The coal bed is named for the Wyodak mine in T. 50 N., R. 71 W., and the designation has been used informally by previous workers. Dobbin and Barnett (1928, p. 14) labeled it coal bed D, but also referred to it as the Roland coal, evidently on the basis of correlations of this coal with the Roland coal of the Sheridan coal field by Stone and Lupton (1910, p. 121–122) and Davis (1912, p. 428). Subsequently, other correlations have been proposed. The local name is used in this report because correlation of the Wyodak coal bed with beds outside the Gillette area is problematical.

This coal bed crops out in the Saddle Horse Butte quadrangle, where it splits into three subzones (W_1, W_2, and W_3) and thins over most of the outcrop area. The W_1 split, the highest in a series of three sequentially numbered from top to bottom, is probably not present in the Caballo Creek area. It may be represented in places by a zone consisting principally of carbonaceous shale overlying the W_2 split. This shale zone often contains coals less than 15 inches (0.4 m) thick, but in sec. 31, T. 47 N., R. 70 W. (Saddle Horse Butte quadrangle), a 2.0-foot (0.60-m) coal occurs.

The W_2 coal is the thickest of the splits on the eastern edge of the Caballo Creek area. Available evidence indicates it to be generally 20–25 feet (6.1–7.6 m) thick, but there are few outcrops where it has not burned. In addition, the lateral limit of the W_2 clinker often marks the lateral extent of the W_2 coal along the outcrop. Unburned areas are commonly where the W_2 coal subzone undergoes a facies change to a carbonaceous shale. West of the outcrop the W_2 and W_3 splits merge and the unit is designated the Wyodak coal bed. Thus, there are few, if any, sizable areas where the W_2 split alone could be economically mined. The lowest split of the Wyodak coal in this area, the W_3 subzone, contains several coals of variable thickness.

The Wyodak coal bed splits in the Pleasantdale quadrangle and may pinch out a short distance west of the Caballo Creek area. At several places within the area the Wyodak zone cannot be positively identified, evidently because of lithologic changes. (Probably the coal grades into a shale.)

C, C′, and C″ coal beds (lower coal zone). – The next coal zone beneath the Felix coal bed contains the C, C′, and C″ coal bed which were collectively named bed C by Dobbin and Barnett (1928, p. 15), who stated: "Bed C as mapped probably consists of a zone of coal lenses***. [It] is replaced by shale within short distances." Three coal beds of economic value are herein identified. One, the C coal bed, is known only through subsurface data. The other two, the C′ and C″, crop out in The Gap SW quadrangle. These coal beds do, indeed, tend to pinch out abruptly along the outcrop, but this may be related to proximity to the eastern edge of their depositional areas where splitting and pinching out are likely.

The C coal bed, lowest and potentially most valuable of the coal beds in this zone, occurs 60–160 feet (18.3–48.8 m) below the C′ bed. Generally, the interval between the C and C′ coal beds thins from west to east. The C coal bed does not crop out in this area. Data from U.S. Geological Survey coal test holes 7311–7313 are interpreted to indicate that the coal changes to carbonaceous shale in the subsurface of The Gap SW quadrangle. From that area, where the coal bed is absent, the coal thickens gradually westward across Rs. 72 and 73 W., and then thickens abruptly in the western part of the Pleasantdale quadrangle. Its maximum thickness in these four quadrangles is 42 feet (12.8 m); subsurface data (logs from Davis Oil-Chorney-Federal No. 1, sec. 12, T. 47 N., R. 75 W., and Superior Oil-Cook-Government No. 14–13, sec. 13, T. 47 N., R. 75 W.) show it to be about 75 feet (22.9 m) thick a short distance west of the area. Overburden ranges in thickness from about 100 to 1,350 feet (30.5 to 411 m); but the coal is thinnest at the shallow depths.

The C′ coal bed, generally about 80 to 90 feet (24.4 to 27.4 m) below the C″, ranges in thickness from 0 to 14 feet (0 to 4.3 m) and seems laterally persistent in the Scaper Reservoir and Pleasantdale quadrangles. Its thickness is commonly 6 to 10 feet (1.8 to 3.0 m), and overburden thickness ranges from 0 to about 1,200 feet (0 to 366 m). Stone and Lupton (1910, p. 14) mistakenly identified this bed as the Felix coal bed where it crops out along Caballo Creek.

The C″ bed, stratigraphically highest of the three, occurs about 100 to 350 feet (30.5 to 107 m) below the Felix. Eastward thinning of this interval corresponds to the general trend. The C″ bed is commonly about 3 feet (0.9) thick and ranges in thickness from 0 to 6 feet (0 to 1.8 m). Although it is apparently missing over large areas, exposures are poor in The Gap SW quadrangle, and the C″ coal bed may extend over a larger area than outcrops indicate. Furthermore, in U.S. Geological Survey coal test hole 7312, 3 feet (0.9 m) of the C″ coal bed was recovered by coring, but there is no indication of this coal bed on the gamma-ray log. Perhaps the coal occurs in other areas even though logs do not so indicate. In areas where logs do indicate the coal to be present, it lies at depths as great as 1,150 feet (351 m).

Felix coal bed (middle coal zone). – This coal bed, named by Stone and Lupton (1910, p. 13), crops out in Tps. 47–48 N., Rs. 72–73 W. Clinker float indicates that it originally extended several miles to the east, but was removed by erosion in late Cenozoic time. The Felix commonly occurs in two benches separated by a parting whose thickness varies abruptly from 0 to 79 feet (0 to 24.1 m). The upper, F_1, subzone ranges in thickness from 5.5 to 12 feet (1.7 to 3.7 m), and the lower, F_2, subzone (or F where no partings are present), ranges from 15.4 to 31 feet (4.7 to 9.4 m). Most commonly, the two splits are 8–9 and 20–25 feet (2.4–2.7 and 6.1–7.6 m) thick, respectively.

Overburden increases westward from the outcrop to about 800 feet (244 m). A large part of the coal resources of the Felix bed lies within 200 feet (61.0 m) of the surface.

The interval between the Felix coal bed and the lowermost coal bed of the upper coal zone is variable and shows substantial thinning from west to east. About 600 feet (183 m) of rock separates the Felix from the Lower Ulm coal bed in T. 47 N., R. 74 W., in the Pleasantdale quadrangle, but the corresponding interval is only about 300 feet (91.4 m) thick in T. 48 N., R. 71 W., north of The Gap SW quadrangle (Galyardt, 1974). The thinning seems to reflect a general thinning of lower Tertiary rocks toward the eastern margin of the basin.

Scott coal bed (upper coal zone). – The Scott coal bed occurs 60 to 100 feet (18.3 to 30.5 m) below the Lower Ulm coal bed and crops out only along the west edge of the Pleasantdale quadrangle. The name is based upon tentative correlation with the Scott coal bed of the Spotted Horse field (Olive, 1957, p. 30). This bed is 7 feet (2.1 m) thick in U.S. Geological Survey coal test hole 7327 (Pleasantdale quadrangle), and resource values have been calculated for the immediate area surrounding this hole. The Scott is not economically significant elsewhere in this area.

Lower Ulm coal bed (upper coal zone). – The Lower Ulm coal bed occurs from 80 to 100 feet (24.4 to 30.5 m) below the A coal bed and crops out only in R. 74 W. along the west edge of the Pleasantdale quadrangle. The Lower Ulm is commonly burned along the outcrop and, where unburned, is poorly exposed. Coal-bed thicknesses average about 10 feet (3.0 m) and overburden thickness ranges from 0 to about 200 feet (0 to 61.0 m). The Lower Ulm is apparently equivalent to the Ulm 2 coal of the Spotted Horse field (Olive, 1957, p. 30).

The A coal bed (upper coal zone). – The A coal bed is stratigraphically and topographically the highest in the mapped area and was originally named by Wegemann, Howell, and Dobbin (1928, p. 8, pl. 3). This bed may correlate with the Ulm 1 coal bed of the Spotted Horse field (Olive, 1957, p. 30). It crops out in Tps. 47–48 N., R. 74 W., along the west edge of the Pleasantdale quadrangle and reaches a maximum thickness of 2 feet (0.6 m).

OIL AND GAS

In past years, oil and gas deposits have been of prime economic interest and several small fields, lying partly or entirely in the area, have been discovered. These are the Basin, Basin NW, Clabaugh, Big Hand, and Breen fields.

Stratigraphic traps are the chief accumulation sites for oil and gas in the four-quadrangle area. Except for two wells in the Breen field, which produce from the Lower Cretaceous Muddy Sandstone Member of the Thermopolis Shale, production is from the Permian and Pennsylvanian Minnelusa Formation where the overlying Permian Opeche Shale forms a barrier along an erosional unconformity (Trotter, 1963). Stratigraphic traps will probably continue to offer the most likely targets for future exploration in the extensive areas which have not been drilled.

SAND, GRAVEL, AND RIPRAP

Three primary sources of construction stone are available in this area: sandstone beds, clinker and lag deposits, and terrace deposits. Numerous friable, quartzose sandstone beds are present and offer an abundant supply of sandstone. In particular, a thick, medium- to coarse-grained sandstone occurring beneath the Felix coal is extensive, friable, and readily accessible because it crops out along Wyoming Highway 59. It is quarried in nearby areas and has much potential as a source of construction stone.

The massive development of clinker offers a great supply of gravel and riprap. Clinker is the primary source of road gravel for all-weather secondary roads. It is also used in highway paving and as ballast along the embankment of the Burlington Northern Railroad spur serving the Belle Ayr mine. Various construction crews associated with development of the mine have extensively quarried the baked and fused rock in sec. 26, T. 48 N., R. 71 W., in the Saddle Horse Butte quadrangle. Another large quarry exists in sec. 35, T. 47 N., R. 72 W., in The Gap SW quadrangle; much stone from this operation is used in highway construction and associated work. Local ranchers have developed numerous small pits for their own needs.

Some clinker is massive enough for use as riprap, and alternate sources are the lag deposits derived from weathering of the White River Formation. The limited extent of the lag deposits reduces their potential, but, nevertheless, the sandstone blocks are admirably suited for riprap. They are heavy and very well indurated, and some are as large as 10 feet (3.0 m) in diameter.

Terrace deposits are a third possible source of stone, but their general thinness and small areal extent probably limit their potential to local use. Some quarrying has evidently been done in the terrace in sec. 16, T. 47 N., R. 70 W. (Saddle Horse Butte quadrangle).

URANIUM

Exploratory work for uranium has been and is being done in the general area (Cameron Engineers, 1969, p. 380–383). No discoveries have been announced, but the stratigraphic relationships and, presumably, the geologic history of this area are similar to those in areas to the south where uranium has been located (Sharp and others, 1964, p. 546–548, 551–559). Mottling of sandstone occurs in the Pleasantdale quadrangle and, in view of the sandstone alteration studies made by Sharp and others (1964, p. 566–567), this alteration pattern may prove to significant in extending known occurrence of uranium.

LEONARDITE

Leonardite—the partially oxidized product of lignite, subbituminous coal, and some carbonaceous shales—is undesirable as a fuel, but is used in water treatment and the production of drilling muds and woods stains. Attempts have been made to use it as a soil conditioner and fertilizer (Fowkes, 1973, p. 72). When mixed with trona, it has numerous other potential uses (Swanson and Ging, 1972). Some exploration for leonardite has been done in the Gillette area, with unreported results (E. M. Schell, oral commun., 1973). Owing to an abundant supply and limited market, leonardite is not, at present, a high-priority exploration target.

SALTS

A hand auger was used for sampling some dry lake beds in The Gap SW quadrangle in secs. 21, 28, and 33, T. 47 N., R. 71 W.; sec. 28, T. 48 N., R. 71 W.; and sec. 26, T. 48 N., R. 72 W. The purpose of the sampling was to determine if any salts are present. No salt laminae were observed in the auger samples. X-ray analysis indicates the presence of gypsum and possibly anhydrite in the beds sampled. The lake bed in sec. 33, T. 47 N., R. 71 W. (The Gap SW quadrangle), also contains dolomite. No other salts were revealed by the analysis.

REFERENCES CITED

Averitt, Paul, 1969, Coal resources of the United States, January 1, 1967: U.S. Geol. Survey Bull. 1275, 116 p. [See also Averitt, 1975, Coal resources of the United States, January 1, 1974: U.S. Geol. Survey Bull. 1412, 131 p.]

Cameron Engineers, 1969, Uranium, *in* Book II—Mineral fuels, *of* Wyoming Mineral Industries review and forecast (a report prepared for Wyoming Nat. Resource Board and State Water Planning Program): 459 p.

Curry, W. H., 3d, 1971, Laramide structural history of the Powder River Basin, Wyoming, *in* Wyoming Geol. Assoc. Guidebook 23d Ann. Field Conf., Wyoming Tectonics Symposium, 1971: p. 49–60.

Davis, J. A., 1912, The Little Powder River coal field, Wyoming: U.S. Geol. Survey Bull. 471, p. 423–440.

Denson, N. M., and Chisholm, W. A., 1971, Summary of mineralogic and lithologic characteristics of Tertiary sedimentary rocks in the Middle Rocky Mountains and the Northern Great Plains, *in* Geological Survey research, 1971: U.S. Geol. Survey Prof. Paper 750-C, p. C117–C126.

Denson, N. M., Keefer, W. R., and Horn, G. H., 1973, Coal resources of the Gillette area, Wyoming: U.S. Geol. Survey Misc. Geol. Inv. Map I–848–C.

Dobbin, C. E., and Barnett, V. H., 1928, The Gillette coal field, northeastern Wyoming: U.S. Geol. Survey Bull. 796–A, p. 1–50.

Fowkes, W. W., 1973, Leonardite, *in* Mineral and water resources of North Dakota: North Dakota Geol. Survey Bull. 63, p. 72–75.

Galyardt, G. L., 1974, Preliminary geologic map and coal resources of The Gap quadrangle, Campbell County, Wyoming: U.S. Geol. Survey Open-File Rept. 74–98.

Olive, W. W., 1957, The Spotted Horse coal field, Sheridan and Campbell Counties, Wyoming: U.S. Geol. Survey Bull. 1050, 83 p.

Sharp, W. N., McKay, E. J., McKeown, F. A., and White, A. M., 1964, Geology and uranium deposits of the Pumpkin Buttes area, Powder River Basin, Wyoming: U.S. Geol. Survey Bull. 1107–H, p. 541–638.

Stone, R. W., and Lupton, C. T., 1910, The Powder River coal field, Wyoming, adjacent to the Burlington Railroad: U.S. Geol. Survey Bull. 381, p. 115–136.

Swanson, V. E., and Ging, T. G., 1972, Possible economic value of trona-leonardite mixtures, *in* Geological Survey research, 1972: U.S. Geol. Survey Prof. Paper 800–D, p. D71–D74.

Trotter, J. F., 1963, The Minnelusa play of the Northern Powder River, Wyoming and adjacent area, *in* Wyoming Geol. Assoc. and Billings Geol. Soc. Guidebook 1st Joint Field Conf., Northern Powder River Basin, 1963: p. 117–122.

U.S. Geological Survey and Montana Bureau of Mines and Geology, 1974, Preliminary report of core drill-hole data and chemical analyses of coal beds in Campbell County, Wyoming: U.S. Geol. Survey Open-File Rept. 74–97, 241 p.

Wegemann, C. H., 1913, The Barber coal field, Johnson County, Wyoming: U.S. Geol. Survey Bull. 531, p. 262–284.

——1917, Wasatch fossils in so-called Fort Union beds of the Powder River Basin, Wyoming, and their bearing on the stratigraphy of the region: U.S. Geol. Survey Prof. Paper 108–D, p. 57–60.

Wegemann, C. H., Howell, R. W., and Dobbin, C. E., 1928, The Pumpkin Buttes coal field, Wyoming: U.S. Geol. Survey Bull. 806–A, p. 1–14.

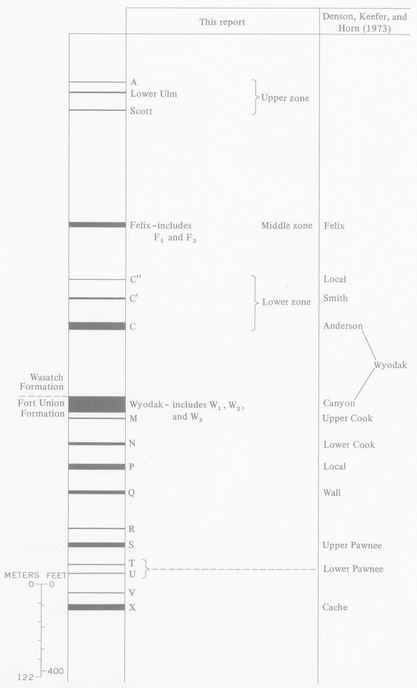

Figure 1. – Generalized columnar section showing stratigraphic position and thickness of coal beds.

Table 2.--Analyses of tipple samples of the Wyodak coal bed from the Amax Coal Co., Belle Ayr mine, Gillette, Wyo.

[NW¼NE¼ sec. 34, T. 48 N., R. 71 W., Saddle Horse Butte quadrangle. Samples collected by E. R. Landis, P. T. Hayes, and R. J. McKay (V. E. Swanson, written commun., 1973). Standard coal analysis (USBM lab. No. K–12883) by U.S. Bureau of Mines, Pittsburgh, Pa.; all other analyses (USGS lab. No. D–160988) by U.S. Geological Survey, Denver, Colo. Semiquantitative analysis: Ag, Au, Bi, Ce, Ge, Sn, Pd, Pt, and W were looked for but not detected. < , less than]

A. Standard coal analysis (weight percent)	As received	Moisture free	Moisture and ash free
Proximate			
Moisture	26.2	-------	----------
Volatile matter	33.6	45.5	49.1
Fixed carbon	34.9	47.3	50.9
Ash	5.3	7.2	----------
Ultimate			
Hydrogen	6.8	5.2	5.7
Carbon	50.7	68.7	74.0
Nitrogen	.7	1.0	1.1
Oxygen	35.9	17.0	18.3
Sulfur	.6	.9	.9
Ash	5.3	7.2	----------
Btu/lb	8,820	11,950	12,880
Sulfate S	.02	.03	.04
Pyritic S	.17	.23	.25
Organic S	.44	.59	.64

B. Major-oxide composition of ash (weight percent)			
Ash	6.64	SiO_2	26.0
Al_2O_3	13.0	Na_2O	1.19
K_2O	.3	CaO	21.0
MgO	3.55	P_2O_5	.1
Fe_2O_3	4.6	SO_3	22.0

C. Quantitative trace-element determinations (ppm)			
As	2.0	F	30.0
Hg	.132	Sb	<.04
Se	1.8	Th	.05
Tl	<.2	U	.6
Cd	1.0	Cu	200.0
Li	28.0	Pb	83.0
Zn	102.0		

D. Semiquantitative analysis, trace elements in ash (ppm)			
B	300	Ba	3,000
Be	3	Co	30
Cr	70	Ga	30
La	150	Mn	300
Mo	7	Nb	20
Ni	70	Sc	30
Sr	500	Ti	5,000
V	200	Y	50
Yb	5	Zr	150

Table 3.--Coal analyses of drill-core samples from coal beds in the Caballo Creek area, Powder River Basin, Campbell County, Wyo.

[Analyses by Montana Bureau of Mines and Geology (U.S. Geological Survey and Montana Bureau of Mines and Geology, 1974). Type of analysis: