Geological Investigations of the Wamsutter Rim Canneloid Coal Bed in the Eocene Niland Tongue of the Wasatch Formation, Northern Washakie Basin, Southwest Wyoming

U.S. GEOLOGICAL SURVEY BULLETIN 2018

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By HENRY W. ROEHLER and RONALD W. STANTON

Location and composition of a coal bed
deposited along a shoreline of Eocene Lake Gosiute

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CONTENTS

PLATE

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FIGURES

TABLES

Geological Investigations of the Wamsutter Rim Canneloid Coal Bed in the Eocene Niland Tongue of the Wasatch Formation, Northern Washakie Basin, Southwest Wyoming

By Henry W. Roehler *and* Ronald W. Stanton

Abstract

The Wamsutter Rim coal bed crops out for about 10 mi along the northern slopes of Wamsutter Rim, an east-west-trending ridge located a few miles southwest of Wamsutter, Wyoming. The coal bed is lenticular in cross section and has a maximum recorded thickness of 7.6 ft. In places, the coal contains thin carbonaceous shale partings.

The stratigraphic relationships of the coal and associated rocks are described and illustrated by measured sections and a regional cross section. Stratigraphic data reveal that the coal was deposited in a peat bog that was located in a backshore area of Eocene Lake Gosiute. Paleogeographic relationships of the lake, shoreline, and backshore are interpreted in a block diagram. Sedimentary structures of shoreline sandstones are discernible in photographs taken along outcrops.

One sample of the Wamsutter Rim coal bed was collected from the outcrop and was analyzed to determine the coal's composition and quality. This analysis is compared to (1) an older analysis of the coal prepared from a sample collected by W.H. Bradley from the working face of a small mine, and (2) analyses of the Vermillion Creek coal bed, which is believed to be chronostratigraphically equivalent to the Wamsutter Rim coal bed. Analysis of the outcrop sample collected during this study indicates that the Wamsutter Rim coal bed is composed mostly of plant tissues and pollen and has a sulfur content of 3.7 percent (on an as-received basis). Heating values were not determined, but compared to the Vermillion Creek coal bed, they should average about 11,500 Btu/lb (on a moist, ash-free basis).

Accurate resource assessments for the coal bed are not possible because no corehole information is available to determine subsurface thicknesses and the extent of the bed downdip from outcrops. The coal bed, however, maintains a thickness of at least 5 ft for 4 mi along outcrops. Using this information, the amount of coal in place in a 12-mi^2 area, where the coal thickness averages about 5 ft, is roughly estimated to be about 68 million short tons.

Manuscript approved for publication December 13, 1991.

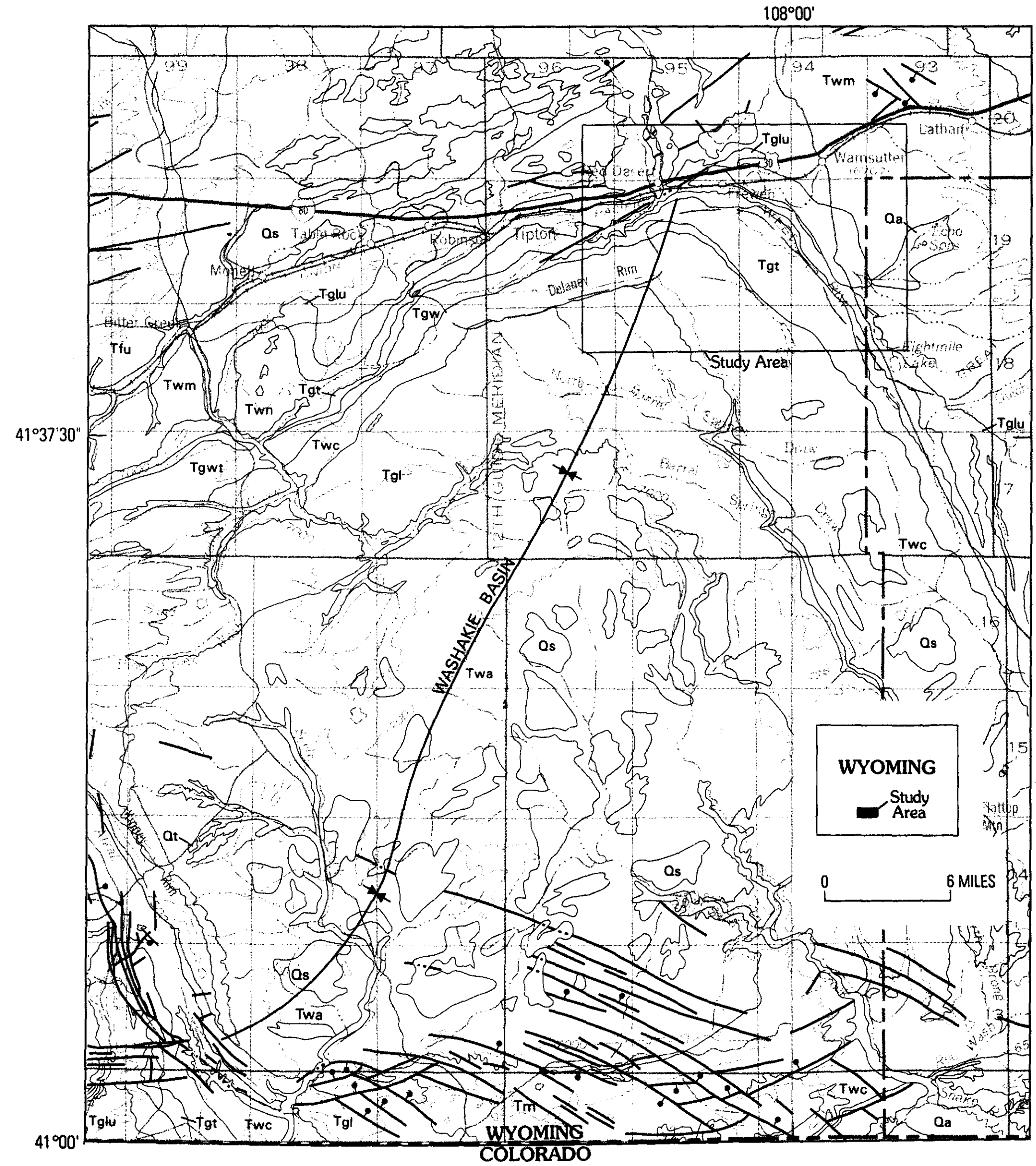
INTRODUCTION

Location and Accessibility of Study Area

The study area is located on Wamsutter Rim in T. 19 N., Rs. 94–95 W., 3–8 mi southwest of the town of Wamsutter, Wyoming, on the northern edge of the Washakie Basin (fig. 1). The study area is accessible from Interstate Highway 80 by improved gravel roads that trend southwest from Wamsutter, Wyoming, and south from Red Desert, Wyoming. From these roads, outcrops of the Wamsutter Rim coal bed are accessible by a number of unimproved roads and trails that parallel the lower and upper slopes of Wamsutter Rim (fig. 2).

Purpose and Methodology

This paper describes research by the U.S. Geological Survey to determine the origin, composition, thickness, and areal extent of the Wamsutter Rim coal bed (a name introduced here). The 13 stratigraphic sections described and (or) illustrated were measured along outcrops using a 6-ft steel engineering tape measure and a 5-ft telescoping Jacob's staff with attached Abney level to compensate for the dip of the strata.



LIST OF MAP UNITS

QUATERNARY:
- Qs - **Sand**
- Qa - **Alluvium**
- Qt - **Terrace gravel**

MIOCENE:
- Tm - **Browns Park Formation**

EOCENE:
- Twa - **Washakie Formation**
- Tgl - **Laney Member of Green River Formation**
- Twc - **Cathedral Bluffs Tongue of Wasatch Formation**
- Tgw - **Wilkins Peak Member of Green River Formation**
- Tgwt - **Undivided Wilkins Peak and Tipton Shale Members of Green River Formation**
- Tgt - **Tipton Shale Member of Green River Formation**
- Twn - **Niland Tongue of Wasatch Formation**
- Tglu - **Luman Tongue of Green River Formation**
- Twm - **Main Body of Wasatch Formation**

PALEOCENE:
- Tfu - **Fort Union Formation**

Syncline

Fault—Showing direction of dip

Figure 1. Geologic map showing location of study area in Washakie Basin in southwest Wyoming. Base from geologic map of Wyoming, scale 1:500,000 (Love and Christiansen, 1985).

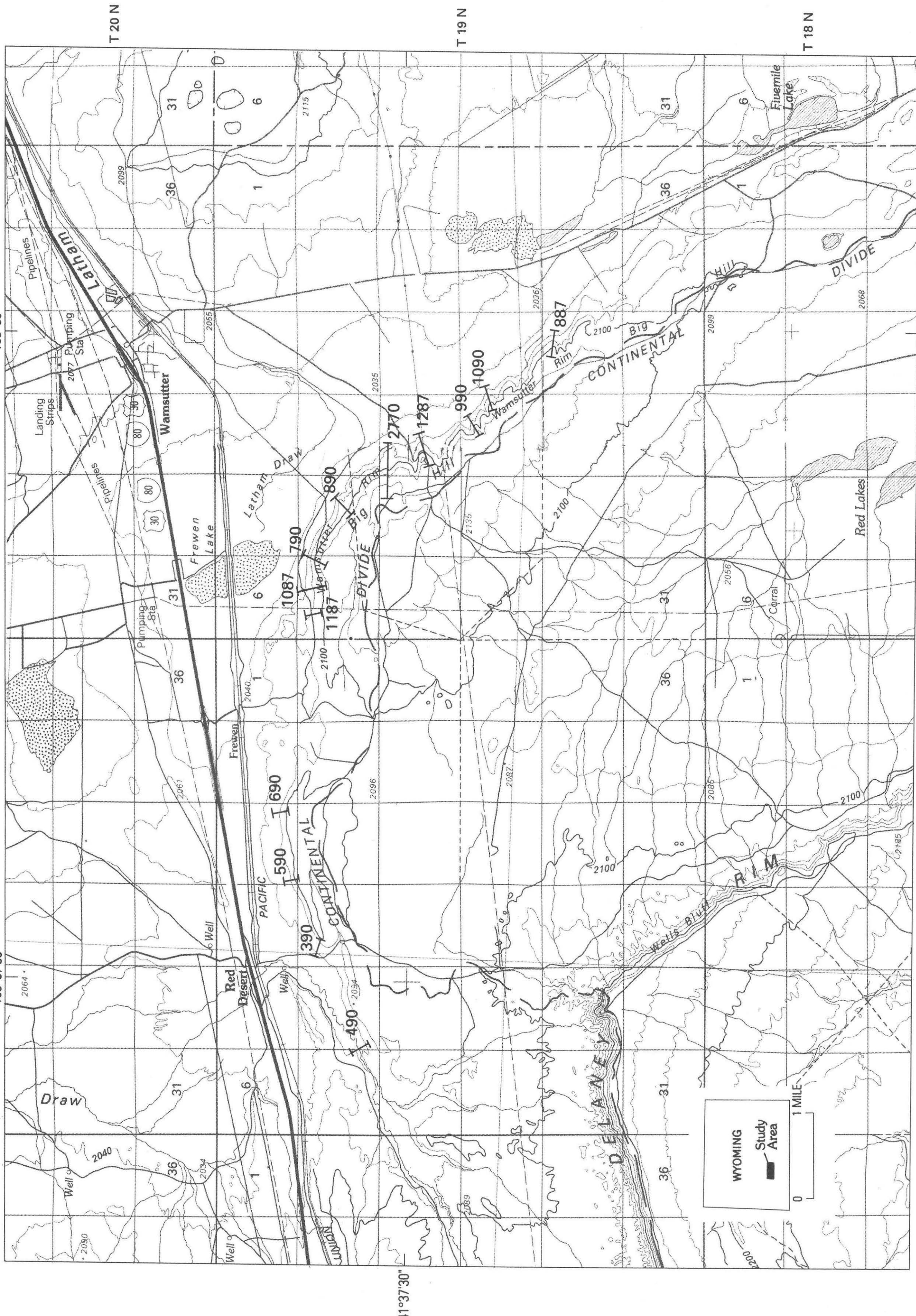


Figure 2. Map showing the location of numbered measured sections along Wamsutter Rim. Topographic contours are in meters (1 m=3.281 ft). Base from U.S. Geological Survey Red Desert and Rawlins, Wyoming, quadrangles, scale 1:100,000.

Figure 3. Outcrops on the slopes of Wamsutter Rim, looking southeast from measured section 890 near the center of sec. 8, T. 19 N., R. 94 W. 1, Top of Wamsutter Rim capped by algal limestone; 2, outcrops of oil shale in Scheggs Bed of Tipton Shale Member of Green River Formation; 3, stratigraphic position of Wamsutter Rim coal bed; and 4, Niland Tongue of Wasatch Formation.

The coal sampled at location B (pl. 1) was petrographically analyzed by Stanton at the Branch of Coal Geology, U.S. Geological Survey, Reston, Virginia. The sample was pulverized in stages to particle size near 860 µm from which a representative split was extracted, mixed with epoxy binder, molded, and polished to a flat, scratch-free plane. This sample was then examined using a reflected-light microscope under white-light and blue-light fluorescence. Maceral abundances were estimated by point-count procedures (Moore and Stanton, 1985), and the reflectance of vitrinite was measured photometrically (ASTM, 1989a). Another representative subsample was sent to a commercial laboratory for standard proximate and sulfur forms analyses (ASTM, 1989b, 1989c).

Geographic Setting of Study Area

Wamsutter Rim is a persistent, east-west-trending, linear ridge that is capped by thin beds of resistant algal limestone. The rim rises 300 ft above steep slopes that are located along the southern margins of an arid plain on which the Union Pacific Railroad, Interstate Highway 80, and the town of Wamsutter, Wyoming, are located (fig. 2). Frewen Lake, a normally dry playa, is also located on this plain. A second linear ridge, Delaney Rim, is located a few miles south of Wamsutter Rim. Delaney Rim stands nearly 600 ft higher than the Wamsutter Rim and is the most prominent topographic feature in the region. Both rims are formed by strata of the Green River Formation that dip 1–4 degrees south and comprise parts of the arcuate northern edge of the bowl-shaped Washakie Basin (fig. 1).

The Wamsutter Rim coal bed crops out near the middle of the sparsely vegetated, north-facing slopes of Wamsutter Rim. It weathers dark gray and is located between smooth, gray-brown slopes composed of mostly oil shale in the Scheggs Bed of the Tipton Shale Member of the Green River Formation that are exposed in the upper part of the rim and tan-gray and gray-brown banded slopes composed of mostly interbedded sandstone, shale, and oil shale in the Niland Tongue of the Wasatch Formation that are exposed in the lower part of the rim (fig. 3). The banded lower slopes of the rim form distinctive outcrops that are visible to the south of Interstate Highway 80 between Wamsutter and Red Desert, Wyoming (fig. 2).

The Continental Divide is located less than 1 mi south of Wamsutter Rim. It generally parallels the rim across the study area (fig. 2).

History of Investigations

The presence of coal in the eastern Great Divide and Washakie Basins has been known since the early surveys of the territories undertaken by Hayden (1873, p. 98). The first attempt to mine coal there was made by the Union Pacific Railroad Company in 1868 (Smith, 1909, p. 240). An early coal investigation by the U.S. Geological Survey, which included the study area and eastern part of the Washakie Basin, was made by Ball (1909). On a geologic map that accompanied this report (Ball, 1909, pl. 13), the Wamsutter Rim coal bed was neither identified nor mapped.

The first definitive stratigraphic investigation of Tertiary rocks in the Washakie Basin was made by Schultz (1920), who named, described, and mapped the Tipton Shale Member and other members of the Green River Formation. Schultz (1920, p. 22) called the beds in the Wasatch Formation that include the interval of the Wamsutter Rim coal bed the "Black Rock coal group," consisting of "* * * alternating layers of white, yellow, and brown sandstones and gray or drab and carbonaceous shales, with coal beds."

The Wamsutter Rim coal bed was described and analyzed by Bradley (1945), who reported it as a 6-ft-thick bed of canneloid coal that can be traced at least 4 mi along the outcrops southwest of Wamsutter. Later, he stated that thin sections of the coal showed that it contained a considerable amount of pollen and leaf-cuticle residues (Bradley, 1964, p. A24). Bradley collected coal samples for thin section, proximate-ultimate, and other analyses from the working face of a small mine that was opened in sec. 7, T. 19 N., R. 94 W (near location A, pl. 1). This mine (now abandoned and collapsed; fig. 4) and a number of very old prospect pits that are located along the length of the coal outcrops suggest that the

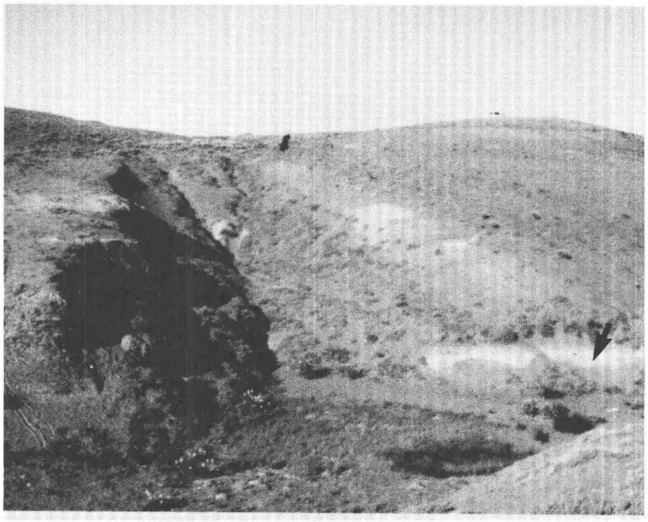


Figure 4. Abandoned and collapsed mine workings in the east-central part of NE1/4 sec. 7, T. 19 N., R. 94 W. The Wamsutter Rim coal bed (covered) underlies a coquina (arrow) that weathers to a light band in outcrops. The collapsed area is about 200 ft long.

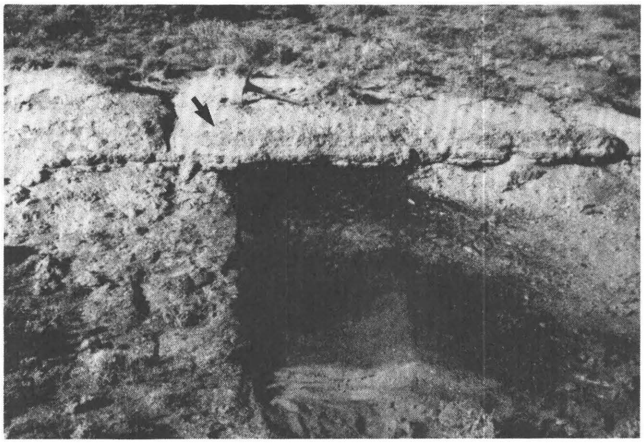


Figure 5. Molluscan coquina (arrow) at base of Tipton Shale Member of Green River Formation. The coquina overlies the Wamsutter Rim coal bed in the east-central part of NE1/4 sec. 7, T. 19 N., R. 94 W., near abandoned mine workings shown in fig. 4. The coal bed here is 4.7 ft thick. Handle of pick is 1.5 ft long.

coal's location and potential value were known long before Bradley's explorations in 1945.

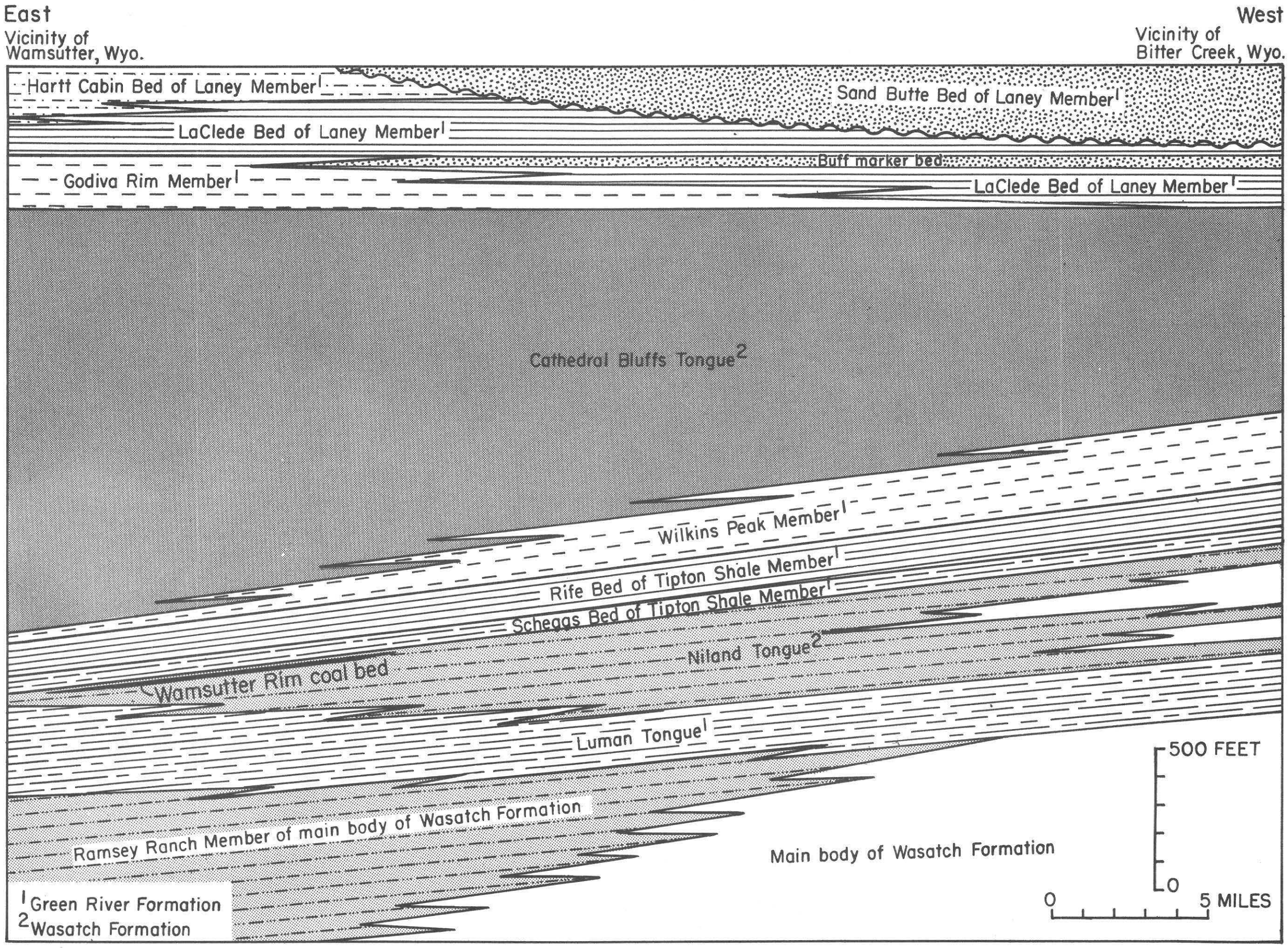
Pipiringos (1955) named and described the Luman Tongue of the Green River Formation and Niland Tongue of the Wasatch Formation during investigations into the occurrence of uranium-bearing coal in the Great Divide Basin and the adjacent northern Washakie Basin. He (Pipiringos, 1961) placed the Wamsutter Rim coal bed in his "upper coal group." He described the bed as a canneloid coal that crops out directly beneath a molluscan coquina at the base of the Tipton Tongue (or Shale Member) of the Green River Formation (fig. 5). Pipiringos did not map the coal bed but did map a persistent overlying algal bed at the top of Wamsutter Rim that he called the "lower algal ball zone" (datum on pl. 1). Pipiringos (1961, p. A59) stated that the coal bed ranged in thickness between 2.5 and 5 ft and formed a lenticular outcrop around the northeast corner of the Washakie Basin.

The Wamsutter Rim coal bed was initially examined by Roehler in 1970 during energy resource investigations of oil-shale deposits in the Washakie Basin. A stratigraphic section (no. 2770) was measured that year, but as shown on plate 1, the coal bed is located in an area where it is covered by slopewash and oil-shale debris. Four stratigraphic sections were measured in 1987 (nos. 887, 1087, 1187, and 1287; pl. 1), at which time the coal bed was sampled for analysis at location 1187. The reported canneloid composition of the coal, its unusual paleogeographic location on the edge of a large lake, and its outcrop location close to transportation facilities provided by the Union Pacific Railroad prompted further studies of the bed to more accurately determine its areal extent, thickness, and minability. Consequently, investigations of the coal bed resumed in 1990, when 8 more stratigraphic sections were measured (nos. 390–1090; pl. 1; see pl. 1 for explanation of numbering scheme for measured sections) to complete the stratigraphic information required for this report.

STRATIGRAPHY

Nomenclature and Lithology

The Eocene rocks exposed along the northern margins of the Washakie Basin are about 3,000 ft thick and are divided into intertongued parts of the Green River and Wasatch Formations. Rocks of predominantly lacustrine origin are normally placed in the Green River Formation, and rocks of fluvial or paludal origins are normally placed in the Wasatch Formation. The Green River Formation was deposited in Eocene Lake Gosiute that, at times, occupied more than 15,000 mi^2 of the ancestral greater Green River Basin in southwest Wyoming, northeast Utah, and northwest Colorado. The tongues and members of the Green River Formation are defined either by their distinctive lithologies that reflect different stages of lacustrine deposition having different water salinities or depositional environments, or by their intertonguing relationships with the Wasatch Formation. The Wasatch Formation is divided into a thick, basal, main body of the formation and thinner overlying parts that intertongue with the Green River Formation. The stratigraphic nomenclature, approximate thicknesses, and intertonguing relationships of the Green River and Wasatch Formations along the northern margins of the Washakie Basin are illustrated in figure 6.



EXPLANATION

Interbedded tan or gray freshwater lacustrine, brown or black paludal, and gray or green flood-plain deposits

Gray or tan tuffaceous lacustrine sandstone deposits

Brown or black saltwater lacustrine oil–shale deposits

Gray or green mudflat mudstone and brown saltwater lacustrine oil-shale deposits

Variegated (red) flood-plain deposits

Tan or brown freshwater lacustrine oil-shale deposits

Gray or green flood-plain deposits

Interbedded tan or gray freshwater lacustrine and gray or green flood-plain deposits

Unconformity

Figure 6 (facing page). Generalized restored cross section of intertongued Wasatch and Green River Formations across northern margin of Washakie Basin showing stratigraphic position of Wamsutter Rim coal bed. Locations of Wamsutter, Wyoming (T. 20 N., R. 94 W.), and Bitter Creek, Wyoming (T. 18 N., R. 99 W.), are shown on figure 1. The diagram is shown in an east-west orientation because this is how the section is seen in outcrop.

The Eocene stratigraphic units measured and described during this investigation (pl. 1) include, in ascending order: (1) the upper part of the Luman Tongue of the Green River Formation, (2) the Niland Tongue of the Wasatch Formation, (3) the Scheggs Bed of the Tipton Shale Member of the Green River Formation, and (4) the lower part of the Rife Bed of the Tipton Shale Member of the Green River Formation. Measured section 1087 (described in the appendix) has lithologies typical of these units. The Luman Tongue, Scheggs Bed of the Tipton Shale Member, and Rife Bed of the Tipton Shale Member of the Green River Formation are composed of brown, low-grade oil shale with very thin interbeds of gray and tan, very fine grained sandstone; siltstone; silty to sandy shale; shale; mudstone; limestone; algal limestone; and some shell coquina. The Niland Tongue of the Wasatch Formation is composed of gray to tan, very fine to fine-grained sandstone and siltstone and interbedded gray, partly silty to sandy shale; brown, low-grade oil shale; dark-gray or dark-brown carbonaceous shale; coal; and thin layers of shell coquina.

The oil-shale beds in the Luman Tongue of the Green River Formation, in most of the Scheggs Bed of the Tipton Shale Member of the Green River Formation, and in the Niland Tongue of the Wasatch Formation are finely laminated, fissile, and generally weather to small, thin, somewhat brittle, brown flakes. However, the oil-shale beds in the upper 20 ft of the Scheggs Bed and in the basal part of the overlying Rife Bed of the Tipton Shale Member of the Green River Formation, although also very fissile, are remarkably papery. These "paper" shales crop out as clusters of flexible sheets that bend like the pages of an open book (fig. 7). The cause for the change in the physical characteristics of these two types of oil shales is unknown, but it is without doubt compositional and probably related to a change in salinity of the waters of Lake Gosiute that took place at (or near) the contact of the Scheggs Bed (a freshwater lacustrine unit) and the Rife Bed (a saltwater lacustrine unit).

Paleontology and Age

Vertebrates

The age of the Wamsutter Rim coal bed is late early Eocene, based on the identification of mammals collected at

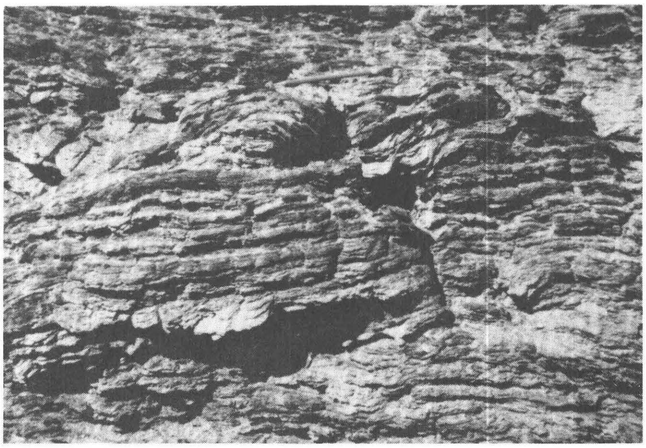


Figure 7. Papery oil shale in outcrops 18 ft below the top of the Scheggs Bed of the Tipton Shale Member of the Green River Formation in measured section 1090, SE¼NE¼ sec. 21, T. 19 N., R. 94 W. Pencil is 0.5 ft long.

a number of fossil sites situated at various stratigraphic levels in the Washakie Basin (Krishtalka and others, 1987, figs. 4.1 and 4.3). No fossil mammals were collected from the stratigraphic units investigated in the study area, but hundreds of specimens of mammal teeth and bones were collected by Roehler in 1958 from the upper part of the Niland Tongue of the Wasatch Formation at the northeast corner of Table Rock (SE¼NE¼ sec. 8, T. 18 N., R. 98 W.), in the vicinity of Bitter Creek, Wyoming (figs. 1 and 6). The fauna from this locality includes *Lambdotherium* sp., *Meniscotherium* sp., and *Hyracotherium* sp., which characterize the late early Eocene.

Fish bones and scales were found in a few beds in the study area, such as beds 1 and 5 in measured section 1087 (in appendix). The specimens were not classified, but they are believed to belong to the superorder Teleostei.

Mollusks

Mollusk fossils are concentrated in thin coquinal layers in oil shale and siltstone beds in the Luman Tongue and Scheggs Bed of the Tipton Shale Member of the Green River Formation and in the Niland Tongue of the Wasatch Formation. The most common freshwater molluscan assemblage consists of the turreted gastropod *Goniobasis tenera,* the large spired gastropod *Viviparus* sp., and the large unionid pelecypod *Lampsilis* sp. This assemblage comprises the persistent coquina at the base of the Scheggs Bed, where it is in contact with the underlying Wamsutter Rim coal bed (fig. 5). The fossils in this bed are white and consist of mostly very soft, weathered shell fragments in a matrix of brown, laminated oil shale (fig. 8). A few dispersed specimens of the planorbid gastropod *Gyraulus* sp. were identified in outcrops in the upper part of the Luman Tongue of the Green River

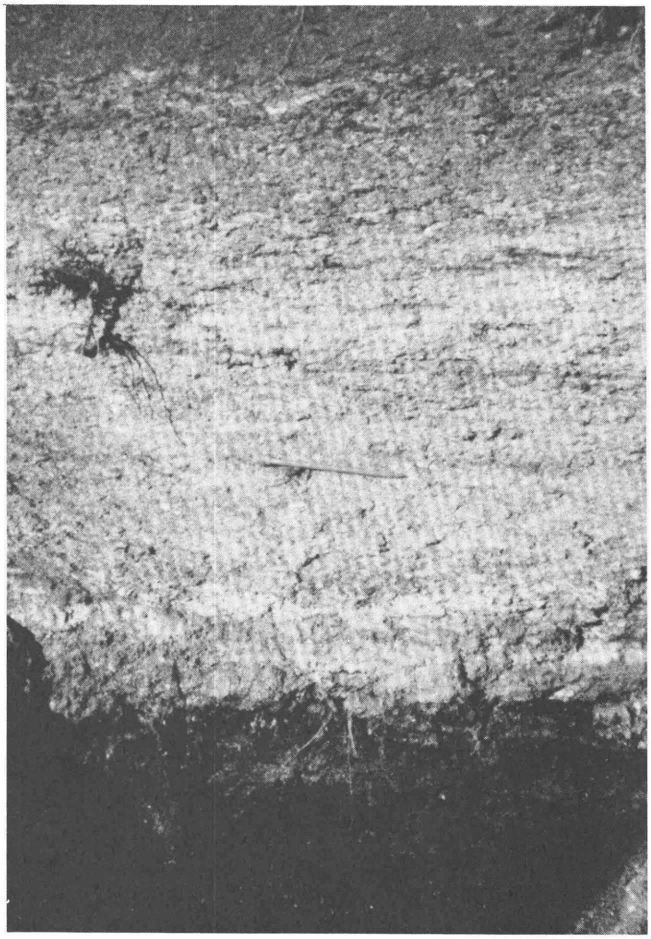


Figure 8. Molluscan coquina in oil shale overlying Wamsutter Rim coal bed in measured section 790, NE¼NE¼ sec. 7, T. 19 N., R. 94 W. Weathered white shell material occurs in irregular layers and as white specks. The coquina here is 1.9 ft thick. Pencil is 0.5 ft long.

Formation, such as beds 1 and 4 in measured section 1087 (in appendix).

Crustaceans

Small, unclassified ostracodes are present in all of the oil-shale beds in the study area. They are commonly concentrated as layers between oil-shale lamina. The specimens are white or tan, unornamented, and less than 1/16 inch long.

Depositional Environments and History

The Wamsutter Rim coal bed is underlain by mostly lacustrine shoreline sandstones that comprise the Niland Tongue of the Wasatch Formation, and it is overlain by thick lacustrine oil-shale beds containing fossils of freshwater origin that comprise the Scheggs Bed of the Tipton Shale Member of the Green River Formation. These stratigraphic relationships indicate that the coal bed was deposited in a peat bog that was located along the shoreline of a large freshwater lake. Because the shoreline sandstones in the Niland Tongue thin eastward across the study area, where they wedge out in oil shales, it follows that the deepest waters of the lake were located east of the study area and that the direction of the trend of the shorelines was generally north-northeast. Using these facts and other sedimentological information discussed below, a progression of depositional events for Lake Gosiute and the Wamsutter Rim coal bed can be interpreted: (1) A large freshwater lake occupied the study area during deposition of the Luman Tongue of the Green River Formation, (2) the Luman lake regressed eastward across the study area, accompanied by prograding (offlapping) sand shorelines that are included in the Niland Tongue, (3) near the end of deposition of the Niland Tongue, the lake regression ended, a stillstand followed, and the Wamsutter Rim peat bog formed upon a stable platform created by abandoned shoreline sands, and (4) a young lake rapidly transgressed westward across the study area inundating and burying the Wamsutter Rim peat bog during deposition of the Scheggs Bed of the Tipton Shale Member. The westward transgression of the lake is believed to be part of a basinwide expansion of Lake Gosiute that took place during deposition of the Scheggs Bed—during this time, Lake Gosiute was transformed from an earlier, small lake that occupied only the southern part of the greater Green River Basin into a later, very large lake that occupied nearly all of the basin. The only evidence for fluvial activity in rocks associated with the peat bog is a carbonaeous-shale-filled channel located a few ft below the Wamsutter Rim coal bed in measured section 1090 (pl. 1). Following the deposition of the Scheggs Bed of the Tipton Shale Member, the outlet of Lake Gosiute closed off, and the lake waters became saline during deposition of the Rife Bed of the Tipton Shale Member.

The inferred paleogeography of the Wamsutter Rim peat bog is portrayed in a block diagram (fig. 9), which was constructed from the stratigraphic data shown on plate 1. Several environmental interpretations have been made on figure 9 from these stratigraphic data: (1) The Wamsutter Rim coal bed was deposited in a peat bog composed largely of highly degraded autochthonous plant material and pollen, (2) the peat bog was interrupted in places by slightly elevated marshes inhabited by herbaceous plants on which organic muds were deposited—these marshes later formed carbonaceous splits in the coal bed, (3) the elevated marshes formed partly along abandoned beach ridges, as suggested on figure 9, (4) a few small streams crossed the peat bog, as indicated by the fluvial channel in measured section 1090, and (5) the peat bog wedged out and was replaced by beach sands between measured sections 887 and 1090.

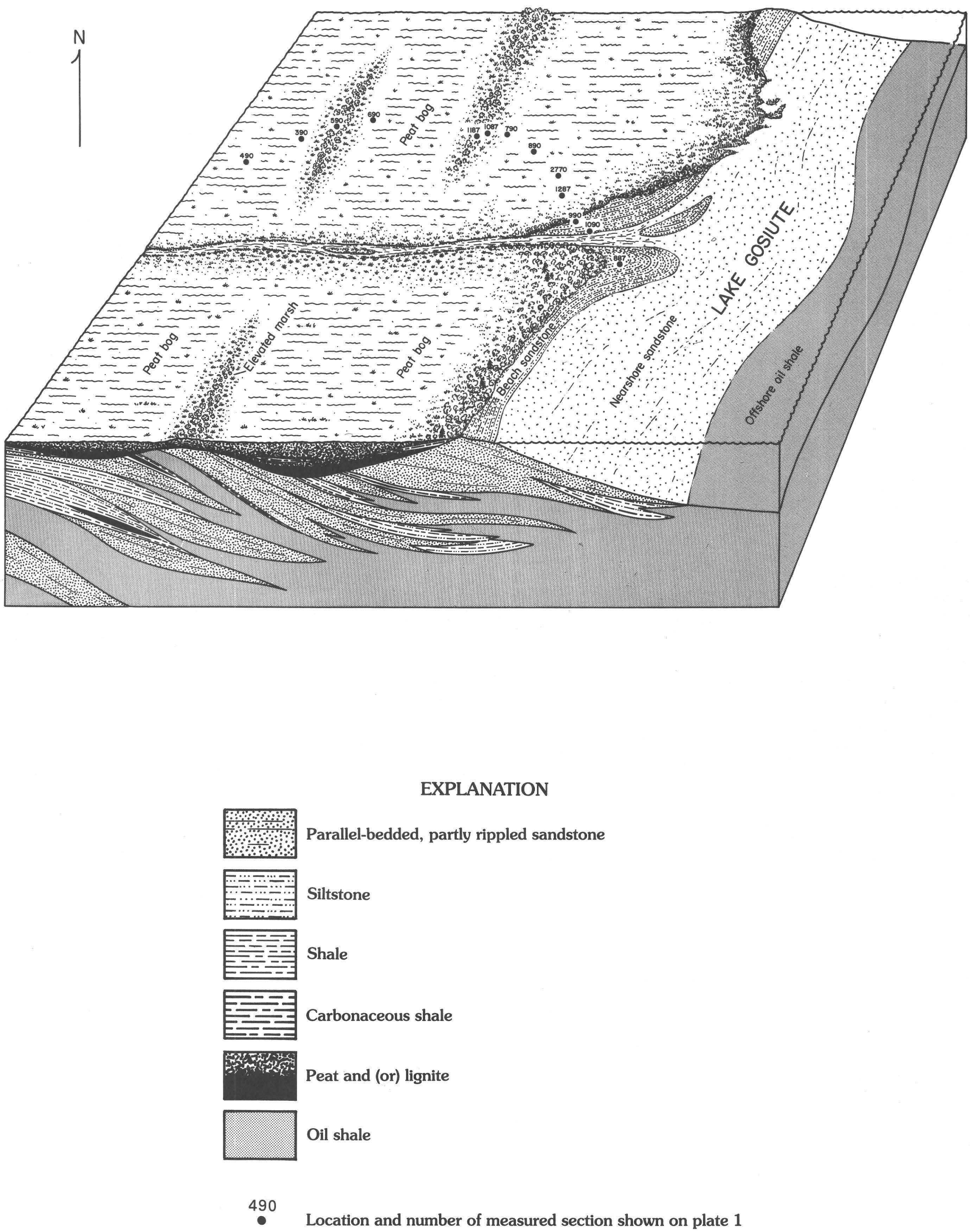


Figure 9. Block diagram illustrating inferred paleogeographic relationships of the Wamsutter Rim peat bog. The approximate locations of measured sections are shown by numbered dots.

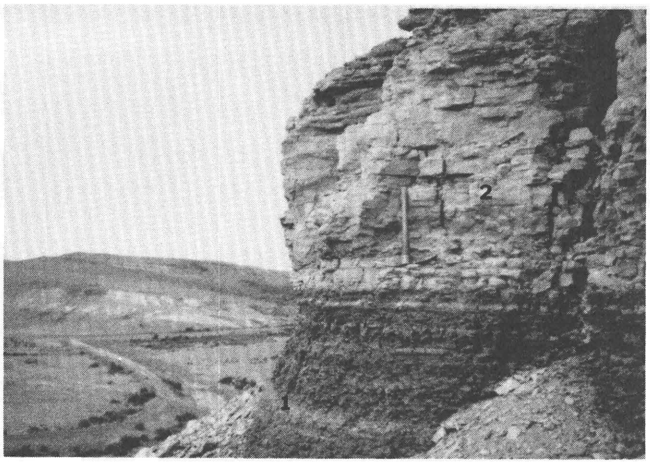


Figure 10. Coarsening upward sequence at the base of thick lacustrine nearshore sandstone in Niland Tongue of Wasatch Formation in measured section 2770. View is south from the south-central part of the NE1/4NW1/4 sec. 16, T. 19 N., R. 94 W. 1, Offshore oil shale and thin interbedded fossiliferous siltstone; and 2, silty, parallel-bedded, nearshore sandstone. Handle of pick is 1.5 ft long.

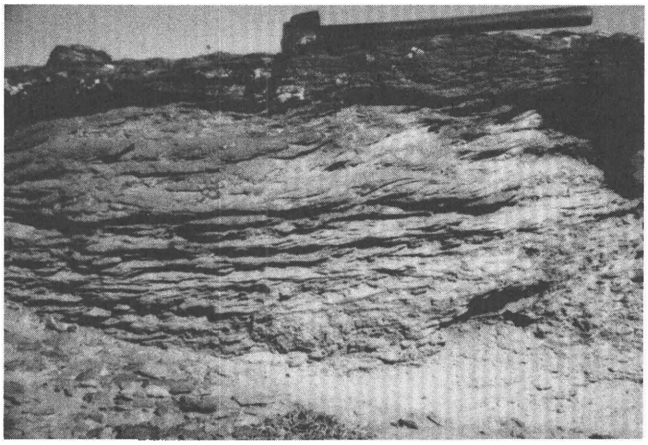


Figure 11. Wave-rippled lacustrine nearshore sandstone near base of Niland Tongue of Wasatch Formation in measured section 890, NW1/4SE1/4 sec. 8, T. 19 N., R. 94 W. Handle of pick is 1.5 ft long.

Composition and Sedimentary Structures of Shoreline Sandstones

The shoreline sandstones in the Niland Tongue are composed of about 75–85 percent of clear to milky quartz grains and about 15–25 percent of miscellaneous varicolored grains, including muscovite, heavy minerals, and calcite cement. Most of the sandstone beds are poorly cemented and weather to soft, loose grains along nonresistant outcrops. Other more firmly cemented beds weather to narrow ledges and small benches. The composition of heavy minerals was not determined in the study area. However, a sample collected from a sandstone bed near the top of the Niland Tongue in sec. 30, T. 16 N., R. 100 W., at the western edge of the Washakie Basin, was analyzed for nonopaque heavy minerals. It was composed of 83 percent garnet, 13 percent zircon, 2 percent green-brown biotite, and 1 percent each of epidote and rutile (Roehler and others, 1990).

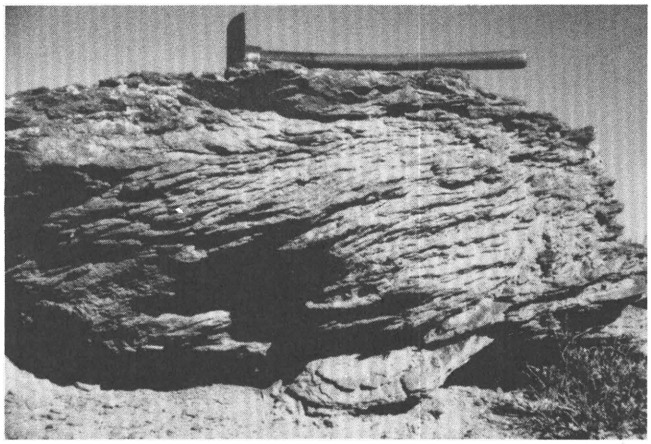


Figure 12. Current-rippled lacustrine nearshore sandstone near base of Niland Tongue of Wasatch Formation in measured section 890, NW1/4SE1/4 sec. 8, T. 19 N., R. 94 W. Handle of pick is 1.5 ft long.

The shoreline sandstones in the Niland Tongue have a linear configuration in directions parallel to the strandlines of Lake Gosiute and are lenticular in cross section in directions perpendicular to the strandlines of the lake (fig. 9). The sandstones coarsen upward and shoreward from very fine grained, silty sandstones near the offshore-nearshore interface (where they wedge out in oil shales) to clean, fine-grained sandstones along the beaches. A coarsening upward sequence at the base of one of the nearshore sandstones is shown in figure 10.

Primary sedimentary structures characteristic of the nearshore and beach sandstones are well preserved near the middle and top parts of the sandstone bed present at the base of the Niland Tongue in measured section 890 (pl. 1). The nearshore sandstones are thin and wavy bedded and are either wave rippled (fig. 11) or current rippled (fig. 12). Along the beaches, the sandstones exhibit thin, parallel to subparallel bedding (fig. 13).

DESCRIPTION OF THE COAL

Coal Outcrops

The Wamsutter Rim coal bed is generally well exposed in the study area but is usually overlain by a veneer of soil and, in places, by thin desert vegetation. It is covered by several feet of slope-wash and oil-shale debris across sec. 8 and

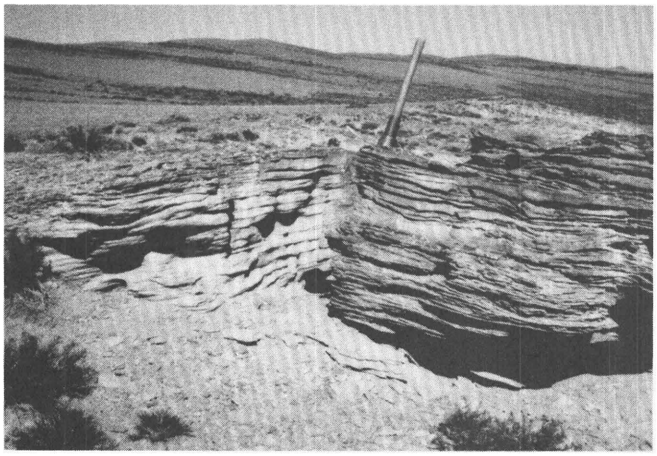


Figure 13. Parallel- and subparallel-bedded lacustrine beach sandstone near base of Niland Tongue of Wasatch Formation in measured section 890, NW¼SE¼ sec. 8, T. 19 N., R. 94 W. Handle of pick is 1.5 ft long.

the northwest part of the adjacent sec. 16, T. 19 N., R. 94 W. (fig. 2). In the southern part of this covered area, most of the Niland Tongue is exposed in a slump block. The beds duplicated in measured section 2770 (pl. 1), which crosses the slump block, suggest that there is about 85 ft of downslope displacement.

The coal bed is lenticular in outcrops that extend for nearly 10 mi along Wamsutter Rim from sec. 7, T. 19 N., R. 95 W. on the west to sec. 22, T. 19 N., R. 94 W. on the east (fig. 2). The bed wedges out between measured sections 1090 and 887 (pl. 1), in the eastern part of the study area. It thickens rapidly from this wedge-out northwestward to measured section 1287 (pl. 1), where it is 6.6 ft thick. The bed, although partly covered, appears to maintain thicknesses ranging from 4.7 to 7.6 ft between measured sections 1287 and 1187 (pl. 1). It thins west of measured section 1187 (pl. 1). Between measured sections 690 and 490 (pl. 1), it thickens and thins irregularly and wedges out in outcrops a short distance west of measured section 490 (pl. 1).

Specimens of the coal from outcrops are clean and shiny. They exhibit a conchoidal fracture and have a very light specific gravity. Coal splits, composed of dark-gray or dark-brown, silty, carbonaceous shale, are present in measured sections 1090, 990, 1187, and 690 (pl. 1). The coal split in measured section 1090 is 0.6 ft thick; in measured section 990, the splits are 0.9 ft thick (bottom) and 0.6 ft thick (top); in measured section 1187, it is 0.7 ft thick; and in measured section 690, the splits are 1.1 ft thick (bottom) and 1.1 ft thick (top).

Thin beds of canneloid(?) coal, as much as 1.1 ft thick, are present below the Wamsutter Rim coal bed in several of the measured sections (pl. 1). These beds appear to have been deposited in small, ephemeral peat bogs that formed behind offlapping shoreline sands, as portrayed in figure 9. They are very lenticular and can be traced for only short distances along outcrops.

Coal Composition and Quality

Proximate Analysis

Bradley (1964, p. A24–A25) sampled the Wamsutter Rim coal bed for proximate analysis at a mine face near location A (pl. 1). In comments concerning the analysis, he stated that the coal contains more sulfur than usual and that it has lower ash and moisture than the subbituminous Wasatch coals analyzed in the Great Divide Basin, north of the study area, by Pipiringos (1961).

The Wamsutter Rim coal bed is similar in appearance and composition to the Vermillion Creek canneloid coal bed that crops out in the southwest part of the Washakie Basin in Ts. 12–13 N., Rs. 99–101 W. The Vermillion Creek coal bed is as much as 10 ft thick and is situated about 60 ft below the top of the Niland Tongue of the Wasatch Formation. As suggested by Roehler (1987, p. 9), the two coal beds, although more than 50 mi apart, have similar origins and may actually be chronostratigraphic equivalents. Proximate analyses for the Wamsutter Rim and Vermillion Creek coal beds are presented in table 1.

For this study, only a weathered outcrop channel sample from the Wamsutter Rim coal bed could be obtained for proximate analysis and petrographic examination. Comparison of the data from Bradley's mine-face sample and the outcrop sample (table 1) show differences in moisture and ash content that can be attributed to sampling differences and to differences in the volatile matter–fixed carbon ratio that may be due to weathering effects. In addition to the proximate data, forms of sulfur are also determined. The high amount of sulfate sulfur indicates a high degree of weathering of this sample; indeed, a high amount of a transparent mineral (possibly gypsum, $CaSO_4 \cdot 2H_2O$) was observed petrographically. Assuming that all of the sulfate sulfur can be attributed to pyrite, this coal contains appreciable amounts of pyrite but even more organic sulfur (2.3 percent, on an as-received basis). Compared to the Vermillion Creek coal samples reported by Hatch (1987), the Wamsutter Rim coal samples contain less total sulfur but have comparable values for organic sulfur. The heating values of the Vermillion Creek coal bed (on a moist, ash-free basis) generally range between 11,100 and 11,800 Btu/lb. From these data, we estimate that the Wamsutter Rim coal bed will average about 11,500 Btu/lb.

Petrographic Analyses

Petrographic analyses were performed on the outcrop sample using reflected light and white-light and blue-light fluorescence microscopy. The data are presented in table 2. Measured vitrinite reflectance was 0.36 percent. Because of

Table 1. Proximate analyses and forms of sulfur in samples from the Wamsutter Rim and Vermillion Creek coal beds

[Analytical data reported in weight percent, on an as-received basis; calorific values were not determined. T, sampled thickness (in feet); M, moisture; VM, volatile matter; FC, fixed carbon; A, ash; S, total sulfur; PS, pyritic sulfur; OS, organic sulfur; SS, sulfate sulfur; –, sample not numbered; nr, not reported]

Sample no.	T	M	VM	FC	A	S	PS	OS	SS
Mine-face sample (Wamsutter Rim coal bed) [1]									
–	6.0	9.9	45.0	40.7	4.4	3.6	nr	nr	nr
Outcrop sample (Wamsutter Rim coal bed) [2]									
–	7.6	18.8	41.3	30.1	11.9	3.7	0.1	2.3	1.3
Vermillion Creek coal bed samples [3]									
(core VC-7) D203076	1.7	12.1	40.1	37.9	9.9	6.6	4.3	2.2	0.1
(core VC-7) D203077	5.9	14.9	38.5	35.3	11.3	4.1	1.1	3.0	0.1
(core VC-8) D203078	3.6	12.5	38.4	39.4	9.7	6.9	3.4	3.4	0.1
(core VC-8) D203079	3.6	11.1	33.5	29.2	26.2	4.6	1.9	2.6	0.1
(core VC-5) D203081	4.1	11.5	34.6	31.6	6.1	6.1	3.0	3.0	0.1
(core VC-5) D203082	3.5	11.2	33.1	25.9	29.8	5.3	2.5	2.7	0.1

[1]Data from Bradley (1964, p. A24–A25); sample collected from east-central part of NE1/4 sec. 7, T. 19 N., R. 94 W. (fig. 4; near loc. A, pl. 1).

[2]Sample collected for this study from NW1/4 SE1/4 NW1/4 sec. 7, T. 19 N., R. 94 W. (loc. B, pl. 1).

[3]Data from Hatch (1987).

the effects of weathering on the macerals, however, the measured reflectance is probably not reliable. The maceral analysis of the Wamsutter Rim coal bed is similar to that in the Vermillion Creek coal bed. The canneloid nature of the Wamsutter Rim coal bed was observed megascopically and was inferred by Bradley (1964) to be the result of considerable quantities of pollen and leaf-cuticle residues; however, our petrographic analysis of the whole-bed channel sample shows only about 11 percent of the sample is composed of liptinite remains. Although this amount of liptinite may enhance the nonbanded (canneloid) character of the coal in hand specimens, the nonbanded character probably results from the abundance of macerals that resulted from the decomposition of plant tissues (desmocollinite and gelocollinite). Of the tissue-derived macerals that display plant structure, the particles are less than 50 µm in size; this enhances the nonbanded character in megascopic observation.

Accessory Minerals

Bradley (1964, p. A24) reported the occurrence of rare minerals in joints and cracks along bedding planes of the Wamsutter Rim coal bed. The most abundant of these minerals is tschermigite, an ammonium alum [$(NH_4)Al(SO_4)_2 \cdot 12H_2O$]. Less abundant are ammoniojarosite, a mineral of the alunite group [$(NH_4)Fe_3(SO_4)_2(OH_6)$], and melanterite, an iron vitriol ($FeSO_4 \cdot 7H_2O$). These minerals are water-soluble sulfates that probably formed from the weathering of pyrites in the coal. Melanterite was also found in pods and fissures in the Vermillion Creek coal bed. Isotope analysis of the melanterite in the Vermillion Creek coal bed indicates it has an $\delta^{34}S$ value of –4.3 (Rye, 1987, p. 168).

Pipiringos (1961) found that nearly all of the coal beds that crop out in the Wasatch Formation in the Great Divide Basin north of Wamsutter Rim contain from 0.001 to 0.003 percent uranium. The Wamsutter Rim coal bed was checked for radioactivity using a hand-held scintillometer, but no significant radioactivity was found. At the measured sections shown on plate 1, the radioactivity ranged from zero to too low to record.

Resource Potential

The Wamsutter Rim coal bed dips 1-3 degrees southwest from where it crops out along Wamsutter Rim. Overburden

Table 2. Maceral varieties for outcrop sample obtained from the Wamsutter Rim coal bed and selected samples from the Vermillion Creek coal bed

[All data in volume percent, moisture-free, whole-coal basis. **, no sample number; T, less than 5 counts in 1,000; –, less than 1 count in 1,000; TC, telocollinite; DG, desmocollinite and gelocollinite; C_p, corpocollinite; S, sporinite; C, cutinite; R, resinite; B, bituminite; L, liptodetrinite; SF, semifusinite; F, fusinite; MM, mineral matter (calculated)]

Sample no.	TC	DG	C_p	S	C	R	B	L	SF	F	MM
				Wamsutter Rim coal bed—outcrop sample [1]							
**	27	34	10	3	1	4	1	2	2	–	18
				Vermillion Creek coal bed samples [2]							
VC-8-5	30	19	38	T	–	7	–	–	1	–	4
VC-7-116	28	33	18	1	T	1	–	–	T	–	19
VC-5 [3]	54	6	20	1	T	5	–	–	3	–	14

[1]Sample collected for this study from NW1/4SE1/4NW1/4 sec. 7, T. 19 N., R. 94 W (loc. B, pl. 1).
[2]Data from Stanton and others (1987).
[3]Weighted average of nine incremental core samples from one core.

on the coal increases at the rate of 100-300 ft per mile downdip from outcrops. The coal bed is not known to be faulted, but it forms a broad, gently basinward-dipping syncline, created by the bending of strata around the northern edge of the Washakie Basin.

The coal resources of the Wamsutter Rim bed cannot be accurately determined without corehole data to establish subsurface thicknesses and extent. There are presently no coreholes in the study area, and no core drilling is planned. It is nonetheless possible to make gross speculations concerning resources using available data.

The sedimentological information acquired during this investigation indicates that the coal bed has an overall linear configuration that is parallel to a former shoreline of Eocene Lake Gosuite. The trend of this shoreline is approximately N. 15°–20° E. The coal averages more than 5 ft in thickness along 4 mi of outcrops along Wamsutter Rim from the western part of sec. 12, T. 19 N., R. 95 W. to the northeast part of sec. 21, T. 19 N., R. 94 W. (fig. 2). Assuming the coal maintains a minable thickness of 5 ft along this northeast trend for at least 3.0 mi downdip of outcrops, there appears to be about 38,400 acre feet of coal present in a 12-mi^2 area in secs. 7, 8, 16, 17, 18, 19, 20, 21, 28, 29, 30, 31, and 32, T. 19 N., R. 94 W. and secs. 11, 12, 13, 14, 23, 24, 25, and 26, T. 19 N., R. 95 W. Using these figures, the total amount of coal in place in this area would be about 68 million short tons of total resources in the measured, indicated, and inferred categories of the U.S. Geological Survey (Wood and others, 1983, p. 39).

SUMMARY AND CONCLUSIONS

The Wamsutter Rim coal bed is closely associated with lacustrine rocks that were deposited in Eocene Lake Gosiute. The peat bog in which the coal bed was deposited trends north-northeast and was located in a backshore area that paralleled the western shores of the lake. The coal bed rests upon shoreline sandstones that offlapped eastward during a regression of the lake, and it is overlain by oil shales that were deposited on the bottom of the lake as it transgressed in the opposite direction (westward). These relationships suggest that the peat was deposited during a protracted stillstand that occurred between the lake regression and transgression. As a consequence of these events, the Wamsutter Rim coal bed is lenticular, is about 10 mi wide in cross section, and is as much as 7.6 ft thick.

The Wamsutter Rim coal bed is correlated to the Vermillion Creek coal bed that crops out in the southwestern part of the Washakie Basin. The Vermillion Creek coal bed is interpreted as resulting from the degradation of woody plant parts in a lacustrine shoreline environment that formed a coal rich in desmocollinite and high in organic sulfur (Stanton and others, 1987). Based on the similarities of associated sediments, petrographic composition, and high organic sulfur, the Wamsutter Rim coal bed and the Vermillion Creek coal bed are believed to have formed under similar physical and geochemical conditions.

An explanation for the high organic sulfur content of the Wamsutter Rim coal samples is consistent with the interpretation presented for the Vermillion Creek coal bed (Stanton and others, 1987). Increased bacterial activity resulting from a high-pH or near-neutral peat-forming environment created humic gels and substances—the predecessors to vitrinite submacerals of desmocollinite and gelocollinite. In addition, low-Eh conditions (indicated by the lack of inertinite macerals that result from oxidative processes) may indicate high water levels that prevailed during accumulation of organic matter. Peat that developed in a high-pH, low-Eh geochemical environment would also be susceptible to concentrating sulfur organically, if available. Similar to the case of the Vermillion Creek coal bed, the encroaching freshwater lake sediments of the Scheggs Bed are inferred to have contained appreciable amounts of sulfur introduced by drainages from bordering highlands that contained concentrations of sulfur-bearing minerals.

The Wamsutter Rim coal bed is a high-quality, canneloid coal suitable for mining along the Wamsutter Rim. Because the ratio of coal to overburden is extremely low, underground mining methods appear to be the most economical way to extract the coal. Outcrops of the coal bed come to within 1 mi of the main line of the Union Pacific Railroad, by which the coal would be shipped to market. The indicated high heating value of the coal makes it especially valuable for use as boiler fuel, but its canneloid composition may make it even more valuable as feedstock for petrochemicals.

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APPENDIX

Measured stratigraphic section 1087 in the center of the W1/2NE1/4sec. 7, T. 19 N., R. 94 W., 1.5 mi southeast of Frewen Station on the Union Pacific Railroad, Sweetwater County, Wyoming

Bed Number	Description	Thickness (feet)
	Rife Bed of the Tipton Shale Member of the Green River Formation (part):	
32.	Algal limestone, gray, banded; weathers to blocks	1.0
31.	Oil shale, brown, flaky, soft	4.0
30.	Algal limestone, gray; weathers to blocks	0.4
29.	Oil shale, brown, flaky to papery, soft	12.4
28.	Coquinal sandstone, tan, crumbly; contains *Goniobasis tenera, Viviparus* sp., and *Lampsilis* sp.	0.9
27.	Oil shale, brown, flaky, soft	9.9
26.	Oil shale, brown, papery, soft; abundant ostracodes	4.3
25.	Algal limestone, medium-brown, banded; in crumbly blocks (the lower algal ball zone of Pipiringos, 1961)	0.6
	Total measured thickness of the Rife Bed	33.5
	Scheggs Bed of Tipton Shale Member of Green River Formation:	
24.	Oil shale, brown, papery, soft; thin laminae of tan tuff 12 ft above the base; some white, weathered mollusk shell fragments	19.3
23.	Tuff, tan, dolomitic, hard; weathers to blocks	0.6
22.	Oil shale, brown, flaky, soft abundant ostracodes; some white shell fragments	46.9
21.	Coquinal oil shale, brown, speckled with white shell fragments of *Goniobasis tenera, Lampsilis* sp., and *Viviparus* sp.	4.1
	Total measured thickness of the Scheggs Bed	70.9
	Niland Tongue of Wasatch Formation:	
20.	Wamsutter Rim coal bed. Coal, clean, bright, shiny; conchoidal fracture; light specific gravity	6.3
19.	Sandstone, gray, fine-grained, some carbonaceous laminae	1.0
18.	Sandstone, light- to medium-gray, very fine grained, argillaceous, mostly soft and loose; some parallel bedding	20.2
17.	Shale, dark-brown, carbonaceous	0.7
	Niland Tongue of Wasatch Formation—Continued:	
16.	Coal	0.2
15.	Shale, dark-brown, carbonaceous	0.8
14.	Shale, gray, soft	1.2
13.	Sandstone, gray, very fine grained, argillaceous, mostly soft and loose; some parallel bedding	13.5
12.	Oil shale, brown, flaky, soft; deeply weathered	2.0
11.	Sandstone, gray, very fine grained, silty; in parallel, current-rippled beds	3.1
10.	Sandstone, light-gray, fine-grained, mostly soft and loose; some parallel bedding	10.2
9.	Shale, gray, silty to sandy, soft	7.6
8.	Shale, dark-brown, flaky, carbonaceous; abundant ostracodes; very low kerogen content	2.3
7.	Shale, gray, silty, soft	2.3
6.	Sandstone, gray, very fine grained, calcareous; in thin, parallel, current-rippled beds and laminae	1.0
5.	Shale, gray, and thin interbedded oil shale, brown, flaky; abundant ostracodes and fish scales	6.8
4.	Oil shale, brown, gray-brown, fissile, soft; abundant ostracodes; some *Gyraulus* sp.	6.5
3.	Oil shale, brown, flaky, soft; the upper 0.5 ft are very silty and contain *Goniobasis tenera, Lampsilis* sp., and *Viviparus* sp.	12.4
2.	Shale, gray, silty, soft	7.6
	Total measured thickness of the Niland Tongue	105.7
	Luman Tongue of the Green River Formation (part):	
1.	Oil shale, brown, flaky, soft; abundant ostracodes; some fish bones and *Gyraulus* sp. in the upper part	118.0

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