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Stratigraphic model of the southern portion of the Jim Bridger coal field, Sweetwater County, Wyoming

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AN ABSTRACT OF THE THESIS OF Paul S. Maywood for the Master of Science in Geology presented July 14, 1987.

Title: Stratigraphic Model of the Southern Portion of the Jim Bridger Coal Field, Sweetwater County, Wyoming.

APPROVED BY MEMBERS OF THE THESIS COMMITTEE:

Richard E. Thoms

Robert O. Van Atta

Leonard A. Palmer

Uppermost Lance and lowermost Fort Union Formation sediments are found in outcrop in the southern portion of the Jim Bridger coal field, located on the northeast flank of the Rock Springs Uplift in Sweetwater County, Wyoming. Twenty-nine surface sections and 581 subsurface (borehole) sections were evaluated and used to construct a stratigraphic model.

Stratigraphic correlations with economically mineable coal seams in the Fort Union Formation north and south of the study area combined with definition of questionable local formational boundary locations are significant objec-

tives of this investigation.

Sandstone (60%), claystone (17%), siltstone (11%), coal (10%), and limestone (2%) are found to be the most abundant lithologic units and exhibit a high degree of lateral and vertical variability. Lateral continuity of major coal seams is shown to be useful for informal chronostratigraphic purposes.

Fossil flora examined in and near the study area indicate accumulation under warm temperate to subtropical conditions. Flora identified include *Cornus nebrascensis* (dogwood), *Selaginella* (fern), *Salvinia* (floating fern), *Cercidiphyllum* (katsura), and *Sabalites* (palm).

The Lance-Fort Union contact is mapped immediately above a distinctive fossil soil horizon up to 2.2 meters (7.2 feet) thick, but multiple paleosols exist within the lower Fort Union, so the formational contact is placed below the lowest significant coal, where present. High sandstone percentages and a noticeable lack of lateral accretion surfaces are interpreted to define sedimentation in low sinuosity, perhaps braided, stream environments. Raised peat swamps and high annual precipitation contributed to an elevated water table which inhibited clastic influx and promoted floral development and channel stability. Paleocurrent directions infer a northerly source, probably the Wind River Range.

STRATIGRAPHIC MODEL OF THE
SOUTHERN PORTION OF THE JIM BRIDGER COAL FIELD,
SWEETWATER COUNTY, WYOMING

by

PAUL S. MAYWOOD

A thesis submitted in partial fulfillment of the
requirements for the degree of

MASTER OF SCIENCE
in
GEOLOGY

Portland State University

1987

TO THE OFFICE OF GRADUATE STUDIES AND RESEARCH:

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This volume is dedicated to Mike Jaworski, the dynamic geologist who showed me the way.

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CHAPTER 1

INTRODUCTION

Exploration and exploitation of Wyoming coal deposits in the vicinity of Rock Springs has, until the late 1970's, occurred almost exclusively in the Late Cretaceous Rock Springs Formation. Increasing electric power demands and location of potentially mineable Fort Union Formation coal deposits on the northeast flank of the Rock Springs Uplift justify detailed stratigraphic analysis of these deposits. Limited drilling data during the 1970's inhibited extensive subsurface analysis. However, the procurement of substantial borehole information in the 1980's makes possible detailed stratigraphic studies which correlate subsurface data with surface exposures.

PURPOSE AND SCOPE

The purposes of this investigation were to define the geology of the southern portion of the Jim Bridger coal deposit and to produce a stratigraphic model. Construction of the model was accomplished by integrating borehole interpretation with outcrop mapping. A major objective has been to provide lithologic-stratigraphic correlations such that geology and engineering planning staffs at the Bridger mine can evaluate mining potential. The stratigraphic model will

be used to show structural effects, facies changes, and rock body interrelationships. The southern portion of the Jim Bridger coal field is currently scheduled to undergo development in 1989 (M. Knapton, 1986, assistant mine engineer, Bridger Coal Co., pers. comm.).

LOCATION AND ACCESSIBILITY

The Jim Bridger coal deposit lies on the northeast flank of the Rock Springs Uplift in Sweetwater County, southwestern Wyoming. Figure 1 places Jim Bridger in perspective with other major coal-bearing areas and drainage basins in the state. The area under permit to mine contains approximately 78 square kilometers (28 square miles) and is located just a few kilometers west of the Continental Divide. Major drainages within the permit area are Deadman Draw, 9 1/2 Mile Draw, and Tenmile Draw (Figure 2), all of which drain into Bitter Creek, which in turn drains into the Green River. This investigation encompasses the 9 1/2 and Tenmile South areas within the permit area of Figure 2.

The area of investigation includes section 36 and the southeastern half of section 35, T21N, R100W, and sections 4, 9, 10, 14, 22, 23, 26, and 35 of T20N, R100W, and portions of sections 3, 5, 8, 11, 13, 15, and 27, T20N, R100W (Figure 2). The study area consists of about 34.7 square kilometers (12.5 square miles).

Access to the area is excellent. Interstate 80 passes

■ Strippable Deposits

1	Adaville	10	Carbon
2	Leucite Hills	11	Dave Johnston
3	JIM BRIDGER	12	Dry Cheyenne
4	Black Butte	13	Wyodak
5	Salt Wells	14	Spotted Horse
6	Red Desert	15	Clear Creek
7	Cherokee	16	Lake DeSmet
8	Northern Little Snake River	17	Wyarno-Verona
9	Hanna	18	Acme-Kleenburn

Figure 1. Major Wyoming coal-bearing areas. Simplified from Glass (1978).

Figure 2. Jim Bridger mine areas.

within about 1.7 kilometers (1 mile) of the southern edge of the study area. Access within the area is provided by a network of infrequently maintained dirt roads which provide good access during dry weather.

The primary center of commerce is Rock Springs (population 19,458 in 1980), about 58 kilometers (35 miles) west. The climate of the region is arid to semiarid (Fisk, 1967) with annual amounts of precipitation in the 18 to 23 centimeter (7 to 9 inches) per year range (Root, Glass, and Lane, 1973). Topographic relief is moderate and ranges from 2042 to 2164 meters (6700 to 7100 feet) in elevation. Characteristics of the study area are steep slopes, hard rocks, cool climate, and sparse vegetation. Outcrops generally persist continuously for many kilometers, except for the area around Tenmile Draw.

PREVIOUS INVESTIGATIONS

The first recorded geological mapping in this region was provided by the Hayden Survey during 1877. This part of Wyoming was divided into the Green River Division and the Sweetwater Division (Hayden, 1879), the axis of the Rock Springs Uplift serving as an approximate boundary between the two. Large areas of this part of Wyoming were investigated, with much emphasis being placed upon finding vertebrate fossils.

Many of the early geological explorations were spurred

by the establishment of the transcontinental railroad right-of-way and, later, the search for coal to fuel the locomotives (Knight, 1955). Rich Tertiary mammalian and fish fossil discoveries also motivated vertebrate paleontologists to study parts of the Green River Basin in considerable detail.

It wasn't until A.R. Schultz mapped the greater Rock Springs Uplift (1909, 1910) that accurate, detailed regional mapping took place, again motivated by the search for coal. A few years later, the Union Pacific Railroad right-of-way was mapped in detail (Lee, 1915). Afterward, significant contributions to the regional geology included the work of Schultz (1920), Sears and Bradley (1925), Nace (1936, 1939), Bradley (1945, 1961), Brown (1949, 1962), Fidler (1950), Phippingos (1955), Carey (1955), Ritzma (1955), Lewis (1961), Roehler (1961, 1965, 1979a, 1979b, 1979c), Fisk (1967), Oriel and Tracey (1970), Land (1972), Hendricks (1983), and Levey (1985). A number of University of Wyoming theses have also provided important information. Among the most important are Hale (1950), Swain (1957), Davis (1958), Johnston (1959), Mogensen (1959), Severn (1959), and Smithson (1959). Figure 3 outlines some of these study areas in relation to this investigation.

Fort Union sediments in the study area were at first placed within the Wasatch Formation by Schultz (1909). It wasn't until much later that the Fort Union Formation was recognized as part of the Paleocene by R.W. Brown (1949) on

Figure 3. Area of investigation

the eastern margins of the Rock Springs Uplift. Similarity of lithologies in the Upper Cretaceous through Eocene formations undoubtedly contributed to this problem.

Several published geologic maps by Welder and McGreevy (1966), Roehler (1977), Madden (1981), and Love and Christiansen (1985) are among those most helpful to this study.

CURRENT COAL MINING OPERATIONS

Coal mined at Bridger north of 9 1/2 Mile Draw has been supplied almost exclusively to the nearby 2000 megawatt Jim Bridger Power Plant (Figure 4) since 1974. The power plant and mine offices are located about 13 kilometers (8 miles) north of Point of Rocks, Wyoming. Current annual production in the 6.4 to 7.2 million tons range is obtained from seams in the Deadman Coal Zone of the Fort Union Formation, named in ascending order, the D1 through D5. The 10 meter (32 feet) thick Deadman 5-1 (abbreviated D51) seam in the Central Mine Area (Figure 2) splits into two seams (D5 and D41) toward the northwest (Deadman North Area of Figure 2) and progressively into two (D54 and D31) and finally four (D5, D4, D3, and D21) seams toward the south and southeast (this investigation). The alpha-numeric naming convention of the Deadman seams was decided upon in the mid-1970's to facilitate computerization. Figure 5 is a cross-sectional representation of these seams through the Jim Bridger deposit. No faults have been found in the active mining area.

Figure 4. Jim Bridger power plant.

Figure 5. Generalized cross section of mineable seams, Jim Bridger Mine. These are reductions from computer output. Nine surfaces are plotted along the same profile line. Vertical exaggeration 16x.

Fort Union coal at the Black Butte Mine south of Interstate-80 has been under production since 1979 (L. Bongirno, project geologist, Black Butte Coal Co., 1987, pers. comm.). The Deadman seams at Bridger correlate well with the Little Valley seams south of the Interstate (Nielsen, 1984). Black Butte Coal Co. is also mining coal from the Lance and Almond Formations. Prospect Point Coal Company operates a small surface mine near Bridger in the Almond Formation. The only other coal mine currently producing in the Rock Springs Uplift is the Swanson Mine, a small underground mine in the Rock Springs Formation near Rock Springs. Most of the mines in the Superior and Rock Springs areas shut down as the railroad converted to more efficient diesel locomotives.

The mining process begins with the exploration phase. In assessing mineable coal reserve potential, boreholes provide by far the greatest source of data. There are over 1500 drill holes at the Jim Bridger field which provide detailed stratigraphic information. However, about 1000 of these holes have penetrated strata in active pit regions so the area south of 9 1/2 Mile Draw has experienced much less drilling activity through 1986.

Because the coal seams dip gently to the east and northeast at one to four degrees, mining progresses in a series of pits more or less parallel to outcrop. Once mining of an area has begun, the excavations proceed downdip from

the former outcrop in a long strip, thus the method is known as strip mining.

Following removal and stockpiling of topsoil (so it can later be reapplied to mined-out areas), the overburden is then drilled and the rock broken up with explosives. When appropriately deep cover is encountered, the overburden and/or parting material may be shot or blast-cast into the adjacent empty pit. The Bridger mine can thus be described as a modified open-cast strip operation. Fragmented overburden is removed with large 65- to 75-cubic yard capacity walking draglines (Figure 6) to expose coal. This is followed by the coal removal sequence where the material is drilled and blasted, then loaded into 120-ton belly dump haul trucks by 20-cubic yard capacity electric shovel, diesel backhoe or front-end-loader. Since the mine contains two seams in most active areas, this entire process (excluding topsoil removal and stockpiling) must be repeated.

METHODS OF INVESTIGATION

Existing color aerial photography was used to select the best localities for section measuring. Some preliminary geologic mapping was also done from these photos.

Dips are low, so Jacob's staff and Brunton methods are ideal for section measuring (Kottlowski, 1965). Where beds are thin, a measuring tape was used as an additional method. Particular attention has been paid to potential sedimentary

Figure 6. Large walking dragline exposing coal. The boom is 99 meters (325 feet) long.

structures which can easily be overlooked in borehole logging. A drilling program was performed during July and August, 1986, which provided 72 additional stratigraphic columns. Eighteen paleocurrent measurements were also taken.

All measured section and borehole data was then coded and input into a computerized database. Geophysical log suites of gamma-gamma, high-resolution bed density, caliper, and microresistivity curves were used in conjunction with core photos and chemical analysis data for final interpretation.

After all borehole locations were plotted onto a base map, the geology was then interpreted and drafted onto the same base. This information included coal seam croplines, burn zones, and known or suspected faults. A fence diagram was constructed with computer assistance using measured section and carefully selected borehole data so as best to illustrate stratigraphic interrelationships. This fence diagram was produced as the base for the stratigraphic model.

CHAPTER 2

REGIONAL GEOLOGY

TECTONIC SETTING

The Green River, Great Divide, and Washakie Basins are located in the Wyoming Basin physiographic province which consists of a series of broad structural and topographic basins (Hunt, 1967). These basins are partially filled with Tertiary deposits and are partially or completely separated by a number of uplifted structures. Basins are structural as well as topographic features. Regional tectonic relationships are illustrated in Figure 7. The Uinta Mountains bound the Green River Basin on the south, while the Overthrust Belt associated with the Absaroka and Darby faults forms the western limit of the basin (Fidlar, 1950). Northern boundaries are formed by the en echelon ranges of the Wind River and Gros Ventre Mountains (Figure 7). The broad, anticlinal dome of the Rock Springs Uplift separates the Green River Basin from the Great Divide and Washakie Basins to the east.

The Rock Springs Uplift is a forty-mile long, doubly plunging, north-south-trending, asymmetrical anticline (Eardley, 1951). It is the largest uplift in the state which still retains its cover of sedimentary Cretaceous rocks (Blackstone, 1955). Other uplifts of comparable size

Figure 7. Structural features of southwestern Wyoming (after Sullivan, 1985).

have been eroded deeply enough to expose a core of Paleozoic or Precambrian rocks. This fact is suggestive of a relatively late uplift. The broad arch of this feature has resulted in many resistant sandstone hogbacks on the west flank and cuerdas on the east flank. Dips are fifteen to thirty degrees on the west side of the uplift, while five to ten degree dips are common on the eastern flank. Many east-west-trending normal faults break up the continuity of outcrop relationships on both flanks of the uplift. Subsequent erosion of the region has exposed late Mesozoic and early- to mid-Tertiary rocks. A geologic map of the Rock Springs Uplift (Plate I) shows these features.

The Wamsutter Arch (Figure 7) is aligned with the greatest eastward bulging of the Rock Springs Uplift, and it has been postulated by Blackstone (1955) that the Arch is a direct continuation of the uplift. A WNW-ESE trending fault zone in the southernmost part of the uplift exhibits suspected reverse faulting, but this has not been demonstrated to any degree of certainty.

REGIONAL STRATIGRAPHY

Precambrian crystalline and pre-Baxter Shale (Late Cretaceous) rocks are not found at the surface in the vicinity of the Rock Springs Uplift. Pre-Baxter Shale rocks are known from exposures in other areas of the state and in the Rock Springs Uplift area from electric well logs.

Subjacent Units

Baxter Shale (Kba on Plate I). Erosion has exposed the Baxter Shale in the center of the Rock Springs Uplift. The Baxter Shale, named by Schultz (1920), is composed of soft, homogeneous, bluish gray to drab, silty and gypsiferous, dark marine shales with thin beds of ripple-marked sandstone and concretionary beds of impure limestone and are 1020 to 1100 meters (3350 to 3600 feet) thick (Randall, 1961; Hale, 1955). The Baxter Shale has been correlated by Hale with the Steele Shale south of Rawlins, with the Hilliard Shale at Church Buttes, and with the Mancos Shale of northwestern Colorado. An intricate intertonguing relationship exists with the overlying Blair and Rock Springs Formations.

Blair Formation (Kbl). Named by Schultz (1920) after a well-exposed sequence near Blair Ranch near Aspen Mountain on the eastern flank of the Uplift, the Blair consists of a 9.1 meter (30 foot) basal sandstone unit overlain by about 396 meters (1000 feet) of gray, silty shale with thin, interbedded ripple-marked sandstone (Randall, 1961).

Rock Springs Formation (Kr). The prolific coal-bearing Rock Springs Formation was given formational status by Schultz (1920) and contains buff sandstone, carbonaceous shale, and bituminous coal beds. The aggregate thickness is about 512 meters (1680 feet) in the northern part of the uplift (Hale, 1955). Subsequent workers in this unit have de-

scribed a series of sandstone and shale tongues (Keith, 1965; Roehler, 1965; Smith, 1965) that were later well correlated along the east and northeastern flanks of the uplift by Hendricks (1983).

Ericson Sandstone (Ke). The Ericson is composed of an interval of 130 to 207 meters (428 to 680 feet) of dominantly cliff-forming sandstones separated by a less resistant zone of thin-bedded, finer grained sandstone, carbonaceous shale, and ironstone concretions (Hale, 1950; 1955). Gill and Cobban (1966) proposed that up to 1097 meters (3600 feet) of strata may have been eroded prior to Ericson deposition but Law, Bucurel-White, and Bader (1983) suggest a conformable relationship with the Rock Springs Formation. Miller (1977) reports that a widespread unconformity existed over much of the region at the end of Rock Springs time, based on biostratigraphy.

Almond Formation (Kal). The coal-bearing Almond Formation, named by Schultz (1920) after the excellent sequence of exposures near the historic Almond stagecoach station at Point of Rocks, contains 213 to 290 meters (700 to 950 feet) of carbonaceous shale, siltstone, mudstone, and sandstone alternating with coal beds of variable thickness and quality (Hale, 1950). The Almond Formation conformably overlies the Ericson Sandstone and is transitional with the Lewis Shale.

The Blair, Rock Springs, Ericson Sandstone, and Almond Formations comprise the Mesaverde Group in the Rock Springs

Uplift area. The total thickness of all four units varies from 850 to 1555 meters (2800 to 5100 feet) (Randall, 1961).

Lewis Shale (Kle). The Lewis Shale, named by Cross and Spencer (1899), is a dark gray marine shale containing siltstone and sandstone beds in the upper portions of its 61 to 610 meter (200 to 2000 foot) thickness. Some interfingering of the Lewis with the underlying Almond Formation has been reported in the Red Desert Basin (Curry, 1969). Because of similar lithologies, the contact between the Lewis and the base of the overlying Fox Hills Sandstone in the Rock Springs Uplift area has been difficult to distinguish in electric well logs. Good exposures are fairly rare.

Fox Hills Sandstone (Kfh, Kfl). The Fox Hills Sandstone is composed of gray, ferruginous, and yellow sandstone and arenaceous clays over an 18 to 76 meter (60 to 250 foot) thickness (Land, 1972). There is considerable intertonguing with the underlying Lewis Shale but Land's interpretation of intertonguing relationships with the overlying Lance Formation has been challenged by H. Roehler (1987, mapping in prep.)

Lance Formation (Kfl, Kl). The latest Cretaceous Lance Formation varies from 0 to 230 meters (0 to 719 feet) in thickness and contains brackish and nonmarine shales, siltstones, coals, and lenticular sandstones that exhibit rapid horizontal and vertical facies changes (Land, 1972). Pre-Fort Union erosion has resulted in truncation of the

Lance and Fox Hills at the northern and southern extremities of the uplift and from east to west across the Wamsutter Arch and Rock Springs Uplift. Roehler (1977) and Love and Christiansen (1985) map the Fort Union Formation atop Almond Formation beds on the western flank of the uplift, except for a very thin strip between Cedar Canyon and Nitch Creek (Plate I).

The uppermost Lance sandstone of Swain (1957) appears to be the same as the basal Fort Union sandstone of Mogensen (1959), but Severn (1959) has probably placed the Lance-Fort Union contact about sixteen meters higher stratigraphically. A distinctive coquina bed has been found in upper Lance sediments in the vicinity of South Table Mountain (Johnston, 1959). This bed is composed mostly of *Ostrea glabra* (?).

Fort Union Formation (Tfu)

The Paleocene type Fort Union Formation is located near the mouth of the Yellowstone River, Buford, North Dakota (Meek and Hayden, 1862). Fort Union sediments on the east flank of the Rock Springs Uplift are similar; the differences are discussed in Chapter 6.

A thin conglomerate bed separates the Lance Formation from the Fort Union Formation on the west flank of the Sierra Madre (Swain, 1957) but in the Rock Springs Uplift this layer is absent except for very localized occurrences. Instead, a fossil soil zone up to 1.8 meters (6 feet) thick separates the two formations (Land, 1972; Ritzma, 1965).

Although not present in all localities, this paleosol is generally a good marker bed.

The Lower Paleocene Fort Union Formation consists of light gray to gray, buff, or tan sandstones, light to dark gray or greenish gray shales, siltstones, and claystones with coals, lignites, and carbonaceous shales and siltstones in the lower part of the formation (Mogensen, 1959). The thickness of the Fort Union sediments on the east flank of the Rock Springs Uplift is 183 to 437 meters (600 to 1435 feet).

Superjacent Units

Wasatch Formation (Twm). The Eocene Wasatch Formation was named by Hayden (1869) and consists of very fine grained to medium grained, lenticular sandstones, and mudstones and claystones with minor amounts of conglomerates, carbonaceous shales, lignites, and coals (Fisk, 1967). The Wasatch Formation is 305 to 914 meters (1000 to 3000 feet) thick.

Green River Formation (Tgl, Tgwt, Tgt, Tglu). The Green River Formation, also of Eocene age, is a discontinuous sequence of lacustrine and paludal deposits generally containing less conglomerate and coarse sandstone than the Wasatch Formation (Fisk, 1967). Its greatest thickness is attained west of Green River, where thinly-laminated chalky shale, buff-brown sandstone, algal limestones, and bedded trona accumulate to a thickness of greater than 470 meters (1500+ feet). East of the Rock Springs Uplift, the Green

River Formation undergoes considerable intertonguing with the Wasatch Formation, reflecting changes in depositional environment over time.

Bishop Conglomerate (Tbi). The Oligocene Bishop Conglomerate contains clasts of red quartzite, gray chert, and limestone in a gray to white tuffaceous sandstone matrix (Love and Christiansen, 1985). It is variable in thickness and present in the southwestern part of the Rock Springs Uplift.

Miocene Rocks Undiff. (Tm). A pale green to tan tuffaceous sandstone and claystone unit of Miocene (?) age with a local basal conglomerate of uncertain correlation is present on the southwestern, central part of the Uplift. This unnamed formation may be related to other large areas of somewhat poorly studied Miocene rocks near the south end of the Wind River Range. Kirschbaum (1985) has mapped some of these deposits as part of the Bishop Conglomerate.

Figure 8 is a composite erosional columnar section showing each of the above units.

GEOLOGIC HISTORY

The Archaeozoic was a time of igneous activity and sedimentation. The Wyoming region had already established its foreland nature during Precambrian time. This status remained unchanged throughout the Paleozoic and Mesozoic. The Cordilleran trough was present to the west, while the

Figure 8. Composite Erosional Columnar Section
Rock Springs Uplift
Sweetwater County, Wyoming

Modified after Root, Glass, and Lane (1973)
and Love and Christiansen (1985)

Front Range Highland stood to the south affecting sedimentation during the Paleozoic and Mesozoic (Lovering, 1929).

Repeated transgressions of the ancient seas that spread eastward from the Cordilleran trough characterized Paleozoic sedimentation. Regressions and erosional cycles occurred often without significant deformation.

Terrestrial deposition occurred during Triassic and Early Jurassic periods. Two major transgressions of the sea were followed by additional terrestrial sedimentation and finally by erosion during the Late Jurassic.

Seas once again transgressed into the region in the Early Cretaceous, depositing shales and sandstones. During Middle and Late Cretaceous time, sedimentation was significantly affected by the Nevadan Orogeny. Newly formed basins became depocenters of vast amounts of sediment as there were many transgressions and regressions during this time (Roehler, 1965). Prominent shoreline fluctuations were superposed upon these thick sandstone-shale-minor limestone sequences. The Late Cretaceous geosyncline extended from what is now Utah to the Mississippi River and from the Gulf of Mexico to the Arctic Ocean. Deposition in this area amounted to 3050 meters (10,000 feet) or more.

The Baxter Shale was deposited during an extended transgression of a Late Cretaceous sea. The alternating-transitional sediments of the Mesaverde Group, including wave-dominated deltaic deposits of the Rock Springs Forma-

tion were a result of gradual eastward regression (Levey, 1985).

Marine shales and thin, interbedded sandstones of the Lewis Shale were produced during a final advance of the Late Cretaceous sea and its lingering withdrawal. The final retreat of the sea was marked by deposition of the Fox Hills Sandstone, a sequence of sandstone and siltstone deposited along a barrier island coastline in littoral, shallow neritic, and estuarine environments (Land, 1972).

Terrestrial deposition commenced at the close of the Cretaceous with the transitional Lance Formation and continued during the general uplifting of the Laramide Orogeny. The Wind River Mountains and Rock Springs Uplift began to become active at this time (Roehler, 1961). The Uinta Mountains may have also begun to rise during the latest Cretaceous (Picard, Bruhn, and Beck, 1983). A temperate to subtropical climate was in effect during Lance time (Dorf, 1938). Pre-Fort Union erosion and uplift was followed by a brief period of reduced sedimentation, permitting floral development.

Paleocene and Early Eocene deposition occurred almost continuously under a warm, moist climate. Reworked detrital materials became a larger percentage of sediments as major source areas in the Uinta Mountains, the Park Range (Front Range Highland), and the Rock Springs Uplift (Beaumont, 1979) were developed. Paleocene (Fort Union) and Eocene

(Wasatch) sediments were deposited over older rocks nearly simultaneously with uplift resulting in unconformable relationships near these structures.

The Green River, Great Divide, and Washakie Basins were all interconnected during the time of Eocene sedimentation and large lakes (Lake Gosiute, Lake Uinta) were a result of uplifting of the Uinta Range and downwarping of the basins (Oriel and Tracey, 1970). The Rock Springs Uplift was not an influential structure at this time. Lacustrine beds of the Green River Formation were thus able to interfinger with the fluviatile and paludal deposits of the Wasatch Formation. Coarse-grained fluvial sediments of the Bridger Formation, now found only over the Green River Formation, followed those of the Wasatch as climatic changes and renewed uplift signaled the demise of the lake by mid-Eocene time. The Rock Springs Uplift began separating the Green River Basin from the Great Divide and Washakie Basins.

Large areas were covered with Oligocene Bishop Conglomerates but much of these sediments were subsequently eroded after a period of mild uplift during Late Oligocene or early Miocene time.

The Miocene was an epoch of accentuated uplift and deposition of coarse, sedimentary debris distributed around the principal uplifts. Similar deposition occurred during the Pliocene after an erosional interval. Post-Miocene normal faulting and subsidence took place as the entire Rocky

Mountain region was uplifted. The only other post-Wasatch sediments found around the Rock Springs Uplift are Quaternary lake, alluvial, and loessian deposits.

A final post-Pliocene regional uplift was followed on the northeast flank of the Rock Springs Uplift by the volcanism of the Leucite Hills. These are remnants of cinder cones and lava sheets that cap hills of Upper Cretaceous through Eocene sedimentary rocks (Carey, 1955). Although presumed to be young, the age of this volcanism has not been adequately determined (Johnston, 1959; Smithson, 1959), but can be no older than mid-Eocene, since many of these features rest upon Green River Formation beds.

CHAPTER 3

DATA COLLECTION

Field work was undertaken during the summer months of 1986. This work consisted of mapping surface outcrops, measuring sections and drilling to obtain subsurface data down-dip. Twenty-nine measured sections were obtained along outcrop. Seventy-two rotary boreholes were drilled in the area of investigation to determine coal seam correlations, coal quality characteristics, parting line geometries, structure and stratigraphy, coal subcrop/oxidation limits, and potential subsurface burn zones. Surface section data is presented in Appendix 1 and subsurface section data used in generating the panel diagram is found in Appendix 2.

AIRPHOTO INTERPRETATION

Prior to field work, 9 x 9 aerial color orthophotos were studied to determine areas of surface burn (clinker) and areas of sufficient surface relief to provide characteristics of a good measured section. These photos were taken during the summer of 1978 as part of a mine-wide vegetation survey.

Locations of coal outcrops were noted where present, but generally these were not discernable from aerial photos. This detail was transferred and sketched onto 1 inch to 800

feet scale topographic maps for use in the field. Refinements and adjustments to these maps were made as the area was traversed and sections measured.

MEASURED SURFACE SECTIONS

Twenty-nine surface sections were measured in the study area. These sections traversed known or suspected coal outcrops. Emphasis was placed on the coal-bearing lower part of the Fort Union and uppermost Lance Formations. All sections measured strata above and below coal seams.

The Fort Union and Lance Formations form a series of low cuestas in this area (Figure 9). West and southwest facing slopes are generally steep, while the northeast and eastern slopes are gentle. Outcrops generally strike between N75W and N10E with associated dips between one and four degrees north to east-northeast.

Measured section locations were plotted as accurately as possible on field topographic maps. Where locations were still somewhat uncertain, some sections were surveyed for more exact locations.

Jacob's staff and Brunton compass methods were used (Figure 10) in section measuring, since dips are generally slight. Kottlowski's (1965) technique was used for each section.

Where thin beds were encountered, a measuring tape was used to determine more accurate bed thickness. Careful mea-

Figure 9. Low cuestas of Fort Union and Lance Formations.

Figure 10. Section measuring with Brunton and Jacob's staff.

surement was necessary because of the effects of erosion and downslope slumping.

SUBSURFACE SECTIONS

Transportable, truck-mounted rotary drilling rigs are vital in the acquisition of exploration and development data (Figure 11). These data can be in the form of rotary or continuous core holes.

Exploration and Development Rotary Holes

Exploration and development rotary holes provide by far the greatest single source of data for assessing mineable coal reserve potential. A total of 581 test borings of shallow depth (less than 200 meters) have penetrated the Fort Union Formation in the study area. Some of these were drilled prior to 1978 and had inadequate or no geophysical logs. Most of the attention of drillsite geologists of the past has been directed to how thick and how deep the coal seams are. More recently (since about 1981), attention has also focussed on lithology, groundwater, sedimentary structure in core holes, and coal quality. The technology of geophysical logging tools has progressed, also providing further refinement of subsurface information.

From a coal exploration and development standpoint, the most useful product of a rotary borehole is the geophysical log suite. The natural gamma or gamma-gamma, high-resolution bed density, caliper, and single point or microre-

Figure 11. Transportable rotary drilling rig used to make exploration boreholes. Note core stands at rear of drilling rig and geophysical logging truck at right.

sistivity curves provide precise definitions of coal bed stratigraphy. Top and bottom contacts can be defined to within 0.03 meter (.1 foot) accuracy. A gamma log can be used as a relative grain-size indicator for sandstone, siltstone, and claystone interpretation. Figure 12 illustrates how a geophysical log suite is used in lithologic determinations.

Chip samples are collected at five-foot intervals as the hole is drilled. Frequently, however, these samples are contaminated by rock chips from upper strata and mingle with chips from the rock layer being drilled. Hence, the geophysical log (specifically, gamma and density) must be consulted for accurately determining the true lithology. At other times, circulation (air or air and water) may be lost causing "no returns" as returning chips become lost in subsurface voids.

Rotary chips are also poor indicators when it comes to defining sedimentary structures. Sometimes it is possible to discern cross-bedding in larger chips, but this is not usually the case. Chip samples are usually not retained or analyzed. Lithologic logs are kept for rotary boreholes (in case of a caving hole which cannot be probed by the logging unit), but these record gross lithologies, when chip samples are present.

Continuous Core Holes

Continuous overburden core holes are cored from the

surface to below the last mineable coal seam and are performed in response to the permitting process. These core holes were completed for the study area in 1985 with a spacing of roughly one hole for every 160 acres.

In addition to the same suite of geophysical logs run for rotary boreholes, detailed lithologic logs are recorded for each core interval according to guidelines proposed by McPhater and MacTiernan (1983) and later tailored for corporate purposes. The core is then bagged and packaged for shipment to the laboratory for analysis. Core recovery is generally very good (greater than 95%), allowing documentation of detailed sedimentary structures, gradational lithologies, grain size and sorting, and other features (i.e., clasts) as well.

The core is photographed at the laboratory before any such analysis is performed. Although Figure 13 is an example of such a photograph, it represents but a small interval of a particular borehole. A continuous core hole may require up to forty or more boxes (photographs) to portray the entire subsurface section.

Exhaustive coal and rock chemistry data, performed under the SCS classification for technical rock types, is produced in addition to the photographs (C. Bowen, geologist, Glenrock Coal Co., pers. comm.). These photos and textural data are then compared to lithologic and geophysical logs for conflict resolution regarding lithology.

Figure 13. Overburden core photograph.

Continuous core holes provide the foundation of the stratigraphic model, with the addition of carefully selected rotary boreholes where required.

PALEOCURRENT MEASUREMENTS

Eighteen paleocurrent measurements were taken in the northwest portion of the study area where a trough cross-bedded sandstone unit in the overburden was particularly well exposed. Paleocurrent directions were measured with a Brunton compass according to the techniques suggested by Compton (1962). This data is presented in Appendix 3.

CHAPTER 4

ANALYTICAL PROCEDURES

Several geological computer programs were utilized in this study. However, in order to use these programs it was necessary to establish IBM-3091 mainframe-resident databases for all field data. This included but was not limited to: digitized outcrop lines, burnlines, faults, parting lines, and surveyed locations of measured sections and boreholes, as well as all lithologic information. Extract software was utilized to produce data files in formats acceptable to applications software.

CODING OF LITHOLOGIC DATA

The purpose of the coding process was to transfer all data from field book to computer where it could be manipulated for graphic output. In so doing, field descriptions were checked for uniformity, proper color chart names, and other parameters before input. Measured surface and representative subsurface sections are compiled in Appendices 1 and 2, respectively.

The three-digit code in the far right column of these printouts is a graphic chart code, simplified from a methodology proposed by Ferm and Berger (1979) to reduce lithologic intervals for each borehole or measured section to a miniature stratigraphic column at any desired scale.

Lithologic types have been limited to the following:

first digit	rock type	graphic output
1	coal
2	shale
3	claystone
4	siltstone
5	sandstone
6	conglomerate
7	limestone
8	surficial deposit
9	thermally altered unit (burn or clinker)
0	other	UNDEFINED

These choices were selected by geologists working in 1980 for the Technical Services Division of NERCO, Inc., Portland, Oregon, as most representative of coal-bearing sequences of the Wasatch and Fort Union Formations in Wyoming and Montana.

GRAPHIC LOGS

Graphic log plotting software (LOGPLOT) has been used to produce hardcopy stratigraphic column output (Figure 14). These columns can then be used in coal seam correlation, cross section, or panel diagram applications. This software was intended primarily for borehole examination and correlations.

PROJECT: STRATIGRAPH
 DRILL HOLE: 850320BC
 NORTHING: 377134
 EASTING: 529881
 ELEVATION: 6764.6
 TOTAL DEPTH: 180.

Figure 14. Graphic log plot.

COAL SEAM CORRELATIONS

In some parts of the study area, coal seam correlations are fairly well known, particularly where drilling density is relatively high. However, after the two thick coal seams (D54 and D31) begin to split, correlations are less certain in a few localities. Furthermore, coal beds in the upper Lance Formation begin to become noticeable on outcrop in the southern portion of the study area. Sometimes the geologist is unsure of the precise seam nomenclature in a particular measured section or borehole.

To aid in the process of coal seam correlation, a sophisticated, menu-driven computer software package called STRATVIEW was developed by ZYCOR, Inc. STRATVIEW will correlate matched seams along a user-selected baseline or between specific boreholes. However, lithologic units other than coal seams are not correlated by the program.

STRATVIEW will adjust each borehole for surface elevation and scaled distance between holes. Figure 15 is an example of such output. Further refinements of this software have permitted graphics plotting capabilities similar to those of LOGPLOT, providing lithologies of each stratigraphic interval. STRATVIEW is particularly well suited to quick definitions of fault and parting line locations along a given baseline. Other options include the capability to add geophysical logs at the same scale for each hole.

PREPARATION OF CROSS-SECTIONS

Representative dip cross-sections were constructed with the aid of STRATVIEW using measured sections and boreholes approximately every 150 meters along the length of the study area. Four cross-sections along strike were constructed for the study area. A few smaller, localized areas required additional cross-sections to determine existence of faults, coal seam correlation questions, local seam washouts or erosion zones, and other problems. Oxidized and burned zones were commonly encountered along outcrop (Plate II), and STRATVIEW was useful to a degree in resolving some of these problem areas.

A final set of cross-sections was designated as the base for the fence diagram. This series was planned to maximize use of the continuous core holes and to optimize the graphic display. Lithologies of measured sections and additional boreholes were added with LOGPLOT. Facies interpretations between each stratigraphic column were added later and the final drafted version was used as an overlay with screened (faded) topography to produce Plates IIIA through IIIC.

CHAPTER 5

STRATIGRAPHIC MODEL

A model can be defined as a facsimile in three dimensions or a reproduction in miniature (Thrush, 1968) of a mine, deposit, or other geological phenomenon. Thus, a stratigraphic model can be defined as a three-dimensional miniature of the stratigraphy of a particular area or region. The model can include lithostratigraphic and chronostratigraphic units.

Stratigraphic modeling was pioneered in the Gulf of Mexico primarily for formational analysis in the exploration of oil and gas (Frink, Wittick, and Dedman, 1977). Dedman, Lindsey, and Schramm (1975) and Neidell (1980) applied stratigraphic modeling to seismic processing in a variety of subsurface applications.

Although primarily geared to interpretation between well logs and seismic geophysics, the basic principles may be applied equally to situations in the mining industry, where shallow borehole geophysics and measured surface sections are commonly encountered in evaluation of stratabound deposits, especially coal and uranium. This study will address lithostratigraphic and chronostratigraphic units in the southern portion of the Jim Bridger coal field.

LITHOSTRATIGRAPHIC SUMMARY

The lowermost portion of the Fort Union Formation in the area of investigation consists of the following lithologies in decreasing order of abundance: sandstone (60.3%, claystone (16.6%), siltstone (10.7%), coal (9.5%), surficial unit (2.6%), limestone (2.4%), and shale (0.04%). Conglomerate, ironstone, and clinker are found in very small quantities. The percentages are based on 1,977 meters (6,487 feet) of representative core drilling (Appendix 2). The total stratigraphic thickness under consideration represents up to about half of the Fort Union Formation and approximately the top ten percent of the Lance Formation.

Lithology and Facies Patterns

The sandstones typically are subarkosic, very fine- to medium-grained, light brownish gray to light yellow brown in surface sections or light olive gray to bluish gray in subsurface (unweathered) sections. Sandstones in surface sections fall generally into one of three types:

I. relatively poorly cemented, light brownish gray, generally structureless, erodes to sloping surfaces.

II. clay cemented, very light gray to white, trough- to planar-cross bedded, typically micaceous, erodes to ledges or slopes.

III. calcite cemented, light reddish brown to orange brown, contorted or trough-cross bedded with or without siderite bands, erodes to ledge.

Types I and III sandstones are illustrated in Figure 16.

Figure 16. Sandstone types I and III. Dominant ledge-forming type III sandstone overlies light colored type I sandstone.

Correlations between surface sandstones and those in the subsurface are less certain due to the lack of weathering and erosional effects.

Contacts are sharp between sandstone types I and III, as shown in Figure 16 or gradational, as with sandstone types II and adjacent lithotypes, both horizontally and vertically.

Siltstones are typically light gray to light brown, include varying amounts of sand and clay, and are found on sloping surfaces. In the subsurface, siltstones are usually olive gray to dark brown, sometimes micaceous, and are found with and without siderite bands. Carbonaceous material may be found along bedding planes, and numerous plant fossil fragments also occur. Complete leaves are relatively rare.

Claystones are generally light brownish gray to gray in sloping surface sections, but may contain silt or cobble-sized rip-up clasts such as those found in MS-86010. In the subsurface, these units are often light olive gray to dark brown, and sometimes shaly, rooted, or burrowed, with associated carbonaceous or woody material. In addition, claystones may be found associated with coal beds, usually as floor and frequently with slickensided surfaces along bedding planes. Claystones are typically laminated, but fissility in mudrocks of the area is very rare. Figure 17 illustrates siltstones and claystones in surface section.

Coal seams are generally found to be the most consis-

Figure 17. Siltstones and claystones in surface section. Rock hammer is just below a dark ironstone bed.

tent lithologic units in terms of horizontal extent (Plates IIIA, IIIB, IIIC). They are typically weathered on outcrop, but are substantially less weathered even just a meter under the surface. The coal seams in the area of investigation are subbituminous B to C in rank, range from low to high in ash (7.56 to 14.11 percent), low to intermediate in sulfur (0.50 to 0.99 percent), intermediate in moisture (18.60 to 21.34 percent), and have average heating values of 8595 to 9597 BTU (as received). In subsurface sections, the coal seams exhibit sharp contacts with subjacent and superjacent units, are generally unoxidized with low to moderate amounts of vitrinite, and locally contain thin partings of carbonaceous shale, claystone, siltstone, or sandstone. Surface coal exposures, on the other hand, are usually fairly well oxidized with weakly developed partings, and locally grade up or down section into claystone or carbonaceous shale, particularly towards the bottom. Figure 18 shows a particularly well exposed coal seam in the Tenmile Draw area. Further, surface sections sometimes encounter clinker (burned coal) deposits (Plate II).

Shales vary from light gray, olive gray, or brown to black. Plant material association is common in the subsurface, while small crystals of gypsum are rather commonly found at the surface. Shales are overall quite rare in the study area, and are very thin (less than 0.25 meters).

Limestones are relatively common (although thin) in

Figure 18. Well exposed coal seam in the Tenmile Draw area.

the overburden, and relatively rare in interburden strata. These units are typically light gray to gray, micritic, and very well indurated; fossils are absent. Thicknesses range from 0.3 to 1.4 meters (1 to 4.5 feet). Generally, however, limestones are very discontinuous, and may only rarely be traced from one borehole to another.

CHRONOSTRATIGRAPHY

Some coal seams are laterally extensive, while others may be discontinuous, split, pinch out, or may contain substantial non-coal material. Peat swamps may develop in a wide range of depositional and tectonic circumstances and under varying paleotopographic conditions (Ward, 1984). The coal deposits of the southern portion of the Jim Bridger coal field, while exhibiting characteristics of all of the above, are dominantly of the laterally extensive type, being everywhere (within the study area) laterally continuous (except for the D3). The major coal seams are interpreted as relative time horizons, since it is presumed by nearly all workers in the region that swampy conditions existed in areas of low relief over broad expanses during early Paleocene time. Although certainly not as ideal a time marker as an ashfall event, for example, the progressive splitting of the coal seams is interpreted to be in response to tectonic (timed) events.

The following presents informal time-stratigraphic

units for the lower portion of the Fort Union Formation in the study area. An attempt is made to provide rock-body descriptions so that future studies may concentrate on rock mechanics or depositional environments. Figure 19 is a generalized stratigraphic cross-section showing chronologic units and can be referred to throughout this section.

Underburden (Unit #1 on Figure 19) is used to describe all rock units below the bottom of the D1 or lowermost Deadman coal seam. The underburden is composed of varying quantities of sandstone, siltstone, and claystone. These sediments are frequently rooted, ripple laminated, contain carbonaceous material at the top (at the contact with the coal), are churned or bioturbated, and contain coal spars or coalified root material. A 0.2 to 1.5 meter (0.8 to 4.8 foot) coal bed, known locally as the Ute seam (Nielsen, 1984) is intermittently present about 12 meters (40 feet) below the bottom of the Lower Deadman (D31) seam. The underburden is frequently penetrated only a few meters when coring. The best information about the underburden is derived from the continuous core holes, when 20 meters (66 feet) or more of drilling has occurred below the D31 or D21 coal.

Although the Fort Union-Lance contact is known to exist not far below the lowermost Deadman coal seam, the stratigraphic location of this occurrence has not been consistently confirmed by drilling. A fossil soil (Figure 20)

Figure 19. Generalized stratigraphic section showing chronostratigraphic units.

has been mapped in the field at several localities but is stratigraphically lower in the section than what is cored in normal practice. In addition, this unit could be difficult to detect on geophysical log suites, its sandy nature being nearly identical to sandstone in gamma and density response.

D31/D21 Coal (Unit #2) ranges from 0.6 to 5 meters (2 to 16.5 feet) in thickness for the D31 and from 0.5 to 4 meters (1.5 to 13 feet) thick for the D21. These beds are black, banded, dull to moderately bright in luster, and hard when unoxidized. The coal generally fractures blocky to semiconchoidally and contains small amounts of pyrite which occur as lenticular masses, euhedral crystals, framboidal aggregates, cell infillings, and as veins on cleat surfaces. Calcite, amber, elemental sulfur, and gypsum occur in trace amounts. In one small locality, a localized clastic parting occurs, which affects mineability of the D31 seam near its outcrop (Plate II). This parting, where present in minor amounts, increases ash content and mineral matter (chiefly silica) of the D31 seam. South of Tenmile Draw, ash increases and thermal quantity (BTU) decreases.

D32 Parting (Unit #3) varies from 0.3 meters (1 foot) to 16.6 meters (54.4 feet) in thickness. It contains primarily very fine grained clastic sediments (siltstone, claystone, and shale) and varies from dark brown to light gray, but contains increasing amounts of sand in thicker interburden locations. However, the sandstone is usually found

Figure 20. Fossil soil at base of Fort Union Formation in section 35, T20N, R100W. Note D31 coal outcrop at upper right.

above or below a siltstone or claystone bed in contact with thick coal seams; sandstone occasionally occurs directly over the D21 seam. There are locally interbedded thin coals and carbonaceous laminae within the unit; limestone is rare.

D3 Coal (Unit #4), an upper 0.03 to 1.5 meter (0.1 to 5 feet) thick split of the D31 coal, is most often black, dull, very hard, and fractures irregularly to blocky. Pyrite occurrences are generally the same as for the D31/D21 coal. However, since the D3 seam possesses fewer cleats than any other seam in the study area, this type of pyrite occurrence is much less common. Plate II also shows a localized area where the D3 seam has either been eroded or is absent due to nondeposition. The D3 coal thins in close proximity to these areas.

D43 Parting (Unit #5) is continuous throughout the study area, varies in thickness from 2.1 to 22.6 meters (7 to 74.3 feet), and typically contains much more sandstone than the D32 parting. This unit is light gray to light brownish gray or light olive gray and contains siltstone, claystone, and shale. Brown to light gray, micritic, limestone is also much more common. Sediments in this unit exhibit siderite bands or nodules, ripple laminations and micaceous sandstones. Less common are pyrite nodules, carbonaceous plant material along bedding planes, thin (less than 0.25 meters) lenses of conglomerate, and flaser bedding. Rooted and carbonaceous claystones are common, particularly

in contact with coal seams.

D54/D4 Coal (Unit #6) ranges from 0.6 to 5.2 meters (2 to 17.1 feet) for the D54 and from 0.5 to 3.5 meters (1.5 to 11.4 feet) for the D4. These seams are black, banded, moderately bright to bright, and generally hard but friable when unoxidized. This coal usually fractures conchoidally to blocky. It commonly contains visible calcium oxide on vertical cleats, and similar pyrite and accessory minerals as the D31/D21 coal. The D4 seam possesses the highest calorific (BTU) values of all coal seams in the study area. Clastic partings are relatively rare or very thin (less than 0.1 meter).

D54 Parting (Unit #7) begins as a thin (0.3 meter) claystone member and includes siltstone if more than about one meter (3.3 feet) in thickness. Once this unit attains a thickness of about 3 meters (10 feet), sandstone becomes more prevalent. This unit reaches a maximum thickness of 12.4 meters (40.8 feet) and is usually light gray or light olive gray. Claystones contain siderite bands and some are carbonaceous with thin laminae. Limestones are rare. Lithologic relationships are well represented in Plate III.

D5 Coal (Unit #8), ranging in thickness from 0.9 to 2.6 meters (3 to 8.5 feet), is similar in most respects to the D31/D21 coal except that it is somewhat thinner and the influence of clastic partings is markedly less severe, although some are still present, affecting ash content south

of Tenmile Draw.

Overburden (Unit #9) has sandstone as the chief constituent. These are cross-bedded, frequently contain ferruginous concretions, are sometimes contorted with slump structures, and contain very minor feldspar and traces of garnet and other minerals. Claystones are thinly laminated. Freshwater limestones are thin but relatively widespread. The overburden is primarily light yellow brown near the surface to light olive gray or gray in unweathered sections. Siderite bands are oxidized and leached near the surface. A thin (0.3 meter), persistent coal rider seam about 9 meters (30 feet) above the D54 coal has been traced from about two kilometers south of 9 1/2 Mile Draw to almost as far north as Deadman Draw in the active mine area. This bed, although not of mineable thickness, is a useful marker bed.

PALEOBOTANY

Although scattered snail fragments have been found in the Fort Union Formation in the area of investigation, they are too broken up to be identified. Three identifiable fossil plants have been discovered, however.

A thin-bedded siltstone in Section 26, T20N, R100W yielded a specimen of *Cornus nebrascensis* (Figure 21) from a surface exposure in overburden strata. This species of dogwood tree is common in the Paleocene (Brown, 1962).

A well-preserved fern, *Selaginella* (Figure 22), was

Figure 21. *Cornus nebrascensis* from section 26, T20N, R100W.

Figure 22. *Selaginella* sp. from section 35, T21N, R101W.

found in massive claystone (interburden) at the northern edge of the study area in Section 35, T21N, R100W. Several fern species have been found north of the study area, among these are *Salvinia* (?), a floating fern (Wing, 1984). An as yet unidentified monocot has been found in abundance in and around this locality. Also found here in a laminated siltstone were a few leaves of *Cercidiphyllum*, or katsura tree, a genus related to the shuihsa of China. *Cercidiphyllum* is an index fossil of the early Paleocene and commonly occurred along streambanks in moist, drained soils, but was rare or absent from swamps (Wing, 1984).

A large, sabal palm specimen was recovered from interburden claystone immediately overlying the D31 seam less than one mile north of 9 1/2 Mile Draw (Figure 23). Known as the palmetto, *Sabalites* ranges into the Holocene and can be found living in Florida (S. Wing, paleobotanist, Dept. of Paleobiology, National Museum of Natural History, 1987, pers. comm.).

Fragmental plant remains frequently can be located in surface section. These are often unidentifiable but are recognizable as twig, bark, root, or stem fragments. Evidence of past luxuriant plant life is confirmed by standing trunks approximately 8 meters (26 feet) in height coalified *in situ* in active pit highwalls immediately adjacent to the study area north of 9 1/2 Mile Draw.

Further detailed paleobotanical studies are needed,

Figure 23. *Sabalites* sp. from Section 34, T21N, R101W (approximate location). This specimen is approximately 1.3 meters (51 inches) across and is displayed at the Sweetwater County Historical Museum in Green River, Wyoming.

as Brown (1962) recognized that many more plant species have transgressed the Cretaceous-Paleocene boundary than was formerly supposed. Active pit areas provide a virtual bounty of unweathered specimens. Paleobotany will also permit more accurate determination of the true age of the Fort Union Formation in the study area.

CHAPTER 6

DISCUSSION AND INTERPRETATION

Regionally, unconformities flanking both the Rock Springs Uplift and the Douglas Creek Arch of northwestern Colorado are similar in structural symmetry and the two structures have fairly complete continuity except for where the Uinta Uplift has removed the evidence. The Douglas Creek Arch and the southern end of the Rock Springs Uplift have jointly been interpreted as a foreland fold in front of the Cretaceous orogenic belt of central and northern Utah (Gow, 1950). The Douglas Creek Arch-Rock Springs Uplift structural element was a large anticlinal nose plunging northward. Major uplift of the Uintas occurred during the Early Paleocene (Picard, Bruhn, and Beck, 1983).

Lance-Fort Union Contact

A conglomerate bed has been mapped at the base of the Fort Union Formation around Baggs, Wyoming, near the Sierra Madre Uplift (Swain, 1957), as previously mentioned in Chapter 2. This layer is absent or undetectable near the study area. Schultz (1910), presumably working near the Black Buttes area, noted a conglomerate which he described as the boundary between the Black Buttes and Black Rock coal groups (basal Wasatch). Severn (1959) measured a surface section in sections 8 and 9, T20N, R100W, and placed the Lance-Fort Union contact just below a 2.7 meter (9 foot) covered inter-

val between two sandstones of similar lithologic characteristics. He generally failed to find the unit described by Schultz and assumed it to be intermittently exposed. However, Severn did encounter a conglomeratic unit in Section 10, T18N, R100W near Black Buttes (Figure 3; Plate I) which was noted as the "basal conglomerate of the Fort Union Formation."

Other workers mapping the eastern flank of the Rock Springs Uplift picked a massive, buff to white sandstone as the base of the Fort Union Formation in this area. The uppermost sandstone of Swain appears to be the same as the basal sandstone of Mogensen (1959), as pointed out in Chapter 2. Johnston's (1959) thesis reported the base of the Fort Union near the Table Mountains is marked by a distinctive, massive, buff sandstone about 6.1 meters (20 feet) thick. Photographs taken by Mogensen near Black Butte bear striking resemblance to sandstones and associated cavernous weathering in the upper units of the Lance Formation noted in the area of investigation.

Finally, the presence of a fossil soil bed was first described by Ritzma (1955) and further studied by Ritzma (1965) and Land (1972). Once recognized as a paleosol, this horizon was mapped by the writer in several localities. A maximum of 2.2 meters (7.2 feet) was cored near measured section MS-86009. The fossil soil consistently lies several meters above the base of the white sandstone and less than

one meter to greater than five meters below the D31 or D21 seams. However, the paleosol in question, that used to denote the lower contact of the Fort Union Formation with the underlying Lance Formation, could be confused at times with up to three other paleosol horizons within the lower portion of the Fort Union. The Lance-Fort Union boundary paleosol can be found consistently in surface sections below mineable Deadman coals, where these are present.

Bown and Kraus (1987) found an inverse relationship between soil maturity and short-term sediment accumulation rate, based on studies of the paleosols of the Lower Eocene Willwood Formation in northwestern Wyoming. Immature soils found in Latest Cretaceous Hell Creek and Paleocene Tullock Formations in Montana and western North Dakota formed in a poorly drained environment with a fluctuating water table (Fastovsky and McSweeney, 1987). Ancient pedogenesis patterns in many regions are becoming more clearly understood. The Lance-Fort Union boundary paleosol in the area of investigation is interpreted to have characteristics similar to Stage-1 (immature) paleosols of Bown and Kraus (1987). This is based upon close (hand lens) visual examination of the horizon best exposed in the southern portion of the study area (Figure 20).

Although the existence of an unconformity at the Lance-Fort Union contact was disputed by some earlier workers (Swain, 1957; Mogensen, 1959), a majority consensus

would support existence of an unconformity (Ritzma, 1955; Smithson, 1959; Johnston, 1959; Land, 1972). Field evidence for an unconformity can be seen where Fort Union sediments rest directly upon Almond Formation rocks on the western flank of the Rock Springs Uplift (Plate I) and on the eastern flank of the uplift the Fort Union rests upon the Lewis Shale at the northern and southern portions of the structure. At the midpoint of the Rock Springs Uplift on the eastern flank (near the southern end of the study area), however, angular discordances between the Lance and Fort Union are less discernible--probably on the order of one to two degrees and become practically unnoticeable with slumping and erosion occurring at outcrop. Figure 24 illustrates some of these relationships, including the continuous nature of the fossil soil horizon, as interpreted by the writer. An unconformity also exists between the Fort Union and Wasatch Formations (Davis, 1958), but was not studied during this investigation.

Although Swain worked primarily along the western margins of the Sierra Madre, the observations of Mogensen probably did not take into account these regional structural characteristics. The Lance Formation was apparently severely truncated by erosion in Late Cretaceous or Early Paleocene time, a concept favored by Weimer (1970). This event was followed by the overlapping of the onlapping Fort Union. Mogensen's claim that the entire interval of Paleocene depo-

Figure 24. Generalized cross section through Upper Cretaceous and Lower Tertiary rocks, east flank of the Rock Springs Uplift (modified from Ritzma, 1955).

sition is represented by the Fort Union Formation cannot be substantiated in the Rock Springs Uplift area.

Structural Regime

The southern portion of the Jim Bridger coal field is generally unaffected by faulting (Plate II), with the exceptions of the following:

Ten Mile Draw--two faults are postulated south of the drainage on most regional geologic maps. It would appear that two faults are needed to explain the radical and deep coal stratigraphy in boreholes 147, 267, and 80085-80096. The illustrated interpretation is an attempt to explain subsurface stratigraphic conditions.

Southern Permit Boundary--two faults are postulated on most regional geologic maps. Although both faults are plotted on Plate II, the location of only the more northerly fault is known by the investigator to any degree of certainty, as borehole 85040 straddles the fault plane.

Regional dips are low, ranging from one to five degrees. Other faulting has been identified as fairly minor. All faults mapped as a part of this study conform to interpreted regional trends.

MODES OF DEPOSITION

Although detailed studies of depositional environments are beyond the scope of this study it is important to discuss some generalizations. Specifically, it should be in-

teresting to compare the Fort Union Formation in the southern portion of the Jim Bridger coal field with the equivalent unit in the Powder River Basin.

Peat formation requires luxuriant vegetative growth with at least some woody or fibrous components, sufficient standing water to prevent oxidation of the organic matter, and the absence of sediment or clastic debris (Ward, 1984). Swamp plants themselves commonly provide baffles and barriers to sedimentary detritus with their extensive root systems.

The importance of high annual rainfall in contributing to the establishment of an elevated water table has often been overlooked. Crevassing and avulsion would otherwise prohibit raised peat swamps from developing extensively (McCabe, 1984). Relief of these swamps inhibits detrital influx and channel migration and avulsion (Flores, 1984; McCabe, 1984).

Flores (1980) demonstrated that concerns of coal exploration such as thickness, lateral continuity, aerial distribution and quality of coals in the Western Interior are directly related to depositional environment. A variety of settings may be responsible for peat formation. Frequently, extensive swamps may accumulate in river floodplains, lakes, deltas, and coastal areas (Ward, 1984), but less extensive and therefore less economically significant coal deposits may be preserved in other, isolated stagnant-water bodies.

Inland freshwater or fluvial coals formed away from marine influence can generally be expected to contain much lower sulfur than marine coals (Frazier and Ozanik, 1969). Combine this with low to moderate ash (Kaiser, 1974; Fisher, 1968), and fluvial coals begin to show the desirable characteristics of a clean, low-polluting energy source. Some investigations (Jacob, 1973, 1975; Wanless et al., 1969; Ferm and Horne, 1979) have shown that maximum coal thickness occurs in deltaic coals. However, because of mining in deltaic environments, this has led in some areas to exploration and definition of fluvial coal-forming environments.

Anastomosed streams have been defined by Smith and Smith (1980, p. 157-158) as those which have "an interconnected network of low-gradient, relatively deep and narrow, straight to sinuous channels with stable banks composed of fine-grained sediment (silt/clay) and vegetation . . . Separating the channels are floodplains consisting of vegetated islands, natural levees, and wetlands." Anastomosing fluvial systems have been interpreted to produce several major coal deposits (Leblanc Smith and Eriksson, 1979; Cairncross, 1980; Smith and Putnam, 1980; Flores and Hanley, 1974; Budai and Cummings, 1987).

Fort Union Formation, Powder River Basin

The extensive literature describing the coal-bearing rocks of the Powder River Basin shall be summarized briefly here. Much of this work has been done in the late 1970s and

1980s in response to mining interests and oil and gas exploration potential.

The Powder River Basin of northeastern Wyoming and southeastern Montana is a large, asymmetrical basin about 160 kilometers (96 miles) long and 80 kilometers (48 miles) wide (Figure 1). The Fort Union Formation in this area is divided into the Tullock, Lebo, and Tongue River Members (Ayers and Kaiser, 1984).

The Tongue River Member, the major coal-bearing unit in the basin, has been interpreted by Flores (1979, 1980, 1981) to consist of alluvial, fluvial-lake, and fluvial environments based upon measured surface sections. Ayers and Kaiser (1984) proposed paludal and lacustrine-interdeltaic models, based upon surface and extensive subsurface data.

In the southern Powder River Basin, Sharp and Gibbons (1964) proposed a northward-flowing, mixed-load system which spread mud across its floodplain during flood stages. Later studies in the same area described fine-grained meander belt systems (Jackson and Ethridge, 1979) in addition to northward-flowing mixed- to bedload channel systems (Galloway, 1979) which interfingered laterally with and evolved down-slope into mixed- and suspended-load systems with gradually changing gradients.

In the northern Powder River Basin, Flores and Hanley (1984) proposed large-scale anastomosis which served as a downflow continuum of basin-margin, conglomeratic, braided

and meandering tributary systems. They suggested that this was initiated by tectonic causes related to the Cedar Creek Anticline in southeastern Montana.

Southern Portion of the Jim Bridger Coal Field

Studies by Swain (1957) and Beaumont (1979) of the Fort Union Formation in the Sierra Madre region suggest that source areas in the major uplifted areas of the Early Paleocene (Park Range, Sierra Madre, and Uinta Uplift) were responsible for supplying gradients and sediments to northward-flowing streams in the Sand Wash and Washakie Basins. High sinuosity streams were replaced by low sinuosity, coal-bearing systems in the upper Fort Union of the Sand Wash Basin. Paleobotanical evidence is suggestive of a warm, moist climate near a low elevation.

The Allegheny deltaic model developed by Horne et al. (1978) has been successfully applied to many coal deposits worldwide. The transitional facies between lower and upper delta plain deposits would appear to explain thick, laterally extensive coal seams, but breaks down when taking into account observed high sand-clay ratios and brackish to marine fossils required for the Allegheny model. Conversely, observed high sand-clay ratios at Jim Bridger fit the upper deltaic plain facies of Horne et al.'s model, but cannot explain thick, laterally continuous coal seams.

The Lower Paleocene in the southern portion of the Jim Bridger coal field has a very high sandstone-claystone ratio

(about 3.6 to 1). Studies of ancient channel occurrences in overburden north of the study area indicate low sinuosity and high width to depth ratios. Thus it would appear that this vertical facies interval has a good correlation with a braided (low sinuosity) model.

The linear distance to the Wind River Mountains, about 66 kilometers (40 miles) from the study area, would tend to indicate a reasonably acceptable gradient for a braided model. Anastomosed channels have high depth/width ratios (Smith and Putnam, 1980), higher than those observed in the study area. However, few lateral accretion surfaces that have been observed in active pit regions in interburden strata exhibit narrow (around 1 meter), relatively deep channels. Whether these features are anastomosed, or are merely small tributaries, remains to be confirmed with future studies.

Gradients decreased and meander belts became stabilized during late Fort Union time as the increasing amounts of clays (up to 95%) inhibited lateral channel migration, compacted and contributed to stable, high sinuosity flood plain characteristics (Royse, 1970). No coal is found in this part of the Fort Union, reflecting better drainage conditions.

Paleocurrent directions measured in the northwest portion of the study area (Figure 25) suggest a northerly sediment source. Hand specimen recognition of abundant (up to

Figure 25. Paleocurrent directions, northwest portion of study area.

about 10%) muscovite grains would tend to support this hypothesis, since the southern Wind River Mountains contain the only active sediment source during the Paleocene with requisite plutonic rocks, with the Precambrian cores of the more northerly Washakie and Owl Creek Ranges being only locally exposed during the Paleocene (Courdin and Hubert, 1969).

The name "Fort Union Formation" in southwestern Wyoming has been extended so far from its type area that it is used to denote a time-transgressive unit rather than a rock-stratigraphic unit (Swain, 1957). Mid- to Late-Paleocene coals in the Powder River Basin are referred to the Fort Union while most of the Fort Union coals around the Rock Springs Uplift are thought to be earliest Paleocene (Puer-can). Only through detailed paleobotanical and palynological studies will the true ages of these sediments be determined, and a greater degree of understanding achieved thereby.

CHAPTER 7

APPLICATION OF STRATIGRAPHIC MODEL

There are several areas of the mining operation which will benefit from using the stratigraphic model. Many of these applications are aimed at reducing unit costs or pinpointing potential problem areas before mining.

Studies by Crosby (1985, 1986) have shown that detailed stratigraphic knowledge combined with joint set mapping can be used to determine suitability of an area for cast blasting. The factors most affecting the suitability for this type of blasting are highwall stability and the presence and amount of groundwater. Success of conventional or cast blasting is reliant upon identification of lateral and vertical rock variabilities. The stratigraphic model will be particularly valuable in potential mining areas with deep overburden, where blasting efficiency is more critical. In addition, this model will lay necessary groundwork for future rock mechanics and other engineering evaluations.

The use of depositional models in mine planning has relied on detailed stratigraphic studies (Horne, et al., 1978). Further depositional studies are often undertaken in an effort to predict coal quality trends. Sodium oxide and other mineral matter content, and sulfur distribution affect combustion, contractual mineability, and blending potential (Hackley, 1984; Cohen, Spackman, and Dolsen, 1971). Future

stratigraphic and depositional studies can be incorporated with groundwater hydrology concepts to determine potential pit water inflow areas. Drilling and coal coring targets for future years can be identified. Enough data have become available in recent years to permit detailed, reliable rock geochemical-lithostratigraphic correlations with *in situ* coal chemistry parameters, which could prove very useful to predictions of potential toxic zones for reclamation planning. During times of reduced profit margins and increased foreign competition, domestic coal mining companies today must take advantage of all geological resources available.

CONCLUSIONS AND RECOMMENDATIONS

Twenty-nine surface sections and 581 subsurface (borehole) sections were evaluated and used to construct a stratigraphic model of the southern portion of the Jim Bridger coal field. Mainframe-computer-resident software, such as LOGPLOT and STRATVIEW were used where possible to assist in production of a fence diagram of the study area. The stratigraphic model includes lithologic and chronologic units.

Sandstone (60%), claystone (17%), siltstone (11%), coal (10%), and limestone (2%) are found to be the most abundant lithologic units and exhibit a high degree of lateral and vertical variability. Lateral continuity of major coal seams is shown to be useful for informal stratigraphic

purposes. Fossil flora examined in and near the study area include *Cornus nebrascensis* (dogwood), *Selaginella* (fern), *Salvinia* (a floating fern), *Cercidiphyllum* (katsura), and *Sabalites* (palm) and indicate accumulation under warm temperate to subtropical conditions.

The Lance-Fort Union contact is mapped immediately above a distinctive fossil soil horizon up to 2.2 meters (7.2 feet) thick. Multiple paleosols exist within the lower Fort Union, so the formational contact is placed below the lowest significant coal, where present. High sandstone percentages and a noticeable lack of lateral accretion surfaces are interpreted to define sedimentation in low sinuosity, perhaps braided, stream environments. Paleocurrent directions infer a northerly source, probably the Wind River Range.

Southward-flowing streams from the Wind River Range shed sediments into active depocenters in the Jim Bridger area during the Early Paleocene. Eroding highlands in Colorado (White River Plateau?, Sierra Madre, Park Range) were also sources of sediment filling the basin from the south. Since the Rock Springs Uplift had begun rising to the west, major drainage must have been to the east through what is now the Washakie Basin.

Further depositional studies could emphasize computer contouring and geostatistics to confirm source areas and possible Markov analysis to separate random depositional

events from normal ordered events. Lateral and vertical variabilities are so great that continued mapping in the study area will be necessary to further understand the complex rock-body geometries.

Future work will need to be emphasized in the highwall stability and blasting optimization areas. Subsequent but no less important opportunities for contributions will come in the fields of paleobotany, geochemistry, and paleosol stratigraphy.

REFERENCES

- Ayers, W.B., Jr., and Kaiser, W.R., 1984, Lacustrine-interdeltaic coal in the Fort Union Formation (Palaeocene) Powder River Basin, Wyoming and Montana, U.S.A., in Rahmani, R.A., and Flores, R.M., eds., *Sedimentology of Coal and Coal-bearing Sequences: International Assoc. of Sedimentologists, Spec. Pub., Volume 7*, p. 61-84.
- Beaumont, E.A., 1979, Depositional environments of Fort Union sediments (Tertiary, northwest Colorado) and their relation to coal: *Am. Assoc. Petroleum Geologists Bull.*, v. 63 p. 194-217.
- Blackstone, D.L. Jr., 1955, Notes on a tectonic map of parts of southwestern Wyoming and adjoining states: *Wyoming Geol. Assoc. Guidebook 10th Ann. Field Conf.*, p. 122-124.
- Bown, T.M., and Kraus, M.J., 1987, Integration of channel and floodplain suites, I. Developmental sequence and lateral relations of alluvial paleosols: *Journal of Sedimentary Petrology*, v. 57, p. 587-601.
- Bradley, W.H., 1945, *Geology of the Washakie Basin, Sweetwater and Carbon Counties, Wyoming, and Moffat County, Colorado*: U. S. Geol. Survey Oil and Gas Map 32.
- , 1961, *Geologic map of a part of southwestern Wyoming and adjacent states*: U. S. Geol. Survey Misc. Geol. Investigation Map I-332, scale 1:250,000.
- Brown, R.W., 1949, *Paleocene deposits of the Rocky Mountains and Plains*: U. S. Geol. Survey Prelim. Map.
- , 1962, *Paleocene floras of the Rocky Mountains and Great Plains*: U. S. Geol. Survey Prof. Paper 375, 257 p.
- Budai, C.M., and Cummings, M.L., 1987, A depositional model of the Antelope coal field, Powder River Basin, Wyoming: *Journal of Sedimentary Petrology*, v. 57, p. 30-38.
- Cairncross, B., 1980, Anastomosing river deposits: paleoenvironmental control on coal quality and distribution, northern Karoo Basin: *Transactions of the Geological Society of South Africa*, v. 83, p. 327-332.

- Carey, B.D., 1955, A review of the geology of Leucite Hills: Wyoming Geol. Assoc. Guidebook 10th Ann. Field Conf., p. 112-113.
- Cohen, A.D., Spackman, W., and Dolsen, C.P., 1971, Occurrence and distribution of sulfur in peat-forming environments of south Florida (Abstract): Geol. Soc. America Abstracts with Program, v. 3, p. 528.
- Compton, R.R., 1962, Manual of field geology: New York, John Wiley and Sons, 378 p.
- Courdin, J.L., and Hubert, J.F., 1969, Sedimentology and Mineralogical differentiation of sandstones in the Fort Union Formation (Paleocene), Wind River Basin, Wyoming: Wyoming Geol. Assoc. Guidebook 21st Ann. Field Conf., p. 29-37.
- Crosby, W.A., 1985, Visit to Bridger Coal Company--June 1985: Mining Resource Engineering Ltd. unpubl. report, 54 p.
- _____, 1986, Visit to Bridger Coal Company--March 1986: Mining Resource Engineering Ltd. unpubl. report, 41 p.
- Cross, W., and Spencer, A.C., 1899, U.S. Geol. Survey La Plata Folio 60: Washington.
- Curry, W.H. III, 1969, Synthetic electric logs in subsurface mapping: Wyoming Geol. Assoc. Guidebook 24th Ann. Field Conf. p. 93-98.
- Davis, R.W., 1958, Stratigraphy of the Wasatch Formation, east flank of the Rock Springs Uplift, Sweetwater County, Wyoming: M.A. thesis, University of Wyoming, 76 p.
- Dedman, E.V., Lindsey, J.P., and Schramm, M.W., 1975, Stratigraphic modeling: A step beyond bright spot: World Oil, v. 180, no. 6, p. 61-65.
- Dorf, E., 1938, Upper Cretaceous floras of the Rocky Mountain region: Carnegie Inst. of Washington Pub. 508, p. 1-78.
- Eardley, A.J., 1951, Structural geology of North America: New York, Harper and Brothers, 624 p.
- Fastovsky, D.E., and McSweeney, K., 1987, Paleosols spanning the Cretaceous-Paleogene transition, eastern Montana and western North Dakota: Geol. Soc. America Bull., v. 99, p. 66-77.

- Ferm, J.C., and Berger, J.T., 1979, A computer graphics system preparing coal bore hole data for mapping: Computer Graphics, v. 2, no. 8, p. 20-26.
- Ferm, J.C., and Horne, J.C., 1979, Carboniferous depositional environments in the Appalachian region: Dept. Geology, University of South Carolina, Columbia, S.C., 760 p.
- Fidlar, M.M., 1950, Structural features of the Green River Basin in Wyoming: Wyoming Geol. Assoc. Guidebook 5th Ann. Field Conf., Southwest Wyoming, p. 86-87.
- Fisher, W.L., 1968, Variations in lignites of fluvial, deltaic, and lagoonal system, Wilcox Group (Eocene) Texas (Abstract): Geol. Soc. America Ann. Meeting Program with Abstracts, p. 97.
- Fisk, E.P., 1967, Groundwater geology and hydrology of the Great Divide and Washakie basins, south central Wyoming: M.S. thesis, University of Southern California, 132 p.
- Flores, R.M., 1979, Coal depositional models in some Tertiary and Cretaceous fields in the U.S. Western Interior: Organic Geochemistry, no. 1, p. 225-235.
- _____, 1980, Comparison of depositional models of Tertiary and Upper Cretaceous coal-bearing rocks in some Western Interior basins of the United States: 1980 Proceedings of the 4th Symposium on the Geology of Rocky Mountain Coal; Colorado Geol. Survey Resource Series 10, p. 17-20.
- _____, 1981, Coal deposition in fluvial paleoenvironments of the Paleocene Tongue River Member of the Fort Union Formation, Powder River area, Powder River Basin, Wyoming and Montana, in Ethridge, F.G., and Flores, R.M., eds., Recent and Ancient Nonmarine Depositional Environments: Models for Exploration: Soc. Econ. Paleon. and Mineralog. Spec. Pub. 31, p. 169-190.
- _____, 1984, Comparative analysis of coal accumulation in Cretaceous alluvial deposits, southern United States Rocky Mountain basins, in Stott, D.F., and Glass, D.J., eds., The Mesozoic of Middle North America: Canadian Soc. Petroleum Geologists Memoir 9, p. 373-385.

- Flores, R.M., and Hanley, J.H., 1984, Anastomosed and associated coal-bearing fluvial deposits: Upper Tongue River Member, Palaeocene Fort Union Formation, northern Powder River Basin, Wyoming, U.S.A., in Rahmani, R.A., and Flores, R.M. eds., *Sedimentology of Coal and Coal-bearing Sequences: International Assoc. of Sedimentologists Spec. Pub., Volume 7*, p. 85-103.
- Frazier, D.E., and Ozanik, A., 1969, Recent peat deposits-Louisiana coastal plain, in Dapples, E.C., and Hopkins, M.E., eds., *Environments of Coal Deposition: Geol. Soc. America Spec. Paper No. 114*, p. 63-85.
- Frink, A.P., Wittick, T.R., and Dedman, E.V., 1977, Interpretive methods of stratigraphic modeling: Preprint, Oil Technology Conf., Houston, May 2-5, 1977.
- Galloway, W.E., 1979, Early Tertiary--Wyoming intermontane basins in Galloway, W.E., Kreiter, C.W., and McGowan, J.H., eds., *Depositional Ground-water Flow Systems in the Exploration for Uranium--A Research Colloquium: Bureau of Econ. Geol., University of Texas, Austin*, p. 197-213.
- Gill, J.R., and Cobban, W.A., 1966, Regional unconformity in Late Cretaceous, Wyoming: Geological Survey Research, U. S. Geol. Survey Prof. Paper 550-B, p. B20-B27.
- Glass, G.B., 1978, Review of Wyoming coal fields: Geol. Survey of Wyoming, Public Information Circular no. 4, 21 p.
- Gow, K., 1950, Douglas Creek gas field: Intermountain Assoc. of Petroleum Geologists Guidebook to the Geology of Utah No. 5, p. 139-146.
- Hackley, K.C., 1984, Sulfur isotope variations in low-sulfur coals from the Rocky Mountain region: M.S. thesis, University of Illinois, 84 p.
- Hale, L.A., 1950, Stratigraphy of the Upper Cretaceous Montana Group in the Rock Springs Uplift, Sweetwater County, Wyoming: M.A. thesis, University of Wyoming, 115 p.
- _____, 1955, Stratigraphy and facies relationship of the Montanan Group in south central Wyoming, northeastern Utah, and northwestern Colorado: Wyoming Geol. Assoc. Guidebook 10th Ann. Field Conf., p. 89-94.
- Hayden, F.V., 1869, Third annual report of the U.S. Geological and Geographical Survey of the Territories: Washington, p. 191.

- _____, 1879, Eleventh annual report of the U.S. Geological and Geographical Survey of the Territories: Washington.
- Hendricks, M.L., 1983, Stratigraphy and tectonic history of the Mesaverde Group (Upper Cretaceous), east flank of the Rock Springs Uplift, Sweetwater County, Wyoming: Ph.D. dissertation, Colorado School of Mines, Golden, Colorado, 213 p.
- Horne, J.C., Ferm, J.C., Caruccio, F.T., and Baganz, B.P., 1978, Depositional models in coal exploration and mine planning in Appalachian region: Am. Assoc. Petroleum Geologists Bull., v. 62, p. 2379-2411.
- Hunt, C.B., 1967, Physiography of the United States: San Francisco, W. H. Freeman and Co., 480 p.
- Jackson, T.J., and Ethridge, F.G., 1979, Floodplain sequences of a fine-grained meander-belt system: the lower Wasatch and upper Fort Union Formations, central Powder River Basin, Wyoming (Abstract): Am. Assoc. Petroleum Geologists Bull., v. 63, p. 831-832.
- Jacob, A.F., 1973, Depositional environments of Paleocene Tongue River Formation, western North Dakota: Am. Assoc. Petroleum Geologists Bull., v. 57, p. 1038-1052.
- _____, 1975, Geology of the upper part of the Fort Union Group (Paleocene), Williston Basin, with reference to uranium: North Dakota Geol. Survey Report of Investigations No. 58, 49 p.
- Johnston, R.H., 1959, Geology of the northern Leucite Hills, Sweetwater County, Wyoming: M.A. thesis, University of Wyoming, 83 p.
- Kaiser, W.R., 1974, Texas lignite: Near-surface and deep-basin resources: Bureau Econ. Geol., University of Texas, Austin, Report of Investigations 79, 70 p.
- Keith, R.E., 1965, Rock Springs and the Blair Formations on and adjacent to the Rock Springs Uplift: Wyoming Geol. Assoc. Guidebook 19th Ann. Field Conf., p. 43-53.
- Kirschbaum, M.A., 1986, Geologic map of the Kappes Canyon quadrangle, Sweetwater County, Wyoming: U.S. Geol. Survey Map GQ-1607, scale 1:24,000.

- Knight, S.H., 1955, Review of the early geological explorations of the Green River Basin area, 1812-1879: Wyoming Geol. Assoc. Guidebook 10th Ann. Field Conf., p. 10-17.
- Kottlowski, F.E., 1965, Measuring stratigraphic sections: New York, Holt, Rinehart and Winston, 253 p.
- Land, C.B., Jr., 1972, Stratigraphy of Fox Hills Sandstone and associated formations, Rock Springs Uplift and Wamsutter Arch area, Sweetwater County, Wyoming: A shoreline-estuary sandstone model for the Late Cretaceous: Colorado School of Mines Quarterly v. 67 no. 2, 69 p.
- Law, B.E., Bucurel-White, H., and Bader, J.W., 1983, Sedimentological aspects of stratigraphic correlations in the Upper Cretaceous Ericson Sandstone, Greater Green River Basin, Wyoming, Colorado, and Utah (Abstract): Geol. Soc. America Rocky Mountain Section Program with Abstracts, p. 333.
- Leblanc Smith, G., and Eriksson, K.A., 1979, A fluvioglacial and glaciolacustrine deltaic depositional model for Permo-Carboniferous coals of the northeastern Karoo Basin, South Africa: Palaeogeography, Palaeoclimatology, Palaeoecology, v. 27, p. 67-84.
- Lee, W.T., 1915, The overland route, with a side trip to Yellowstone Park: Part B of Guidebook of the Western United States: U. S. Geol. Survey Bull. 612.
- Levey, R.A., 1985, Depositional model for understanding geometry of Cretaceous coals: major coal seams, Rock Springs Formation, Green River Basin, Wyoming: Am. Assoc. Petroleum Geologists Bull., v. 69, p. 1359-1380.
- Lewis, J.L., 1961, The stratigraphy and depositional history of the Almond Formation in the Great Divide Basin, Sweetwater County, Wyoming: Wyoming Geol. Assoc. Guidebook 16th Ann. Field Conf., p. 87-95.
- Love, J.D., and Christiansen, A.C., 1985, Geologic map of Wyoming: U. S. Geol. Survey Map, scale 1:500,000.
- Lovering, T.S., 1929, Geologic history of the Front Range, Colorado: Colorado Sci. Soc. Proc., v. 12 no. 4, p. 59-111.

- Madden, D.J., 1981, Geologic map and coal sections of the Point of Rocks quadrangle, Sweetwater County, Wyoming: U. S. Geol. Survey Open-File Report 81-869, scale 1:24,000.
- McCabe, P.J., 1984, Depositional environments of coal and coal-bearing strata, in Rahmani, R.A., and Flores, R.M., eds., *Sedimentology of Coal and Coal-bearing Sequences: International Assoc. of Sedimentologists, Spec. Pub., Volume 7*, p. 13-42.
- McPhater, D., and MacTiernan, B., 1983, *Well-site geologist's handbook: Tulsa, Oklahoma*, PennWell Publishing, 77 p.
- Meek, F.B., and Hayden, F.V., 1862, Descriptions of new fossils collected in Nebraska, by the exploring expedition under the command of Capt. Wm. F. Reynolds: *Acad. Nat. Sci. Philadelphia Proc.*, v. 13, p. 432-435.
- Miller, F.X., 1977, Biostratigraphic correlation of the Mesaverde Group in southwestern Wyoming and northwestern Colorado: *Rocky Mountain Assoc. of Geologists 1977 Symposium*, p. 117-137.
- Mogensen, P., 1959, Fort Union Formation, east flank of the Rock Springs Uplift, Sweetwater County, Wyoming: M.A. thesis, University of Wyoming, 86 p.
- Nace, R.L., 1936, Summary of the late Cretaceous and early Tertiary stratigraphy of Wyoming: *Wyoming Geol. Survey Bull.* 26, 271 p.
- , 1939, Geology of the northwest part of the Red Desert, Sweetwater and Fremont Counties, Wyoming: *Wyoming Geol. Survey Bull.* 27, 51 p.
- Neidell, N.S., 1980, Stratigraphic modeling and interpretation: geophysical principles and techniques: *Am. Assoc. of Petroleum Geologists Cont. Education Course Notes*, 145 p.
- Nielsen, G.F., ed., 1984, *Keystone coal industry manual*: New York, McGraw-Hill, 1388 p.
- Oriel, S.S., and Tracey, J.I., 1970, Uppermost Cretaceous and Tertiary stratigraphy of Fossil basin, Southwestern Wyoming: *U. S. Geol. Survey Prof. Paper* 635, 53 p.

- Picard, M.D., Bruhn, R.B., and Beck, S.L., 1983, Mesozoic and early Tertiary paleostructure and sedimentology of Central Wasatch Mountains, Uinta Mountains, and Uinta Basin (Abstract): Am. Assoc. Petroleum Geologists Bull., v. 67, p. 1351-1352.
- Pipiringos, G.N., 1955, Tertiary rocks in the central part of the Great Divide Basin, Sweetwater County, Wyoming: Wyoming Geol. Assoc. Guidebook 10th Ann. Field Conf., p. 100-104.
- Randall, A.G., 1961, Catalog of formation names for Post-Niobrara Pre-Eocene Rocks of Wyoming and adjacent areas: Wyoming Geol. Assoc. Guidebook 16th Ann. Field Conf., p. 9-15.
- Ritzma, H.R., 1955, Late Cretaceous and early Cenozoic structural pattern, southern Rock Springs Uplift, Wyoming: Wyoming Geol. Assoc. Guidebook 10th Ann. Field Conf., p. 135-137.
- _____, 1965, Fossil soil at base of Paleocene rocks, southern Rock Springs Uplift, Wyoming: Wyoming Geol. Assoc. Guidebook 19th Ann. Field Conf., p. 10-12.
- Roehler, H.W., 1961, The Late Cretaceous-Tertiary boundary in the Rock Springs Uplift, Sweetwater County, Wyoming: Wyoming Geol. Assoc. Guidebook 16th Ann. Field Conf., p. 96-100.
- _____, 1965, Summary of pre-Laramide Late Cretaceous sedimentation in the Rock Springs Uplift area: Wyoming Geol. Assoc. Guidebook 19th Ann. Field Conf. p. 11-12.
- _____, 1977, Geologic map of the Rock Springs Uplift and adjacent areas, Sweetwater County, Wyoming: U. S. Geol. Survey Open-File Report 77-242, scale 1:125,000.
- _____, 1979a, Geology and energy resources of the Sand Butte Rim NW Quadrangle, Sweetwater County, Wyoming: U. S. Geol. Survey Prof. Paper 1065-A, 54 p.
- _____, 1979b, Geology of the Cooper Ridge NE Quadrangle, Sweetwater County, Wyoming: U. S. Geol. Survey Prof. Paper 1065-B, 45 p.
- _____, 1979c, Geology and mineral resources of the Mud Springs Ranch Quadrangle, Sweetwater County, Wyoming: U. S. Geol. Survey Prof. Paper 1065-C, 35 p.

- Root, F.K., Glass, G.B., and Lane, D.W., 1973, Sweetwater County, Wyoming, geologic map atlas and summary of economic mineral resources: Geol. Survey of Wyoming County Resource Series No. 2.
- Royse, C.F., Jr., 1970, A sedimentological analysis of the Tongue River-Sentinel Butte interval (Paleocene) of the Williston Basin, western North Dakota: Sed. Geology, v. 4, p. 19-80.
- Schultz, A.R., 1909, The northern part of the Rock Springs coal field, Sweetwater County, Wyoming in Coal fields of Wyoming: U. S. Geol. Survey Bull. 341-B, pt. 2, p. 256-282.
- _____, 1910, The southern part of the Rock Springs coal field, Sweetwater County, Wyoming, in Coal fields of Wyoming: U. S. Geol. Survey Bull. 381, pt. 2, p. 214-281.
- _____, 1920, Oil possibilities in and around the Baxter Basin, in the Rock Springs Uplift, Sweetwater County, Wyoming: U. S. Geol. Survey Bull. 702, 107 p.
- Sears, J.D., and Bradley, W.H., 1925, Relations of the Watsatch and Green River Formations in northwest Colorado and southern Wyoming: U. S. Geol. Survey Prof. Paper 132-F, p. 93-107.
- Severn, W.P., 1959, Stratigraphy of late Upper Cretaceous, Paleocene, and early Eocene deposits within the east flank of the Rock Springs Uplift, Sweetwater County, Wyoming: M.A. thesis, University of Wyoming, 90 p.
- Sharp, W.N., and Gibbons, A.B., 1964, Geology and uranium deposits of the southern part of the Powder River Basin, Wyoming: U.S. Geol. Survey Bull. 1147-D, 59 p.
- Smith, D.G., and Putnam, P.E., 1980, Anastomosed river deposits: Modern and ancient examples in Alberta, Canada: Canadian Journal of Earth Sciences, v. 17, p. 1396-1406.
- Smith, D.G., and Smith, N.D., 1980, Sedimentation in anastomosed river systems: Examples from alluvial valleys near Banff, Alberta: Journal of Sedimentary Petrology, v. 50, p. 157-164.

- Smith, J.H., 1965, A summary of stratigraphy and paleontology, Upper Colorado and Montana Groups, south central Wyoming, northeastern Utah, and northwestern Colorado: Wyoming Geol. Assoc. Guidebook 19th Ann. Field Conf., p. 13-25.
- Smithson, S.B., 1959, The geology of the southeastern Leucite Hills, Sweetwater County, Wyoming: M.A. thesis, University of Wyoming, 92 p.
- Sullivan, R., 1985, Origin of lacustrine rocks of Wilkins Peak Member, Wyoming: Am. Assoc. Petroleum Geologists Bull. v. 69, p. 913-922.
- Swain, B.W., 1957, Fort Union Formation, west flank of the Sierra Madre, Carbon County, Wyoming: M.A. thesis, University of Wyoming, 132 p.
- Thrush, P.W., comp., 1968, A dictionary of mining, mineral, and related terms, compiled and edited by Paul W. Thrush and the Staff of the Bureau of Mines: U.S. Dept. of the Interior, Bureau of Mines, 1269 p.
- Wanless, H.R., Baroffio, J.R., and Trescott, P.C., 1969, Conditions of deposition of Pennsylvanian coal beds, in Dapples, E.C., and Hopkins, M.E., eds., Environments of Coal Deposition: Geol. Soc. America Special Paper No. 114, p. 105-142.
- Ward, C.R., ed., 1984, Coal geology and coal technology: Carlton, Victoria, Australia, Blackwell Scientific Publications, 345 p.
- Weimer, R.J., 1970, Rates of deltaic sedimentation and intrabasin deformation, Upper Cretaceous of Rocky Mountain region, in Morgan, J.P., ed., Deltaic Sedimentation, Modern and Ancient: Soc. Econ. Paleon. and Mineralog. Spec. Pub. 15, p. 270-292.
- Welder, G.E., and McGreevy, L.J., 1966, Ground-water reconnaissance of the Great Divide and Washakie Basins and some adjacent areas, southwestern Wyoming: U. S. Geol. Survey Hydrologic Investigations Atlas HA-219, sh. 1, scale 1:250,000.
- Wing, S.L., 1984, Relation of paleovegetation to geometry and cyclicity of some fluvial carbonaceous deposits: Journal of Sedimentary Petrology, v. 54, p. 52-66.

APPENDIX 1

MEASURED SURFACE SECTIONS

DATE: 10/01/87

N E R C O, I N C.

PAGE: 1

MASTER DATASET
JIM BRIDGER COAL FIELD

MEASURED SECTION: MS85001

NORTH 393468
EAST 514007
ELEVATION: 6857.6
COMMENTS:

SECTION 35
TOWNSHIP: 21N
RANGE: 100W

COORDINATE SYSTEM: SP
SURVEY/EST: S
CONFIDENCE: 11

MINING COMPANY: BCC
CONTRACTOR:
FIELD REP: PSM

YEAR: 86
TOTAL DEPTH: 45
SECTION TYPE: SU
GEOPHYSICAL LOGS:

TOP DEPTH	BOTTOM DEPTH	LITH	LITHOLOGIC DESCRIPTION	SEAM	NOTE	CODE
=====	=====	=====	=====	=====	=====	=====
0.0	5.0	SL	LT YELL BROWN			470
5.0	7.0	CL	LT BRN GRAY, SILTY			340
7.0	17.0	CO	BLK, MOD HARD, VX AT SURFACE	D54	VX	120
17.0	27.0	SL	LT YELL BROWN, SLOPE			470
27.0	31.0	SS	FGR, LT BROWN-LT YELL BROWN, VX BROWN-ORNG BROWN, ARKOSIC, TROUGH X-BEDS, CALC			570
31.0	37.0	UN	COVERED			30
37.0	40.0	CO	BLK	D31		120
40.0	45.0	UN	COVERED; SILTY CLAY, VX COAL, LT GRAY TO LT BRN GRAY			30

MEASURED SECTION: MS85002

NORTH 393346
EAST 514419
ELEVATION: 6823.2
COMMENTS:

SECTION 35
TOWNSHIP: 21N
RANGE: 100W

COORDINATE SYSTEM: SP
SURVEY/EST: S
CONFIDENCE: 11

MINING COMPANY: BCC
CONTRACTOR:
FIELD REP: PSM

YEAR: 86
TOTAL DEPTH: 21
SECTION TYPE: SU
GEOPHYSICAL LOGS:

TOP DEPTH	BOTTOM DEPTH	LITH	LITHOLOGIC DESCRIPTION	SEAM	NOTE	CODE
=====	=====	=====	=====	=====	=====	=====
0.0	1.5	SL	BROWN VX TO BRN GRAY			440
1.5	11.0	CO	BLK, SOFT, VX, V VX 9.0-11.0	D54	VX	130
11.0	21.0	CL	LT GRAY, SILTY			330

MEASURED SECTION: MS86003

NORTH 390700
EAST 514110
ELEVATION: 6846.0
COMMENTS:

SECTION 5
TOWNSHIP: 20N
RANGE: 100W

COORDINATE SYSTEM: SP
SURVEY/EST: E
CONFIDENCE: 11

MINING COMPANY: BCC
CONTRACTOR:
FIELD REP: PSM

YEAR: 86
TOTAL DEPTH: 25
SECTION TYPE: SU
GEOPHYSICAL LOGS:

TOP DEPTH	BOTTOM DEPTH	LITH	LITHOLOGIC DESCRIPTION	SEAM	NOTE	CODE
0.0	3.5	SS	FGR, LT YELL BROWN, HARD, TROUGH X-BEDS, WX FELDS, CALC CEMENT, LEDGE			570
3.5	9.5	SS	FGR-MGR, LT GRAY, WX TO SILT, MASSIVE			530
9.5	10.5	SL	LT BRN GRAY			440
10.5	16.5	CO	BLK, OXIDIZED			120
16.5	24.5	CL	MOD DK GRAY, SILTY, SLOPE			320

MEASURED SECTION: MS86004

NORTH 390345
EAST 514160
ELEVATION: 6858.0
COMMENTS:

SECTION 5
TOWNSHIP: 20N
RANGE: 100W

COORDINATE SYSTEM: SP
SURVEY/EST: E
CONFIDENCE: 11

MINING COMPANY: BCC
CONTRACTOR:
FIELD REP: PSM

YEAR: 86
TOTAL DEPTH: 50
SECTION TYPE: SU
GEOPHYSICAL LOGS:

TOP DEPTH	BOTTOM DEPTH	LITH	LITHOLOGIC DESCRIPTION	SEAM	NOTE	CODE
0.0	2.0	SS	VFGR, LT GRAY TO LT BRN GRAY WX TO LT ORNG BROWN, TROUGH X-BEDS, LEDGE			530
2.0	10.0	SL	LT BRN GRAY, SLOPE			440
10.0	15.0	SS	VFGR, LT GRAY TO LT BRN GRAY WX TO LT ORNG BROWN, TROUGH X-BEDS, LEDGE			530
15.0	18.0	SL	LT BRN GRAY, WX TO CLAY, SLOPE			440
18.0	23.0	CO	V DK GRAY, SOFT, WX, SLOPE	D3	WX	130
23.0	27.5	CL	BRN GRAY, WX			340
27.5	29.0	CO	BRN-BLK TO DK GRAY, SOFT, V WX, SLOPE, REMNANT CLEATS	D21	WX	130
29.0	33.0	CL	LT GRAY, SILTY, MASSIVE, SLOPE			330
33.0	50.0	SS	VFGR, V LT BRN GRAY, SILTY, LEDGE			540

MEASURED SECTION: MS86005

NORTH 390360	SECTION 5	COORDINATE SYSTEM: SP	MINING COMPANY: BCC	YEAR: 86
EAST 514445	TOWNSHIP: 20N	SURVEY/EST: E	CONTRACTOR:	TOTAL DEPTH: 16
ELEVATION: 6851.0	RANGE: 100W	CONFIDENCE: 11	FIELD REP: PSM	SECTION TYPE: SU
COMMENTS:				GEOPHYSICAL LOGS:

TOP DEPTH	BOTTOM DEPTH	LITH	LITHOLOGIC DESCRIPTION	SEAM	NOTE	CODE
0.0	3.0	SS	VFGR, LT GRAY TO LT BRN GRAY WX TO LT ORNG BRN, HARD, TROUGH X-BEDS, LEDGE			530
3.0	5.0	SS	VFGR, V LT BRN GRAY, MASSIVE, SLOPE			540
5.0	9.5	SL	BRN GRAY, SLOPE			440
9.5	10.0	CO	V DK GRAY, WX TO CARB CLAYST, SOFT	D31	PSWX	130
10.0	16.0	SS	VFGR, BRN GRAY, WX TO SILTST, SLOPE			540

MEASURED SECTION: MS86006

NORTH 389880	SECTION 5	COORDINATE SYSTEM: SP	MINING COMPANY: BCC	YEAR: 86
EAST 514875	TOWNSHIP: 20N	SURVEY/EST: E	CONTRACTOR:	TOTAL DEPTH: 24
ELEVATION: 6858.0	RANGE: 100W	CONFIDENCE: 11	FIELD REP: PSM	SECTION TYPE: SU
COMMENTS:				GEOPHYSICAL LOGS:

TOP DEPTH	BOTTOM DEPTH	LITH	LITHOLOGIC DESCRIPTION	SEAM	NOTE	CODE
0.0	1.0	SS	FGR, V LT BRN GRAY WX ORNG BROWN, MOD IND, V SORTED, LEDGE			540
1.0	7.9	SS	VFGR, LT YELL BRN, GYPS, WX TO SILTST, LEDGE			570
7.9	8.3	CL	LT YELL GRAY, LEDGE			330
8.3	8.8	CL	LT RED GRAY, LEDGE			320
8.8	12.5	CO	BLK, SOFT, DULL TO MOD BRIGHT, PYR (WX), WELL DEVELOPED CLEATING	D31	PSWX	130
12.5	15.5	CL	LT GRAY, SILTY, SLOPE			330
15.5	24.0	SL	BRN GRAY, SLOPE, WX TO CLAY			440

MEASURED SECTION: MS86007

NORTH 389570
EAST 515028
ELEVATION: 6870.0
COMMENTS:

SECTION 4
TOWNSHIP: 20N
RANGE: 100W

COORDINATE SYSTEM: SP
SURVEY/EST: E
CONFIDENCE: 11

MINING COMPANY: BCC
CONTRACTOR:
FIELD REP: PSM

YEAR: 86
TOTAL DEPTH: 44
SECTION TYPE: SU
GEOPHYSICAL LOGS:

TOP DEPTH	BOTTOM DEPTH	LITH	LITHOLOGIC DESCRIPTION	SEAM	NOTE	CODE
0.0	1.5	SS	VFGR-FGR, LT BRN GRAY WX TO LT ORNG BROWN, HARD, CALC CEMENT, LEDGE			540
1.5	9.6	SS	VFGR, V LT BRN GRAY, SOFT, THIN INTBD HARD STRGRS, RIP-UP CLASTS FM ABOV, SLOPE			540
9.6	10.0	CL	LT PINK GRAY, SOFT, SLOPE			330
10.0	14.5	CO	BLK, SOFT TO MOD HARD, SLTLY WX, THIN CLASTIC PTG, LEDGE	D31	PSWX	120
14.5	23.5	SL	LT GRAY TO LT BRN GRAY, SLOPE			430
23.5	43.5	SS	VFGR, V LT GRAY TO WHITE, TROUGH AND PLANAR X-BEDS, LEDGE TO SLOPE			530

MEASURED SECTION: MS86008

NORTH 389405
EAST 514990
ELEVATION: 6881.0
COMMENTS:

SECTION 4
TOWNSHIP: 20N
RANGE: 100W

COORDINATE SYSTEM: SP
SURVEY/EST: S
CONFIDENCE: 11

MINING COMPANY: BCC
CONTRACTOR:
FIELD REP: PSM

YEAR: 86
TOTAL DEPTH: 60
SECTION TYPE: SU
GEOPHYSICAL LOGS:

TOP DEPTH	BOTTOM DEPTH	LITH	LITHOLOGIC DESCRIPTION	SEAM	NOTE	CODE
0.0	1.5	SS	VFGR-FGR, LT BRN GRAY WX TO LT RED BRN, HARD, CALC CEMENT, LEDGE			540
1.5	9.5	SS	VFGR, LT BRN GRAY, SOFT, SLOPE			540
9.5	11.5	CO	BLK, SOFT TO MOD HARD, WX, THIN CLASTIC PTG AT BOTTOM	D31	PSWX	130
11.5	16.0	SL	LT BRN GRAY			440
16.0	28.5	SS	VFGR, V LT GRAY TO WHITE, TROUGH X-BEDS, SILICA CEMENT, STEEP SLOPE			530
28.5	29.5	CL	BRN, SHALY, SLOPE			340
29.5	39.5	SS	VFGR, V LT GRAY TO WHITE, TROUGH X-BEDS, SILICA CEMENT, LEDGE			530
39.5	42.0	SS	VFGR-FGR, LT BRN GRAY WX TO LT RED BRN, HARD, HARD, CALC CEMENT, LEDGE			540
42.0	59.5	SS	VFGR, V LT GRAY TO WHITE, TROUGH X-BEDS, SILICA CEMENT, LEDGE			530

MEASURED SECTION: MS86009

NORTH 389168	SECTION 5	COORDINATE SYSTEM: SP	MINING COMPANY: BCC	YEAR: 86
EAST 514660	TOWNSHIP: 20N	SURVEY/EST: S	CONTRACTOR:	TOTAL DEPTH: 80
ELEVATION: 6896.0	RANGE: 100W	CONFIDENCE: 11	FIELD REP: PSM	SECTION TYPE: SU
COMMENTS:				GEOPHYSICAL LOGS:

TOP DEPTH	BOTTOM DEPTH	LITH	LITHOLOGIC DESCRIPTION	SEAM	NOTE	CODE
=====	=====	=====	=====	=====	=====	=====
0.0	1.5	SS	FGR-VFGR, LT BRN GRAY WX TO ORNG BROWN, MOD IND, SUBRND, V SORTED, LEDGE			540
1.5	9.0	SS	VFGR, LT YELL GRAY, INTBD THIN HARD SANDST STRGRS, LEDGE			570
9.0	15.0	CO	BLK, SOFT TO MOD HARD, DULL TO MOD BRIGHT, PYR (WX), LEDGE TO SLOPE	D31		120
15.0	32.0	CL	BROWN, SILTY, SLOPE			340
32.0	40.0	SS	VFGR-FGR, V LT GRAY TO WHITE			530
40.0	47.5	SL	BRN GRAY, STEEP SLOPE WX TO CLAY, TRACES OF UTE(?) CLINKER			440
47.5	80.0	SS	VFGR-FGR, LT BRN GRAY, SLOPE, WX TO SILTST			540

MEASURED SECTION: MS86010

NORTH 388638	SECTION 4	COORDINATE SYSTEM: SP	MINING COMPANY: BCC	YEAR: 86
EAST 515268	TOWNSHIP: 20N	SURVEY/EST: S	CONTRACTOR:	TOTAL DEPTH: 125
ELEVATION: 6957.4	RANGE: 100W	CONFIDENCE: 11	FIELD REP: PSM	SECTION TYPE: SU
COMMENTS:				GEOPHYSICAL LOGS:

TOP DEPTH	BOTTOM DEPTH	LITH	LITHOLOGIC DESCRIPTION	SEAM	NOTE	CODE
=====	=====	=====	=====	=====	=====	=====
0.0	11.0	SS	VFGR, LT BRN GRAY WX TO RED BRN, X-BEDS, SID BANDS, CONTORTED, LEDGE			540
11.0	29.0	SS	VFGR, PALE BRN GRAY, SOFT, SLOPE			530
29.0	29.5	CO	BLK, SOFT, WX, SULFATE SULF WX	D54	PSWX	130
29.5	51.0	SL	LT BRN GRAY, SOFT, SLOPE			440
51.0	53.0	SL	OLIVE BRN, MASSIVE, SLOPE			470
53.0	58.0	SS	VFGR, PALE BRN GRAY, SOFT, SLOPE			540
58.0	68.0	SS	VFGR, LT BRN GRAY, X-BEDS, CREMULATED, SID NODS IN .2' BANDS 58.8-61.4, LEDGE			540
68.0	71.1	CL	LT GRAY TO LT ORNG BRN, MASSIVE, COBBLE-SIZE RIP-UP CLAISTS 68.0-69.2, SLOPE			330
71.1	71.5	SH	LT GRAY, CARB PLANT REMAINS ALONG BEDDING, GYPS			230
71.5	75.0	CO	BLK TO BRN-BLK, SOFT TO MOD HARD, REMNANT CLEATS, WX, SLOPE	D31	PS	120
75.0	94.0	CL	LT GRAY TO V LT GRAY, SILTY, SLOPE			330
94.0	116.8	SL	BRN GRAY, SANDY, MASSIVE, SLOPE			440
116.8	117.0	CK	DK RED BRN			910
117.0	119.5	SS	VFGR, V LT GRAY, FAINT X-BEDS, SUBRND-SUBANG, LEDGE			530
119.5	120.9	CL	LT BRN GRAY, MASSIVE			340
120.9	121.4	CO	BRN-BLK, SOFT, WX, SLOPE		WX	130
121.4	122.5	CL	BRN GRAY, MASSIVE, SILTY, SLOPE			340
122.5	125.0	SS	VFGR, V LT GRAY TO WHITE, MASSIVE, LEDGE TO SLOPE			530

MEASURED SECTION: MS86011

NORTH 387964	SECTION 9	COORDINATE SYSTEM: SP	MINING COMPANY: BCC	YEAR: 86
EAST 515109	TOWNSHIP: 20N	SURVEY/EST: S	CONTRACTOR:	TOTAL DEPTH: 8
ELEVATION: 6877.1	RANGE: 100W	CONFIDENCE: 11	FIELD REP: PSM	SECTION TYPE: SU
COMMENTS:				GEOPHYSICAL LOGS:

TOP DEPTH	BOTTOM DEPTH	LITH	LITHOLOGIC DESCRIPTION	SEAM	NOTE	CODE
0.0	2.8	CG	LT BRN GRAY, SANDY MATRIX, P SORT, CLASTS V ANG, LEDGE			600
2.8	7.0	CO	BLK, MOD HARD, DULL TO MOD BRIGHT, WELL DEVELOPED CLEATS, SLOPING LEDGE	D31		120
7.0	7.5	SS	VFGR, LT BRN GRAY, SOFT, SLOPE			540

MEASURED SECTION: MS86012

NORTH 385800	SECTION 9	COORDINATE SYSTEM: SP	MINING COMPANY: BCC	YEAR: 86
EAST 517268	TOWNSHIP: 20N	SURVEY/EST: E	CONTRACTOR:	TOTAL DEPTH: 88
ELEVATION: 6992.0	RANGE: 100W	CONFIDENCE: 11	FIELD REP: PSM	SECTION TYPE: SU
COMMENTS:				GEOPHYSICAL LOGS:

TOP DEPTH	BOTTOM DEPTH	LITH	LITHOLOGIC DESCRIPTION	SEAM	NOTE	CODE
0.0	3.0	SS	VFGR, LT BRN GRAY WX TO LT ORNG BRN, HARD, CALC, LEDGE			540
3.0	5.0	SS	CONGLOMERATIC, V LT GRAY TO WHITE, SLOPE			530
5.0	10.8	SS	VFGR, V LT GRAY TO WHITE, SID BANDS, LEDGE			530
10.8	19.0	CO	BLK, V SOFT, DULL, WX, SLOPE	D54	PSWX	130
19.0	80.0	SS	VFGR, LT BRN GRAY, SOFT, SILTY, LEDGE TO SLOPE			540
80.0	81.0	SS	VFGR, LT GRAY WX LT ORNG BRN, TRANSPORTED (?)			530
81.0	84.0	SS	VFGR, LT BRN GRAY, SOFT, SLOPE			540
84.0	87.0	CO	BLUE GRAY TO BLK, V SOFT, WX	D31	PSWX	140
87.0	88.0	CL	DK GRAY BROWN, MASSIVE, SLOPE			340

MEASURED SECTION: NS86013

NORTH 384382	SECTION 10	COORDINATE SYSTEM: SP	MINING COMPANY: BCC	YEAR: 86
EAST 521614	TOWNSHIP: 20N	SURVEY/EST: E	CONTRACTOR:	TOTAL DEPTH: 24
ELEVATION: 6878.0	RANGE: 100W	CONFIDENCE: 11	FIELD REP: PSM	SECTION TYPE: SU
COMMENTS:				GEOPHYSICAL LOGS:

TOP DEPTH	BOTTOM DEPTH	LITH	LITHOLOGIC DESCRIPTION	SEAM	NOTE	CODE
=====	=====	----	-----	=====	=====	=====
0.0	1.5	SS	VFGR, LT BRN GRAY WX TO BROWN, V WELL IND, CALC CEMENT, LEDGE			540
1.5	8.5	SL	LT GRAY, MASSIVE, IRON BANDED			430
8.5	15.5	CO	BLK TO BRN-BLK, SOFT TO MOD HARD, WX, STEEP SLOPE	D54	PSWX	130
15.5	17.5	SL	BRN GRAY, SOFT, WX, SLOPE			440
17.5	23.5	SS	WHITE TO V LT GRAY, SILTY, MASSIVE, WX, SLOPE			530

MEASURED SECTION: NS86014

NORTH 383438	SECTION 10	COORDINATE SYSTEM: SP	MINING COMPANY: BCC	YEAR: 86
EAST 524120	TOWNSHIP: 20N	SURVEY/EST: E	CONTRACTOR:	TOTAL DEPTH: 50
ELEVATION: 6869.0	RANGE: 100W	CONFIDENCE: 11	FIELD REP: PSM	SECTION TYPE: SU
COMMENTS:				GEOPHYSICAL LOGS:

TOP DEPTH	BOTTOM DEPTH	LITH	LITHOLOGIC DESCRIPTION	SEAM	NOTE	CODE
=====	=====	----	-----	=====	=====	=====
0.0	30.8	SS	VFGR, V LT GRAY, SOFT, SILTY, INTBD SILTST, THIN COAL STRGRS 5.5-6.0, SLOPE			530
30.8	33.0	CO	DK BRN GRAY TO DK GRAY, SOFT, LIM, V WX, SLOPE	D54	PSWX	140
33.0	50.0	CL	LT GRAY, SOFT, SLTLY SILTY, LIM ON SURFS, WX, LOCAL RIDER SEAM BURN 43, SLOPE			330

MEASURED SECTION: MS86015

NORTH 381442	SECTION 14	COORDINATE SYSTEM: SP	MINING COMPANY: BCC	YEAR: 86
EAST 526310	TOWNSHIP: 20N	SURVEY/EST: S	CONTRACTOR:	TOTAL DEPTH: 59
ELEVATION: 6830.0	RANGE: 100W	CONFIDENCE: 11	FIELD REP: PSM	SECTION TYPE: SU
COMMENTS:				GEOPHYSICAL LOGS:

TOP DEPTH	BOTTOM DEPTH	LITH	LITHOLOGIC DESCRIPTION	SEAM	NOTE	CODE
=====	=====	=====	=====	=====	=====	=====
0.0	0.3	SS	VFGR, LT BRN GRAY WX TO RED BROWN, HARD, TROUGH X-BEDS, CALC CEMENT, LEDGE			540
0.3	1.0	CK	RED BROWN, HARD, LEDGE			910
1.0	9.0	CL	LT GRAY TO V LT GRAY, MASSIVE, SLOPE			330
9.0	9.5	SS	VFGR, LT BRN GRAY WX TO RED BROWN, HARD, TROUGH X-BEDS, CALC CEMENT, LEDGE			540
9.5	16.0	CL	LT GRAY TO V LT GRAY, MASSIVE, SLOPE			330
16.0	19.0	SS	VFGR, LT BRN GRAY WX TO RED BROWN, HARD, TROUGH X-BEDS, CALC CEMENT, LEDGE			540
19.0	45.0	SS	VFGR, LT GRAY TO LT BRN GRAY, SOFT, SILTY, LEDGE TO SLOPE			530
45.0	47.0	CO	BRN-BLK TO DK GRAY, SOFT, WX, SLOPE	D54	PSWX	130
47.0	51.5	SS	VFGR, LT GRAY TO WHITE, SOFT, SLOPE			530
51.5	59.0	SS	VFGR, V LT BRN GRAY, SOFT, SLOPE			540

MEASURED SECTION: MS86016

NORTH 380522	SECTION 14	COORDINATE SYSTEM: SP	MINING COMPANY: BCC	YEAR: 86
EAST 527435	TOWNSHIP: 20N	SURVEY/EST: S	CONTRACTOR:	TOTAL DEPTH: 21
ELEVATION: 6761.0	RANGE: 100W	CONFIDENCE: 11	FIELD REP: PSM	SECTION TYPE: SU
COMMENTS:				GEOPHYSICAL LOGS:

TOP DEPTH	BOTTOM DEPTH	LITH	LITHOLOGIC DESCRIPTION	SEAM	NOTE	CODE
=====	=====	=====	=====	=====	=====	=====
0.0	1.0	SS	VFGR-FGR, LT GRAY WX TO V LT RED BROWN, HARD, CALC CEMENT, LEDGE			530
1.0	12.0	SL	LT BRN GRAY, SOFT, SANDY, MASSIVE, SLOPE			440
12.0	13.5	CO	DK GRAY, SOFT, WX, SOIL ON TOP, SLOPE	D3	WVCU	130
13.5	21.0	SS	VFGR, LT BRN GRAY, SOFT, SLOPE			540

MEASURED SECTION: MS86017

NORTH 379840
EAST 526650
ELEVATION: 6758.0
COMMENTS:

SECTION 14
TOWNSHIP: 20N
RANGE: 100W

COORDINATE SYSTEM: SP
SURVEY/EST: S
CONFIDENCE: 11

MINING COMPANY: BCC
CONTRACTOR:
FIELD REP: PSM

YEAR: 86
TOTAL DEPTH: 80
SECTION TYPE: SU
GEOPHYSICAL LOGS:

TOP DEPTH	BOTTOM DEPTH	LITH	LITHOLOGIC DESCRIPTION	SEAM	NOTE	CODE
0.0	8.0	SS	VFGR, LT BRN GRAY WX TO ORNG BROWN, CALC, LEDGE			540
8.0	26.3	SS	VFGR, LT BRN GRAY, SOFT, WX TO SILT, FAIRLY STEEP SLOPE			540
26.3	27.0	CO	BLK TO BRN-BLK, V WX	D21	PSWX	130
27.0	43.0	SS	VFGR, LT BRN GRAY, SOFT, WX TO SILT, FAIRLY STEEP SLOPE			540
43.0	46.0	SS	VFGR, WHITE TO V LT GRAY, MOD HARD, LEDGE			530
46.0	49.5	SL	LT BROWN, CLAYEY			470
49.5	55.5	SS	VFGR, WHITE TO V LT GRAY, MOD HARD, LEDGE			530
55.5	58.0	SS	VFGR, LT BRN GRAY WX RED BROWN, HARD, FLAGGY, X-BEDS, CALC, LEDGE			540
58.0	63.0	SL	V LT BRN GRAY, MASSIVE, CLAYEY, SLOPE			440
63.0	65.0	SS	FGR, PINKISH GRAY TO V DK GRAY, HARD, STEEP SLOPE			520
65.0	80.0	SS	VFGR, WHITE TO V LT GRAY, MOD HARD, LEDGE TO SLOPE			530

MEASURED SECTION: MS86018

NORTH 378618
EAST 529035
ELEVATION: 6707.0
COMMENTS:

SECTION 14
TOWNSHIP: 20N
RANGE: 100W

COORDINATE SYSTEM: SP
SURVEY/EST: S
CONFIDENCE: 11

MINING COMPANY: BCC
CONTRACTOR:
FIELD REP: PSM

YEAR: 86
TOTAL DEPTH: 40
SECTION TYPE: SU
GEOPHYSICAL LOGS:

TOP DEPTH	BOTTOM DEPTH	LITH	LITHOLOGIC DESCRIPTION	SEAM	NOTE	CODE
0.0	10.0	SS	VFGR, LT BRN GRAY, SOFT, MASSIVE, SLOPE			540
10.0	11.0	SS	VFGR-FGR, LT YELL BROWN, TROUGH X-BEDS, CALCITE CEMENT, LEDGE			570
11.0	18.5	SL	LT BRN GRAY, CLAYEY, WX			440
18.5	21.2	CO	BLK, SOFT, WX, LIM, FACE CLEATS	D3	WX	130
21.2	31.8	SS	VFGR, LT BROWN, SOFT, SLOPE			570
31.8	32.0	CL				300
32.0	35.0	CO	BLK, WX, LIM, FACE CLEATS	D21	PSWX	130
35.0	38.5	SS	VFGR, M LT GRAY, SILTY			530
38.5	40.0	SS	VFGR, WHITE TO LT BRN GRAY, MASSIVE, WX			540

MEASURED SECTION: MS86019

NORTH 377152
EAST 529789
ELEVATION: 6766.0
COMMENTS:

SECTION 23
TOWNSHIP: 20N
RANGE: 100W

COORDINATE SYSTEM: SP
SURVEY/EST: 5
CONFIDENCE: 11

MINING COMPANY: BCC
CONTRACTOR:
FIELD REP: PSM

YEAR: 86
TOTAL DEPTH: 35
SECTION TYPE: SU
GEOPHYSICAL LOGS:

TOP DEPTH	BOTTOM DEPTH	LITH	LITHOLOGIC DESCRIPTION	SEAM	NOTE	CODE
=====	=====	----	-----	-----	----	----
0.0	2.0	SS	VFGR, LT GRAY VX TO LT RED BROWN, HARD, TROUGH X-BEDS, CALC CEMENT, LEDGE			530
2.0	13.5	SS	VFGR, V LT BRN GRAY, SLOPE			540
13.5	17.0	SL	LT GRAY, SOFT, POSS VX COAL 13.7, STEEP SLOPE			430
17.0	30.5	SS	VFGR, V LT BRN GRAY, SOFT, STEEP SLOPE			540
30.5	31.8	CO	BLK, SOFT, VX, SOIL 30.5-30.9, TRACE BURN 30.7, SLOPE	D4	PSWX	130
31.8	35.0	SS	VFGR, V LT BRN GRAY, SOFT, SLOPE			540

MEASURED SECTION: MS86020

NORTH 372520
EAST 526835
ELEVATION: 6854.0
COMMENTS:

SECTION 23
TOWNSHIP: 20N
RANGE: 100W

COORDINATE SYSTEM: SP
SURVEY/EST: E
CONFIDENCE: 11

MINING COMPANY: BCC
CONTRACTOR:
FIELD REP: PSM

YEAR: 86
TOTAL DEPTH: 36
SECTION TYPE: SU
GEOPHYSICAL LOGS:

TOP DEPTH	BOTTOM DEPTH	LITH	LITHOLOGIC DESCRIPTION	SEAM	NOTE	CODE
=====	=====	----	-----	-----	----	----
0.0	3.1	CK	DK RED BROWN, FRACT, LEDGE	D4	PSBU	910
3.1	16.0	SS	VFGR, LT BRN GRAY, MASSIVE, SOFT, SLOPE			540
16.0	18.2	SS	VFGR, LT GRAY VX TO RED BROWN, HARD, CALC CEMENT, LEDGE			530
18.2	30.7	SS	VFGR, V LT GRAY TO WHITE, SOFT, SLOPE			530
30.7	31.0	CO	BLK, SOFT, VX, SLOPE	D31	PSWX	130
31.0	36.0	SS	VFGR, LT BRN GRAY, SOFT, MASSIVE, SLOPE			540

MEASURED SECTION: MS86021

NORTH 370725	SECTION 26	COORDINATE SYSTEM: SP	MINING COMPANY: BCC	YEAR: 86
EAST 525340	TOWNSHIP: 20N	SURVEY/EST: S	CONTRACTOR:	TOTAL DEPTH: 85
ELEVATION: 6880.0	RANGE: 100W	CONFIDENCE: 11	FIELD REP: PSM	SECTION TYPE: SU
COMMENTS:				GEOPHYSICAL LOGS:

TOP DEPTH	BOTTOM DEPTH	LITH	LITHOLOGIC DESCRIPTION	SEAM	NOTE	CODE
0.0	3.6	UN	DN-80257 AND COVERED			30
3.6	5.0	SS	VFGR, LT BRN GRAY WX TO LT RED BROWN, HARD, CALC CEMENT, LEDGE			540
5.0	22.0	SS	VFGR, LT BRN GRAY, SOFT, SLOPE			540
22.0	26.5	CK	DK RED BROWN, HARD, GYPS, LEDGE	D31	PSBU	910
26.5	41.0	SS	VFGR, LT BRN GRAY TO LT BROWN, SOFT, SLOPE			540
41.0	55.0	SS	FGR-VFGR, V LT GRAY TO WHITE, HARD, X-BEDS, BLOCKY, LEDGE			530
55.0	62.0	SS	VFGR, V LT GRAY TO WHITE, SOFT, SLOPE			530
62.0	67.2	CL	LT BRN GRAY, SILTY AT SURF			340
67.2	67.3	CK	DK BROWN, WX, LEDGE	UTE	PSCU	910
67.3	85.0	SS	FGR-VFGR, V LT GRAY TO WHITE, LEDGE			530

MEASURED SECTION: MS86022

NORTH 368420	SECTION 26	COORDINATE SYSTEM: SP	MINING COMPANY: BCC	YEAR: 86
EAST 527355	TOWNSHIP: 20N	SURVEY/EST: E	CONTRACTOR:	TOTAL DEPTH: 115
ELEVATION: 6925.0	RANGE: 100W	CONFIDENCE: 11	FIELD REP: PSM	SECTION TYPE: SU
COMMENTS:				GEOPHYSICAL LOGS:

TOP DEPTH	BOTTOM DEPTH	LITH	LITHOLOGIC DESCRIPTION	SEAM	NOTE	CODE
0.0	0.1	CO		D4	PSWX	130
0.1	10.1	UN	COVERED			30
10.1	21.1	SL	V LT GRAY, LT BRN GRAY AT TOP, SLOPE			430
21.1	24.1	UN	COVERED			30
24.1	25.6	SS	VFGR, LT BRN GRAY WX TO LT ORNG BROWN, FAINT X-BEDS, CLAC, LEDGE			540
25.6	46.1	SS	VFGR, LT BRN GRAY TO LT BROWN, STEEP SLOPE			540
46.1	66.4	SL	LT GRAY TO LT BRN GRAY, CLAYEY ZONES, WX, SLOPE			430
66.4	68.1	CO	BLK, SOFT, WX, SLOPE	D31	PSWX	130
68.1	70.1	CL	GRAY, SILTY AT TOP, SLOPE			320
70.1	77.1	SS	VFGR-FGR, V LT GRAY TO WHITE, SLOPE			530
77.1	87.1	SS	VFGR, LT BRN GRAY, SLTLY CLAYEY, SLOPE			540
87.1	115.0	SS	FGR-VFGR, V LT GRAY TO WHITE, TROUGH X-BEDS, LEDGE			530

MEASURED SECTION: MS86023

NORTH 367669
EAST 526933
ELEVATION: 6891.0
COMMENTS:

SECTION 26
TOWNSHIP: 20N
RANGE: 100W

COORDINATE SYSTEM: SP
SURVEY/EST: E
CONFIDENCE: 11

MINING COMPANY: BCC
CONTRACTOR:
FIELD REP: PSM

YEAR: 86
TOTAL DEPTH: 61
SECTION TYPE: SU
GEOPHYSICAL LOGS:

TOP DEPTH	BOTTOM DEPTH	LITH	LITHOLOGIC DESCRIPTION	SEAM	NOTE	CODE
=====	=====	=====	=====	=====	=====	=====
0.0	1.0	SS	VFGR, LT BRN GRAY WX TO LT ORNG BROWN, CALC, LEDGE			540
1.0	34.5	SS	VFGR, LT BRN GRAY, SILTY, SLOPE			540
34.5	35.5	CK	RED TO DK RED BROWN, LEDGE	D31	PSBU	910
35.5	51.7	SS	VFGR, LT BRN GRAY, SLOPE			540
51.7	52.0	CO	BLK, SOFT, WX	UTE	CU	130
52.0	61.0	SS	VFGR, V LT GRAY TO WHITE, LEDGE TO SLOPE			530

MEASURED SECTION: MS86024

NORTH 366949
EAST 527400
ELEVATION: 6889.0
COMMENTS:

SECTION 35
TOWNSHIP: 20N
RANGE: 100W

COORDINATE SYSTEM: SP
SURVEY/EST: E
CONFIDENCE: 11

MINING COMPANY: BCC
CONTRACTOR:
FIELD REP: PSM

YEAR: 86
TOTAL DEPTH: 49
SECTION TYPE: SU
GEOPHYSICAL LOGS:

TOP DEPTH	BOTTOM DEPTH	LITH	LITHOLOGIC DESCRIPTION	SEAM	NOTE	CODE
=====	=====	=====	=====	=====	=====	=====
0.0	4.0	SS	FGR-MGR, FLAGGY, CLACITE CEMENT			500
4.0	7.0	SS				500
7.0	14.0	SL				400
14.0	16.0	SS	VFGR, LT BRN GRAY, X-BEDDED, MASSIVE TO FLAGGY			540
16.0	23.0	CL	LT GRAY TO ORANGE			330
23.0	24.0	CO	BURNED, INTBD CLINKER	D31	PSBU	140
24.0	33.0	SL	LT BRN GRAY, CLAYEY, STEEP SLOPE			440
33.0	38.0	SL	LT BROWN TO LT YELL BROWN WX TO LT RED BROWN, SANDY, SLOPE			470
38.0	43.0	SL	LT BRN GRAY, SANDY			440
43.0	46.0	CL	GRAY TO LT GRAY, MASSIVE			320
46.0	49.0	SS	VFGR, V LT GRAY, TROUGH X-BEDS, IRON STAINED 48.8-49.0			530

MEASURED SECTION: NS86025

NORTH 365582
EAST 527119
ELEVATION: 6921.0
COMMENTS:

SECTION 35
TOWNSHIP: 20N
RANGE: 100W

COORDINATE SYSTEM: SP
SURVEY/EST: E
CONFIDENCE: 11

MINING COMPANY: BCC
CONTRACTOR:
FIELD REP: PSM

YEAR: 86
TOTAL DEPTH: 62
SECTION TYPE: SU
GEOPHYSICAL LOGS:

TOP DEPTH	BOTTOM DEPTH	LITH	LITHOLOGIC DESCRIPTION	SEAM	NOTE	CODE
=====	=====	=====	=====	=====	=====	=====
0.0	0.7	SS	VFGR, LT BRN GRAY WX TO LT RED BROWN, HARD, LEDGE			540
0.7	11.7	SS	VFGR, LT BROWN, INTBD CLINKER TO 2.7, INTBD SILTST 4.7-10.7, LEDGE			570
11.7	13.7	CL	GRAY, INTBD CLINKER .1			320
13.7	23.5	SL	LT BRN GRAY, STEEP SLOPE			440
23.5	23.8	CL	BROWN, SHALY, SLOPE			340
23.8	24.7	CO	BLK, SOFT TO MOD HARD, WX, STEEP SLOPE	D31	PSWX	120
24.7	37.5	SS	VFGR, LT BRN GRAY, SLOPE			540
37.5	38.2	CO	BLK, MOD HARD, WX	UTE	WX	120
38.2	39.7	SL	BRN GRAY, SLOPE			440
39.7	55.7	SS	VFGR-FGR, V LT GRAY TO WHITE			530
55.7	61.7	SS	FGR, LT BROWN TO V LT BRN GRAY, LEDGE			570

MEASURED SECTION: NS86026

NORTH 365095
EAST 526361
ELEVATION: 6895.0
COMMENTS:

SECTION 35
TOWNSHIP: 20N
RANGE: 100W

COORDINATE SYSTEM: SP
SURVEY/EST: E
CONFIDENCE: 11

MINING COMPANY: BCC
CONTRACTOR:
FIELD REP: PSM

YEAR: 86
TOTAL DEPTH: 36
SECTION TYPE: SU
GEOPHYSICAL LOGS:

TOP DEPTH	BOTTOM DEPTH	LITH	LITHOLOGIC DESCRIPTION	SEAM	NOTE	CODE
=====	=====	=====	=====	=====	=====	=====
0.0	0.7	SS	VFGR, LT BRN GRAY WX TO LT RED BROWN, CALC CEMENT, LEDGE			540
0.7	17.2	SS	VFGR, LT GRAY, SLOPE TO LEDGE			530
17.2	18.1	CO	BLK, MOD HARD, WX, WELL DEVELOPED CLEATS	D31	PSWX	120
18.1	18.4	SL	LT BRN GRAY, SLOPE			440
18.4	28.0	SS	VFGR, V LT BRN GRAY WX TO BROWN, THIN INTBD CLINKER, SLOPE			540
28.0	28.2	CO	BRN-BLK, MOD HARD TO SOFT, WX, SLOPE	UTE	WX	120
28.2	35.7	SS	VFGR, V LT GRAY TO WHITE, SLOPE TO LEDGE			530

MEASURED SECTION: MS86027

NORTH 364220 SECTION 35 COORDINATE SYSTEM: SP MINING COMPANY: BCC YEAR: 86
 EAST 526518 TOWNSHIP: 20N SURVEY/EST: E CONTRACTOR: TOTAL DEPTH: 20
 ELEVATION: 6928.0 RANGE: 100V CONFIDENCE: 11 FIELD REP: PSM SECTION TYPE: SU
 COMMENTS: GEOPHYSICAL LOGS:

TOP DEPTH	BOTTOM DEPTH	LITH	LITHOLOGIC DESCRIPTION	SEAM	NOTE	CODE
=====	=====	----	-----	-----	----	----
0.0	1.7	SL	LT BRN GRAY, SLOPE			440
1.7	4.6	CK	ORANGE TO RED, HARD, WX, SLOPE TO LEDGE	D31		910
4.6	5.0	SH	GRAY, HARD, THERMALLY ALTERED, LEDGE			220
5.0	15.1	SS	VFGR, LT BRN GRAY TO LT GRAY, STEEP SLOPE			540
15.1	15.4	CO	BRN-BLK, WX, PARTIALLY BURNED	UTE	PB	140
15.4	15.6	SL	LT BRN GRAY			440
15.6	20.0	SS	VFGR, LT BRN GRAY, SLOPE			540

MEASURED SECTION: MS86028

NORTH 363150 SECTION 35 COORDINATE SYSTEM: SP MINING COMPANY: BCC YEAR: 86
 EAST 526240 TOWNSHIP: 20N SURVEY/EST: E CONTRACTOR: TOTAL DEPTH: 34
 ELEVATION: 6970.0 RANGE: 100V CONFIDENCE: 11 FIELD REP: PSM SECTION TYPE: SU
 COMMENTS: GEOPHYSICAL LOGS:

TOP DEPTH	BOTTOM DEPTH	LITH	LITHOLOGIC DESCRIPTION	SEAM	NOTE	CODE
=====	=====	----	-----	-----	----	----
0.0	1.0	SS	VFGR, LT BRN GRAY WX TO LT RED BROWN, FAINT TROUGH X-BEDS, CALC CEMENT, LEDGE			540
1.0	9.8	SS	VFGR, LT GRAY TO LT BRN GRAY, SLOPE			530
9.8	11.1	CK	ORANGE TO RED, LEDGE	D31		910
11.1	28.7	SS	VFGR, LT BROWN TO LT BRN GRAY, SILTY, SLOPE			570
28.7	29.5	CK	RED BROWN WX TO LT ORNG BROWN, HARD, LEDGE			910
29.5	29.7	CO	V DK GRAY, SHALY	UTE		140
29.7	33.5	SS	VFGR, LT GRAY, SLOPE			530

MEASURED SECTION: MS86029

NORTH 392030
EAST 513880
ELEVATION: 6906.0
COMMENTS:

SECTION 5
TOWNSHIP: 20N
RANGE: 100W

COORDINATE SYSTEM: SP
SURVEY/EST: E
CONFIDENCE: 11

MINING COMPANY: BCC
CONTRACTOR:
FIELD REP: PSM

YEAR: 86
TOTAL DEPTH: 108
SECTION TYPE: SU
GEOPHYSICAL LOGS:

TOP DEPTH	BOTTOM DEPTH	LITH	LITHOLOGIC DESCRIPTION	SEAM	NOTE	CODE
=====	=====	=====	=====	=====	=====	=====
0.0	2.0	SS	VFGR, LT BRN GRAY, CALC. LEDGE			540
2.0	6.0	SL	LT BROWN			470
6.0	22.0	SS	VFGR, WHITE TO V LT GRAY, X-BEDDED, BURN 12.0-15.0, THIN COAL 19.0-19.3			530
22.0	33.0	UN	COVERED, SILTY			30
33.0	46.0	SL	LT GRAY, CLAYEY, LEDGE			430
46.0	51.0	SS	VFGR, V LT GRAY, X-BEDDED, LEDGE			530
51.0	55.0	CL	LT GRAY, CARB BANDS, SLOPING LEDGE			330
55.0	67.0	SL	V LT BRN GRAY, SLOPE			440
67.0	70.0	SS	VFGR, LT BRN GRAY, HARD, CALC. LEDGE			540
70.0	108.0	UN	COVERED, CLAYEY SILT AT SURF			30

APPENDIX 2

SELECTED SUBSURFACE SECTIONS

DATE: 10/02/87

NERCO, INC.

PAGE: 1

MASTER DATASET
JIM BRIDGER COAL FIELD

DRILL HOLE NUMBER: 101108C

NORTH 386901	SECTION 9	COORDINATE SYSTEM: SP	MINING COMPANY: NER	YEAR: 77
EAST 516414	TOWNSHIP: 20N	SURVEY/EST: S	CONTRACTOR: BCC	TOTAL DEPTH: 240
ELEVATION: 7019.8	RANGE: 100W	CONFIDENCE: 11	FIELD REP: WLG	DRILL HOLE TYPE: OC
COMMENTS:				GEOPHYSICAL LOGS: GRS

TOP DEPTH	BOTTOM DEPTH	LITH	LITHOLOGIC DESCRIPTION	SEAM	NOTE	CODE
=====	=====	=====	=====	=====	=====	=====
0.0	1.7	SS	LT BRN;FG;LIMONITE STN:P.IND;DRY;CALC;WX			570
1.7	6.4	SS	LT BRN-GRY;FG-VFG;GYP;LIMONITE STN:V.V.IND;DRY;V.CALC			540
6.4	10.1	UN				30
10.1	10.7	SS	LT BRN-GRY;FG-VFG;GYP;LIMONITE STN:V.V.IND;DRY;V.CALC			540
10.7	32.1	SS	LT GRY-BRN;FG-VFG;MASSIVE;CARB;MINOR CLYST;M.IND;DRY;N.CALC			540
32.1	35.5	CL	GRY;SANDY;CARB;COALY;M.IND;DRY			330
35.5	48.9	SS	LT GRY-BRN;FG-VFG;CARB;LIMONITE STN:M.IND;DRY;N.CALC			540
48.9	55.5	CL	DK GRY;HARD COAL 51.4-52.25;COALY STRNGRS;FISL;M.IND;DRY;N.CALC			320
55.5	73.8	SS	GRY;FG-VFG;SOME LAM;CARB STRNGRS;M.IND;DRY			530
73.8	76.0	SL	DK GRY;INTBD COALY MATERIAL;M.IND;DRY;N.CALC			420
76.0	83.4	SS	LT GRY;FG;CARB STRNGRS;MASSIVE;M.IND;DRY;CALC			530
83.4	85.6	SS	LT GRY;FG-VFG;CARB SLTST INTBD;MASSIVE;M.IND;DRY;CALC			530
85.6	96.2	SS	GRY;FG-VFG;COAL 89-90.1;CLYST;CARB;PYR;M.IND;DRY;CALC			530
96.2	98.3	SL	DK GRY;CARB;COALY MATERIAL;COAL STRNGR;M.IND;DRY;N.CALC			420
98.3	102.0	SS	LT GRY;FG;COALY MATERIAL;MASSIVE;M.IND;DRY;S.CALC			530
102.0	103.7	SL	DK GRY;CLYST;CARB;M.IND;DRY;N.CALC			420
103.7	119.4	CO	BLK;HARD;VITRAIN;DRY;PYR & GYP IN FRACS;SS @ 105.8-105.85,111.82-111.87	D54		110
119.4	121.6	SL	DK GRY;V.IND SS INTBDS;CARB;M.IND;DRY;N.CALC			420
121.6	141.8	SS	GRY-LT GRY;VFG-FG;MASSIVE;CARB/COALY STRNGRS;CALC;P.IND-M.IND			530
141.8	142.8	SL	DK GRY;CARB/COAL INTBDS;M.IND;DRY;N.CALC			420
142.8	154.5	CO	BLK;HARD;VITRAIN;GYP & PYR IN FRACS	D31		110
154.5	159.5	SL	DK GRY;CARB;COALY MATERIAL;BECOMES V.IND SS;N.CALC;DRY			420
159.5	162.0	SS	LT GRY;FG;COAL FRAGS;V.V.IND;DRY;CALC			530
162.0	169.0	SS	LT GRY;VFG;SLTST INTBD;M.IND;DRY;CALC			530
169.0	173.0	SL	DK GRY;CLYST INTBD;M.IND;DRY;S.CALC			420
173.0	179.0	SS	LT GRY;FG-VFG;M.IND;DRY;S.CALC			530
179.0	205.0	SS	GRY-DK GRY;VFG;SLTST INTBDS;M.IND;DRY;S.CALC			520
205.0	215.0	SS	LT GRY;FG-VFG;M.IND;DRY;N.CALC			530
215.0	240.0	SS	GRY-DK GRY;FG-VFG;INTBD SLTST & COALY FRAGS;M.IND;BECOMES V.CALC			520

DRILL HOLE NUMBER: 10130BC

NORTH 383747	SECTION 15	COORDINATE SYSTEM: SP	MINING COMPANY: NER	YEAR: 77
EAST 526417	TOWNSHIP: 20N	SURVEY/EST: S	CONTRACTOR: BCC	TOTAL DEPTH: 245
ELEVATION: 5831.8	RANGE: 100W	CONFIDENCE: 11	FIELD REP: WLG	DRILL HOLE TYPE: OC
COMMENTS:				GEOPHYSICAL LOGS: GRS

TOP DEPTH	BOTTOM DEPTH	LITH	LITHOLOGIC DESCRIPTION	SEAM	NOTE	CODE
=====	=====	----	-----	-----	----	----
0.0	6.8	SS	LT BRN:FG:P.IND-M.IND;DRY;V.CALC;WX			570
6.8	10.1	CL	DK GRY:SANDY;GYP:COALY;M.IND:S.DAMP;N.CALC			320
10.1	13.8	SS	LT BRN-GRY;VFG:CLYST INTBDS:CARB:P.IND-M.IND;N.CALC			540
13.8	26.4	SS	LT BRN:FG-VFG:LIMONITE STN:M.IND-V.W.IND;N.CALC;DRY			570
26.4	33.6	SS	LT BRN:FG-VFG:RED OX ZONES:LIMONITE STN;FORESET BD;M.IND;DRY			570
33.6	51.1	SS	LT BRN-GRY:FG-VFG:CARB:CLYST ZONES;M.IND V/THIN V.W.IND ZONES;DRY			540
51.1	52.7	SL	DK GRY:MASSIVE:COALY MATERIAL;BECOMES CLAY;M.IND;DRY;N.CALC			420
52.7	76.1	SS	LT GRY:FG:MASSIVE:CARB:COALY STRNGRS:PYR;M.IND;DRY;N.CALC			530
76.1	81.1	CO	BLK:HARD:PYR:SS @ 77.34-.45,78.0-.32	D5		110
81.1	82.9	UN	PTG			30
82.9	90.7	CO	BLK. HARD. PYR	D4		110
90.7	132.0	SS	LT GRY:FG:MASSIVE;INTBD MICA:P.IND-M.IND;S.CALC;MINOR COAL			530
132.0	133.2	CL	DK GRY:CARB;M.IND;N.CALC;DAMP			320
133.2	135.7	CO	BLK;VITRAIN;DAMP;HARD:PYR IN FRAC	D3		110
135.7	156.6	SS	DK BRN-GRY;VFG-FG:CLYST @ 136;CARB:PYR;M.IND;MASSIVE;N.CALC			540
156.6	175.7	SS	GRY:FG;SUBRND;W.SORT:MICA:P.IND;MASSIVE;MOIST;BECOMES COALY			530
175.7	183.5	CO	BLK:HARD:PYR:GYP:SS V/COALY STRNGRS @ 177.75-178.15	D21		110
183.5	186.3	SS	DK BRN:FG:COALY:CARB;M.IND;DAMP;N.CALC			540
186.3	188.3	SL	DK GRY:MASSIVE;M.IND;DAMP;N.CALC			420
188.3	190.2	SS	DK BRN:FG:CARB STRNGRS;M.IND;DAMP;N.CALC			540
190.2	200.0	SS	DK GRY:FG:CLAY;M.IND;WET			520
200.0	212.0	CL	DK GRY:COALY FRAGS;SS;M.IND;WET;N.CALC			320
212.0	245.0	SS	GRY-BRN:FG:COAL FRAGS;M.IND;WET;CALC			540

DRILL HOLE NUMBER: 820170BC

NORTH 384893
EAST 523321
ELEVATION: 6889.6
COMMENTS:

SECTION 10
TOWNSHIP: 20N
RANGE: 100W

COORDINATE SYSTEM: SP
SURVEY/EST: S
CONFIDENCE: 11

MINING COMPANY: NER
CONTRACTOR: JC
FIELD REP: CCE

YEAR: 82
TOTAL DEPTH: 250
DRILL HOLE TYPE: OC
GEOPHYSICAL LOGS: GDRC

TOP DEPTH	BOTTOM DEPTH	LITH	LITHOLOGIC DESCRIPTION	SEAM	NOTE	CODE
=====	=====	=====	=====	=====	=====	=====
0.0	4.0	SU	YEL GRY, FG SAND, UNCONSOL			830
4.0	19.8	SS	YEL GRY, FG, W.SORT, SUBRND, RIPPLE LAM, V.P. IND, FRAC @ 14'			530
19.8	21.7	CL	OL GRY, 0.2' COALY ZONE @ BASE			350
21.7	24.7	SS	BRN GRY-GRY, FG, CLAYEY, HEAVY SIDERITE STN, P. IND			540
24.7	27.7	SL	M. GRY, CLAYEY, THIN CALCITE VEIN, COALY ZONE @ BASE			420
27.7	31.0	SS	YEL GRY, FG, W. SORT, SUBANG, ROOTED @ TOP, P. IND			530
31.0	32.0	CL	OL GRY, P. IND			350
32.0	36.0	SS	YEL GRY, FG, V. SORT, SUBANG, ROOTED @ TOP, P. IND			530
36.0	40.5	SL	OLV GRY, MASSIVE, MAJOR FRAC @ 37', P. IND			450
40.5	41.5	SS	BRN-GRY, FG, SILTY, P. SORT, P. IND			540
41.5	52.2	SL	OLV GRY, RIPPLE LAM, BURROWED, THIN SS INTBD			450
52.2	55.0	SS	LT GRY, FG, RIPPLE LAM, P. IND			530
55.0	57.0	SL	M. GRY, MINOR COAL, RIPPLE LAM			420
57.0	66.2	SS	LT GRY, FG, RIPPLE LAM, MINOR COAL, P. IND			530
66.2	71.1	SL	M. GRY, MASSIVE, M. IND			420
71.1	72.0	CL	OL GRN, ROOTED, P. IND			350
72.0	75.1	SL	M. GRY, ROOTED, M. IND, GRADATIONAL LOWER CONTACT			420
75.1	80.9	SS	LT - M. GRY, FG, V. SORT, RIPPLE LAM, SIDERITE STREAKS			530
80.9	83.1	SL	M. GRY, RIPPLE LAM, ROOTED, 0.5' CARB ZONE @ 82', M. IND			420
83.1	94.7	SS	VFG, P. IND, P. SORT, SILTY, RIPPLE LAM, ROOT			500
94.7	100.0	SL	M. GRY, FEW PLANT FRAGS, RIPPLE LAM, ROOTED, SIDERITE STRKS, M. IND			420
100.0	100.4	CL	CARB, ROOTED, 0.2' COAL			300
100.4	106.0	SS	M. GRY, FG, SILTY, ROOT, RIPPLE LAM			520
106.0	113.7	SL	M. GRY, MASSIVE, FEW ROOT & SIDERITE STRKS			420
113.7	114.3	CL	M. GRY, SLTLY FISSILE			320
114.3	129.0	CO	BAND, 10-15% VIT, M. DULL, SILKY, FRAC, V. THIN CARB SLT, 0.3' BONEY ZONE 116.5 D54			110
129.0	135.1	CL	M. GRY, ROOTED			320
135.1	145.8	SL	M. GRY, CLYST INTBDS, RIPPLE LAM, MINOR COAL, SANDY @ TOP, PLANT			420
145.8	161.2	SS	FG, RIPPLE, SOFT SED DEFORMATION			500
161.2	161.8	CL	M. GRY, SLTLY FISSILE, ROOTED			320
161.8	165.6	CO	BLK, BAND, 15% VIT, FRAC, HACKLY, 0.25' BONEY ZONE @ 164.4'	D3		110
165.6	173.8	SS	M. GRY, FG, M.V. SORT, RIPPLE LAM, ROOT & SILTY @ TOP, P. IND			520
173.8	178.7	CO	BLK, BANDED, 15% VIT, CONCH FRAC, SILKY, CLEAT, PYR, THIN CARB SLT, 0.2' BONE	D21		110
178.7	180.0	SS	BRN-GRY, FG, ROOTED, P. SORT, SILTY			540
180.0	250.0	SS	BRN-GRY, FG, INTBD CLAY			540

DRILL HOLE NUMBER: 820590BC

NORTH 366180
EAST 529632
ELEVATION: 6899.1
COMMENTS:

SECTION 35
TOWNSHIP: 20N
RANGE: 100W

COORDINATE SYSTEM: SP
SURVEY/EST: S
CONFIDENCE: 11

MINING COMPANY: NER
CONTRACTOR: JC
FIELD REP: PSN

YEAR: 82
TOTAL DEPTH: 263
DRILL HOLE TYPE: OC
GEOPHYSICAL LOGS: GDRC

TOP DEPTH	BOTTOM DEPTH	LITH	LITHOLOGIC DESCRIPTION	SEAM	NOTE	CODE
=====	=====	=====	=====	=====	=====	=====
0.0	12.0	SU	LT BRN-LT OR BRN. SAND, SILT, CLAY; UNCONSOL			900
12.0	29.5	SS	LT BRN. VFG. V.V. SORT. P-M. IND. V. FRAC 16.4-17.1, 19.5-20.3			570
29.5	32.9	CL	GRY, V. IND			330
32.9	34.9	SS	RED BRN-GRY, VFG, V.V. IND			580
34.9	36.1	CL	DK BRN-DK GRY BRN. V. FRAC			340
36.1	39.2	SS	GRY, FG, CARB PLANT REMAINS, P-M. IND			530
39.2	49.3	CL	LT BRN, M-V. IND, COAL STRNGR @ 42.5'			370
49.3	52.0	SL	DK GRY, CLAYEY, V. WELL IND			420
52.0	62.0	SS	GRY, VFG-FG, COALY @ 54'			530
62.0	62.6	CL	DK GRY			320
62.6	66.0	SS	GRY, FG, M-V. IND			530
66.0	67.2	CL	LT-DK GRY; YEL-BRN V.V. IND LAM			320
67.2	79.0	SS	FG-VFG, M-V. IND, CLYST STRNGRS 69.55-69.65, 71.5-71.8			500
79.0	85.6	CO	BLK, HARD, CLAR-DUR, CLEAT NOT V. DEVELOPED, RARE PYR, MINOR CLAY ON CLEAT	D5		110
85.6	86.5	CL	DK GRY, CARB			320
86.5	88.9	SS	GRY, VFG, P. IND			530
88.9	91.3	CL	GRY, SILTY			330
91.3	99.9	SS	GRY, VFG, SLTLY CLAYEY 94-96			530
99.9	108.4	CO	BLK, HARD, CLAR-DUR, HIGHLY FRAC 99-99.5, RARE MARC & PYR	D4		110
108.4	109.0	SS	DK GRY, VFG-FG			520
109.0	110.5	CL	LT GRY			330
110.5	165.7	SS	GRY, VFG, P-M. IND			530
165.7	168.7	CL	GRY, M-V. IND			330
168.7	173.7	SS	GRY, VFG-FG, P. IND			520
173.7	176.2	CL	GRY, M. IND, COAL 173.9-174			320
176.2	189.6	CO	BLK, M. HARD, BAND, V. DEV. VERT CLEAT, PYR & MARC	D31		110
189.6	191.0	SS	GRY, VFG, V. IND			530
191.0	263.0	UN	COAL STRNGRS @ 206', 237'			30

DRILL HOLE NUMBER: 830060BC

NORTH 388941	SECTION 4	COORDINATE SYSTEM: SP	MINING COMPANY: NER	YEAR: 83
EAST 516499	TOWNSHIP: 20N	SURVEY/EST: S	CONTRACTOR: JC	TOTAL DEPTH: 220
ELEVATION: 6988.0	RANGE: 100W	CONFIDENCE: 11	FIELD REP: CCE	DRILL HOLE TYPE: OC
COMMENTS: 1.2% OB CORE LOSS				GEOPHYSICAL LOGS: GDRC

TOP DEPTH	BOTTOM DEPTH	LITH	LITHOLOGIC DESCRIPTION	SEAM	NOTE	CODE
=====	=====	=====	=====	=====	=====	=====
0.0	4.0	SU	RED-OR, SILT AND SAND, UNCONSOL TO V SLIGHTLY IND			820
4.0	14.2	SS	YEL TO YEL-OR TO LT GRY, VFGR TO FGR, P SORT, S TO M IND, CALC			570
14.2	20.0	CL	GRN-GRY, S IND, CARB IN PART, SILTY IN PART, OCC FE STAIN			350
20.0	28.6	SS	LT GRY, TO YEL-GRY, VFGR, P SORT, M IND, OCC ROOT, CARB AND SILTY IN PART			530
28.6	30.3	CL	M GRY, MASS, FE STAIN, SILTY			330
30.3	34.7	SL	M GRY, SANDY, M IND, MASS, OCC FE STAIN			420
34.7	38.5	CL	M GRY, S IND, MASS, PLANT FRAGMENTS, COAL STRGR AT BASE			330
38.5	45.0	SL	M GRY, M IND, SANDY, ROOT AT TOP, GRD TO CLAYEY, OCC SID NOD			420
45.0	47.8	SS	M GRY, VFGR TO SILTY, M IND, LAM			520
47.8	52.7	SL	M GRY, M IND, MASS W/ LARGE SID NOD, BECOMING CARB AND CLAYEY			420
52.7	61.2	SS	LT GRY, VFGR TO SILTY, P SORT, S IND, RIP LAM, ROOT AT TOP			530
61.2	64.6	SL	GRN-GRY, M IND, ROOT, RIP LAM, CLAYST BANDS			450
64.6	70.7	SS	LT GRY, VFGR, SILTY, P SORT, S TO W IND, SLIGHTLY TO V CALC, LAM			530
70.7	73.7	SL	GRN-GRY, M IND W/ SID STREAKS, RIP LAM, ROOT			450
73.7	79.7	CL	GRN-GRY, S TO M IND, SILTY, LAM, ROOT, SID NOD, CARB STRGR			350
79.7	89.3	SS	LT GRY, VFGR, S IND, HIGHLY FRAC, OCC PYR NOD, SILTY IN PART			530
89.3	90.0	SL	GRN-GRY, S IND, PLANT FRAG, SID STREAKS			450
90.0	91.5	CL	GRN-GRY, SILTY, THIN COAL AT BASE			350
91.5	96.9	SL	GRN-GRY, S TO M IND, RIP LAM, ROOT, BURR			450
96.9	100.7	SS	M GRY, FGR, SILTY AT TOP, OCC PYR NOD, BECOMES X-BED			520
100.7	102.0	SL	GRN-GRY, CLAYEY, LAM, COAL AT BASE			450
102.0	104.4	SS	BRN-GRY, FGR, LAM, ROOT			540
104.4	118.6	CO	BLK, BAND, DULL, MASS, CLEATING P TO W DEV, OCC BOWEY BANDS	D54		110
118.6	120.3	CL	BRN TO M GRY, ROOT, BECOMES SILTY			340
120.3	121.8	SS	LT GRY, FGR, X-BED, CARB LAM, PYR NOD			530
121.8	124.3	SL	M GRY, SANDY, M IND, RIP LAM, SID NOD			420
124.3	126.7	SS	LT GRY, M IND, RIP LAM, ROOT AT TOP, X-BED, PYR NOD			530
126.7	131.4	SL	M GRY, S TO M IND, RIP LAM, MASS			420
131.4	137.4	CO	BLK, BAND, DULL, VITRAIN 15%, W DEV CLEATING, SOME PYR	D31		110
137.4	164.5	SS	BRN-GRY, FGR, M TO W SORT, ROOT, RIP LAM			540
164.5	168.5	CL	VFGR, P SORT, M IND W/ INTBD SITLST			300
168.5	199.5	SS	LT GRY, FGR, M SORT, M IND			530
199.5	220.0	CL	DK GRY, SILTY, M TO S IND			320

DRILL HOLE NUMBER: 830640BC

NORTH 385286
EAST 527488
ELEVATION: 6813.3
COMMENTS:

SECTION 11
TOWNSHIP: 20N
RANGE: 100W

COORDINATE SYSTEM: SP
SURVEY/EST: S
CONFIDENCE: 11

MINING COMPANY: NER
CONTRACTOR: JC
FIELD REP: PSN

YEAR: 83
TOTAL DEPTH: 300
DRILL HOLE TYPE: OC
GEOPHYSICAL LOGS: GDRC

TOP DEPTH	BOTTOM DEPTH	LITH	LITHOLOGIC DESCRIPTION	SEAM	NOTE	CODE
=====	=====	=====	=====	=====	=====	=====
0.0	9.0	SU	V LT OR-BRN, SAND, M IND, CALC, AEOLIAN			833
9.0	42.0	SS	LT OR-BRN TO LT YEL-BRN, FGR, V S IND, CL IN PART, ARENACEOUS, CO SPAR IN PART			590
42.0	47.0	CL	OLIVE-GRY, CARB STRGR			350
47.0	53.0	SS	GRY TO BRN, VFGR, V W IND IN PART, MINOR GYP, ARENACEOUS, CLAYEY IN PART			520
53.0	59.0	CL	LT GRY-BRN TO GRY, SLIGHTLY SILTY IN PART			340
59.0	61.0	SL	GRY			420
61.0	75.0	SS	LT GRY, VFGR, MINOR SID			530
75.0	77.0	CL	GRY TO LT GRY, CARB SH & CO STRGR			320
77.0	96.0	SS	LT GRY, VFGR, CLAYEY IN PART, CARB IN PART, ROOT W/ CO SPARS IN PART			530
96.0	98.0	CL	GRY			320
98.0	120.6	SS	LT GRY, VFGR, ARENACEOUS, MINOR SID, OCC CL BANDS			530
120.6	127.4	CO	BLK, MID LUST, CLARAIN, HARD, VITRAIN 15%, MINOR PYR ON VERT CLEATS, SL PTG	D5		120
127.4	129.0	CL	GRY, W IND			320
129.0	136.9	CO	BLK, BRIGHT, HARD, VITRAIN 20%, COMPETENT THRU, MINOR PYR	D4		110
136.9	140.0	CL	GRY			320
140.0	144.0	SL	GRY			420
144.0	185.0	SS	LT GRY TO V LT GRY, VFR, ARENACEOUS, V W IND AT BASE			530
185.0	186.1	SL	GRY, W IND, MINOR SID BANDS, BECOMING CLAYEY			420
186.1	188.8	CO	BLK, M BRIGHT TO MID LUST, HARD, MINOR PYR, GRD BRN-BLK W/ INTBD CARB SH	D3		120
188.8	190.2	SH	BLK, CARB			210
190.2	194.0	CL	GRY W/ MINOR COAL LAM, M W IND			320
194.0	204.0	SS	LT GRY, VFGR, LAM W/ V THIN COALY DEBRIS, MINOR SID BANDS			530
204.0	210.0	SL	GRY W/ INTBD COAL			420
210.0	211.0	CL	LT GRY			330
211.0	218.5	CO	BLK, M HARD, CLARAIN, VITRAIN 10%, MINOR PYR, FRAC IN PART	D21		120
218.5	221.7	SS	LT GRY, VFGR, INTBD W/ ABUNDANT CARB PLANT MATERIAL			530
221.7	223.0	CL	GRY TO LT GRY, W IND			320
223.0	280.5	SS	LT GRY, VFGR, ARENACEOUS IN PART, BECOMING V LT GRY			530
280.5	284.2	CO	BLK, M BRIGHT, HARD			120
284.2	300.0	SS	BRN, VFGR, BECOMING V LT GRY-BRN & COARSENING TO FGR			570

DRILL HOLE NUMBER: 8501808C

NORTH 390325
EAST 517126
ELEVATION: 6958.6
COMMENTS:

SECTION 4
TOWNSHIP: 20N
RANGE: 100W

COORDINATE SYSTEM: SP
SURVEY/EST: S
CONFIDENCE: 11

MINING COMPANY: BCC
CONTRACTOR: JC
FIELD REP: DGB

YEAR: 85
TOTAL DEPTH: 275
DRILL HOLE TYPE: OC
GEOPHYSICAL LOGS: GDRG

TOP DEPTH	BOTTOM DEPTH	LITH	LITHOLOGIC DESCRIPTION	SEAM	NOTE	CODE
=====	=====	=====	=====	=====	=====	=====
0.0	7.0	SL	LT ORNG. CLAYEY			490
7.0	24.2	SS	FGR-MGR. LT ORNG. MASSIVE TO PARALLEL BEDDED			590
24.2	24.7	CL	OLIVE GRAY, SILTY			350
24.7	71.6	SS	MGR-FGR. LT OLIVE GRAY, MICACEOUS, CLAYEY ZONES, SUBRND. LIM			550
71.6	85.0	SL	LT OLIVE GRAY AND GRAY TO BLUE GRAY, CLAYEY			450
85.0	91.0	SS	BLUE GRAY, THIN LAM, RIPPLE CROSS STRATIFIED			560
91.0	104.0	CL	MED GRAY, DENSE, THIN LAM, THIN COAL STRGRS			320
104.0	110.0	SS	VFGR, MED GRAY, CARB LAMS, BURR			520
110.0	114.0	SL	GRAY			420
114.0	145.2	SS	MGR. MED GRAY, MASSIVE TO PARALLEL BEDDED, PLANT MATERIAL			520
145.2	148.0	CL	MED GRAY, THIN LAM			320
148.0	148.9	CO				120
148.9	162.2	CL	INTBD SANDST, THIN LAM, SILTY AT BOTTOM			300
162.2	178.1	CO	BLK. HARD, THIN PTGS, PYR, AMB AT BASE	D54		120
178.1	184.8	CL	CARB AT TOP			300
184.8	193.5	SS	FGR, CLAYEY, GRADATIONAL CONTACT AT TOP AND BOTTOM			500
193.5	196.3	CL	SANDY			300
196.3	208.8	CO	BLK. HARD, PTG 200.3-201.0, MINOR PYR	D31		120
208.8	230.0	CL	MED GRAY, WELL IND, SANDY INTERVALS			320
230.0	239.0	SL				400
239.0	245.0	SS				500
245.0	275.0	SL				400

DRILL HOLE NUMBER: 850220BC

NORTH 384682	SECTION 9	COORDINATE SYSTEM: SP	MINING COMPANY: BCC	YEAR: 85
EAST 520145	TOWNSHIP: 20N	SURVEY/EST: S	CONTRACTOR: JC	TOTAL DEPTH: 160
ELEVATION: 6909.8	RANGE: 100W	CONFIDENCE: 11	FIELD REP: PSM	DRILL HOLE TYPE: OC
COMMENTS:				GEOPHYSICAL LOGS: GDRG

TOP DEPTH	BOTTOM DEPTH	LITH	LITHOLOGIC DESCRIPTION	SEAM	NOTE	CODE
=====	=====	=====	=====	=====	=====	=====
0.0	2.0	SU	LT YELL BROWN SANDS, NONIND, CALC			830
2.0	4.0	LS	LT GRAY, MICRITIC, V WELL IND			700
4.0	8.0	CL	YELL BROWN TO YELL GRAY, SILTY			370
8.0	10.0	SL	YELL GRAY, WELL IND			430
10.0	21.5	SS	FGR, LT GRAY TO LT ORNG BROWN, ARENACEOUS, IRON STAINED, INTBD CLAYST			530
21.5	24.5	CL	GRAY, SID BANDS			320
24.5	29.5	SS	FGR, LT YELL BROWN TO LT YELL GRAY, ARENACEOUS			570
29.5	30.3	CO	BLK, SOFT, DULL, MOD VX			130
30.3	36.0	CL	GRAY TO YELL GRAY, STICKY AT TOP, GYPS 32.7			320
36.0	41.8	SS	FGR, LT YELL BROWN			570
41.8	47.0	CL	GRAY			320
47.0	61.1	CO	BLK, BANDED, HARD, CLAR-DUR, MINOR SILTST PTGS	D54		120
61.1	66.1	CL	GRAY, SID BANDS, MINOR BURR			320
66.1	75.8	SS	FGR, LT GRAY, ARENACEOUS, MINOR INTBD CLAYST, FINING DOWNWARDS			530
75.8	77.8	SL	LT GRAY, SID BANDS			430
77.8	79.4	CL	GRAY			320
79.4	80.3	CO	BLK, HARD, CLAR-DUR, PYR, SILTST PTGS 83.6-84.3, 86.8-86.9	D31		120
80.3	131.0	SS	FGR-VFGR, DK BROWN TO LT BROWN, ROOTED AT TOP			540
131.0	160.0	CL	GRAY			320

DRILL HOLE NUMBER: 8502408C

NORTH 387493
EAST 526351
ELEVATION: 6851.3
COMMENTS:

SECTION 11
TOWNSHIP: 20N
RANGE: 100W

COORDINATE SYSTEM: SP
SURVEY/EST: S
CONFIDENCE: 11

MINING COMPANY: BCC
CONTRACTOR: JC
FIELD REP: PSN

YEAR: 85
TOTAL DEPTH: 400
DRILL HOLE TYPE: OC
GEOPHYSICAL LOGS: GDRG

TOP DEPTH	BOTTOM DEPTH	LITH	LITHOLOGIC DESCRIPTION	SEAM	NOTE	CODE
0.0	13.3	SU	LT YELL GRAY TO LT YELL BROWN SANDS, NOWIND, CALC. MINOR CLAYS			830
13.3	25.0	SS	FGR, LT OLIVE GRAY TO LT ORNG BROWN, MINOR CLAYST INTBDS			550
25.0	29.0	CL	OLIVE GRAY, MINOR INTBD CLAYST			350
29.0	45.0	SS	FGR, LT OLIVE GRAY, INTBD IRON-STAINED YELL BROWN CLAYST			550
45.0	56.7	SL	GRAY TO LT GRAY BROWN, CLAYEY			420
56.7	104.0	SS	VFGR-FGR, LT GRAY TO LT GRAY BROWN, CARB LAMS, FGR-MGR 81-91, CLAYST INTBDS			530
104.0	107.5	CL	GRAY, SILTY, CARB BANDS			320
107.5	124.0	SS	VFGR-FGR, LT GRAY BROWN TO LT OLIVE GRAY, ARENACEOUS			540
124.0	129.0	CL	LT OLIVE GRAY, SILTY			350
129.0	134.0	SS	FGR-VFGR, LT OLIVE GRAY, CLAYEY			550
134.0	148.0	SL	GREEN GRAY, MINOR INTBD SANDST			450
148.0	191.1	SS	FGR-VFGR, LT GRAY BROWN, MINOR INTBD GRAY BROWN CLAYST WITH SID BANDS			540
191.1	191.6	CO	BLK			120
191.6	195.0	CL	GREEN GRAY			350
195.0	203.5	SS	FGR, LT GRAY BROWN, CARB LAMS			540
203.5	207.8	CL	COAL SPARS			300
207.8	214.3	CO	BLK, HARD, CLAR-DUR, MINOR CARB PTGS	D5		120
214.3	218.5	CL	GRAY BROWN, COAL STRGR 215.0-215.3			340
218.5	225.8	CO	BLK, BANDED, HARD, CLAR, PYR	D4		120
225.8	269.0	SS	VFGR, LT GRAY BROWN, CARB AT TOP			540
269.0	270.1	CL				300
270.1	272.6	CO	BLK, HARD, MOD BRIGHT TO DULL, PYR, V THIN CARB PTG	D3		120
272.6	272.9	SS	FGR, BLK, CARB, COAL INTBDS			510
272.9	288.0	SL	GRAY TO GRAY BROWN, CARB AT TOP, INTBD CLAYST, SANDY ZONES			420
288.0	304.3	SS	FGR, LT GRAY BROWN, MINOR INTBD CLAYST, SILTY ZONES, ARENACEOUS			540
304.3	305.0	CO	BLK			120
305.0	308.2	CL	GRAY			320
308.2	315.2	CO	BLK, HARD, MOD BRIGHT, PYR	D21		120
315.2	318.6	SL	LT GRAY, COARSENING DOWNWARDS			430
318.6	333.0	SS	FGR, LT GRAY BROWN, ARENACEOUS			540
333.0	338.5	SL	BROWN, MINOR INTBD LT GRAY TO WHITE CLAYST			440
338.5	353.6	SS	SILTY AT BOTTOM			500
353.6	355.9	CO	BLK, BANDED, HARD, DULL, PTG 354.1-355.0	UTE		120
355.9	400.0	SS	FGR-VFGR, V LT GRAY TO WHITE			530

DRILL HOLE NUMBER: 850270BC

NORTH 382294
EAST 532883
ELEVATION: 6721.9
COMMENTS:

SECTION 13
TOWNSHIP: 20N
RANGE: 100W

COORDINATE SYSTEM: SP
SURVEY/EST: S
CONFIDENCE: 11

MINING COMPANY: BCC
CONTRACTOR: JC
FIELD REP: DGB

YEAR: 85
TOTAL DEPTH: 370
DRILL HOLE TYPE: OC
GEOPHYSICAL LOGS: GORC

TOP DEPTH	BOTTOM DEPTH	LITH	LITHOLOGIC DESCRIPTION	SEAM	NOTE	CODE
=====	=====	=====	=====	=====	=====	=====
0.0	2.0	SU	CLAYEY SANDS			830
2.0	4.0	CL	DK YELL ORNG. WELL IND			390
4.0	9.5	SS	LT OLIVE GRAY			550
9.5	66.0	SS	MGR-FGR. DK GRAY TO GRAY, P IND, THIN BEDDED			520
66.0	66.5	CO	BRIGHT			120
66.5	91.0	SS	VFGR. GRAY, BURR 78.0-78.5, SILTY ZONES, MINOR CLAYST INTBDS			520
91.0	98.0	SS	OLIVE TO GRAY, BIOTURB. LT TAN SILTST 97.4-97.5			550
98.0	102.5	CL	LT GRAY TO BLUE GRAY			330
102.5	118.0	SS	VFGR. MED GRAY, THIN LAM WITH THIN INTBDS OF BLUE CLAYST, CONTORTED BEDDING			530
118.0	133.0	CL	BLUE GRAY, SILTY AT TOP			360
133.0	134.8	LS	GRAY, V WELL IND			700
134.8	145.3	SS	VFGR. GRAY, MASSIVE WITH MINOR CONTORTED BEDDING			520
145.3	152.5	CL	VERY THIN SANDY INTBDS, CARB AT BOTTOM			300
152.5	163.2	SS	MASSIVE TO CONTORTED			500
163.2	163.7	CO				120
163.7	188.3	CL	GRAY, MASSIVE, SHALY 172.1-173.2			320
188.3	195.3	CO	BRIGHT, MINOR PYR ALONG VERT CLEATS	D5		120
195.3	204.0	CL	GRAY, STICKY AT TOP			320
204.0	213.7	SS	VFGR. MASSIVE			500
213.7	222.7	CO	BLK. BRIGHT, PYR ALONG VERT CLEATS	D4		120
222.7	231.0	CL	GRAY, SANDST INTBDS			320
231.0	248.0	SS	CLAYST INTBDS WITH PLANT MATERIAL ALONG BEDDING			500
248.0	253.5	CL				300
253.5	257.8	CO	MINOR V THIN PTGS	D3		120
257.8	282.5	SS	VFGR. GRAY, INTBD SILTST AND CLAYST			520
282.5	285.2	CL	GRAY, PARALLEL LAM. MINOR CARB MATERIAL			320
285.2	292.5	CO	BLK. DULL. MINOR PYR	D21		120
292.5	298.0	CL	SANDY, WAVY BEDDED AT TOP, CARB			300
298.0	332.0	SS	VFGR. GRAY			520
332.0	334.0	CL				300
334.0	339.0	SS				500
339.0	341.0	CL				300
341.0	344.8	CO		UTE		120
344.8	348.2	CL				300
348.2	357.5	SS				500
357.5	365.0	CL				300
365.0	370.0	NR				30

DRILL HOLE NUMBER: 850280BC

NORTH 381412
EAST 529803
ELEVATION: 6720.6
COMMENTS:

SECTION 14
TOWNSHIP: 20N
RANGE: 100W

COORDINATE SYSTEM: SP
SURVEY/EST: S
CONFIDENCE: 11

MINING COMPANY: BCC
CONTRACTOR: JC
FIELD REP: PSM

YEAR: 85
TOTAL DEPTH: 220
DRILL HOLE TYPE: OC
GEOPHYSICAL LOGS: GDRC

TOP DEPTH	BOTTOM DEPTH	LITH	LITHOLOGIC DESCRIPTION	SEAM	NOTE	CODE
=====	=====	=====	=====	=====	=====	=====
0.0	8.0	SU	V LT YELL BROWN BLOW SANDS, NONIND. CALC			833
8.0	17.8	CL	GRAY, SID BANDS, INTBD SANDST			320
17.8	23.0	SS	FGR, LT BROWN, IRON STAINED			570
23.0	28.9	CL	LT BROWN, IRON STAINED, SLTLY SILTY			370
28.9	30.3	CO	BLK, SOFT, WX	D5	WX	130
30.3	35.5	CO	BLK, HARD, CLAR-DUR	D5		120
35.5	36.4	CL	GRAY			320
36.4	44.0	SS	FGR, LT BROWN TO LT GRAY, CARB LAMS, BECOMING VFGR 41.4			570
44.0	47.3	CL	GRAY WITH INTBD COAL STRGRS			320
47.3	54.9	CO	BLK, BANDED, HARD, CLAR	D4		120
54.9	61.7	SS	FGR, LT BROWN TO LT GRAY, COAL SPARS 54.9-55.5, INTBD CLAYST			570
61.7	69.2	CL	LT GRAY, MINOR SID BANDS AND INTBD SANDST			330
69.2	83.8	SS	FGR, LT GRAY, CARB LAMS, SID BANDS			530
83.8	86.6	CL	GRAY, SID BANDS, SLTLY SILTY			320
86.6	89.8	CO	BLK, HARD, CLAR-DUR	D3		120
89.8	95.0	CL	BROWN, STICKY			340
95.0	125.3	SS	FGR, LT GRAY, STRUCTURELESS			530
125.3	126.2	CL	GRAY TO BLK, BROWN 125.5-126.2			320
126.2	132.9	CO	BLK, HARD, MINOR CARB PTGS, PYR	D21		120
132.9	176.7	SS	FGR, LT GRAY BROWN, CARB AT TOP WITH COAL SPARS, MINOR INTBD CLAYST			540
176.7	177.5	CO		UTE		120
177.5	220.0	SS				500

DRILL HOLE NUMBER: 850310BC

NORTH 378723
EAST 530264
ELEVATION: 6724.6
COMMENTS:

SECTION 14
TOWNSHIP: 20N
RANGE: 100W

COORDINATE SYSTEM: SP
SURVEY/EST: S
CONFIDENCE: 11

MINING COMPANY: BCC
CONTRACTOR: JC
FIELD REP: PSM

YEAR: 85
TOTAL DEPTH: 180
DRILL HOLE TYPE: OC
GEOPHYSICAL LOGS: GDRC

TOP DEPTH	BOTTOM DEPTH	LITH	LITHOLOGIC DESCRIPTION	SEAM	NOTE	CODE
=====	=====	=====	=====	=====	=====	=====
0.0	12.0	SU	LT RED BROWN TO LT BROWN SANDS AND CLAYS MIXED			830
12.0	14.9	SS	FGR-MGR, LT BROWN, P IND, IRON STAINED, MICACEOUS, CLAYST INTBDS			570
14.9	18.5	CL				300
18.5	32.0	SL	RED BROWN			480
32.0	42.0	CL	GRAY BROWN WITH MINOR RED BROWN ZONES			340
42.0	58.5	SS	VFGR-FGR, LT YELL GRAY, IRON STAINED, SLUMP AND FOLD STRUCTURES			530
58.5	61.5	LS	GRAY, MICRITIC, RIP UP CLASTS(?)			700
61.5	63.4	SL	GRAY			420
63.4	66.4	CO	BLK, HARD, CLAR-DUR, MINOR CARB BANDS	D3		120
66.4	71.0	SL	LT OLIVE GRAY			450
71.0	81.0	SS	FGR-MGR, LT GRAY, CARB LAMS, MINOR CLAYST INTBDS, SOME CGR ZONES W/V ANG GRAINS			530
81.0	95.0	SL	INTBD CLAYST			400
95.0	97.4	CL	GRAY			320
97.4	98.0	CL	V DK BROWN TO BLK			340
98.0	104.9	CO	BLK, BANDED, HARD, CLAR-DUR	D21		120
104.9	150.0	SS	FGR, LT GRAY TO LT BROWN, SOME MGR ZONES			530
150.0	153.4	CL				300
153.4	162.3	SS	FGR, V LT GRAY TO WHITE			530
162.3	164.0	CL				300
164.0	171.0	SS	FGR, V LT GRAY TO WHITE			530
171.0	180.0	CL	GRAY TO DK GRAY			320

DRILL HOLE NUMBER: 8503208C

NORTH 377134
EAST 529881
ELEVATION: 6764.6
COMMENTS:

SECTION 23
TOWNSHIP: 20N
RANGE: 100W

COORDINATE SYSTEM: SP
SURVEY/EST: 5
CONFIDENCE: 11

MINING COMPANY: BCC
CONTRACTOR: JC
FIELD REP: PSM

YEAR: 85
TOTAL DEPTH: 180
DRILL HOLE TYPE: OC
GEOPHYSICAL LOGS: GDRC

TOP DEPTH	BOTTOM DEPTH	LITH	LITHOLOGIC DESCRIPTION	SEAM	NOTE	CODE
=====	=====	=====	=====	=====	=====	=====
0.0	13.7	SU	LT YELL GRAY TO LT RED BROWN SANDS AND CLAYS, NONIND TO P IND			830
13.7	16.0	SS	FGR, LT BROWN, SOME V WELL IND ZONES, CONTORTED BEDDING, MINOR CLAYST			570
16.0	30.0	SL				400
30.0	34.0	CL	RED BROWN			380
34.0	45.0	SS	FGR, LT RED BROWN			580
45.0	46.5	CO		D4	PSWX	130
46.5	65.0	CL	BROWN TO GRAY WITH RED IRON STAINING, INTBD SANDST			340
65.0	81.0	SS	FGR, LT BROWN, IRON STAINED, CARB LAMS, V WELL IND 76.8-78.8			570
81.0	82.9	CL				300
82.9	87.5	CO	BLK, HARD, MOD DULL	D3		120
87.5	90.5	CL	GRAY BROWN, CARB AT TOP, MINOR SANDST INTBDS			340
90.5	94.0	SS	VFGF-FGR, LT GRAY, CARB LAMS			530
94.0	95.6	SL	LT GRAY			430
95.6	103.5	CO	BLK, HARD, CLAR, MINOR VIT, FAIRLY COMPETENT	D21		120
103.5	110.5	SS	VFGF-FGR, V LT GRAY, CARB STRGRS AT TOP			530
110.5	112.2	LS				700
112.2	153.2	SS				500
153.2	154.3	CL				300
154.3	156.3	SL				400
156.3	159.1	CO		UTE		120
159.1	170.0	SS	VFGF, LT BROWN, V WELL IND, SILICA CEMENT			570
170.0	180.0	CL	GRAY			320

DRILL HOLE NUMBER: 850330BC

NORTH 373370	SECTION 23	COORDINATE SYSTEM: SP	MINING COMPANY: BCC	YEAR: 85
EAST 528371	TOWNSHIP: 20N	SURVEY/EST: S	CONTRACTOR: JC	TOTAL DEPTH: 220
ELEVATION: 6800.1	RANGE: 100W	CONFIDENCE: 11	FIELD REP: DGB	DRILL HOLE TYPE: OC
COMMENTS:				GEOPHYSICAL LOGS: GDRC

TOP DEPTH	BOTTOM DEPTH	LITH	LITHOLOGIC DESCRIPTION	SEAM	NOTE	CODE
=====	=====	=====	=====	=====	=====	=====
0.0	7.0	SS	VFGR, LT ORNG			590
7.0	19.0	CL	ORNG, BECOMING SILTY AT BOTTOM			390
19.0	29.0	SS	VFGR, ORNG TO DK ORNG, P CEMENTED, CLAYEY			590
29.0	31.0	CL	ORNG TO DK ORNG, OXIDIZED ROOTLETS, MINOR SID BANDS			390
31.0	36.2	SS	VFGR, LT ORNG			590
36.2	42.8	CO	BRIGHT 36.7-38.2, DULL BLK DETRITUS 38.2-42.2, BRN BLK 41.3-42.8	D5	WX	130
42.8	54.0	SS	V POORLY CEMENTED, CLAYEY, DIRTY AT TOP, ROOTED			500
54.0	59.3	CL	GRAY, MASSIVE, SILTY			320
59.3	67.7	CO	BLK, HARD, PYR ON VERT CLEATS	D4		120
67.7	131.0	SS	FGR, LT OLIVE GRAY TO LT YELLOW, SLUMP STRUCTS, INTBD SILTST, CONGLON 91.9-92.7			550
131.0	134.5	CL	GRAY TO DK GRAY, SILTY, WAVY BEDDED AND STICKY AT BASE			320
134.5	149.0	CO	BLK, MOD BRIGHT, INTBD CLASTIC PTGS 134.5-140.0	D31		120
149.0	153.0	CL	GRAY			320
153.0	161.0	SS				500
161.0	166.0	CL	GRAY			320
166.0	172.0	SS	GRAY			520
172.0	204.0	SL	LT GRAY			430
204.0	209.0	SS				500
209.0	220.0	CL	GRAY TO DK GRAY, SANDY			320

DRILL HOLE NUMBER: 850340BC

NORTH 371507
EAST 529954
ELEVATION: 6833.8
COMMENTS:

SECTION 26
TOWNSHIP: 20N
RANGE: 100W

COORDINATE SYSTEM: SP
SURVEY/EST: S
CONFIDENCE: 11

MINING COMPANY: BCC
CONTRACTOR: JC
FIELD REP: PSM

YEAR: 85
TOTAL DEPTH: 300
DRILL HOLE TYPE: OC
GEOPHYSICAL LOGS: GDRC

TOP DEPTH	BOTTOM DEPTH	LITH	LITHOLOGIC DESCRIPTION	SEAM	NOTE	CODE
=====	=====	=====	=====	=====	=====	=====
0.0	10.0	SU	LT YELL BROWN BLOW SANDS, NONIND. CALC			833
10.0	19.5	SS	FGR, LT GRAY BROWN TO LT OLIVE GRAY, CLAYEY ZONES			540
19.5	20.6	LS	GRAY, MICRITIC, V WELL IND			700
20.6	31.0	SS	FGR-VFGR, GRAY TO LT OLIVE BROWN, CLAYEY AT BOTTOM			520
31.0	35.0	CL	LT ORNG TO ORNG, SID AND OXIDIZED ORGANIC MATERIAL ALONG BEDDING			390
35.0	38.0	SL	GRAY TO ORNG, SANDY, LIMONITE ZONES			420
38.0	86.0	SS	VFGR, GRAY TO LT OLIVE GRAY, ROOTLETS 38-41, P CEMENTED, CONTORTED 56.3-59.4			520
86.0	94.0	CL	GRAY			320
94.0	109.0	SS	VFGR-FGR, LT GRAY, MINOR INTBD CLAYST, CARB LAMS, RIPPLE CROSS LAM			530
109.0	111.6	CL	LT GRAY, MINOR SID BANDS, INTBD SANDST AND SILTST			330
111.6	119.7	SS	FGR-VFGR, LT GRAY			530
119.7	126.6	CO	BLK, BANDED, HARD, CLAR-DUR	D5		120
126.6	126.8	CL	LT GRAY			330
126.8	134.9	SS	FGR, LT BROWN			540
134.9	136.1	LS	GRAY, MICRITIC, V WELL IND			700
136.1	146.2	CL	GRAY, SLTLY SILTY, INTBD SANDST			320
146.2	154.8	CO	BLK, BANDED, HARD, MOD BRIGHT, PYR	D4		120
154.8	170.6	SS	VFGR-FGR, LT OLIVE GRAY, CARB AT TOP, INTBD CLAYST WITH SID BANDS, RIPPLE LAM			550
170.6	172.1	LS	LT GRAY, MICRITIC, V WELL IND			700
172.1	183.0	CL	GRAY, SID BANDS, INTBD SANDST			320
183.0	187.2	SS	LT GRAY BROWN			540
187.2	188.7	LS	GRAY, MICRITIC, V WELL IND			700
188.7	192.0	CL	GRAY WITH LINY LENSES			320
192.0	203.9	SS	FGR, LT GRAY, CARB LAMS			530
203.9	207.3	CL	GRAY			320
207.3	211.2	CO	BLK, BANDED, HARD, CLAR-DUR, PYR, GRAY BROWN CLAYST PTG 208.3-208.7	D3		120
211.2	215.3	SL	BLK, CARB, SANDY			410
215.3	224.6	CO	BLK, HARD, MOSTLY DULL	D21		120
224.6	228.0	CL	GRAY BROWN, SILTY			340
228.0	248.0	SS	FGR, V LT GRAY BROWN, ARENACEOUS			540
248.0	251.0	CL				300
251.0	254.5	SS				500
254.5	259.0	CL				300
259.0	300.0	SS	VFGR, DK GRAY BROWN, CLAYEY			540

DRILL HOLE NUMBER: 8503608C

NORTH 370068	SECTION 26	COORDINATE SYSTEM: SP	MINING COMPANY: BCC	YEAR: 85
EAST 527883	TOWNSHIP: 20N	SURVEY/EST: S	CONTRACTOR: JC	TOTAL DEPTH: 260
ELEVATION: 6896.4	RANGE: 100W	CONFIDENCE: II	FIELD REP: PSM	DRILL HOLE TYPE: OC
COMMENTS:				GEOPHYSICAL LOGS: GDRG

TOP DEPTH	BOTTOM DEPTH	LITH	LITHOLOGIC DESCRIPTION	SEAM	NOTE	CODE
=====	=====	=====	=====	=====	=====	=====
0.0	12.5	SU	V LT GRAY BROWN TO LT YELL GRAY BLOW SANDS, NONIND TO P IND, DRY, CALC			833
12.5	26.5	CL	OLIVE GRAY			350
26.5	34.0	SS	FGR-MGR, LT OLIVE GRAY, FELDS, GARNET, COAL 34.8-35.0			550
34.0	41.0	SL	LT OLIVE, COAL SPARS, INTBD CLAYST			450
41.0	46.0	SS	FGR, LT OLIVE GRAY			550
46.0	48.0	SL	LT GRAY, COAL STRGRS AND ROOTLETS			430
48.0	64.9	SS	FGR-VFGR, LT OLIVE GRAY, INTBD CLAYST			550
64.9	65.7	CL				300
65.7	71.9	CO	BLK, HARD, CLAR-DUR	D5		120
71.9	76.2	SS	FGR, LT GRAY BROWN			540
76.2	79.0	CL	GRAY			320
79.0	86.1	SS	VFGR-FGR, LT GRAY BROWN, MICACEOUS, CARB LAMS			540
86.1	94.4	CO	BLK, BANDED, HARD, MOD BRIGHT	D4		120
94.4	155.6	SS	FGR, LT BROWN, CARB LAMS, SOME LIMY ZONES			570
155.6	159.8	CL	GRAY			320
159.8	174.0	CO	BLK, BANDED, HARD, MOD BRIGHT TO DULL, MINOR CARB PTGS	D31		120
174.0	177.5	CL	GRAY BROWN TO LT OLIVE GRAY, CARB AT TOP			340
177.5	182.8	SS				500
182.8	183.8	CO				120
183.8	188.0	CL				300
188.0	195.0	SS	FGR-VFGR, LT OLIVE GRAY			550
195.0	200.0	CL				300
200.0	243.0	SS	LT OLIVE GRAY TO DK GRAY			550
243.0	260.0	SL	LT OLIVE GRAY, SANDT			450

DRILL HOLE NUMBER: 8503808C

NORTH 367713	SECTION 26	COORDINATE SYSTEM: SP	MINING COMPANY: BCC	YEAR: 85
EAST 528074	TOWNSHIP: 20N	SURVEY/EST: S	CONTRACTOR: JC	TOTAL DEPTH: 220
ELEVATION: 6932.8	RANGE: 100W	CONFIDENCE: 11	FIELD REP: PSM	DRILL HOLE TYPE: OC
COMMENTS:				GEOPHYSICAL LOGS: GDRC

TOP DEPTH	BOTTOM DEPTH	LITH	LITHOLOGIC DESCRIPTION	SEAM	NOTE	CODE
=====	=====	=====	=====	=====	=====	=====
0.0	6.5	SU	V LT YELL BROWN SANDS, NONIND. CALC. CLAYEY ZONES			830
6.5	19.0	CL	LT YELL GRAY, SANDY ZONES, MINOR YELL ORNG AND ORNG BROWN ZONES			330
19.0	25.0	SS	OLIVE GRAY, MICACEOUS, COMMON CARB LAMS			550
25.0	27.4	CL	DK OLIVE GRAY, CARB, LIM ALONG BEDDING			350
27.4	43.2	SS	LT OLIVE GRAY TO LT ORNG, MICACEOUS, LIM			550
43.2	49.2	CO	BLK, DULL, PYR, TRACE OXIDATION ON HORIZ CLEATS	D5		120
49.2	58.0	SS	FGR, OLIVE GRAY, ROOTED, DIRTY			550
58.0	60.0	CL	GRAY			320
60.0	63.9	SL	GRAY, SANDY			420
63.9	71.7	CO	BLK, BANDED, BRIGHT, THIN PTG 64.6-64.7	D4		120
71.7	91.5	SS	VFGR-FGR, LT GRAY BROWN, CARB AT TOP			540
91.5	92.4	LS				700
92.4	107.0	SS	VFGR-FGR, LT GRAY BROWN			540
107.0	109.7	SL	ORNG BROWN TO LT GRAY, IRON STAINED, SID BANDS, CLAYEY			490
109.7	123.6	SS	FGR, LT BROWN, P IND TO MOD IND, MICACEOUS, HEM, CARB LAMS, CRENULED BEDDING			570
123.6	125.8	SL	GRAY			420
125.8	139.2	CO	BLK, BANDED, HARD, CLAR-DUR, PYR, IRREGULAR FRACTS	D31		120
139.2	200.0	SS	FGR-VFGR, LT GRAY BROWN TO DK GRAY, CARB, CLAYEY, INTBD SILTST			540
200.0	203.0	CL	BROWN BLK, DENSE, FAINT LOCAL COMPACTION, SLICK			310
203.0	220.0	SL	GRAY TO DK GRAY, SANDY, DULL BLK 209.0-210.0, CARB			420

DRILL HOLE NUMBER: 850390BC

NORTH 365063
EAST 528096
ELEVATION: 6969.8
COMMENTS: NO GAMMA

SECTION 35
TOWNSHIP: 20N
RANGE: 100W

COORDINATE SYSTEM: SP
SURVEY/EST: S
CONFIDENCE: 11

MINING COMPANY: BCC
CONTRACTOR: JC
FIELD REP: DGB

YEAR: 85
TOTAL DEPTH: 210
DRILL HOLE TYPE: OC
GEOPHYSICAL LOGS: DRC

TOP DEPTH	BOTTOM DEPTH	LITH	LITHOLOGIC DESCRIPTION	SEAM	NOTE	CODE
=====	=====	=====	=====	=====	=====	=====
0.0	4.0	CL	LT OLIVE GRAY TO LT ORNG			350
4.0	11.9	SS	VFGR, LT ORNG			590
11.9	12.4	SS	VFGR, DK ORNG			590
12.4	23.7	CL	LT OLIVE GRAY TO DK OLIVE GRAY, STICKY AND DK ORNG 13.5-14.5, LIM			350
23.7	26.5	SL	DK OLIVE GRAY			450
26.5	33.5	SS	FGR-MGR, LT ORNG TO ORNG, MICACEOUS, THIN CARB LAMS			590
33.5	37.0	CL	DK OLIVE TO GRAY			350
37.0	41.1	CL	LT ORNG TO ORNG, SID ZONES, SANDY IN PLACES			390
41.1	52.3	SS	FGR-VFGR, LT ORNG TO LT OLIVE GRAY, MICACEOUS, CALC, SID BAND 48.0-48.1			590
52.3	58.8	CO	DK BROWN ON FRACTS, SILTY PTG 56.3-56.4	D5		120
58.8	71.2	CL	GRAY, THINLY BEDDED TO MASSIVE, INTBD SANDST			320
71.2	79.8	CO	BRIGHT, MINOR PYR	D4		120
79.8	111.5	CL	GRAY TO BLUE GRAY, MINOR INTBD SANDST, THIN CARB BEDS, LIM, STICKY ZONES			320
111.5	122.0	SS	GRAY, INTBD CLAYST, THIN LAMS			520
122.0	135.3	CO	BRIGHT, MINOR PYR	D31		120
135.3	146.0	SS	FGR, GRAY, FAIRLY CLEAN			520
146.0	146.5	CO				120
146.5	210.0	SS	FGR, LT GRAY, V CLEAN, CLAYEY			530

APPENDIX 3

PALEOCURRENT DATA

These paleocurrent directions were measured at three localities in sections 4 and 9, T20N, R100W (Figure 25) on a prominent trough cross bedded sandstone unit in the overburden.

060	215
135	158
158	163
040	190
050	090
185	135
170	172
202	167
215	138