

Geology and Energy Resources of the Sand Butte Rim NW Quadrangle, Sweetwater County, Wyoming

GEOLOGICAL SURVEY PROFESSIONAL PAPER 1065-A



Geological and Energy Resources of the Sand Butte Rim NW Quadrangle, Sweetwater County, Wyoming

By HENRY W. ROEHLER

GEOLOGY OF THE SOUTHEAST PART OF THE ROCK SPRINGS UPLIFT,
WYOMING

GEOLOGICAL SURVEY PROFESSIONAL PAPER 1065-A

*Outcrops of Cretaceous and Tertiary
strata are mapped and described, and
resources of coal, oil and gas, and
oil shale are appraised*



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CONTENTS

	Page		Page
Abstract	A1	Economic geology	A17
Introduction	1	Coal	17
Location and extent of area	1	Outcrops	17
Physiography	1	Name and stratigraphic position of beds	17
Scope of report and fieldwork	1	Rank and thickness	17
History of geologic investigations and mineral exploitation ..	3	Resources	17
Coal	3	Unnamed beds having little lateral extent	20
Oil and gas	4	Bluff bed	20
Oil shale	4	Little Valley bed	20
Acknowledgments	4	Hail bed	20
Stratigraphy	4	Big Burn bed	20
Upper Cretaceous rocks	4	Leaf bed	21
Lewis Shale	4	Unmapped subsurface coal beds more than	
Fox Hills Sandstone	9	2.5 feet thick	23
Lance Formation	9	Almond coal group (Almond Formation)	23
Paleocene rocks	9	Black Buttes coal group (Fort Union Formation)	
Fort Union Formation	9	and Black Rock coal group (Lance Formation) ..	23
Eocene rocks	11	Geochemical analyses	23
Main body of the Wasatch Formation	11	Oil and gas	25
Luman Tongue of the Green River Formation	13	Antelope field	25
Niland Tongue of the Wasatch Formation	13	Brady field	27
Tipton Shale Member of the Green River Formation ..	13	Resources	31
Wilkins Peak Member of the Green River Formation ..	14	Analyses	31
Cathedral Bluffs Tongue of the Wasatch Formation ...	14	Oil shale	31
LaCledde Bed of the Laney Member of the		Outcrops	31
Green River Formation	15	Oil yields of oil shales	35
Sand Butte Bed of the Laney Member of the		Resources	39
Green River Formation	16	Assays	39
Structure	16	References cited	54
Surface rocks	16		
Subsurface rocks	16		

ILLUSTRATIONS

		Page
PLATE	1. Stratigraphic sections showing the positions of coal beds in the Sand Butte Rim NW quadrangle	In Pocket
FIGURE	1. Index map showing the location of the Sand Butte Rim NW quadrangle in southwest Wyoming	A2
	2. Geologic map of the Sand Butte Rim NW quadrangle	6
	3. Typical spontaneous potential and resistivity electric-log curves for Cenozoic and Mesozoic formations, Sand Butte Rim NW quadrangle	7
	4. Typical spontaneous potential and resistivity electric-log curves for Mesozoic and Paleozoic formations, Sand Butte Rim NW quadrangle	8
	5. Cross section of rocks penetrated in wells in the Sand Butte Rim NW quadrangle	10
	6. Section of the LaCledde Bed of the Laney Member of the Green River Formation, showing oil yields of oil shales	15
	7. Map showing structure contours on the top of the Weber Sandstone at Brady field	18

FIGURE	8. Northwest-southwest cross section of producing formations of Paleozoic and Mesozoic age at Brady field	Page A19
	9. Graphic sections of unnamed coal beds having little lateral extent	21
	10. Isopach map of unnamed coal beds having little lateral extent, showing thickness of overburden	22
	11. Graphic sections of the Bluff coal bed	25
	12. Isopach map of the Bluff coal bed showing thickness of overburden	26
	13. Isopach map of the Little Valley coal bed showing thickness of overburden	28
	14. Graphic sections of the Little Valley coal bed	30
	15. Graphic sections of the Hail coal bed	31
	16. Isopach map of the Hail coal bed showing thickness of overburden	32
	17. Graphic sections of the Big Burn coal bed	34
	18. Isopach map of the Big Burn coal bed showing thickness of overburden	36
	19. Graphic sections of the Leaf coal bed	38
	20. Isopach map of the Leaf coal bed showing thickness of overburden	40
	21. Map showing structure contours on the W marker in the Lewis Shale	50
	22. Map showing areas of oil-shale outcrops	51

TABLES

TABLE	1. Geologic formations in the Sand Butte Rim NW quadrangle	Page A5
	2. Mesozoic invertebrate fossils collected from the Lance Formation	11
	3. Paleocene and Cretaceous palynomorphs from the vicinity of the Sand Butte Rim NW quadrangle	12
	4. Proximate, ultimate, Btu, and sulfur analyses of coal beds in the Fort Union and Lance Formations	19
	5. Cumulative original coal resources by thickness categories and geographic location	24
	6. Inferred coal resources in the Almond coal group, in four beds 2.5-5.0 feet thick having an estimated cumulative thickness of 10 feet, under less than 3,000 feet of overburden	39
	7. Unmapped, inferred coal beds in the Black Buttes and Black Rock coal groups, more than 2.5 feet thick, under less than 3,000 feet of overburden indicated by resistivity curves on electric logs of oil and gas drill holes ..	41
	8. Neutron-activation determinations of uranium and thorium of coal-bed channel samples	42
	9. X-ray fluorescence for oxide composition and selenium for coal-bed channel samples	43
	10. Semiquantitative six-step spectrographic analysis for trace elements in the ash of coal-bed channel samples	44
	11. Quantitative chemical analyses of coal-bed channel samples	46
	12. The amount of trace and minor elements in the ash of samples from coal beds compared to crustal abundance and to other western coals	47
	13. Drill-hole data for the Sand Butte Rim NW quadrangle	48
	14. General characteristics of crude oil from producing intervals in Brady Unit 1 well, Brady field	52
	15. Analyses of gas from producing intervals in Brady Unit 1 well, Brady field	52
	16. Cumulative thicknesses and estimated average oil yields of oil-shale beds in the Green River Formation	52
	17. Inferred total shale oil in place, on the basis of thickness and yield data shown on table 15	52
	18. Estimated oil resources for selected oil shales in the LaCledde Bed of the Laney Member of the Green River Formation	53
	19. Oil yields by Fischer assay of channel samples of oil-shale outcrops in the LaCledde Bed of the Laney Member of the Green River Formation	53

ENGLISH-METRIC CONVERSION

[The metric system is not currently used to compute coal, oil, and gas resources in the United States]

English unit		Metric unit
Short ton	=	0.907 Metric tonne
Mile	=	1.609 Kilometers
Square mile	=	2.59 Square kilometers
Acre	=	.4047 Hectare
Foot	=	.3048 Meter
Cubic foot	=	.0283 Cubic meter
Btu	=	.252 Kilogram calorie

ABBREVIATIONS

Am.	American	Fm.	formation	Phil.	philosophical
Assoc.	association	ft.	foot	Prof.	professional
A.P.I.	American Petro- leum Institute	ft ³	cubic foot	ppm	parts per million
avg.	average	gal.	gallon	pt.	part
B.	bottom	gal/ton	gallon per ton	R.	range
bbl.	barrel	Geog.	geographical	ref.	reference
bbl/mi ²	barrel per square mile	Geol.	geological	Rept.	report
Btu.	British thermal unit	in.	inch	SE	southeast
Bull.	bulletin	Inc.	incorporated	sec.	section
Bur.	bureau	Inv.	investigation	Soc.	society
C.	celcius	Jour.	journal	sp.	species not determined
cf.	compare	km.	kilometer	SS	sandstone
Chapt.	chapter	km ²	square kilometer	SW	southwest
Circ.	circular	m.	meter	t.	tonne
Co.	Company	MCF	thousand cubic feet	T.	township
commun.	communication	mi.	mile	T.	top
Conf.	conference	mi ²	square mile	TD	total depth
cm.	centimeter	mtg.	meeting	Terr.	territories
do.	ditto	N.	north	U.S.	United States
E.	east	NE	northeast	USGS	U.S. Geological Survey
ed.	edition	No. (no.)	number	Vol. (v)	volume
F.	fahrenheit	NW	northwest	W.	west
Fed.	federal	p.	page	Wyo.	Wyoming
fig.	figure	pl.	plate		
		Proc.	proceedings		

GEOLOGY AND ENERGY RESOURCES OF THE SAND BUTTE RIM NW QUADRANGLE, SWEETWATER COUNTY, WYOMING

By HENRY W. ROEHLER

ABSTRACT

The Sand Butte Rim NW 7½-minute quadrangle occupies 56 square miles of an arid, windy, sparsely vegetated area of ridges and valleys on the east flank of the Rock Springs uplift in southwest Wyoming. The area is underlain by a succession of sedimentary rocks, about 20,000 feet thick, that includes 28 formations ranging in age from Cambrian to Tertiary. Upper Cretaceous and lower Tertiary formations crop out and dip 3°–6° southeast. They are unfaulted and generally homoclinal, but a minor anticlinal nose is present. Older rocks in the subsurface are faulted and folded.

Coal resources are estimated to be nearly 1 billion short tons of subbituminous coal, in beds more than 2.5 feet thick, under less than 3,000 feet of overburden, in the Fort Union Formation of Paleocene age and the Lance and Almond Formations of Cretaceous age.

INTRODUCTION

LOCATION AND EXTENT OF AREA

The Sand Butte Rim NW 7½-minute quadrangle occupies 56 mi². It is in Sweetwater County in southwest Wyoming on the east flank of the Rock Springs uplift. It is 25 mi southeast of the city of Rock Springs, and 6 mi southwest of Bitter Creek station on the Union Pacific Railroad (fig. 1).

The quadrangle is accessible by an improved gravel road that trends southwest from Bitter Creek station to Brady oil and gas field. Numerous trails and seismograph roads branch from this road. The quadrangle is also accessible by an improved gravel road that trends eastward to the Brady oil and gas field from Wyoming Highway 430, 15 mi southeast of Rock Springs.

PHYSIOGRAPHY

The quadrangle area is a windy desert. The mean annual precipitation is less than 7 in. (Root and others, 1973). Extremes of temperature range from about –25°F in winter to 95°F in summer. Diurnal temperature

changes average about 25°F. Prevalent westerly winds occur almost daily. The landscape is mainly a series of broad valleys interrupted by several northwest-facing escarpments that rise 200–600 ft above the valleys. The altitudes of these escarpments increase in a southeasterly direction across the quadrangle. Maximum altitude ranges from less than 6,700 ft along Patrick Draw near the northeast corner of the quadrangle to more than 8,100 ft on Sand Butte Rim in the southeast corner. The lower slopes of Sand Butte Rim are characterized by landslide debris that locally forms minor vegetated terraces or hummocky topography.

There are no perennial streams in the quadrangle. The primary drainage system is Patrick Draw and its tributaries which join Bitter Creek a few miles northeast of the quadrangle. All runoff from the quadrangle eventually joins Bitter Creek, which flows westward through the city of Rock Springs to join the Green River at the city of Green River.

Thin, brown, sandy soils are present on ridges in the quadrangle where the vegetation consists mostly of sparse desert grasses and short sage. In valleys the soils are thicker and the vegetation consists of tall sage and some cactus, weeds, and wildflowers. The quadrangle is essentially devoid of trees. Wildlife includes antelope, coyote, bobcat, badger, and varieties of rodents and birds.

No towns or ranch buildings are present in the quadrangle. The only industries are cattle and sheep grazing, and oil and gas exploration and production.

SCOPE OF REPORT AND FIELDWORK

The report represents the results of geologic studies that included mapping and resource evaluation in the Sand Butte Rim NW quadrangle. Field investigations were undertaken during July and August, 1974, as part

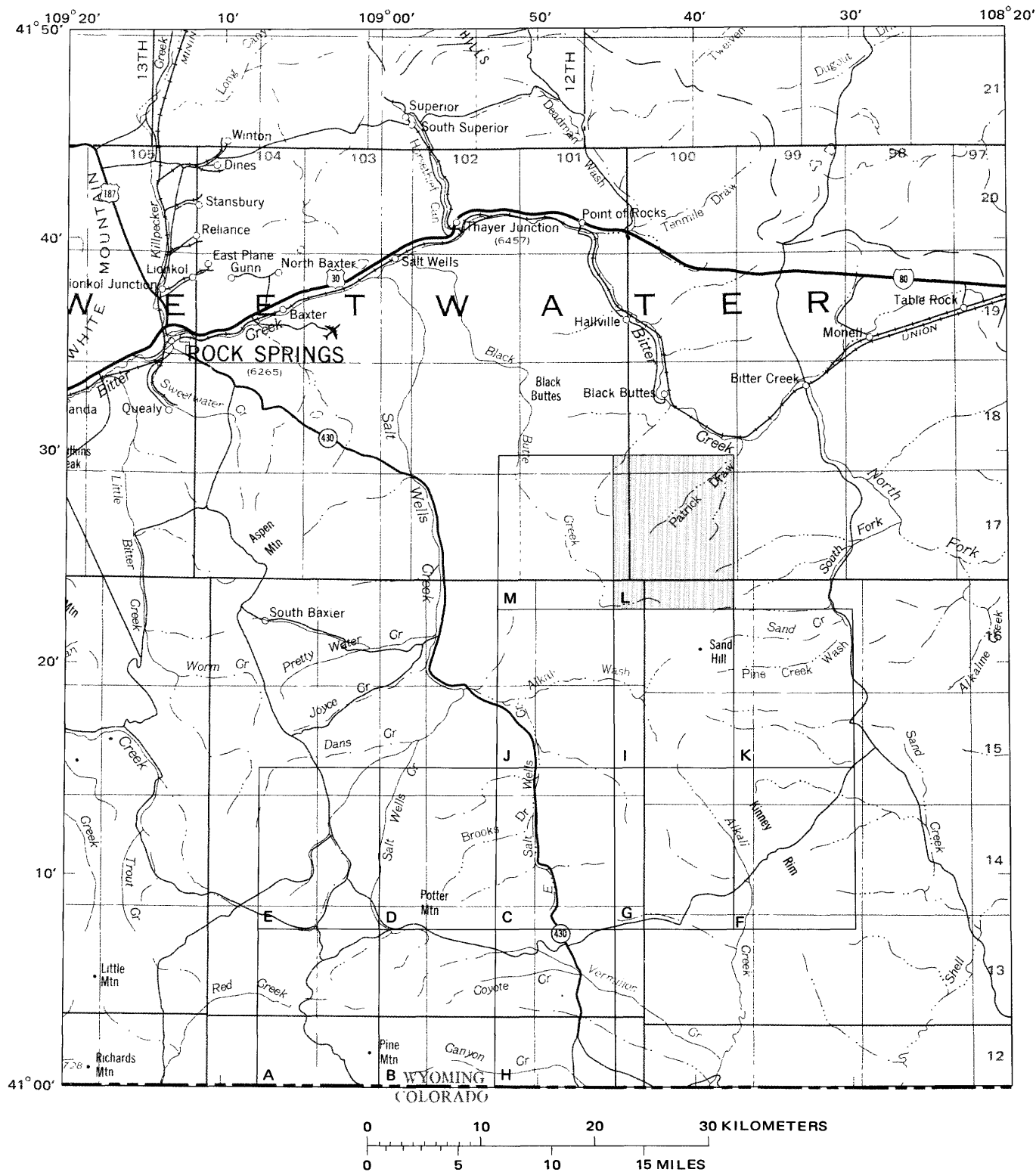


FIGURE 1.—Index map showing the location of the Sand Butte Rim NW quadrangle (patterned) in southwest Wyoming.

Quadrangles shown in figure 1 and published in the Geological Survey Geologic Quadrangle map series

Index letter and quadrangle	GQ	Index letter and quadrangle	GQ
A. Red Creek Ranch	1001	H. Scrivner Butte	1166
B. Four J Rim	1002	I. Pine Butte	1199
C. Erickson-Kent Ranch	1056	J. Burley Draw	1200
D. Potter-Mountain	1082	K. Sand Butte Rim SE	1231
E. Titsworth Gap	1083	L. Sand Butte Rim NW	1362
F. Chicken Creek East	1128	M. Cooper Ridge NE	1363
G. Chicken Creek West	1139		

of a U.S. Geological Survey investigation of coal deposits on public lands in the Rock Springs coal field. A geologic map (Roehler, 1977) of the quadrangle was prepared on a topographic base to determine rock-stratigraphic relationships, to delineate coal beds, and to locate oil, gas, and oil-shale deposits. The mapping was done by planetable methods and on aerial photographs, and map compilation was done on an ER-55 photogrammetric plotter.

Cross sections and penetration charts of oil and gas wells show the depth and thickness of producing formations. Electric logs illustrate typical spontaneous potential and resistivity curves for strata penetrated in producing wells. Structure contours are drawn on an electric-log horizon in the Lewis Shale using data from 16 drill holes. A composite measured section describes the lithologies of 5,500 ft of rocks exposed in the quadrangle. A stratigraphic cross section was compiled from 19 measured sections; the sections show the positions of nearly 40 coal beds that range in thickness from less than 1 ft to more than 13 ft. Forty-five detailed measured sections show coal thickness and parting relationships on outcrops. Thirty-six channel samples of coal outcrops were analyzed for geochemical composition, and four samples were analyzed for heat value and sulfur content. Seven analyses show the characteristics of crude oil and natural gas produced at Brady field. Fifty-two oil-shale beds that crop out in the Laclede Bed of the Laney Member of the Green River Formation on Sand Butte Rim were sampled and assayed for oil yield.

Fossils were used to determine the age and depositional environments of stratigraphic units. The geographic and (or) stratigraphic locations are listed for 43 Eocene, 3 Paleocene, and 2 Cretaceous fossil-vertebrate sites; 19 Paleocene and 1 Cretaceous fossil-spore and -pollen sites; 8 Paleocene, 1 Eocene, and 1 Cretaceous fossil-leaf sites; and 8 Mesozoic and 11 Eocene fossil-invertebrate sites.

HISTORY OF GEOLOGIC INVESTIGATIONS AND MINERAL EXPLOITATION COAL

The Sand Butte Rim NW quadrangle is near the eastern edge of the Rock Springs coal field. The presence of coal in the field has been known since the early nineteenth century, but mining did not begin until 1868 following the completion of the Union Pacific Railroad across southwest Wyoming (Schultz, 1909, p. 275). The coal was used mainly by the railroad until steam-powered locomotives were replaced by diesel-powered locomotives between 1950 and 1960. Mining reached a peak during World War II, when coal production exceeded 6 million short tons a year; since 1945 it has steadily declined. In 1972 production was less than 500,000 tons.

The Pacific Power and Light Co. and the Idaho Power Co. own and operate the Jim Bridger coal-fired electric generating plant in the Rock Springs field 25 mi northeast of Rock Springs. The plant site is a few miles from where subbituminous coal is strip mined in the basal part of the Fort Union Formation. The plant is designed to consume 250 short tons/hour of coal at maximum load, and to produce 1,500 megawatts of power.

Coal has not been mined within the Sand Butte Rim NW quadrangle. The nearest mine is the Hall mine, 2 mi north of the quadrangle and 2 mi southwest of Black Buttes station on the Union Pacific Railroad (fig. 1). The Hall mine opened in 1907 and was abandoned a few years later.

Coal beds near Black Buttes station were mentioned by Hayden (1872, p. 71) in his fourth annual report of the geological and geographical survey of the territories. A year later Bannister (1873, p. 526-528) published a stratigraphic section measured there in which he described a coal-bearing interval that is now included in the Lance Formation.

A. R. Schultz (1909, 1910) published comprehensive studies of the Rock Springs coal field in which he divided the field into (1) the Rock Springs coal group of the Rock Springs Formation, (2) the Almond coal group of the Almond Formation, (3) the Black Buttes coal group of the Lance Formation, and (4) the Black Rock coal group of the Fort Union Formation. Only the Black Buttes and Black Rock coal groups crop out in the quadrangle, but parts of the Almond coal group are present within 3,000 ft of the surface in the northwest part of the quadrangle. A geologic map published by Schultz (1910), at scale 1:250,000 on a planimetric base, shows six coal beds in the quadrangle. Three coal outcrops were measured by

him in sec. 31, T. 18 N., R. 100 W., but they are not located stratigraphically.

Appraisals of coal resources in the Rock Springs field have been made by Berryhill, Brown, Brown, and Taylor (1950), and by Root, Glass and Lane (1973). These appraisals indicated original coal resources, in beds more than 2.5 ft thick, under less than 3,000 ft of overburden, range from 80 to 100 million short tons within the quadrangle area.

OIL AND GAS

Little interest was shown in oil and gas exploration in the quadrangle area until oil was discovered in 1959 at Patrick Draw field, which is 5 mi northeast of the quadrangle. Oil and gas were subsequently discovered within a few miles of the east boundary of the quadrangle at Stage Stop field in 1966, Neff field in 1968, Higgins field in 1969, and Antelope field in 1970.

The first hole drilled for oil and gas within the quadrangle was the Sand Butte 14-1 well drilled in 1959 in sec. 14, T. 17 N., R. 100 W. It was dry, and abandoned. The first commercial well was Jackknife Spring 2, drilled in 1961 in sec. 2, T. 16 N., R. 101 W. Gas was found in the quadrangle in the Almond Formation at the west edge of Antelope field in 1971 in sec. 24, T. 17 N., R. 100 W. Petroleum exploration reached a peak in 1973 following the discovery of large quantities of oil and gas in Paleozoic formations in the Brady Unit 1 well in sec. 11, T. 16 N., R. 101 W. (Jackknife Spring field was renamed the Brady field in 1973).

OIL SHALE

The presence of oil-shale beds in the Green River Formation in the vicinity of the Rock Springs uplift in southwest Wyoming was noted by Hayden (1872, p. 71, 142). The use of oil shale from the area as a source for crude oil and ammonia was discussed by Schultz (1920, p. 65-69). The chemical character of the shale was analyzed by Winchester (1923, p. 16-17). The ultimate composition of organic material in oil shale was determined by Smith (1961, p. 1-14).

Schultz (1920, p. 48-49) divided the oil-shale beds of the Green River in the quadrangle area into two members, one underlying the Cathedral Bluffs Tongue of the Wasatch Formation—the Tipton Shale Member, and the other overlying it—the Laney Member. A number of oil-shale beds were described in a section that was measured by him (Schultz, 1920, p. 54-56) in the southeast part of the quadrangle. Additional geologic and oil-yield data were presented by the U.S. Bureau of Mines and U.S. Geological Survey (Trudell and others, 1973).

ACKNOWLEDGMENTS

The writer is indebted to a number of individuals and organizations for assistance in acquiring and synthesizing data. Jay Valcarce aided the writer in the field in sampling beds and in preparing the geologic map. T. K. Martin compiled data on coal resources. Proximate, ultimate, Btu, and sulfur analyses of coal samples were made by the U.S. Bureau of Mines, Pittsburgh, Pa. Geochemical analyses of coal samples were made by the U.S. Geological Survey, Denver, Colo. Champlin Petroleum Co., Mountain Field Supply Co., and Amoco Production Co. provided structural information and oil and gas analytical data for Brady field. H. D. MacGinitie of the University of California and R. H. Tschudy identified fossil plants; W. A. Cobban identified fossil invertebrates; D. E. Savage of the University of California and C. L. Gazin identified fossil vertebrates.

STRATIGRAPHY

Sedimentary rocks in the Sand Butte Rim NW quadrangle are about 20,250 ft thick and range in age from Cambrian to Tertiary. The composite stratigraphic succession is shown in table 1. The sequence that crops out is about 5,500 ft thick and consists of Upper Cretaceous and lower Tertiary rocks (fig. 2; Roehler, 1977). The age, thickness, and lithologies of rocks penetrated in oil and gas wells are described in table 1. Stratigraphic units are identified by typical resistivity and spontaneous potential electric-log curves in figures 3 and 4.

UPPER CRETACEOUS ROCKS

LEWIS SHALE

The Lewis Shale is the oldest exposed formation. It weathers to a northeast-trending valley that has smooth dark-gray slopes and low rounded hills. Only the upper 600 ft crops out in the northwest corner of the quadrangle (fig. 2), but the formation is more than 1,000 ft thick in the subsurface along the east edge of the quadrangle.

The Lewis Shale is mostly dark-gray silty shale and a few beds of light-gray siltstone and sandstone. It is dated Late Cretaceous from sparse ammonite fossils collected a few miles north of the quadrangle. The presence of *Baculites clinolobatus* in the upper part in T. 21 N., R. 101 W., indicates an early Maestrichtian age (Weimer, 1961, p. 90-91). *Baculites baculus* in the upper part of the Almond Formation in sec. 10, T. 20 N., R. 101 W., suggests a late Campanian age for the upper part of the Almond Formation and the lower part of the Lewis Shale (fossil collection by J. R. Gill from USGS Mesozoic locality D6870).

TABLE 1.—Geologic formations in the Sand Butte Rim NW quadrangle, Sweetwater County, Wyoming

Age	Formation	Thickness (ft)	Description
Eocene-----	Laney Member of Green River Formation.	550- 610	Tan, gray, and brown tuffaceous sandstone and siltstone in the upper part; brown flaky oil shale and thin interbedded tan tuffaceous siltstone and brown limestone in the lower part.
	Cathedral Bluffs Tongue of Wasatch Formation.	400- 700	Variegated mudstone and sparse thin gray and brown shale, siltstone, and dolomite.
	Wilkins Peak Member of Green River Formation.	210- 550	Gray, green, and brown mudstone and very thin interbedded tan and gray limestone, dolomite, tuff, and shale, and brown oil shale.
	Tipton Shale Member of Green River Formation.	35- 60	Brown flaky oil shale.
	Niland Tongue of Wasatch Formation.	375- 400	Gray mudstone and sandstone and thin beds of brown, carbonaceous shale and oil shale, and gray siltstone and shale.
	Luman Tongue of Green River Formation.	285- 350	Brown flaky oil shale and thin interbedded gray and brown sandstone, limestone, shale and mudstone.
	Main body of Wasatch Formation.	1,280-2,150	Gray, green, and sparse variegated mudstone and gray sandstone; a few thin beds of gray shale and siltstone, brown carbonaceous shale, and gray and tan limestone.
Paleocene-----	Fort Union Formation.	950-1,650	Gray mudstone and interbedded gray sandstone, brown carbonaceous shale, coal, and gray siltstone.
Late Cretaceous--	Lance Formation-----	260- 650	Gray and brown carbonaceous shale, gray sandstone, coal, gray siltstone, and gray and green mudstone.
	Fox Hills Sandstone---	150- 350	Gray to white sandstone; some gray shale and siltstone.
	Lewis Shale-----	750-1,150	Dark-gray partly silty shale; a few very thin beds of gray sandstone.
	Almond Formation-----	225- 400	Gray shale and sandstone, gray and brown carbonaceous shale, coal, and gray siltstone.
	Ericson Sandstone-----	1,050-1,300	Light-gray sandstone; sparse thin gray carbonaceous shale.
	Rock Springs Formation.	1,000-1,300	Gray silty shale; some interbedded gray sandstone and siltstone.
	Blair Formation-----	1,100-1,300	Gray siltstone and sandstone and thin interbedded gray shale.
Early Cretaceous--	Baxter Shale-----	1,675-1,800	Gray shale; sparse thin beds of gray siltstone and sandstone.
	Frontier Formation----	3,100-3,200	Light-gray sandstone and thin interbedded gray shale.
		300- 350	
Early Cretaceous--	Mowry Shale-----	175- 250	Very dark gray siliceous shale; thin beds of bentonite.
	Dakota Sandstone-----	175- 275	Gray sandstone and interbedded gray and brown partly carbonaceous shale.
Late Jurassic----	Morrison Formation----	300- 350	Variegated mudstone and interbedded gray sandstone and siltstone.
	Curtis Formation (of drillers)-----	110- 125	Tan limestone in the upper part; dark-gray-green shale and interbedded gray silty sandstone in the lower part.
	Entrada Sandstone (of drillers)-----	75- 125	Light-gray sandstone.
Late and Middle Jurassic.	Carmel Formation (of drillers)-----	60- 110	Dark-brown to red shale and thin interbedded tan dolomite, and gray to red siltstone.
Jurassic(?) and Triassic(?).	Nugget Sandstone-----	525- 600	Light-brown to gray sandstone; some interbedded light-gray siltstone near the base.
Late Triassic----	Popo Agie Formation---	140- 175	Variegated shale and thin interbedded gray and pink to orange sandstone and siltstone.
	Jelm Formation-----	170- 190	Orange to red siltstone; very thin interbedded red to brown shale; some interbedded orange sandstone.
Early Triassic--	Red Peak Formation----	825- 875	Variegated siltstone, mudstone, and shale.
Permian-----	Park City Formation---	210- 240	Tan, gray, and brown dolomite; a few very thin beds of green shale and white anhydrite.
Permian, Late and Middle Pennsylvanian.	Weber Sandstone-----	625- 725	Tan to gray sandstone; some interbedded tan limestone near base.
Pennsylvanian---	Amsden Formation-----	675- 725	Tan, brown and variegated dolomite and limestone and thin interbedded variegated shale and siltstone.
Late and Early Mississippian.	Madison Limestone-----	650- 700	Tan, gray and brown limestone and dolomite.
Late and Middle Cambrian.	Gros Ventre Formation.	430- 460	Green shale and gray sandstone and siltstone.
Middle Cambrian-	Flathead Sandstone----	300- 350	Gray to tan sandstone.

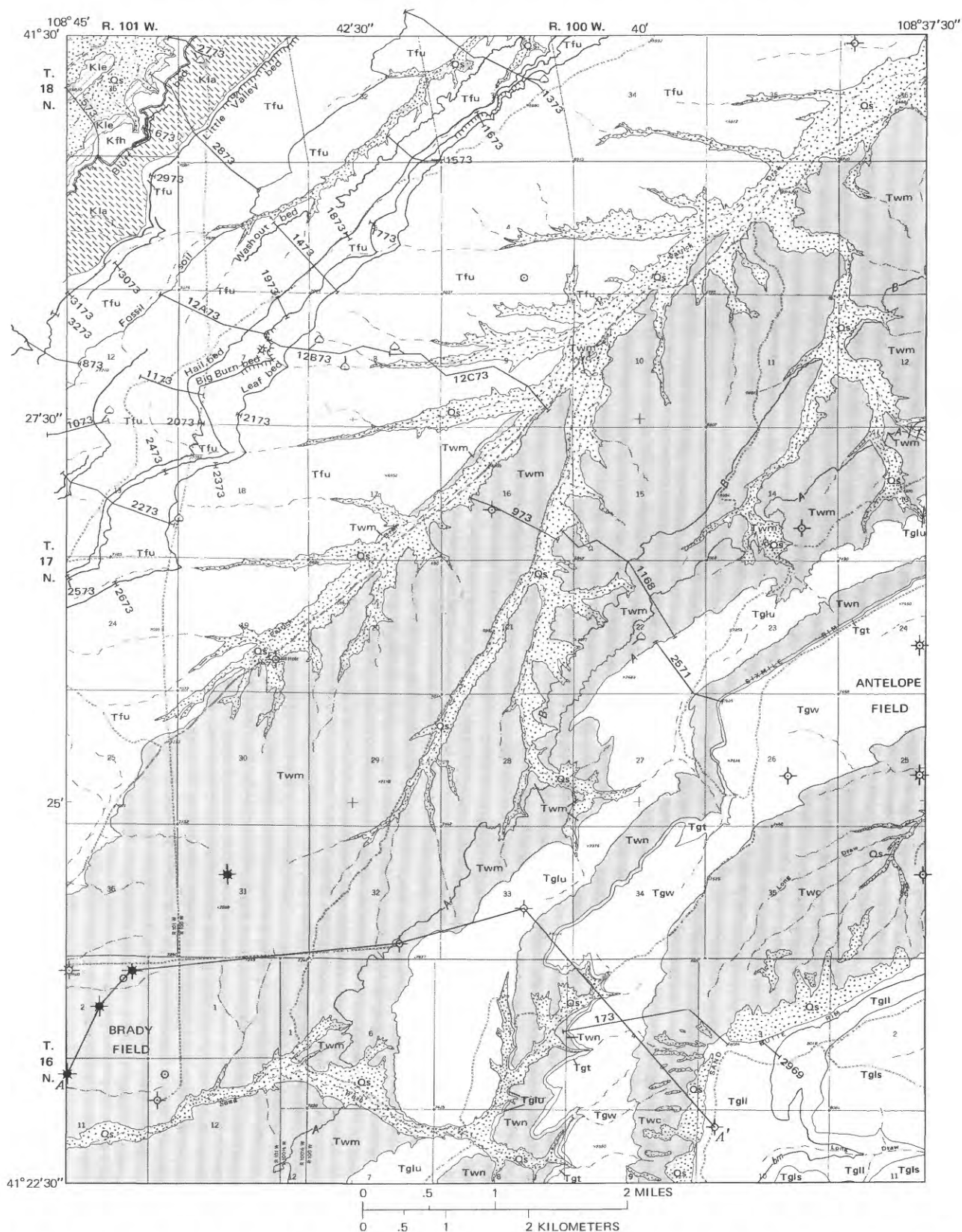
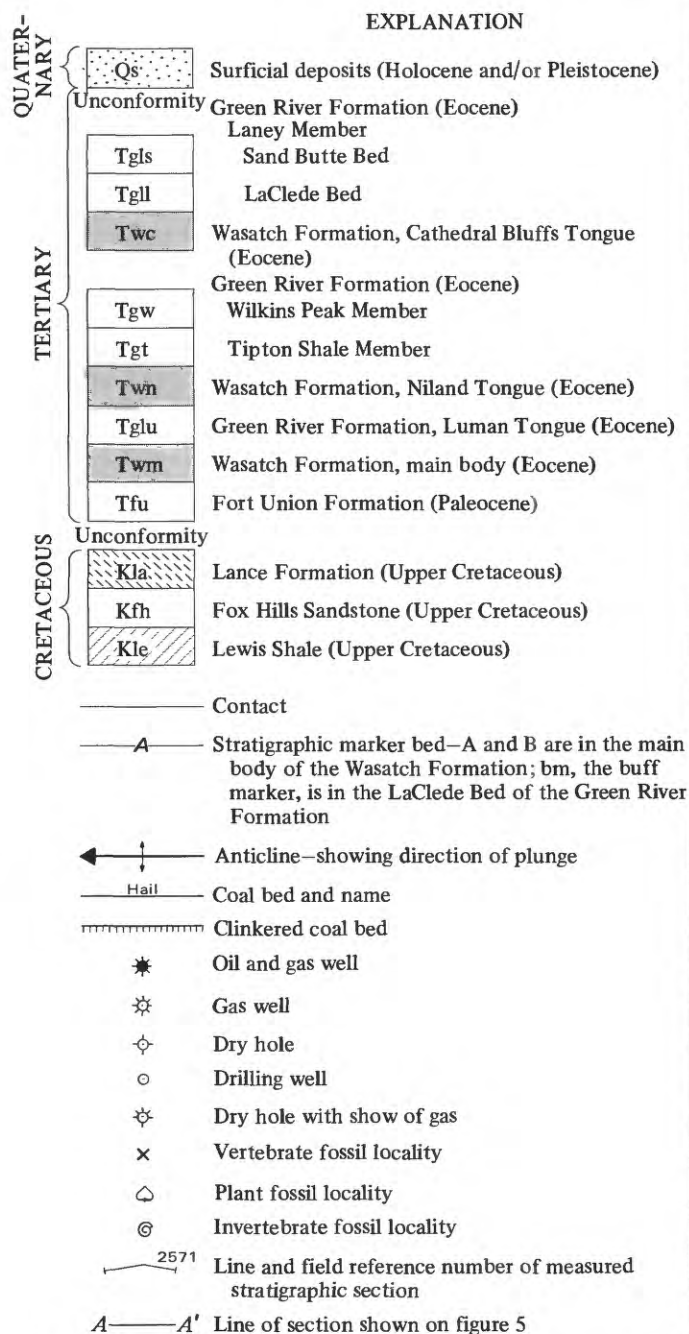


FIGURE 2.—Geologic map of the Sand Butte Rim NW quadrangle. Geology mapped by H. W. Roehler and Jay Valcarce, 1973. Base from U.S. Geological Survey Sand Butte Rim NW topographic quadrangle, 1968, scale 1:24,000.



The Lewis Shale was deposited mostly as mud in a marine embayment along the western coastline of an epicontinental sea that covered central North America in Late Cretaceous time. This indentation of the coastline has been called the Hallville Embayment (Lewis, 1961, p. 92). It was irregularly shaped, but was approximately 75 mi long (north-south) and 100 mi wide (east-west). The area of the Sand Butte Rim NW quadrangle lies in the central southwestern part.

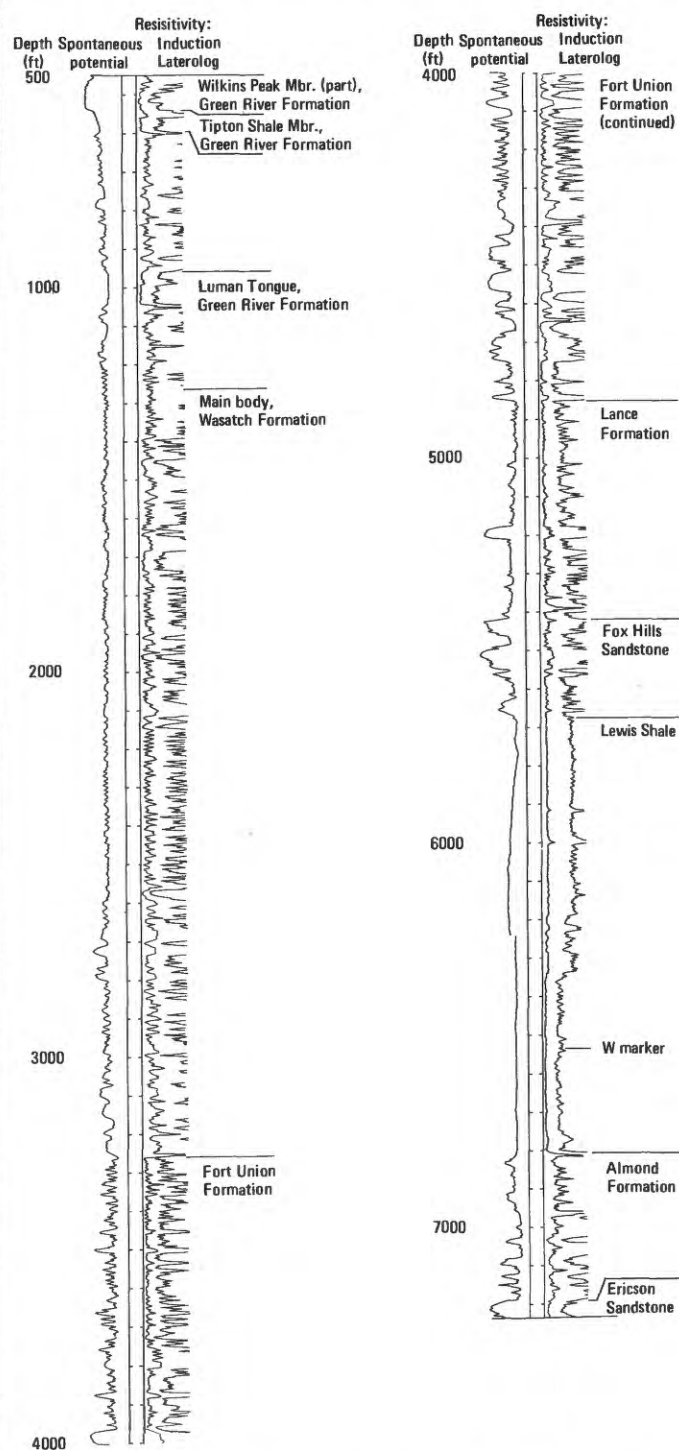


FIGURE 3.—Typical spontaneous potential and resistivity electric-log curves for Cenozoic and Mesozoic formations, Sand Butte Rim NW quadrangle. Log from Anadarko Production Co. Antelope-Wyoming 1-36 well, sec. 36, T. 17 N., R. 100 W.

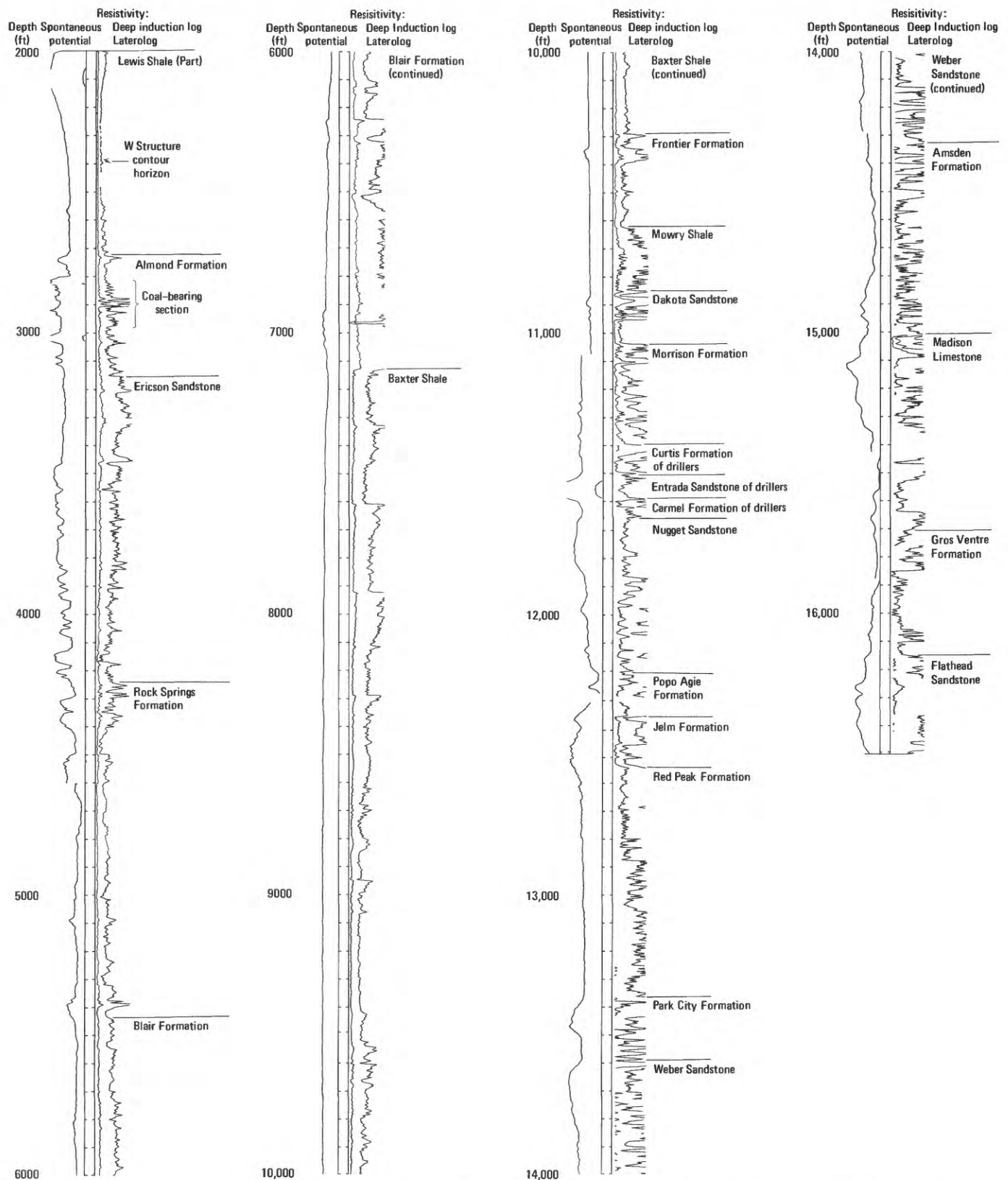


FIGURE 4.—Typical spontaneous potential and resistivity electric-log curves for Mesozoic and Paleozoic formations, Sand Butte Rim NW quadrangle. Log from Champlin Petroleum Co. Brady Unit 1 well, sec. 11, T. 16 N., R. 101 W.

FOX HILLS SANDSTONE

Outcrops of the Fox Hills Sandstone are confined to the northwest corner of the quadrangle, where they are white- and tan-weathering ledges that rise precipitously above a valley formed by the Lewis Shale. The ledges form an escarpment that is traceable for more than 30 mi along the east flank of the Rock Springs uplift. The Fox Hills is about 155 ft thick where it crops out, but it reaches a thickness of nearly 350 ft in the subsurface in other parts of the quadrangle.

The Fox Hills Sandstone is mainly white to gray, very fine to fine-grained, partly carbonaceous and calcareous crossbedded sandstone in the upper part. In the lower part, the sandstone is finer textured, less crossbedded, and finely interbedded and interlaminated with dark-gray partly silty shale and gray siltstone. Fossils are fairly abundant and include crustacean tracks, trails, and borings, worm borings, and mollusks. The Fox Hills Sandstone has not been dated by fossils collected in the quadrangle, but on the basis of regional correlations, its age is early Maestrichtian.

The Fox Hills Sandstone was deposited during the eastward retreat of the Lewis Sea from the Hallville Embayment during Late Cretaceous times. It was deposited in a steplike succession of beaches and bars that rise in section and become progressively younger to the east. In vertical section the Fox Hills Sandstone marks a transition from marine shale in the underlying Lewis Shale to continental shale, coal, and lenticular stream-channel sandstone in the overlying Lance Formation. The stratigraphic relations are indicated on a cross section (fig. 5).

LANCE FORMATION

The Lance Formation is moderately well exposed in northeast-trending light-gray sandstone ridges and dark-gray shale valleys in the northwest part of the quadrangle. The formation thickens northeastward in surface and subsurface rocks from about 100 to 650 ft. It is composed of interbedded brown and gray carbonaceous shale, gray and green mudstone, gray siltstone, coal, and gray very fine to fine-grained sandstone. Late Cretaceous age was established for the formation by the discovery of an ornithischian dinosaur, *Agathaumas sylvestris*, 0.5 mi east of Black Buttes station in sec. 9, T. 18 N., R. 100 W., north of the quadrangle (Cope, 1873). Mollusks are fairly common in the lower 50 ft. Collections from this interval are listed in table 2.

The lower 100 ft of the Lance Formation consists largely of dark-gray carbonaceous shale, coal, and gray sandstone that were deposited in lagoons (landward) of the Fox Hills Sandstone. The brackish-water conditions of these lagoons are attested by the presence of large numbers of the fossil clam *Leptesthes fracta* (W. A. Cobban,

written commun., 1974). From approximately 100 ft above the base to the top of the formation, deposition was mainly in a forest and swamp environment. This environment is indicated by the large amounts of organic material such as coal, wood, and leaves found in the rocks, and by the presence of lenticular crossbedded fluvial sandstone.

An unconformity is present at the Cretaceous-Tertiary boundary where rocks in the underlying Lance Formation dip 1°–3° more steeply southeastward than rocks in the overlying Fort Union Formation. The unconformity resulted from very late Cretaceous erosion upon the east flank of the ancestral Rock Springs uplift following the Laramide orogeny (Roehler, 1961, fig. 1). The thickness of the Lance Formation removed by this erosion is unknown, but it may have been more than 1,000 ft.

PALEOCENE ROCKS**FORT UNION FORMATION**

The Fort Union Formation crops out in the northwest part of the quadrangle in northeast-trending tan- and brown-weathering sandstone ridges and drab-gray and drab-brown-weathering shale valleys. The upper 300 ft of the formation is largely soil covered or poorly exposed beneath long vegetated dip slopes. The formation is about 1,375 ft thick in stratigraphic sections 2873, 12A73, 12B73, and 12C73 measured in sec. 31, T. 18 N., R. 100 W., sec. 12, T. 17 N., R. 101 W., and secs. 6, 7, 8, and 9, T. 17 N., R. 100 W. (pl. 1). It thickens eastward in the subsurface and is nearly 1,650 ft thick in oil and gas drill holes along the east edge of the quadrangle.

The formation is composed of gray and brown carbonaceous shale, gray shale, gray and green mudstone, gray very fine to medium-grained sandstone, and minor thin gray limy siltstone, gray claystone, and coal. Fossils and lithologies suggest the rocks were deposited in a subtropical climate in swamps and on forested flood plains, probably not more than 900–1,300 ft above sea level.

The fossils indicate a Paleocene age for the formation. R. H. Tschudy has identified palynomorphs in a number of gray shales near the west boundary of the quadrangle (table 3). The collecting sites of most of these plant microfossils are shown in figure 2 and plate 1 (See also Roehler, 1977). Tschudy believes that rocks of only early and late Paleocene age are represented in the Fort Union Formation in the quadrangle (written commun., 1973). Middle Paleocene rocks are missing by erosion. The level of this erosion is identified in outcrops by a 3- to 10-ft-thick fossil soil composed of light-gray limy hard siltstone containing abundant root impressions (Roehler, 1977). The fossil soil is distinct and easily recognized in outcrops

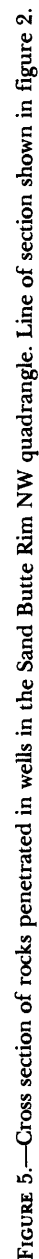


FIGURE 5.—Cross section of rocks penetrated in wells in the Sand Butte Rim NW quadrangle. Line of section shown in figure 2.

TABLE 2.—Mesozoic invertebrate fossils collected from the Lance Formation in the Sand Butte Rim NW quadrangle
[See fig. 1 for location of collecting sites]

USGS Locality No.	Location (T.)	(R.)	(sec.)	Stratigraphic position above base of Lance Formation (ft)	Upper Cretaceous Fauna
D8886---	17 N.	101 W.	1	10	<i>Leptesthes fracta</i> (Meek)
D8887---	18 N.	100 W.	31	47	<i>Leptesthes fracta</i> (Meek) <i>Crassostrea</i> sp. <i>Teredina</i> sp. (tubes only)
D8888---	18 N.	101 W.	36	17	<i>Leptesthes fracta</i> (Meek) <i>Crassostrea</i> sp. <i>Teredina</i> sp. (tubes only)
D8889---	18 N.	101 W.	36	18	<i>Leptesthes fracta</i> (Meek) <i>Crassostrea</i> sp. <i>Teredina</i> sp. (tubes only)

because it weathers very light gray and contrasts sharply with the underlying and overlying rocks that weather dark drab gray and drab brown.

Well-preserved fossil leaves are abundant, especially in gray shales that overlie coal beds. The geographic locations and stratigraphic positions of leaf sites are shown in figure 2 and plate 1. (See also Roehler, 1977). Fossil leaves were not collected in the quadrangle, but rather large collections have been made in stratigraphically correlatable rocks in the Fort Union Formation a few miles to the north near the Union Pacific Railroad in T. 18 N., Rs. 99 and 100 W. (Brown, 1962). The taxa include *Dennstaedtia americana*, *Glyptostrobus nordenskioldi*, *Betula stevensoni*, and others (Brown, 1962, p. 42, 49, and 57). According to Brown (written commun., 1959), plant megafossils indicate an early Paleocene age for the lower part and a late Paleocene age for the upper part of the Fort Union Formation; these age assignments agree with those made by Tschudy.

Fossil vertebrates were discovered by the writer and collected by field parties from the University of California at their localities V-73151, V-73152, and V-73153, in sec. 8, T. 17 N., R. 100 W. The fauna include *Champsosaurus* sp., crocodile, turtle, lizard, multituberculate, insectivore, and rodent remains (D. E. Savage, written commun., 1973). These fossils place the upper 400 ft of the formation in the late Paleocene.

EOCENE ROCKS

Rocks of Eocene age are assigned to the intertongued Wasatch and Green River Formations. These formations have distinct lithologies that reflect their environments of deposition. Lacustrine rocks, such as oil shale, are normally included in the Green River Formation, while fluvial rocks, such as variegated mudstone, are normally included in the Wasatch Formation.

MAIN BODY OF THE WASATCH FORMATION

The thick basal part of the Wasatch Formation, which everywhere underlies the Green River Formation, is

designated the main body. The main body is equivalent to the Red Desert Tongue named by Pipiringos (1961, p. A14) and to the Hiawatha Member named by Nightingale (1930, p. 1023).

The main body is present in a northeast-trending band of outcrops, nearly 3 mi wide, across the central part of the quadrangle. It is exposed locally in gray badlands as ridges and terraces; between exposures large areas are covered by soil and thin vegetation consisting mostly of sage and grass. The main body thickens greatly south-eastward from about 1,280 ft in outcrops to more than 2,133 ft in the subsurface near the southeast corner of the quadrangle (fig. 5).

The dominant lithologies are gray and green and some variegated partly silty and sandy mudstone alternating with gray very fine to fine-grained micaceous sandstone. Sparse thin beds of mollusk-bearing limestone, gray limy siltstone, gray shale, and brown carbonaceous shale are present in places in the section. Two persistent mollusk-bearing limestones were mapped and designated bed A and bed B (fig. 2). Pulmonate gastropods in these beds include *Physa pleromatis*, *Helix* sp., *Valvata* sp., and *Australorbia* sp., as well as several taxa of pelecypods including fingernail clams.

The main body of the Wasatch Formation is of early Eocene age, or Wasatchian provincial age of Wood and others (1941) on the basis of fossil vertebrate collections. Vertebrate paleontologists (Wood and others, 1941, p. 9-10) have subdivided the Wasatchian into faunal zones. The Gray Bull, or lower faunal zone, is present in the lower part of the main body, and the middle and upper faunal zones of, Lysite and Lost Cabin age respectively, are present in the upper part. USGS vertebrate-fossil locality D792, in the southwest part of sec. 15, T. 17 N., R. 100 W., is in rocks of early Gray Bull age. Mammals collected there by the writer and identified by C. L. Gazin are *Apheliscus insideosus*, *Cynodontomys* sp., *Peratherium* sp., *Pelycodus* sp., *Hyopsodus* cf. *H. miticulus*, *Hyracotherium* sp., *Wasatchia* sp., and miscellaneous paramyid rodents. Field parties from the University of California at Berkeley, under the supervision of D. E. Savage, collected thousands of fossil vertebrates from 35 localities in the main body in the quadrangle (pl. 1) in 1970-73. Most of the specimens are disarticulated bones and isolated teeth and jaws. The most prolific collecting sites are in rocks that are interpreted as having been deposited at the margins of shallow Eocene ponds and in pockets in stream-channel sandstones.

Rocks composing the main body of the Wasatch Formation were deposited mostly by distributary streams upon flood plains in an intermontane basin. The rarity of red beds in the section suggests that the Eocene soils were moist or water saturated, and that iron compounds were

TABLE 3.—*Paleocene and Cretaceous palynomorphs from the vicinity of the Sand Butte Rim NW quadrangle, Sweetwater County, Wyoming*
 [Pl. 1 and fig. 2 show locations of collection sites; see also Roehler, 1977. Identifications and age assignments by R. H. Tschudy]

Locality no.	Location (T.) (R.) (sec.)			Approximate stratigraphic position above or below base of the Fort Union Formation (ft)	Assemblage	Suggested age
D5187-A--	17	N.	101 W. 12	-95	<i>Polypodiumsporites</i> ----- <i>Abietinaepollenites</i> 3 species----- <i>Gleicheniidites</i> ----- <i>Tricolpites</i> ----- <i>Ulmipollenites?</i> ----- <i>Klukisporites</i> ----- <i>Araucariacites</i> ----- <i>Foraminisporis</i> ----- <i>Proteacidites</i> ----- <i>Aquilapollenites</i> ----- <i>Anemia</i> ----- <i>Erdtmanipollis</i> ----- <i>Rugubivesiculites</i> -----	Late Cretaceous.
D5187-C--	17	N.	101 W. 12	25	<i>Momipites</i> ----- <i>Maceopolipollenites tenuipolus</i> ----- <i>Abietinaepollenites</i> ----- <i>Tricolpites reticulatus</i> ----- <i>Ulmipollenites</i> ----- <i>Arecipites</i> ----- <i>Gleicheniidites</i> ----- <i>Pandaniidites</i> -----	Early Paleocene.
D5187-D--	17	N.	101 W. 12	155	<i>Maceopolipollenites tenuipolus</i> ----- <i>Maceopolipollenites leboensis</i> ----- <i>Alnus</i> 5 pored----- <i>Ulmipollenites</i> ----- <i>Polypodiumsporites</i> ----- <i>Abietinaepollenites</i> ----- CP3-417-----	Early Paleocene.
D5187-F--	17	N.	101 W. 12	235	<i>Maceopolipollenites tenuipolus</i> ----- <i>Maceopolipollenites leboensis</i> ----- <i>Polypodiumsporites</i> ----- <i>Ulmipollenites</i> , 3 pored, 4 pored--- <i>Alnus</i> , 6 pored----- <i>Abietinaepollenites</i> ----- <i>Inaperturopollenites</i> ----- CP3-rl7-----	Upper part of early Paleocene.
D5071-A--	17	N.	101 W. 13	290	<i>Ulmipollenites</i> ----- <i>Alnus</i> -----	
D5072-A--	18	N.	100 W. 29	300	<i>Ulmipollenites</i> ----- <i>Alnus</i> ----- <i>Maceopolipollenites</i> -----	Lower part of late Paleocene.
D5071-B--	17	N.	101 W. 13	315	<i>Carya</i> ----- <i>Pistillipollenites</i> ----- <i>Maceopolipollenites triobicularis</i> ---	Lower part of late Paleocene.
D5071-C--	17	N.	101 W. 13	340	<i>Taxodiaceous pollen</i> -----	
D5070-A--	17	N.	101 W. 12	360	<i>Maceopolipollenites tenuipolus</i> ----- <i>Carya</i> -----	Late Paleocene.
D5070-B--	17	N.	100 W. 7	405	<i>Ulmipollenites</i> ----- Large algal cells	
D5071-D--	17	N.	101 W. 13	490	<i>Carya</i> ----- 4 pored Juglandaceous pollen----- <i>Ulmipollenites</i> ----- <i>Alnus</i> -----	
D5072-B--	17	N.	100 W. 33	505	<i>Carya</i> -----	Lower part of Paleocene.
D5050-C--	17	N.	100 W. 7	510	<i>Carya</i> ----- <i>Maceopolipollenites tenuipolus</i> ----- <i>Taxodiaceous pollen</i> -----	
D5072-C--	18	N.	100 W. 33	535	<i>Carya</i> ----- <i>Maceopolipollenites tenuipolus</i> ----- <i>Pistillipollenites</i> -----	
D5072-D--	18	N.	100 W. 33	625	<i>Carya</i> ----- <i>Maceopolipollenites tenuipolus</i> ----- <i>Pistillipollenites</i> -----	
D5073-A--	17	N.	100 W. 6	650	<i>Ulmipollenites</i> ----- <i>Sparganium?</i> -----	
D5073-B--	17	N.	100 W. 5	790	<i>Carya</i> ----- <i>Pistillipollenites</i> ----- Juglandaceous pollen----- <i>Pterocarya</i> -----	Late Paleocene.
D5070-D--	17	N.	100 W. 7	810	<i>Pistillipollenites</i> ----- <i>Carya</i> -----	Late Paleocene.
D5074----	18	N.	100 W. 32	830	<i>Carya</i> ----- <i>Pistillipollenites</i> -----	Late Paleocene.
D5070-E--	17	N.	100 W. 8	1,020	<i>Carya</i> ----- <i>Pistillipollenites</i> ----- Juglandaceous pollen----- <i>Pterocarya</i> -----	Latest Paleocene.

reduced and formed gray and green pigments. Altitudes in the intermontane basin were probably about 1,000 ft above sea level; the surrounding mountains rose 2,000-

3,000 feet higher. Sparse fossil plant collections from lower Eocene rocks in and adjacent to the quadrangle, mainly wood, seeds, leaves, spores, and pollen, indicate a

pond and forest landscape having abundant hardwood trees including hackberry and walnut. Modern analogs suggest vegetation of this type preferred a humid temperate climate, having little or no frost, an average annual temperature of about 60°F, and an average annual precipitation of about 35 in. Plants from a soft lignitic shale near the center of sec. 22, T. 17 N., R. 100 W., were collected and identified by H. D. MacGinitie in 1972. The floral list includes *Platycarya* sp., *Salix* sp., *Typha* sp., and monocot leaves, sedges, palm pinnae and a water lily (H. D. MacGinitie, written commun., 1972).

LUMAN TONGUE OF THE GREEN RIVER FORMATION

The Luman Tongue is the lowermost stratigraphic unit of the Green River Formation. It is exposed along a drab-gray- and brown-weathering ridge-forming escarpment in the southeast part of the quadrangle (fig. 2). The ridge is capped by a brown-weathering sandstone that dips 4° southeast. The lower part of the tongue is well exposed in steep northwest-facing slopes below the sandstone. The tongue is only partly exposed above the sandstone in a series of long slopes that, with the overlying Niland Tongue of the Wasatch Formation, form a shallow valley. The Luman Tongue is 285-350 ft thick.

Brown flaky (varved) oil shales compose most of the Luman Tongue. Interbedded with the oil shale, especially in the lower part, are gray fine- to coarse-grained sandstone, gray and green mudstone, and gray and brown partly carbonaceous shale. Very coarse grained very arkosic sandstone is present at the top of a butte identified by elevation (7,489 ft) in the southern part of sec. 22, T. 17 N., R. 100 W. The source of the arkose is problematical; the closest granite crops out 70 mi to the north in the Wind River Range. No vertebrate fossils were collected from the tongue itself, but collections from the Wasatch Formation above and below it are Lost Cabin in age. Mollusks present in coquina limestones and some sandstones are mainly prosobranch gastropods, about 80 percent *Goniobasis* sp. and 15 percent *Viviparus* sp., but about 5 percent of the mollusks present are pelecypods, usually *Lampsilis* sp.

The Luman Tongue comprises the earliest sedimentary rocks that were deposited in Lake Gosuite, a large body of water which occupied parts of southwest Wyoming for a 10-million-year period during the lower and middle Eocene. At its maximum size the lake in Luman time occupied an area of about 6,000 mi². The depositional axis of the lake, the line connecting its deepest parts, trended southwestward from the Great Divide Basin across the northwest part of the Washakie Basin and southern part of the Rock Springs uplift and then westward along the southern part of the Green River

Basin. The Sand Butte Rim NW quadrangle area was well out into the lake, north of the depositional axis. The Luman Tongue intertongues with the underlying main body and overlying Niland Tongue of the Wasatch Formation. The intertonguing resulted from a slow advance and retreat of the lake across the area during its depositional history. Fossil plants indicate the climate at this time was warm and humid.

NILAND TONGUE OF THE WASATCH FORMATION

The Niland Tongue is exposed in a northeast-trending band of outcrops less than 0.6 mile wide in the northwest-facing slopes of Sixmile Rim in the southeast part of the quadrangle. The most conspicuous outcrops are gray-weathering ledgy sandstones. Parts of the outcrop area are covered by soil, slopewash, and vegetation. The tongue is 375-400 ft thick.

The Niland Tongue is mainly interbedded gray fine-grained sandstone, gray and green mudstone, and gray shale, and minor thin beds of brown flaky oil shale, brown carbonaceous shale and gray siltstone. A few sandstones contain *Goniobasis* sp., *Viviparus* sp. and *Elliptio* sp., fossil worm borings, and turtle remains. The ages of the fossil mammals *Lambdotherium* sp., *Meniscotherium* sp., *Hyracotherium*, and others collected by McGrew and Roehler (1960, p. 158) from a sandstone in the Niland Tongue at the northeast corner of Table Rock in NE¼ sec. 8, T. 18 N., R. 98 W., 9 mi northeast of the quadrangle, are early Eocene, late Wasatchian provincial age of Wood and others, (1941) or Lost Cabin age.

The Niland Tongue was deposited in a topographically low, unstable area formerly covered by Lake Gosuite during deposition of the Luman Tongue. Changes in environments during the deposition of the Niland Tongue are shown by changes in lithologies. Gray mudstone and gray lenticular stream-channel sandstones that were deposited on flood plains were irregularly replaced by dark-gray and brown carbonaceous shales that were deposited in swamps, and by brown flaky oil shales that were deposited in small freshwater lakes.

TIPTON SHALE MEMBER OF THE GREEN RIVER FORMATION

The Tipton Shale Member is exposed in drab-brown-weathering slopes below the top of the northwest face of Sixmile Rim (fig. 2). It is 35-60 ft thick and is composed of brown flaky oil shale and some interbedded very thin, brown, tuffaceous siltstone. An early Eocene, Wasatchian provincial age of Wood and others, (1941) or Lost Cabin age, has been established for the Tipton by vertebrate fossils collected from the Wasatch Formation above and below it.

The rocks composing the Tipton Shale Member were deposited in Lake Gosiute when it covered an area of more than 12,000 mi². The Sand Butte Rim NW quadrangle area was toward the center of the lake, north of the east-trending depositional axis of the lake basin. A low carbonate content, abundant clays such as illite and kaolinite, and large prosobranch gastropods in the rocks testify that the lake waters were fresh. Fossil plants suggest that the average annual temperature may have been about 65°F, and the average annual precipitation nearly 50 in.

WILKINS PEAK MEMBER OF THE GREEN RIVER FORMATION

The Wilkins Peak Member crops out as gray-weathering rocks at the top of Sixmile Rim and in low hills and valleys southeast of the rim. Much of the member is covered by thin soils and vegetation consisting of patches of sage and grass. The thickness is variable because the Wilkins Peak Member intertongues extensively with the overlying Cathedral Bluffs Tongue of the Wasatch Formation. The member may be 210-550 ft thick, depending on where the upper contact is placed within the inter-tongued sequence. The upper contact, as defined in this report, is placed at the base of the lowermost red mudstone, the lithology that composes the bulk of the overlying Cathedral Bluffs Tongue. The lower contact is distinct and easily recognized because the lower part of the member weathers chalky gray in contrast with the underlying Tipton Shale Member, which weathers drab brown.

The lower 200 ft of the Wilkins Peak Member is mostly brown flaky dolomitic oil shale and some very thin interbedded gray dolomite, gray tuff, brown tuffaceous siltstone, and tan and brown algal, oolitic, and ostracodal limestone. The upper 350 ft of the member is mostly gray and green, partly dolomitic mudstone and thin interbedded gray dolomite, gray tuff, and gray siltstone. Tuff and dolomite beds in the member, usually less than 1 ft thick, often weather orange brown. Fossils are rare, except for ostracodes. The age of the member has not been determined in the Sand Butte Rim NW quadrangle, but on the basis of regional stratigraphic correlations and fossil vertebrate collections, it appears to be late early Eocene, Wasatchian provincial age of Wood and others, (1941) or Lost Cabin age.

The oil shales in the lower part of the Wilkins Peak Member were deposited in Lake Gosiute during a hot and arid period of the lower Eocene when the outlet of the lake closed, evaporation exceeded precipitation and runoff, and the waters became saline. The maximum size of the lake at this stage was about 6,000 mi²; the Sand Butte Rim NW quadrangle area was in the north-central

part of the lake. Saline water conditions are suggested by a high carbonate content in the rocks, an absence of large prosobranch gastropods, and high oil yields of oil shale reflecting blooms of planktonic blue-green algae. The mudstones in the upper part of the member were deposited on mud flats that occupied large areas of former lake bottom when the lake was much reduced in size and when it retreated from the area of the quadrangle. At these times trona and halite precipitated from supersaline pond waters near the depositional centers of the lake, which were about 50 mi to the west, in the southern part of the Green River Basin. Algal limestones formed when the lake periodically expanded outward from the depositional centers and covered the quadrangle area. The average annual precipitation during the period of deposition of the Wilkins Peak Member fluctuated between 20 and 40 in. a year. The average annual temperature was about 67°F.

CATHEDRAL BLUFFS TONGUE OF THE WASATCH FORMATION

The Cathedral Bluffs Tongue crops out in red- and gray-weathering badlands in a broad valley below Sand Butte Rim in the southeast part of the quadrangle. The tongue is 400-700 ft thick. It is 430 ft thick in stratigraphic section 173 (fig. 2), measured in secs. 3 and 4, T. 16 N., R. 100 W., but thickens rapidly to more than 2,000 ft in the subsurface 12 mi southeast of the quadrangle in the central-western part of the Washakie Basin.

The bulk of the Cathedral Bluffs Tongue is variegated mudstone interbedded with thin gray dolomite, gray sandstone, and gray siltstone. A few thin beds of brown carbonaceous shale and brown oil shale are locally present near the upper contact, where the Cathedral Bluffs intertongues with the overlying Laney Member of the Green River Formation. The upper contact is placed at the base of the lowermost mappable oil-shale bed in the Laney Member of the Green River Formation.

The age of the Cathedral Bluffs Tongue is early Eocene, Wasatchian provincial age of Wood and others (1941) or Lost Cabin age in the lower part, and middle Eocene, Bridgerian provincial age of Wood and others (1941) or Bridger A and B, in the upper part. Morris (1954) collected lower Eocene vertebrates that included *Didymictus* cf. *D. altidens* and middle Eocene vertebrates that included *Trogosus* sp. and *Orohippus* sp. from several localities in the tongue in Ts. 18 and 19 N., Rs. 94 and 95 W., in the northern part of the Washakie Basin. McGrew and Roehler (1960, p. 158) collected the middle Eocene rodent *Sciuravus nitidus* from the upper 100 ft of the tongue in sec. 5, T. 15 N., R. 93 W., in the eastern part of the Washakie Basin. A small bird, reptile, and mammal

fauna collected by the writer (USGS vertebrate locality D791) from approximately 200 ft above the base of the tongue near the northwest corner of sec. 24, T. 12 N., R. 99 W., was dated early Eocene because of the presence of *Hyracotherium* sp.

The Cathedral Bluffs Tongue was deposited on flood plains between Lake Gosiute and mountains that encircled the southwest Wyoming area during the Eocene. The red pigments that give the tongue its bright banded colors probably resulted from the in-place oxidation of iron compounds in well-drained aerated soils that were deposited in areas of moderately high relief. The paleontology and mineralogy indicate the climate was hot and arid.

LACLEDE BED OF THE LANEY MEMBER OF THE GREEN RIVER FORMATION

The LaCledde Bed is a basal oil-shale section of the Laney Member. The bed is 410 ft thick and weathers drab brown. It is fairly well exposed in the steep northwest-facing slopes of Sand Butte Rim, but on the gentle southeast slopes of the rim it is mostly covered by soil and patches of sage.

Oil shales compose 65–70 percent of the LaCledde Bed. Some of the shales yield quantities of oil by Fischer assay (the yields are discussed below under Economic Geology). Interbedded with the oil shales are tan and gray tuffaceous siltstone, and thin beds of tan algal limestone, tan ostracodal and oolitic limestone, brown dolomite, gray fine-grained sandstone and brown carbonaceous shale, and gray to green mudstone. Lithologies of the bed are described in table 1 and illustrated on figure 6.

A 40-ft-thick bed of tan-weathering tuffaceous siltstone in the upper part of the LaCledde Bed has been named the buff marker (fig. 6). The buff marker is non-resistant and weathers to a groove in more resistant slopes composed of mostly oil shale. It is easily recognized in outcrops almost everywhere in the Washakie Basin; on electric logs of oil and gas wells it shows a very low resistivity (Trudell and others, 1973, fig. 3, p. 7).

Ostracods and calcareous algae are common in the LaCledde Bed. Mollusks are rare. Small fossil fish, tentatively assigned to genus *Knightia*, are common in oil shales in a section 30 ft thick below the base of the buff marker. Fossil vertebrates collected above and below the LaCledde Bed east of the quadrangle in the Washakie Basin are middle Eocene, Bridgerian provincial age of Wood and others (1941) or Bridger A and B age. *Nyctitherium serotinum* and *Omomys* sp. (USGS vertebrate locality D777) were collected by the writer from a black chert layer about 6 ft below the top of the LaCledde Bed in SW $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 36, T. 18 N., R. 95 W., in the northeast part of the Washakie Basin.

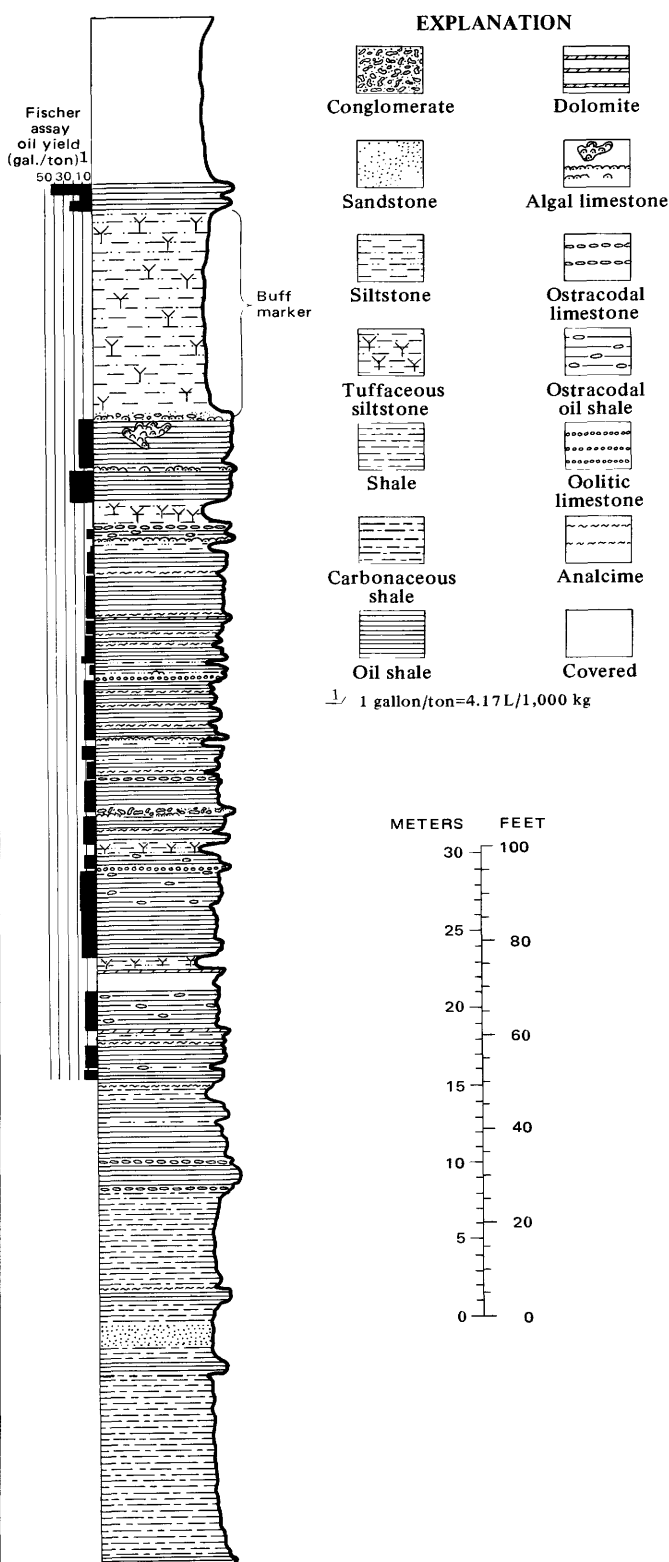


FIGURE 6.—Section of the LaCledde Bed of the Laney Member of the Green River Formation measured in NW $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 3, T. 16 N., R. 100 W., showing oil yields of oil shales. Assays are of weathered channel samples that normally yield about 10 percent less oil than core samples.

The LaCledde Bed is composed of very fine grained sedimentary rocks, rich in organic matter, that were deposited in the largest stage of Lake Gosiute. The lake during these times occupied an area of more than 15,000 mi² in southwest Wyoming, northwest Colorado and northeast Utah; the area of the Sand Butte Rim NW quadrangle was in the southeast part. Tuffaceous siltstone defines periods of air-fall volcanic ash. The siltstone and other detrital rock fragments that compose much of the tuffaceous beds suggest that the ash was reworked by stream and lake currents prior to burial and lithification. The organic matter deposited in the bottom sediments mostly by seasonal mortalities of planktonic blue-green algae did not decompose but was altered to kerogen. Deep-water deposition is suggested by tan and dark-brown laminations or varves, which formed at water depths below wave base. Shallower water conditions are suggested by thin conglomerates, algal limestones, and oolites, normally associated with shorelines. The mineralogy of the oil shales, including Ca:Mg ratios, clays, and zeolites, suggest that the lake waters ranged from fresh to brackish.

Fossil spores and pollen collected by the writer from the LaCledde Bed a few miles south of the quadrangle suggest the middle Eocene climate during the deposition of the LaCledde Bed was hot and humid, bordering on subtropical (Estella Leopold, oral commun., 1972). Increased rainfall during these times was undoubtedly responsible for enlarging the size of Lake Gosiute. The average annual temperature is estimated to have been near 70°F and the average annual precipitation about 60 in.

SAND BUTTE BED OF THE LANEY MEMBER OF THE GREEN RIVER FORMATION

The Sand Butte Bed comprises a sequence of tuffaceous rocks in the middle of the Laney Member. It crops out in the rounded hills and valleys in an area of less than 2 mi² in the southeast corner of the quadrangle. The bed has a total thickness of nearly 800 ft, but only the lower 200 ft are present within the quadrangle.

The Sand Butte Bed unconformably overlies the LaCledde Bed. It is composed of mostly tan and gray tuffaceous sandstone and siltstone and thin interbedded tan and gray tuff.

The Sand Butte Bed is middle Eocene, Bridgerian provincial age of Wood and others, (1941) or Bridger A and B age. Fossil vertebrates are rare, but *Microsyrphops* cf. *M. elegans*, *Peratherium* sp., *Hyopsodus* sp., and miscellaneous fish and reptile remains were collected by the writer and D.E. Savage from the upper part of the bed in SE $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 14, T. 16 N., R. 99 W., about 5 mi southeast of the quadrangle. Two small vertebrate col-

lections by W. D. Turnbull from the lower 150 ft of the overlying Washakie Formation southeast of the quadrangle are also Bridger A and B age (Roehler, 1973, p. 23).

The Sand Butte Bed has a complex depositional history that reflects tectonic and volcanic events which changed the Eocene landscape in the southwest Wyoming area. Near the end of the period of deposition of the LaCledde Bed the Rock Springs uplift was gently upwarped. This event created an island near the center of Lake Gosiute. Subaerial erosion on the uplifted lake bottom removed several hundred feet of strata composing the LaCledde Bed (nearly 300 ft were eroded in the quadrangle area). The Sand Butte Bed was deposited upon this erosion surface.

Volcanic activity began contemporaneously with the upwarping of the Rock Springs uplift. (The center of the volcanic activity is unknown, but it is thought to have been in the Absaroka Range in northwest Wyoming.) Large quantities of volcanic ash entered the atmosphere and began to fall upon Lake Gosiute and adjoining areas. This resulted in a cooling of the Eocene climate, and Lake Gosiute began to dry up and retreat in a southeasterly direction across southwest Wyoming. The Sand Butte Bed was deposited in the quadrangle area as beaches and deltas by the retreating, drying lake.

STRUCTURE

SURFACE ROCKS

The Sand Butte Rim NW quadrangle is on the southeast flank of the Rock Springs uplift, where strata dip 3°–6° southeastward into the northwest part of the Washakie Basin. The overall structure within surface rocks is homoclinal, but a minor southeast-plunging anticlinal nose, Jackknife Spring anticline, is near the southwest corner of the quadrangle at Brady oil and gas field. The axis of the Jackknife Spring anticline plunges about 4° southeast in surface rocks. The age of folding is believed to be middle Tertiary.

A minor synclinal fold is in Eocene rocks along Sand Butte Rim in the southeast corner of the quadrangle. The reversal of dips is apparent there by a change in the strike of Eocene outcrops from N. 15° E. in sec. 9, T. 16 N., R. 100 W., to N. 60° E. in sec. 23, T. 17 N., R. 100 W. (Roehler, 1977).

No faults were mapped in surface rocks in the quadrangle.

SUBSURFACE ROCKS

A number of faults and folds that are present in Cretaceous and older rocks are missing in Tertiary rocks that crop out across the quadrangle. Tertiary rocks rest un-

comfortably upon the Cretaceous rocks thereby masking the underlying structure.

The Brady fault is a high-angle reverse fault in Cretaceous and older rocks (fig. 7). It strikes approximately N. 30° E. and dips 80°–85° southeast. There are nearly 1,000 ft of closure against the fault along the southeast, upthrown, side. Where the Jackknife Spring anticlinal nose crosses the fault at nearly right angles in the northeast part of T. 16 N., R. 101 W., a reversal of dips takes place along the southeast side of the fault. This creates nearly 250 ft of anticlinal closure in Paleozoic rocks that is independent of fault closure. Mountain Field Supply Co. has furnished a cross section of Brady field (fig. 8) that shows the general structure relations and names producing formations. The Brady fault is probably of Late Cretaceous age. It has maximum displacement in Precambrian basement rocks, it dies out upward, and it is missing in uppermost Cretaceous rocks. The northeast strike of the fault identifies it as one of a number of echelon faults that dissect the Rock Springs uplift. These faults show strike-slip movement having pronounced right-lateral separation.

ECONOMIC GEOLOGY

The Sand Butte Rim NW quadrangle is unusual in that it has large energy resources of coal, oil and gas, and oil shale in a small geographic area. Movable coal is mostly present in the northwest part of the quadrangle, oil and gas is mostly present diagonally in a northeast direction across the center of the quadrangle, and movable oil shale is present near the southwest corner of the quadrangle. The heating value of the combined energy resources is estimated in excess of 10^{16} Btu.

COAL OUTCROPS

Outcrops of coal beds are restricted to a 10-mi² area. Coal beds weather to shallow drab-gray slopes and valleys between ridge-forming sandstones. They usually have a thin cover of soil and vegetation, are fairly soft, and are weathered for several feet below the surface. The coal is bright, but in the weathered zone it often consists of small blocky fragments. Minerals associated with weathering include selenite, limonite, and in some places calcite pseudomorphs after selenite. Locally, the coal outcrops were burned to orange-red clinker beds.

NAME AND STRATIGRAPHIC POSITION OF BEDS

Nearly 40 beds of coal, ranging in thickness from 0.3 to 14 ft, are present in the Fort Union Formation (Black Rock coal group) and the Lance Formation (Black Buttes coal group) that crop out in the quadrangle. The strati-

graphic position and thickness of the beds are shown on plate 1. Six persistent beds more than 2 ft thick were named and mapped (fig. 2). The upper four, named the Leaf, Big Burn, Hail, and Washout beds, in descending order, are in a 165-ft-thick interval 650–815 ft above the base of the Fort Union Formation (pl. 1). The Little Valley bed is in the basal 75 ft of the Fort Union Formation. The Bluff bed is in the basal 40 ft of the Lance Formation. The names of coal beds were assigned by the author. There is no record that any of them have been previously named.

RANK AND THICKNESS

Four channel samples from outcrops of the Big Burn and Little Valley coal beds were submitted for proximate, ultimate, Btu, and sulfur analyses. The heating value on a moist mineral-matter-free basis was determined by the Parr formula (American Society for Testing and Materials, 1971, p. 59). The values range between 6,500 and 7,200 Btu/lb, which classified the coal as Lignite A rank. However, it should be classified as Subbituminous C because weathering has reduced the heating value. The sulfur content, dominantly of organic origin, ranges between 0.2 and 0.9 percent (table 4).

Coal thicknesses, partings, and the lithologies of overlying and underlying rocks are shown on detailed sections (figs. 9, 11, 14, 15, 17, and 19). The thickest coal bed measured is the Little Valley bed, which is more than 13 ft thick in SW $\frac{1}{4}$ sec. 31, T. 18 N., R. 100 W. Most of the coal beds have minor thin partings composed of either siltstone or carbonaceous shale. The only significant split was found in the Big Burn bed in NE $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 7, T. 17 N., R. 100 W., where a 8.5-ft-thick lens of sandstone divides the bed into 6.8- and 0.8-ft-thick segments.

RESOURCES

Coal resources were computed for the Bluff, Little Valley, Hail, Big Burn, and Leaf beds, and for five unnamed coal beds having little lateral extent that are 2.5 ft or more thick, including partings. The resources are listed by geographic location—township, range, and section, including the parts of incomplete sections that are within the quadrangle. The resources were computed by sections rather than by townships, because the quadrangle encompasses parts of seven townships, none of which is entirely within the quadrangle. Basic reporting categories are (1) reliability of data (measured and indicated, and inferred), (2) overburden (0–1,000 ft, 1,000–2,000 ft, and 2,000–3,000 ft), and (3) thickness (2.5–5.0 ft, 5.0–10.0 ft, and more than 10.0 ft). The combined measured and indicated categories include coal within 1.5 miles of measured outcrops. The inferred category includes data from geophysical logs of oil and gas test wells.

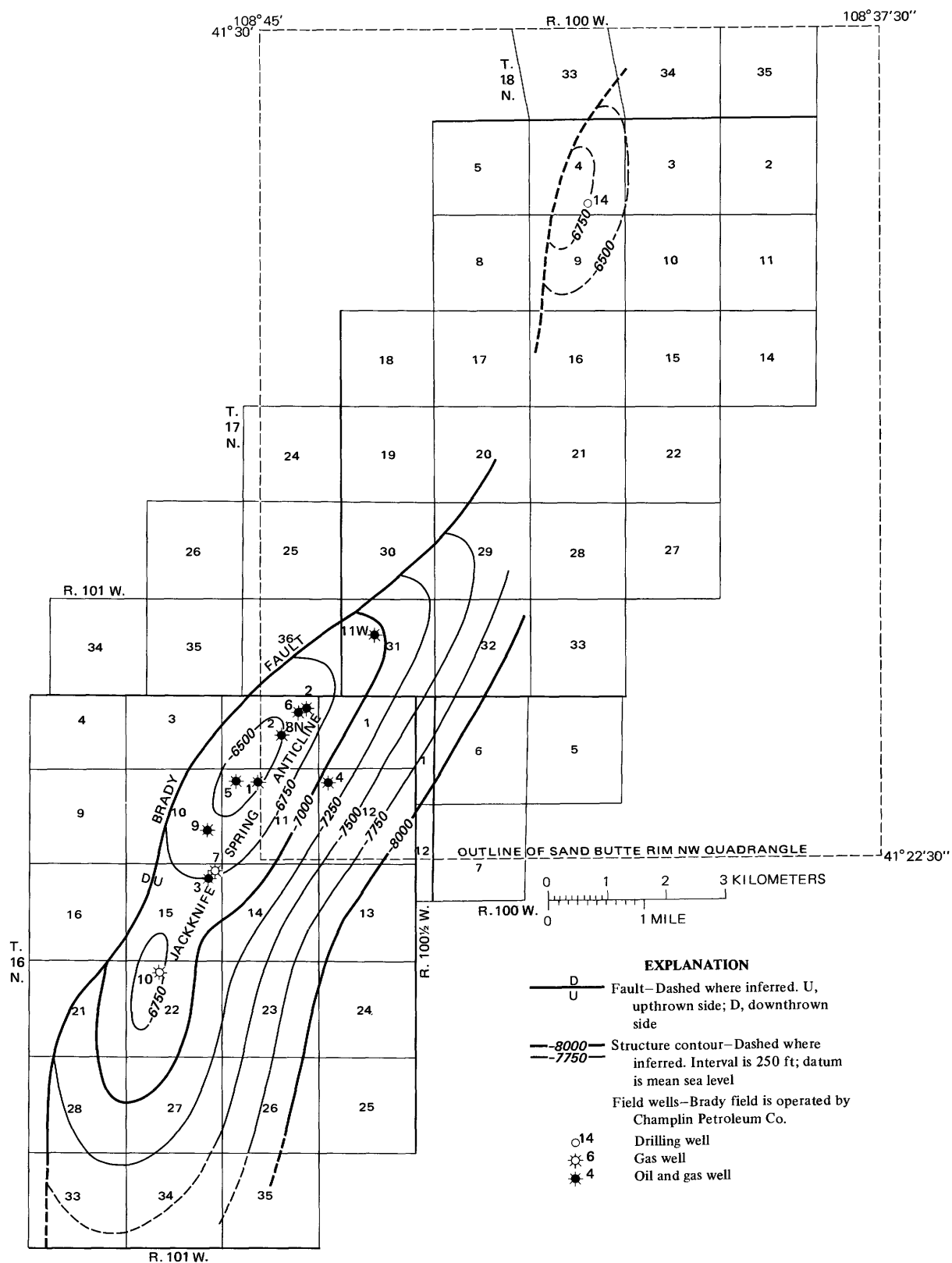


FIGURE 7.—Structure contours on the top of the Weber Sandstone at Brady field, Sweetwater County. Contours from a structure map furnished by Champlin Petroleum Co., Mountain Fuel Supply Co., and Amoco Production Co.; published with permission.

TABLE 4.—Proximate, ultimate, Btu, and sulfur analyses of coal beds in the Fort Union and Lance Formations in the Sand Butte Rim NW quadrangle
[All analyses in percent except Btu]

Sample No.-----	1			2			3			4		
	As received	Moisture free	Moisture and ash free	As received	Moisture free	Moisture and ash free	As received	Moisture free	Moisture and ash free	As received	Moisture free	Moisture and ash free
Moisture-----	27.0	--	--	27.3	--	--	26.7	--	--	30.4	--	--
Volatile matter---	32.9	45.2	50.1	31.6	43.4	53.6	29.4	40.0	46.3	28.2	40.6	47.8
Fixed Carbon-----	32.9	44.9	49.9	27.3	37.6	46.4	33.9	46.4	53.7	30.9	44.3	52.2
Ash-----	7.2	9.9	--	13.8	19.0	--	10.0	13.6	--	10.5	15.1	--
Hydrogen-----	5.4	3.3	3.7	5.5	3.3	4.1	5.2	3.0	3.4	5.4	2.9	3.5
Carbon-----	42.9	58.8	65.3	35.8	49.3	60.9	42.1	57.5	66.5	39.2	56.3	66.3
Nitrogen-----	1.3	1.8	2.0	1.1	1.5	1.8	1.2	1.7	1.9	1.1	1.5	1.8
Oxygen-----	42.6	25.4	28.1	43.3	26.2	32.3	41.1	23.6	27.5	43.6	24.0	28.1
Sulfur-----	0.6	0.8	0.9	0.5	0.7	0.9	0.4	0.6	0.7	0.2	0.2	0.3
Ash-----	7.2	9.9	--	13.8	19.0	--	10.0	13.6	--	10.5	15.1	--
Btu-----	6,590	9,030	10,020	5,530	7,610	9,390	6,380	8,710	10,080	5,920	8,510	10,020
Forms of Sulfur:												
Sulfate-----	0.05	0.07	0.08	0.02	0.03	0.04	0.03	0.05	0.05	0.00	0.00	0.00
Pyritic-----	0.03	0.05	0.05	0.07	0.10	0.12	0.08	0.10	0.12	0.05	0.07	0.08
Organic-----	0.48	0.66	0.73	0.41	0.57	0.70	0.31	0.42	0.49	0.13	0.18	0.21

SAMPLE DESCRIPTION

No.	USBM Lab. No.	USGS Lab. No.	Channel sample No.	Description
1----	K-31006	D165063	227331 (top)-----	Upper 4.3 ft of Big Burn coal bed; Fort Union Formation; Paleocene age.
2----	K-31007	D165064	227331 (bottom)---	Lower 4.2 ft of Big Burn coal bed; Fort Union Formation; Paleocene age.
3----	K-31008	D165078	287338 (top)-----	Upper 6.6 ft of Little Valley coal bed; Lance Formation; Late Cretaceous age.
4----	K-31009	D165079	287338 (bottom)---	Lower 6.6 ft of Little Valley coal bed; Lance Formation; Late Cretaceous age.

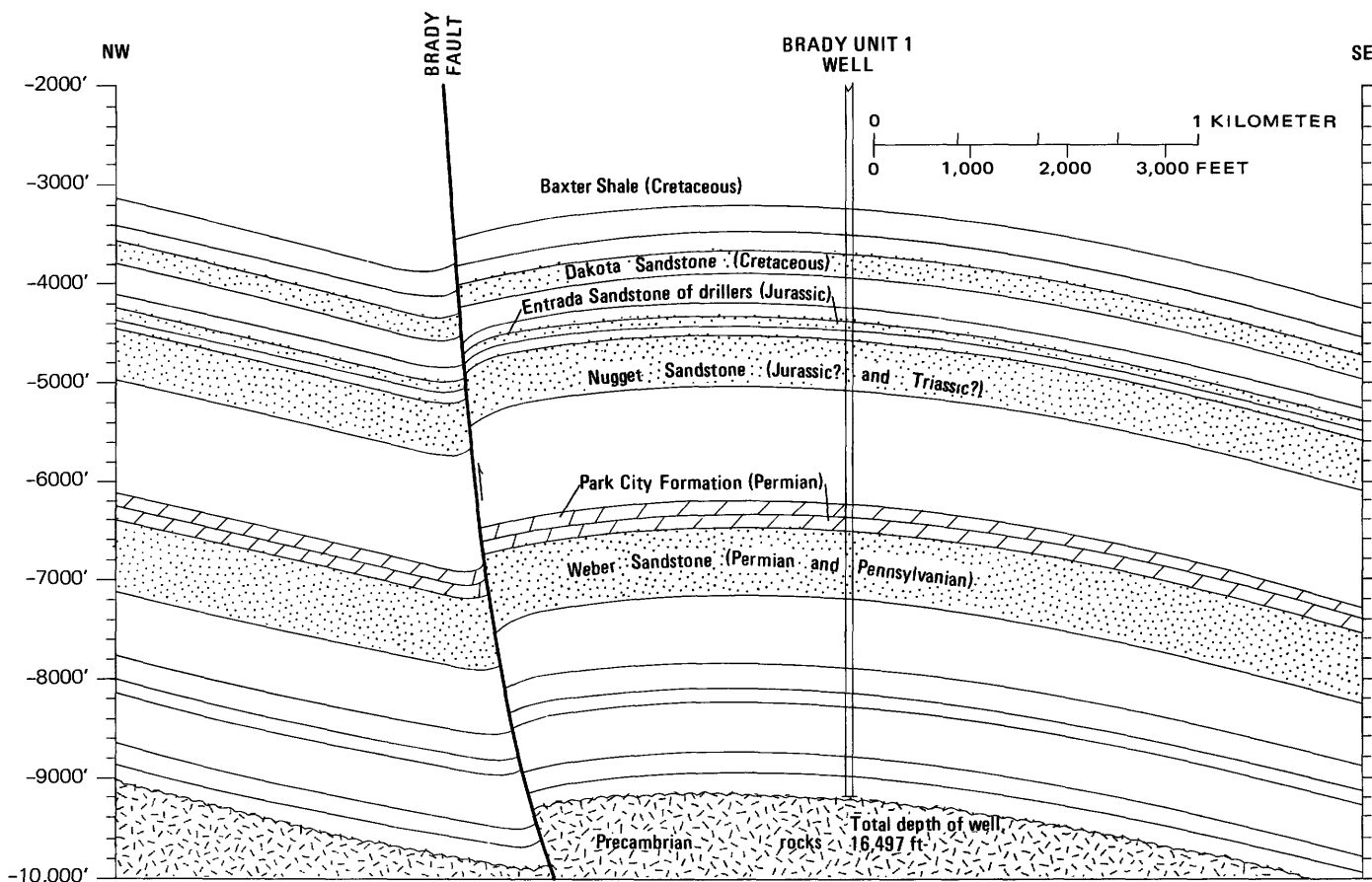


FIGURE 8.—Northwest-southeast cross section of producing formations of Paleozoic and Mesozoic age at Brady field, Sweetwater County. Cross section furnished by Champlin Petroleum Co., Mountain Fuel Supply Co., and Amoco Production Co.; published with permission.

No core-hole data were available for the resource computations.

A seven-step procedure was followed in calculating the resources of each coal bed. (1) A structure-contour map of the bed was prepared using outcrop and well elevations. (2) Overburden lines of 1,000, 2,000 and 3,000 feet were drawn by subtracting structural elevations from surface elevations. (3) The measured and indicated categories were determined by plotting a line at 1½-mile distances from measured coal outcrops. The inferred category includes the area between this line and 3,000 ft of overburden. (4) An isopach map of the bed was prepared using measured outcrop thicknesses and the thicknesses indicated on well logs (well-log thicknesses were rounded to the closest one-half foot); 2.5 feet was the minimum thickness used for isopachs. (5) A compensating polar planimeter was used to find the area in acres for the parts of each section that fall within the various reliability and overburden categories; corrections were applied to compensate for the dip of the bed. (6) A weighted average bed thickness was visually determined for each reporting category in each section by averaging maximum and minimum thicknesses, taking into account the geographic configuration of isopachs. (7) Coal resources were calculated for each reporting category in each section using an assumed average weight for the coal of 1,770 short tons/acre rounded to the closest 1,000 tons and recorded in millions of tons on tables of resources for the bed.

The cumulative original coal resources, by thickness categories as shown in table 5, were compiled from the data shown in figures 10, 12, 13, 16, 18, and 20.

UNNAMED BEDS HAVING LITTLE LATERAL EXTENT

The six unnamed coal beds that are present in the Lance and Fort Union Formations along the west margin of the quadrangle are lenticular, have doubtful economic value, and are included as resources only because they are more than 2.5 ft thick (figs. 9, 10). The combined resources of these beds are slightly more than 3 million short tons, less than 1 percent of the total for the quadrangle.

BLUFF BED

The Bluff coal bed is more than 5.0 ft thick in a 1.5–2.5-mi-wide area in the subsurface that trends northeast across the northwest part of the quadrangle (figs. 11, 12). This thickening and other thickness irregularities are attributed to deposition of organic material in a lagoon northwest of a barrier bar along a Late Cretaceous marine shoreline. The Bluff bed grades laterally into barrier-bar sandstone which in turn grades laterally into marine shale in a southeastward direction across the

quadrangle. The intertonguing of these continental and marine rocks is shown in figure 5.

The Bluff bed is composed of clean bright coal; one minor parting, 0.3 ft thick, was observed near the middle of the bed in outcrops near the northern edge of the quadrangle in sec. 31, T. 18 N., R. 100 W. (stratigraphic section 2773, fig. 11). The estimated original resources of the Bluff bed are nearly 170 million tons.

LITTLE VALLEY BED

The Little Valley bed may have been deposited in a swamp northeast of a topographic rise in the central western part of the quadrangle area. This paleogeographic relationship is suggested by the fact that the Little Valley bed thins and wedges out to the southwest across the northeast part of the quadrangle; it is missing in the Mountain Fuel Supply Co. Homestead 2 dry hole in sec. 19, T. 17 N., R. 100 W. (fig. 13).

The Little Valley bed is more than 13 ft thick in the southwest part of sec. 31, T. 18 N., R. 100 W.; it appears to thicken northeast of that locality and behind burned outcrops it is probably more than 15 ft thick near the northeast corner of sec. 31, T. 18 N., R. 100 W. (fig. 13). Where the bed is less than 7.4 ft thick, it has no partings (fig. 14). Where it is more than 7.4 ft thick, partings appear in the upper part of the bed. This relationship suggests that the bed thickens by the addition of the coal section at the top.

The estimated original resources for the Little Valley bed in the Sand Butte Rim NW quadrangle are more than 170 million tons. Measured and indicated resources of more than 13.5 million tons for the bed in sec. 32, T. 18 N., R. 100 W., are the largest for any bed in one section of the quadrangle.

HAIL BED

The Hail bed ranges in thickness from 3.9 to 5.1 feet in outcrops (fig. 15). It thickens to the southwest in a U-shaped area that is open to the northwest, in the southwest part of the quadrangle (fig. 16). The paleogeography is unclear, but the bed may have been deposited in the southeast part of a large swamp.

The bed is composed of bright coal. Partings were observed where the coal was measured in outcrops in secs. 5 and 7, T. 17 N., R. 100 W. (fig. 15). The original resources for the Hail bed are estimated at nearly 110 million tons.

BIG BURN BED

The Big Burn bed is easily recognized in burned outcrops that weather bright orange red in sec. 7, T. 17 N., R. 100 W., and in sec. 33, T. 18 N., R. 100 W. (fig. 2). Where the bed is not burned, it weathers to drab-gray sparsely vegetated slopes. The bed is present everywhere in the quadrangle except in the northwest corner where it is

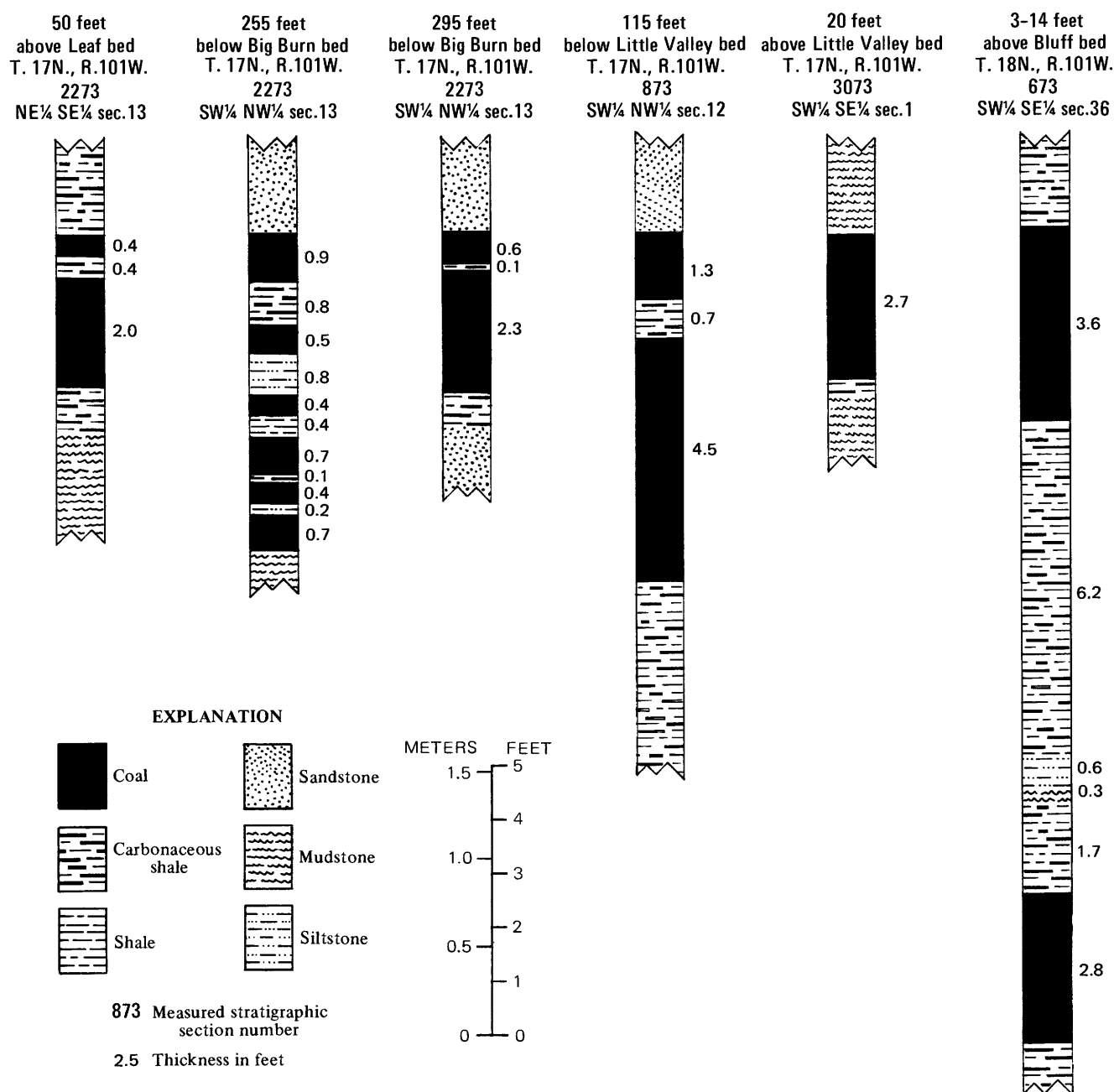


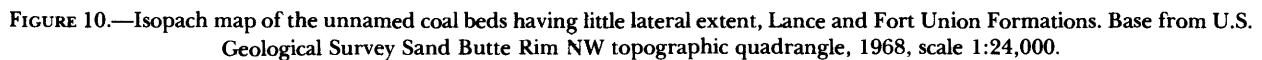
FIGURE 9.—Graphic sections of unnamed coal beds having little lateral extent in the Lance and Fort Union Formations, Sand Butte Rim NW quadrangle.

eroded. It is less than 2.5 ft thick along the southern edge of the quadrangle, but it thickens irregularly northward and is inferred to be more than 9 ft thick in secs. 33 and 34, T. 18 N., R. 100 W. (figs. 17, 18). It has a very thin but persistent shale and siltstone parting in the upper 1 ft, and is locally split by an 8.5 ft-thick sandstone lens in sec. 7, T. 17 N., R. 100 W. The coal is usually underlain by dull-black carbonaceous shale or carbonaceous claystone. Original coal resources are estimated at nearly 245 mil-

lion tons, about one third of the total calculated for the quadrangle.

LEAF BED

The Leaf bed is the youngest coal bed of economic importance that crops out in the Sand Butte Rim NW quadrangle. The bed is more than 4 ft thick in the north-central part of the quadrangle, but it thins greatly southward and is less than 2.5 ft thick in the subsurface in the



Original coal resources of unnamed coal beds, overburden thickness 0-1,000 feet, having little lateral extent

Location			Strati- graphic section (fig. 9)	Unnamed local bed	Measured and indicated reserves		Total coal reserves	
(T.)	(R.)	(sec.)			Bed thickness (weighted avg. in ft)	Coal reserves (million tons)	(million tons) For section	For township
18 N.	101 W.	36	673	14 ft (4.3 m) above Bluff bed-----	3.0	0.263	0.263	0.263
				3 ft (0.9 m) above Bluff bed-----	2.7	.140	.140	.140
17 N.	101 W.	1	3073	20 ft (0.6 m) above Little Valley bed----	2.6	.101	.101	.101
		12	2273	255 ft (68.6 m) below Big Burn bed-----	2.5	.158	.158	
		13		----do-----	3.0	2.037	2.307	
		24		----do-----	2.7	.434	.434	2.899
		13		295 ft (89.9 m) below Big Burn bed-----	2.8	.073	.073	.073

southern half of the quadrangle (figs. 19, 20). The bed is composed of bright coal, but it has carbonaceous shale partings in the upper and lower parts (fig. 19). Original resources totaled more than 75 million tons.

UNMAPPED SUBSURFACE COAL BEDS MORE THAN 2.5 FEET THICK

ALMOND COAL GROUP (ALMOND FORMATION)

The Almond coal group does not crop out within the Sand Butte Rim NW quadrangle, but outcrops are present west of the quadrangle within 1 mi of the northwest corner. At the northwest corner the Almond coal group is under less than 600 ft of overburden; the northwest one-third of the quadrangle has overburden of less than 3,000 ft.

No reliable resource data are available on coal beds in the Almond coal group within the quadrangle. Schultz (1910, p. 231) measured seven sections of Almond coal that range in thickness from 3 ft 10 in. to 5 ft 1 in. in secs. 8, 9, and 17, T. 17 N., R. 101 W., a few miles west of the quadrangle. Resistivity curves on electric logs of oil and gas wells drilled in the quadrangle suggest that many of the beds that he measured are present in the subsurface across the quadrangle (see coal-bearing section, Almond Formation, fig. 4). Using a conservative cumulative thickness of 10 ft for at least four beds in the 2.5-5.0-ft-thick category and overburden thickness of as much as 3,000 ft, inferred resources for coal beds in the Almond coal group are about 168 million tons (table 6).

BLACK BUTTES (FORT UNION FORMATION) AND BLACK ROCK COAL GROUPS (LANCE FORMATION)

Resistivity curves on electric logs of oil and gas drill holes indicate that several coal beds that do not crop out are present in the eastern and southern parts of the quadrangle. Two of the beds are worthy of mention, as they have thicknesses of as much as 10 ft. The lowermost bed, about 220 ft above the base of the Fort Union Formation, at 1,332 ft depth in the Chandler and Simpson Chorney State 2 drill hole in sec. 36, T. 18 N., R. 100 W., is about 7 ft thick on electric logs. It correlates with similar

beds at 1,523 ft in the Skelly Oil Co. Wyo. 1-D drill hole in sec. 16, T. 17 N., R. 100 W., at 1,223 ft in the Mountain Fuel Supply Co. Homestead 2 drill hole in sec. 19, T. 17 N., R. 101 W., and at 3,805 ft in the Skelly Oil Co. Antelope 1-B drill hole in sec. 26, T. 17 N., R. 100 W. The upper bed, about 315 ft above the base of the Fort Union Formation, at 1,235 ft in the Chandler and Simpson Chorney State 2 drill hole, is about 10 ft thick. It correlates with a similar bed at 3,712 ft in the Skelly Oil Co. Antelope 1-B drill hole. The depths of these and other unmapped coal beds found in drill holes are listed in table 7.

The coal beds indicated on electric logs are not included in the coal resources for the Sand Butte Rim NW quadrangle because drill-sample and core-hole data are lacking. These beds could add 200 million tons to the calculated minable resources.

GEOCHEMICAL ANALYSES

Thirty-six channel samples were collected from outcrops and analyzed to determine their geochemical composition. The beds sampled and the number of samples analyzed are as follows: Leaf bed, 4; Big Burn bed, 9; Hail bed, 2; Washout bed, 3; Little Valley bed, 6; Bluff bed, 2; and unnamed beds having little lateral extent, 10. The geographical locations of the sample sites are listed on tables 7, 8, 9 and 10. The stratigraphic positions of the samples are shown on plate 1. Five analytical methods were used: (1) proximate, ultimate, Btu, and sulfur of the coal as received, table 4; (2) neutron activation of uranium and thorium of the coal as received, table 8; (3) X-ray fluorescence on coal ash, table 9; (4) semi-quantitative spectrographic analysis of coal ash, table 10; and (5) quantitative chemical analysis of the coal as received and of the ash, table 11. The analyses indicate the coal has a low sulfur content (consistently less than 1 percent) and fairly good heating value (table 3). The analyses, unfortunately, can be used for neither the identification nor the stratigraphic correlation of coal beds because the geochemistry is variable and does not distinguish one bed from another.

GEOLOGY OF THE SOUTHEAST PART OF THE ROCK SPRINGS UPLIFT, WYOMING

TABLE 5.—Cumulative original coal resources in millions of tons by thickness categories and geographical location, in the Sand Butte Rim NW quadrangle
[Leaders (- - -), none]

Overburden thickness (in ft)----- Beds (thickness in ft)-----		Measured and indicated resources			Inferred resources									Total coal reserves Township
		10-1,000			0-1,000			1,000-2,000			2,000-3,000			
		2.5- 5.0	5.0- 10.0	More than 10.0	2.5- 5.0	5.0- 10.0	More than 10.0	2.5- 5.0	5.0- 10.0	More than 10.0	2.5- 5.0	5.0- 10.0	More than 10.0	
T. 18 N., R. 100 W.														
Sec.	31	4.744	--	7.269	--	--	--	--	--	--	--	--	--	144.216
	32	.106	5.159	13.589	--	0.262	--	--	0.455	--	--	--	--	
	33	4.273	5.081	6.743	--	.834	2.636	--	4.698	3.672	--	--	--	
	34	7.815	10.339	--	--	--	.023	--	6.414	12.486	--	--	--	
	35	3.391	5.207	--	0.119	--	--	1.421	16.284	--	--	3.908	--	
	36	.130	--	--	--	--	--	2.591	7.085	--	3.143	4.339	--	
T. 18 N., R. 101 W.														
Sec.	36	1.112	--	0.002	--	--	--	--	--	--	--	--	--	1.114
T. 17 N., R. 100 W.														
Sec.	1	--	--	--	--	--	--	2.368	5.178	--	2.829	6.062	--	527.774
	2	0.068	0.109	--	--	--	--	4.589	12.815	--	5.277	5.363	--	
	3	3.644	6.424	--	0.175	0.305	--	1.367	17.184	--	--	.863	--	
	4	8.462	8.884	0.026	--	1.095	--	--	14.734	--	--	--	--	
	5	5.876	12.019	--	--	2.386	--	--	5.195	--	--	--	--	
	6	4.279	10.512	--	--	--	--	--	.215	--	--	--	--	
	7	6.940	5.119	--	.361	--	--	3.946	--	--	--	--	--	
	8	9.546	7.990	--	--	2.401	--	2.864	5.949	--	--	--	--	
	9	5.647	6.343	--	.014	.618	--	.889	13.280	--	--	.199	--	
	10	.224	.222	--	.119	.244	--	4.410	13.805	--	4.256	2.460	--	
	11	--	--	--	--	--	--	3.440	7.384	--	4.631	8.041	--	
	12	--	--	--	--	--	--	.343	.735	--	2.880	8.089	--	
	13	--	--	--	--	--	--	--	--	--	.419	4.959	--	
	14	--	--	--	--	--	--	.411	1.020	--	5.808	7.264	--	
	15	--	--	--	--	--	--	3.166	6.459	--	8.736	.749	--	
	16	.831	.624	--	--	.521	--	6.778	8.231	--	3.884	--	--	
	17	7.327	7.021	--	.060	.101	--	2.353	6.587	--	--	--	--	
	18	3.611	13.579	--	--	--	--	--	5.759	--	--	--	--	
	19	.791	12.156	--	--	.423	--	--	7.152	--	--	--	--	
	20	.777	1.713	--	.082	--	--	4.813	9.319	--	1.321	--	--	
	21	--	--	--	--	--	--	1.098	5.842	--	5.240	--	--	
	22	--	--	--	--	--	--	.127	1.326	--	7.554	--	--	
	23	--	--	--	--	--	--	--	--	--	--	4.198	--	
	26	--	--	--	--	--	--	--	--	--	.029	--	--	
	27	--	--	--	--	--	--	--	--	--	3.839	--	--	
	28	--	--	--	--	--	--	3.895	--	--	2.501	--	--	
	29	--	--	--	--	--	--	8.964	5.695	--	2.942	--	--	
	30	--	2.001	--	.176	.154	--	8.485	6.397	--	.735	--	--	
	31	--	--	--	.028	--	--	5.073	7.227	--	.993	--	--	
	32	--	--	--	--	--	--	3.787	5.226	--	1.247	--	--	
	33	--	--	--	--	--	--	.588	--	--	4.895	--	--	
	34	--	--	--	--	--	--	--	--	--	1.015	--	--	
T. 17 N., R. 101 W.														
Sec.	1	3.440	3.642	--	--	--	--	--	--	--	--	--	--	69.875
	12	4.728	--	--	0.195	--	--	0.182	--	--	--	--	--	
	13	2.456	5.359	--	1.076	--	--	2.944	--	--	--	--	--	
	24	.502	11.788	--	--	--	--	--	4.946	--	--	--	--	
	25	4.390	5.012	--	.321	0.533	--	--	5.468	--	--	--	--	
	36	.644	.410	--	2.033	2.269	--	4.072	3.465	--	--	--	--	
T. 16 N., R. 100 W.														
Sec.	4	--	--	--	--	--	--	--	--	--	0.020	--	--	9.559
	5	--	--	--	--	--	--	--	--	--	2.642	--	--	
	6	--	--	--	--	--	--	2.768	--	--	3.807	--	--	
	7	--	--	--	--	--	--	.088	--	--	.233	--	--	
	8	--	--	--	--	--	--	--	--	--	.001	--	--	
T. 16 N., R. 100½ W.														
Sec.	1	--	--	--	--	--	--	1.523	--	--	--	--	--	1.574
	12	--	--	--	--	--	--	.051	--	--	--	--	--	
T. 16 N., R. 101 W.														
	1	--	--	--	--	--	--	1.406	4.623	--	--	--	--	10.766
	2	--	--	--	0.633	--	--	2.787	--	--	--	--	--	
	11	--	--	--	--	--	--	.141	--	--	--	--	--	
	12	--	--	--	--	--	--	1.176	--	--	--	--	--	
Total		95.754	146.713	27.629	5.392	12.146	2.659	94.904	226.152	16.158	80.877	56.494	--	764.878

¹ Small insignificant areas on the map have overburden exceeding 1,000 ft.

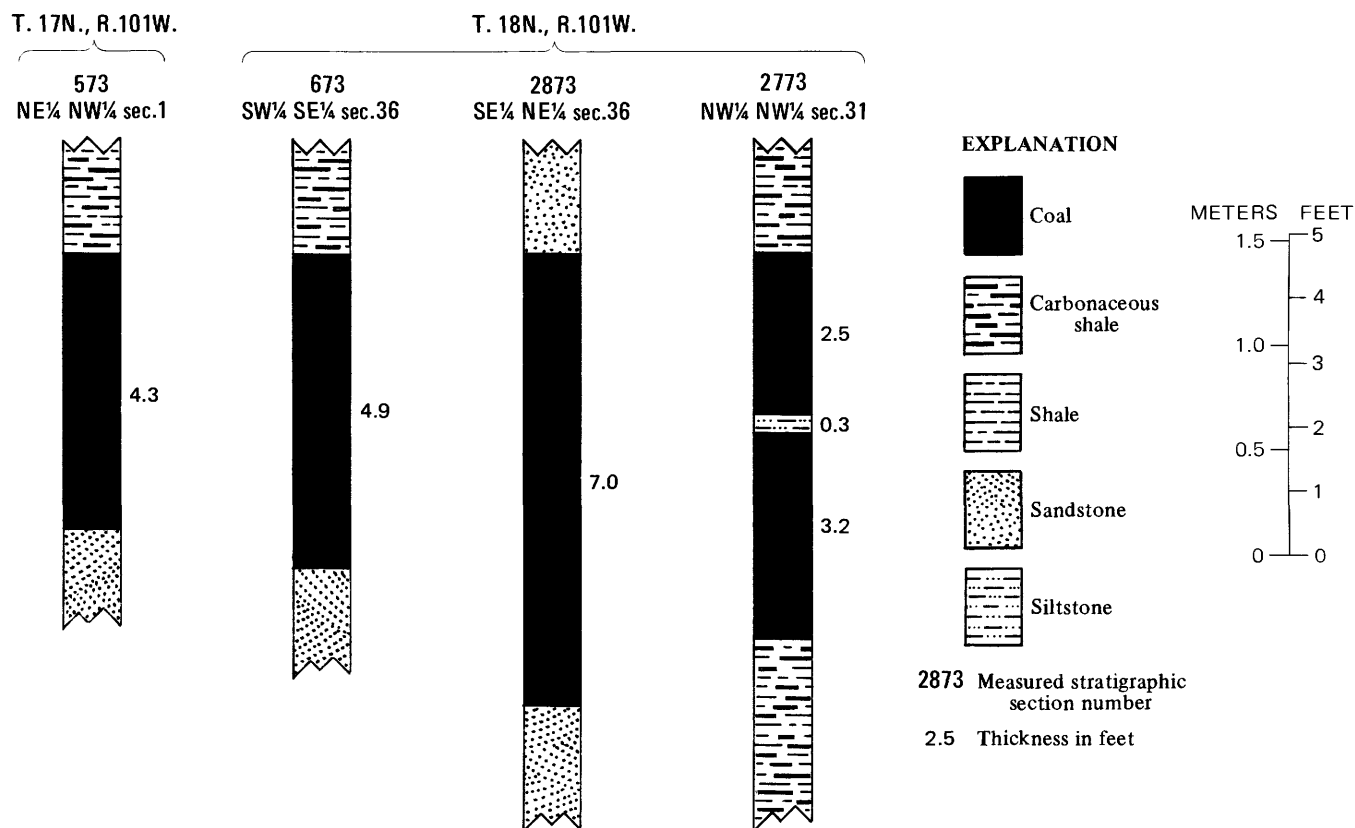


FIGURE 11.—Graphic sections of the Bluff coal bed in the Lance Formation, Sand Butte Rim NW quadrangle.

The range and average amounts of trace elements (about 0.1 percent or less, in ash) and minor elements (about 1 percent or more, in ash) in coal beds in the quadrangle are listed in table 12. The 35 elements listed are generally present in normal amounts, with a few exceptions. Arsenic, antimony, barium, cadmium, copper, mercury, nickel, selenium, strontium, thorium, uranium, and vanadium are present in amounts larger than the average for crustal rocks and for coals in the western United States. Arsenic, cadmium, copper, mercury, nickel, and selenium have been classified as toxic (Wood, 1974, table 1), but it is doubtful that they are present in quantities large enough to become air or water pollutants as a result of coal mining.

OIL AND GAS

Eighteen oil and gas test wells have been drilled in the Sand Butte Rim NW quadrangle since the first wildcat well was drilled in 1959. Drill-hole data are shown in table 13. Of the 18 holes drilled, two are commercial gas wells and four are commercial oil and gas wells. Gas is produced from the western part of the Antelope field near the eastern edge of the quadrangle, and gas and oil are produced from the northern part of the Brady field

which extends from the southwest corner in a northeast direction across the central part of the quadrangle. Production at these fields is from structural and stratigraphic traps in formations of Mesozoic and Paleozoic age at depths ranging from 5,900 to 14,300 ft.

ANTELOPE FIELD

Antelope field is operated by the Amoco Production Co. Production from eight wells in 1972 was 2,542,417 MCF of natural gas and 1,470 bbl of 41.7-gravity oil (Wyoming Geological Association, 1973, p. 18). Only the two westernmost wells in the field are in the Sand Butte Rim NW quadrangle. The field produces from stratigraphic traps formed by the westward updip wedging out of marine and littoral sandstones at the top of the Almond Formation. The sandstones were deposited by a Late Cretaceous transgressive sea that moved westward across the area. They intertongue with marine shale that composes the Lewis Shale and with paludal and lagoonal shales and carbonaceous shale that compose the Almond Formation.

The structure at the west edge of Antelope field is homoclinal—strata dip uniformly 8°–9° southeast on the east flank of the Rock Springs uplift. Structure contours

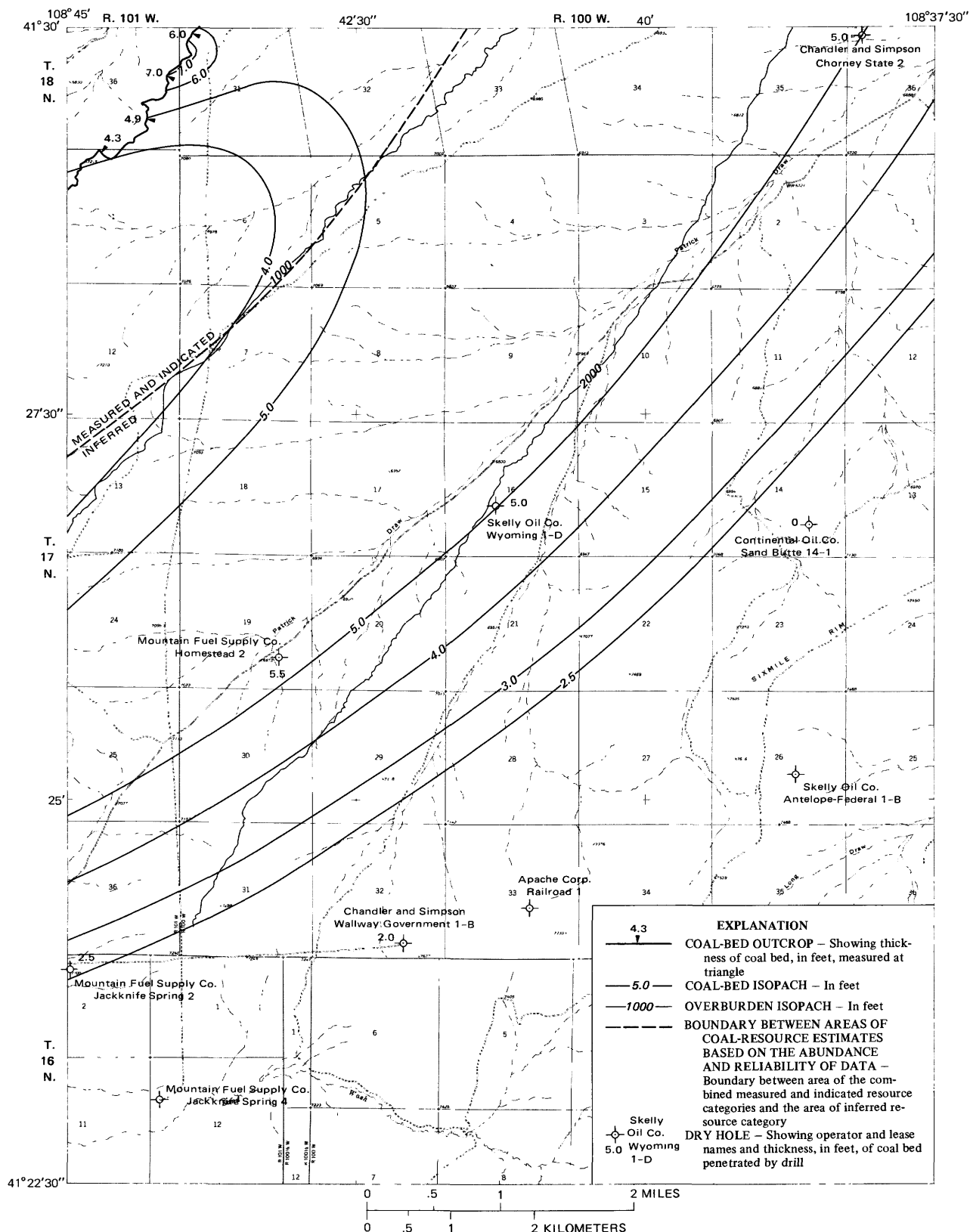


FIGURE 12.—Isopach map of the Bluff coal bed, Lance Formation, showing thickness of overburden. Base from U.S. Geological Survey Sand Butte Rim NW topographic quadrangle, 1968, scale 1:24,000.

Original coal resources of the Bluff coal bed
[Leaders (- - -), no resources for that category]

Overburden thickness (in ft)-----		Measured and indicated resources		Inferred resources						Total coal reserves (million tons) For section For township	
		1		0-1,000		1,000-2,000		2,000-3,000			
		0-1,000		0-1,000		1,000-2,000		2,000-3,000			
		Bed thickness (weighted avg. in ft)	Coal reserves (million tons)	Bed thickness (weighted avg. in ft)	Coal reserves (million tons)	Bed thickness (weighted avg. in ft)	Coal reserves (million tons)	Bed thickness (weighted avg. in ft)	Coal reserves (million tons)		
T. 18 N., R. 100 W.											
Sec.	31	4.9	4.744	--	--	--	--	--	--	4.744	
	32	3.3	5.080	5.2	0.262	5.2	0.455	--	--	5.797	
	33	5.5	.457	5.5	.834	5.5	4.698	--	--	5.989	
	34	--	--	--	--	5.4	6.414	--	--	6.414	
	35	--	--	--	--	5.1	2.042	5.1	3.568	5.610	
	36	--	--	--	--	--	--	4.4	3.143	3.143	31.697
T. 18 N., R. 101 W.											
Sec.	36	4.9	0.709	--	--	--	--	--	--	0.709	0.709
T. 17 N., R. 100 W.											
Sec.	1	--	--	--	--	--	--	3.5	2.648	2.648	
	2	--	--	--	--	5.1	0.075	4.6	5.277	5.352	
	3	--	--	--	--	5.3	5.131	5.1	.863	5.994	
	4	--	--	--	--	5.4	6.151	--	--	6.151	
	5	4.6	1.010	--	--	5.1	4.689	--	--	5.699	
	6	4.0	4.198	--	--	4.4	.215	--	--	4.413	
	7	3.8	1.020	4.0	0.085	4.7	3.946	--	--	5.051	
	8	--	--	--	--	5.2	5.949	--	--	5.949	
	9	--	--	--	--	5.2	5.779	5.1	.199	5.978	
	10	--	--	--	--	5.1	1.352	4.8	4.256	5.608	
	11	--	--	--	--	--	--	3.7	4.184	4.184	
	12	--	--	--	--	--	--	3.0	1.025	1.025	
	14	--	--	--	--	--	--	3.0	1.367	1.367	
	15	--	--	--	--	--	--	3.8	4.328	4.328	
	16	--	--	--	--	5.1	2.373	4.7	3.181	5.554	
	17	--	--	--	--	5.2	5.991	--	--	5.991	
	18	--	--	--	--	5.1	5.759	--	--	5.759	
	19	--	--	--	--	5.1	5.809	--	--	5.809	
	20	--	--	--	--	5.0	4.190	4.1	1.321	5.511	
	21	--	--	--	--	4.9	.048	3.5	3.929	3.977	
	22	--	--	--	--	--	--	3.0	1.338	1.338	
	28	--	--	--	--	--	--	2.8	.729	.729	
	29	--	--	--	--	4.4	3.434	3.2	2.942	6.376	
	30	--	--	--	--	4.5	4.203	3.5	.735	4.938	
	31	--	--	--	--	3.3	.859	2.8	.993	1.852	
	32	--	--	--	--	--	--	2.7	.158	.158	111.739
T. 17 N., R. 101 W.											
Sec.	1	3.6	3.339	--	--	--	--	--	--	3.339	
	12	3.7	3.263	4.0	0.195	4.0	0.182	--	--	3.640	
	13	3.7	.241	3.8	1.076	4.7	2.944	--	--	4.261	
	24	--	--	--	--	5.1	4.946	--	--	4.946	
	25	--	--	--	--	5.1	4.996	--	--	4.996	
	36	--	--	--	--	3.5	3.207	--	--	3.207	24.389
T. 16 N., R. 101 W.											
Sec.	2	--	--	--	--	2.6	0.093	--	--	0.093	0.093

1

Small insignificant areas on the map in this category have overburden exceeding 1,000 feet.

on the W marker, an electric-log horizon in the Lewis Shale (fig. 3), which is about 275 ft above the producing zones in the Almond, are shown in figure 21. Stratigraphic relations are shown by Roehler (1977, section A-A').

BRADY FIELD

Brady field is operated by the Champlin Petroleum Co., a subsidiary of the Union Pacific Railroad. Champlin Petroleum Co. and Mountain Fuel Supply Co. each own a 41.25 percent interest and Amoco Production Co. a 17.5

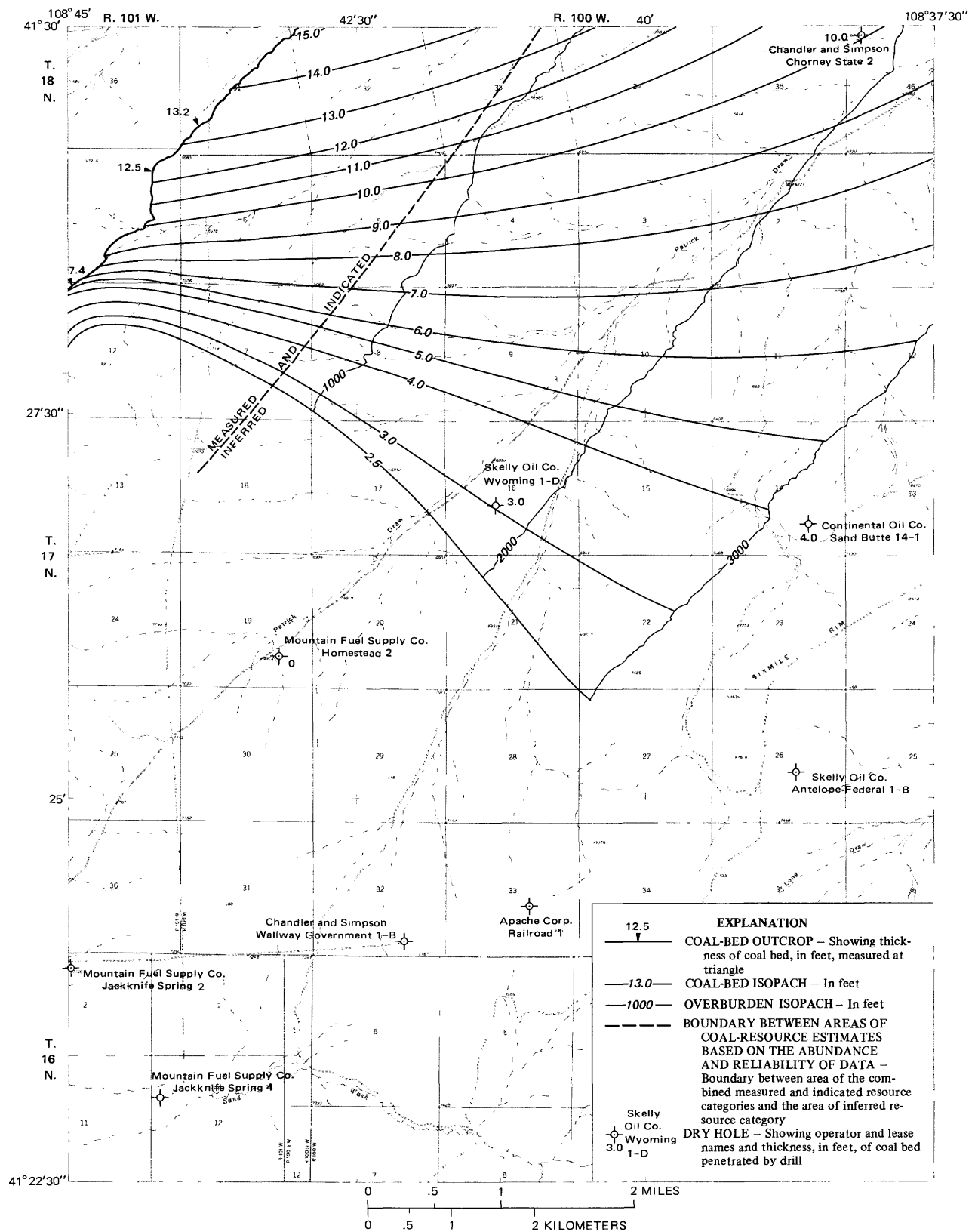


FIGURE 13.—Isopach map of the Little Valley coal bed, Fort Union Formation, showing thickness of overburden. Base from U.S. Geological Survey Sand Butte Rim NW topographic quadrangle, 1968, scale 1:24,000.

Original coal resources of the Little Valley coal bed

[Leaders (- - -), no resources for that category]

Overburden thickness (in ft)---		Measured indicated resources		Inferred resources								Total coal resources (million tons) For sectionFor township	
		0-1,000		0-1,000		1,000-2,000		2,000-3,000					
		Bed thickness (weighted avg. in ft)	Coal reserves (million tons)	Bed thickness (weighted avg. in ft)	Coal reserves (million tons)	Bed thickness (weighted avg. in ft)	Coal reserves (million tons)	Bed thickness (weighted avg. in ft)	Coal reserves (million tons)				
T. 18 N., R. 100 W.													
Sec.	31	13.4	7.269	--	--	--	--	--	--	7.269			
	32	13.2	13.589	--	--	--	--	--	--	13.589			
	33	13.2	6.743	12.2	2.636	10.8	3.672	--	--	13.051			
	34	--	--	13.2	.023	10.9	12.486	--	--	12.509			
	35	--	--	--	--	9.9	10.841	8.7	0.340	11.181			
	36	--	--	--	--	9.8	2.073	8.8	4.339	6.412	64.011		
T. 18 N., R. 101 W.													
Sec.	36	13.9	0.002	--	--	--	--	--	--	0.002	0.002		
T. 17 N., R. 100 W.													
Sec.	1	--	--	--	--	--	--	7.4	5.611	5.611			
	2	--	--	--	--	8.6	3.932	7.7	5.363	9.295			
	3	--	--	--	--	8.2	9.328	--	--	9.328			
	4	10.6	0.026	9.7	1.095	8.4	8.583	--	--	9.704			
	5	9.3	7.496	8.1	2.386	7.4	.506	--	--	10.388			
	6	9.7	10.512	--	--	--	--	--	--	10.512			
	7	4.4	2.799	3.2	.276	--	--	--	--	3.075			
	8	6.3	.497	6.5	2.401	4.0	2.864	--	--	5.762			
	9	--	--	--	--	5.4	6.195	--	--	6.195			
	10	--	--	--	--	6.2	4.398	5.6	2.460	6.858			
	11	--	--	--	--	--	--	6.0	6.854	6.854			
	12	--	--	--	--	--	--	6.2	3.219	3.219			
	13	--	--	--	--	--	--	5.3	.004	.004			
	14	--	--	--	--	--	--	4.5	2.930	2.930			
	15	--	--	--	--	4.3	.154	3.7	4.112	4.266			
	16	--	--	--	--	3.4	3.087	3.2	.703	3.790			
	17	--	--	--	--	2.9	1.085	--	--	1.085			
	21	--	--	--	--	2.6	.064	2.7	1.239	1.303			
	22	--	--	--	--	--	--	2.9	2.095	2.095			
	27	--	--	--	--	--	--	2.5	.002	.002	102.276		
T. 17 N., R. 101 W.													
Sec.	1	9.0	3.642	--	--	--	--	--	--	3.642			
	12	4.0	1.307	--	--	--	--	--	--	1.307	4.949		

percent interest in Brady unit, which embraces 39,012 acres in parts of Tps. 15, 16, 17, and 18 N., Rs. 100, 100½, and 101 W. The overall length of Brady field, established by current drilling, is more than 10 mi; the width is unknown, but it is probably less than 3 mi. The northeast half of the field is in the Sand Butte Rim NW quadrangle. Hydrocarbons are structurally trapped. The Blair and Dakota Formations, a Jurassic sandstone (Entrada of drillers), Nugget, Park City, and Weber Formations are capable of sustained oil and gas production.

Jackknife Spring gas field (now Brady field) was discovered in 1960, but no gas was produced there until 1972 when a pipeline was completed that joined the Mountain Fuel Supply Co. gas-pipeline system at the

South Baxter Basin field, 18 mi west of the field. Gas production from two wells completed in the Blair Formation totaled 310,804 MCF in 1972 (Wyoming Geological Association, 1973, p. 17).

The Brady 1 discovery well, drilled in 1972 in sec 11, T. 16 N., R. 101 W., was completed in the Weber Sandstone with an initial production potential of 3,818 MCF of gas and 976 bbl of condensate per day. The Brady 2 well, drilled a year later in sec. 2, T. 16 N., R. 101 W., was completed in the Weber with an initial production potential of 14,000 MCF of gas and 3,345 bbl of condensate per day. The Brady 8N well, also in sec. 2, T. 16 N., R. 101 W., was completed in the Nugget Sandstone in 1973 with an initial production potential of 1,126 bbl of

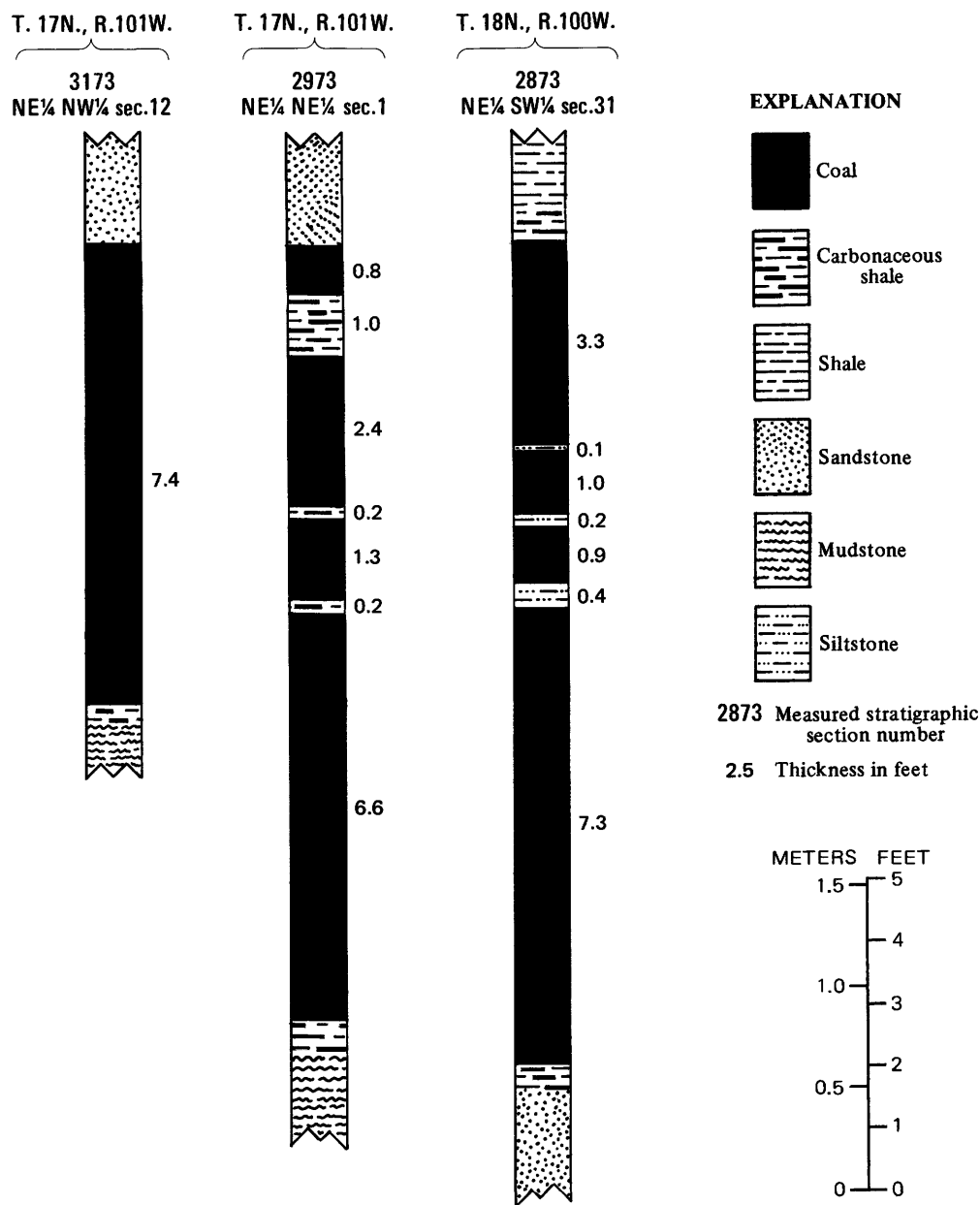


FIGURE 14.—Graphic sections of the Little Valley coal bed in the Fort Union Formation, Sand Butte Rim NW quadrangle.

oil and 1,167 MCF of gas per day. By the end of 1973 Brady field had eight wells producing or capable of producing gas and oil from the Dakota, Nugget, and Weber Sandstones. The Odessa Natural Gas Pipeline Co. has recently (about 1974) completed an oil pipeline that ties the Brady field to the service pipeline system about 15 mi north of the field.

The discovery of commercial quantities of oil and gas in the Entrada Sandstone of drillers and the Nugget Sandstone in the Brady 14 well in sec. 4, T. 17 N., R. 100 W., in April and May 1974, extended the Brady field 5 miles northeast of previously established production.

Forty-six feet of the Entrada of drillers there are productive. Perforations from 11,622 to 11,668 feet tested 14,000 MCF/day of gas. The gas has a heating value of 736 Btu/ft³. It is 39 percent inert and contains 15 ppm hydrogen sulfide. About 100 feet of the Nugget Sandstone is productive. A drill-stem test of the Nugget from 11,751 to 11,762 feet produced 52 gravity oil at the rate of 1,080 bbl/day and 3,200 MCF/day of gas. The gas is 69 percent inert, and the inert part is 68 percent carbon dioxide and 0.06 percent hydrogen sulfide. The top of the Nugget in the Brady 14 well is nearly 250 feet structurally lower than the Brady 8N well in sec. 2, T. 16 N.,

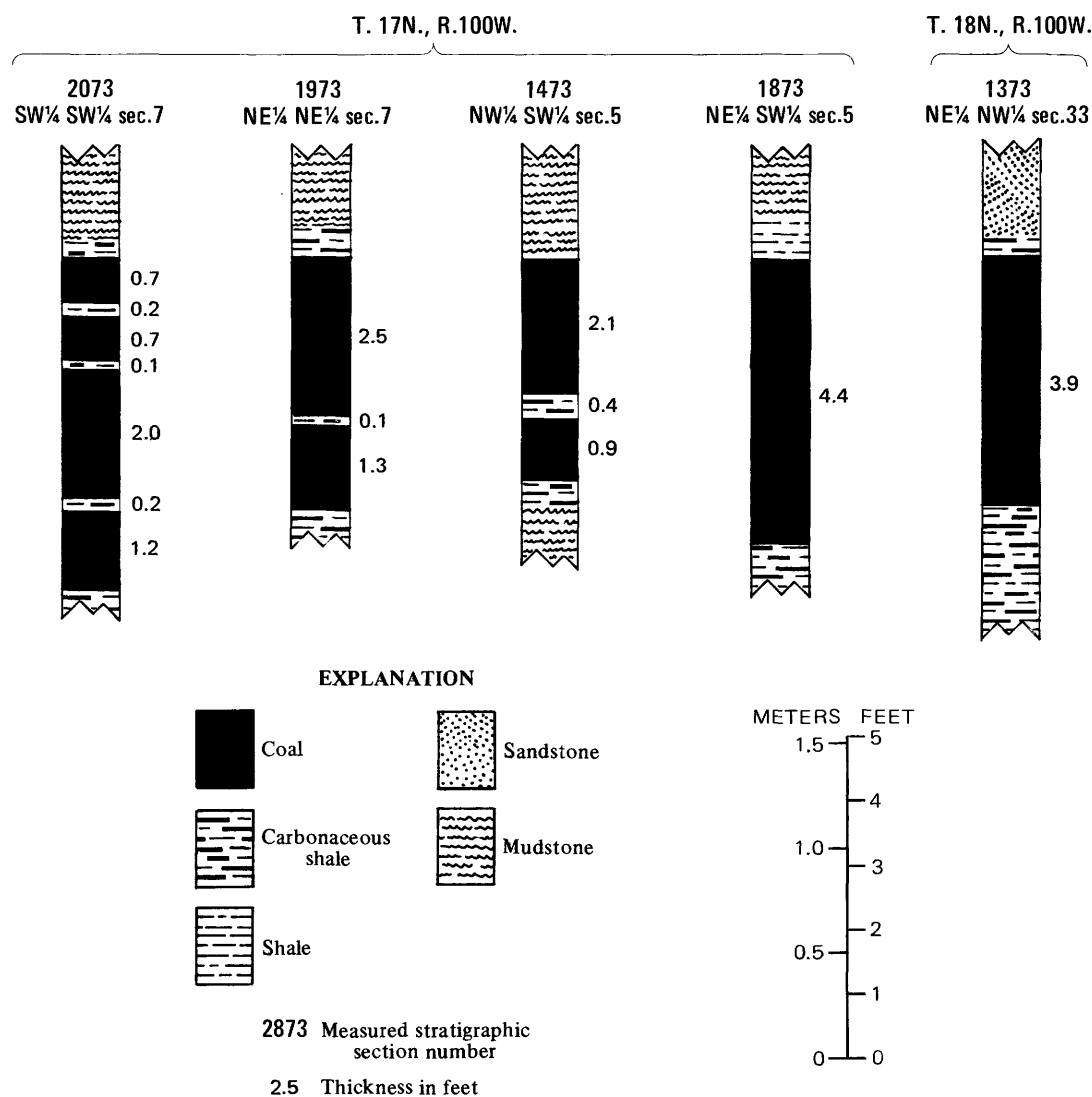


FIGURE 15.—Graphic sections of the Hail coal bed in the Fort Union Formation, Sand Butte Rim NW quadrangle.

R. 101 W. This change in structural elevation suggests a separate closure against the Brady fault in the vicinity of the Brady 14 well.

RESOURCES

Total oil and gas resources in the Sand Butte Rim NW quadrangle are unknown, and they cannot be computed using available data. The boundaries of Antelope and Brady fields have not been firmly established by drilling, and only a few wells are in production.

ANALYSES

Analyses of oil and gas from the Dakota, Nugget, Park City, and Weber Formations in the Brady Unit 1 well are listed in tables 14 and 15. The characteristics of oil and gas in the Jurassic sandstone (Entrada of drillers) were discussed above. The oil in the Nugget, Park City, and

Weber Formations is high gravity, has a low pour point, and is good-quality crude. Gas in the Dakota Sandstone is only 1 percent inert and has high heating value. Gas in the Nugget, Park City, and Weber Formations is 31-55 percent inert and has moderate heating value. The gas in the Phosphoria Formation is composed of more than 30 percent hydrogen sulfide, which is poisonous; the gas will require special processing before it can be produced.

OIL SHALE OUTCROPS

Oil-shale outcrops are mostly confined to three stratigraphic intervals in the southeast part of the Sand Butte Rim NW quadrangle (fig. 22). The lower interval, about 300 ft thick, is in the Luman Tongue of the Green River Formation. It is composed of 50-60 percent oil shale. The middle interval, 230 ft thick, is in the Tipton Shale

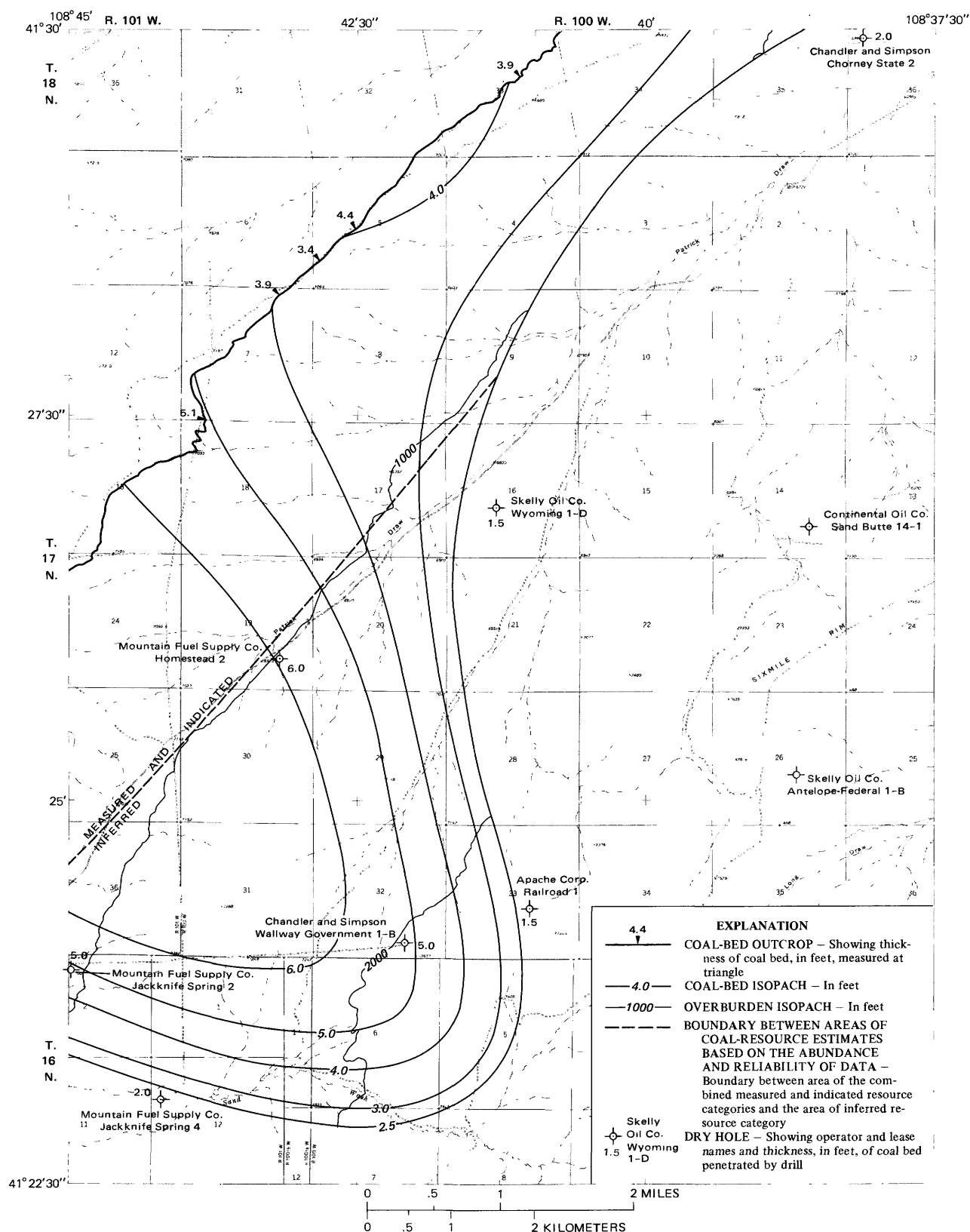


FIGURE 16.—Isopach map of the Hail coal bed, Fort Union Formation, showing thickness of overburden. Base from U.S. Geological Survey Sand Butte Rim NW topographic quadrangle, 1968, scale 1:24,000.

Original coal resources of the Hail coal bed
[Leaders (- - -), no resources for that category]

Overburden thickness (in ft)---	Measured and indicated resources			Inferred resources						Total coal resources (million tons)	
	0-1,000		0-1,000		1,000-2,000		2,000-3,000				
	Bed thickness (weighted avg. in ft)	Coal reserves (million tons)	Bed thickness (weighted avg. in ft)	Coal reserves (million tons)	Bed thickness (weighted avg. in ft)	Coal reserves (million tons)	Bed thickness (weighted avg. in ft)	Coal reserves (million tons)	For section	For township	
T. 18 N., R. 100 W.											
Sec.	32	4.3	0.105	--	--	--	--	--	--	0.105	
	33	3.8	2.177	--	--	--	--	--	--	2.177	
	34	3.0	2.987	--	--	--	--	--	--	2.987	
	35	2.7	.356	--	--	--	--	--	--	.356	5.625
T. 17 N., R. 100 W.											
Sec.	3	2.7	0.307	--	--	--	--	--	--	0.307	
	4	3.1	3.223	--	--	--	--	--	--	3.223	
	5	3.8	2.875	--	--	--	--	--	--	2.875	
	6	3.8	.081	--	--	--	--	--	--	.081	
	7	4.3	3.121	--	--	--	--	--	--	3.121	
	8	3.6	4.118	--	--	--	--	--	--	4.118	
	9	2.8	1.349	--	--	2.6	0.097	--	--	1.446	
	16	3.0	.011	--	--	2.7	.382	--	--	.393	
	17	3.8	2.881	3.9	0.060	3.1	1.145	--	--	4.086	
	18	5.1	5.560	--	--	--	--	--	--	5.560	
	19	6.0	5.282	5.9	.423	5.8	.972	--	--	6.677	
	20	4.8	.188	4.6	.082	4.1	4.470	--	--	4.740	
	21	--	--	--	--	2.6	.195	--	--	.195	
	28	--	--	--	--	2.9	.783	2.6	0.010	.793	
	29	--	--	--	--	5.0	5.695	--	--	5.695	
	30	6.3	.674	6.3	.154	6.3	6.397	--	--	7.225	
	31	--	--	--	--	6.3	7.227	--	--	7.227	
	32	--	--	--	--	5.3	5.226	4.8	.073	5.929	
	33	--	--	--	--	3.6	.322	3.3	1.525	1.847	65.538
T. 17 N., R. 101 W.											
Sec.	13	6.1	2.521	--	--	--	--	--	--	2.521	
	24	6.3	5.987	--	--	--	--	--	--	5.987	
	25	6.3	5.012	6.3	0.533	6.3	0.472	--	--	6.017	
	36	6.3	.410	6.2	2.269	6.3	3.465	--	--	6.144	20.669
T. 16 N., R. 100 W.											
Sec.	5	--	--	--	--	--	--	3.2	2.031	2.031	
	6	--	--	--	--	4.8	2.179	4.3	3.324	5.503	
	7	--	--	--	--	2.7	.088	2.7	.233	.321	
	8	--	--	--	--	--	--	2.5	.001	.001	7.856
T. 16 N., R. 100½ W.											
Sec.	1	--	--	--	--	4.7	1.246	--	--	1.246	
	12	--	--	--	--	2.6	.051	--	--	.051	1.297
T. 16 N., R. 101 W.											
Sec.	1	--	--	--	--	5.3	4.623	--	--	4.623	
	2	--	--	4.8	0.218	4.2	2.119	--	--	2.337	
	11	--	--	--	--	2.7	.141	--	--	.141	
	12	--	--	--	--	3.2	1.176	--	--	1.176	8.277

¹ Small insignificant areas on the map have overburden exceeding 1,000 ft.

Member and in the lower part of the Wilkins Peak Member of the Green River Formation. It is composed of about 75 percent oil shale. The upper interval, 325 ft thick, is in the LaCledé bed of the Laney Member of the Green River Formation. It is composed of about 60 percent oil shale. Minor thin beds of oil shale are also present

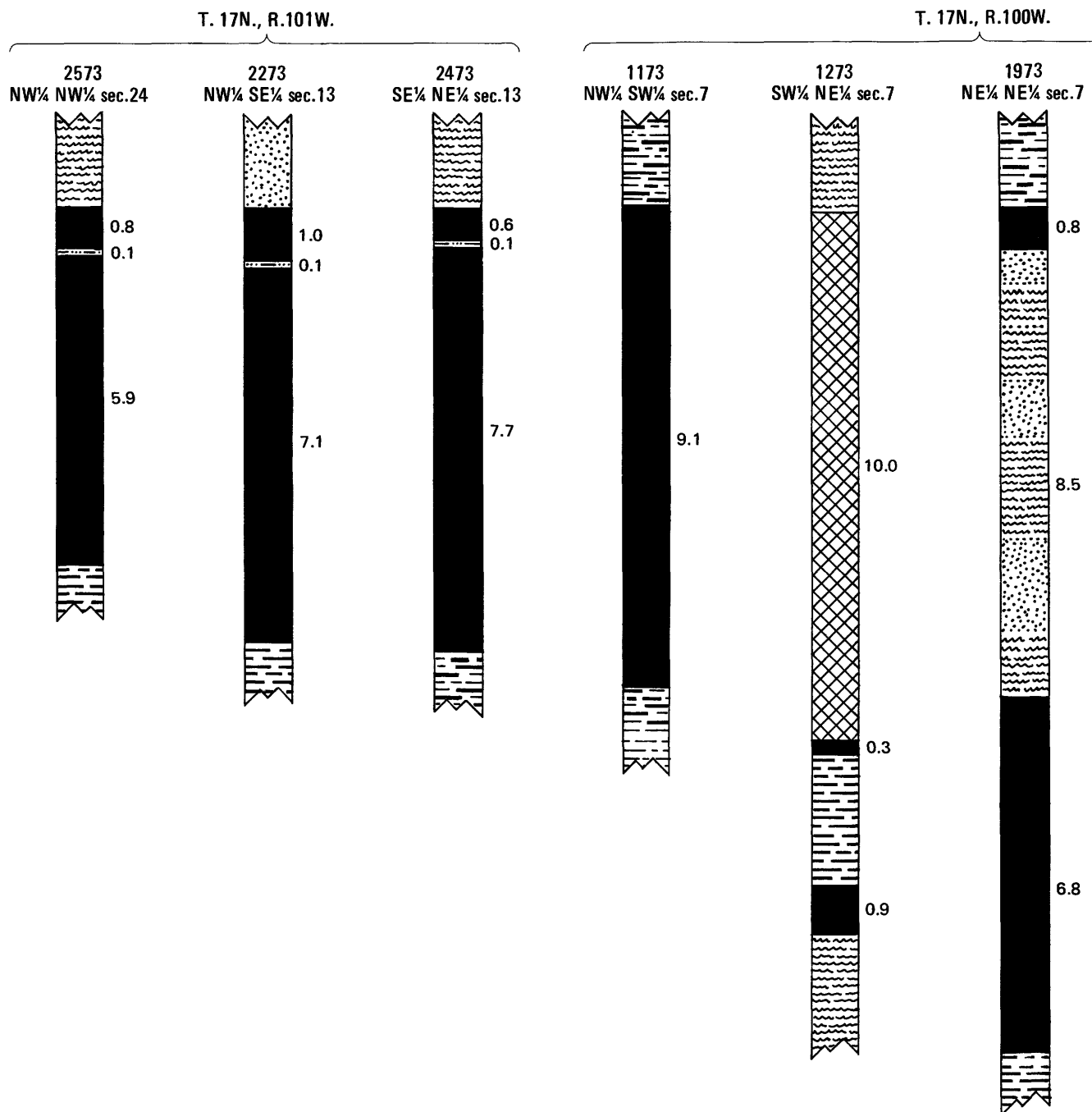
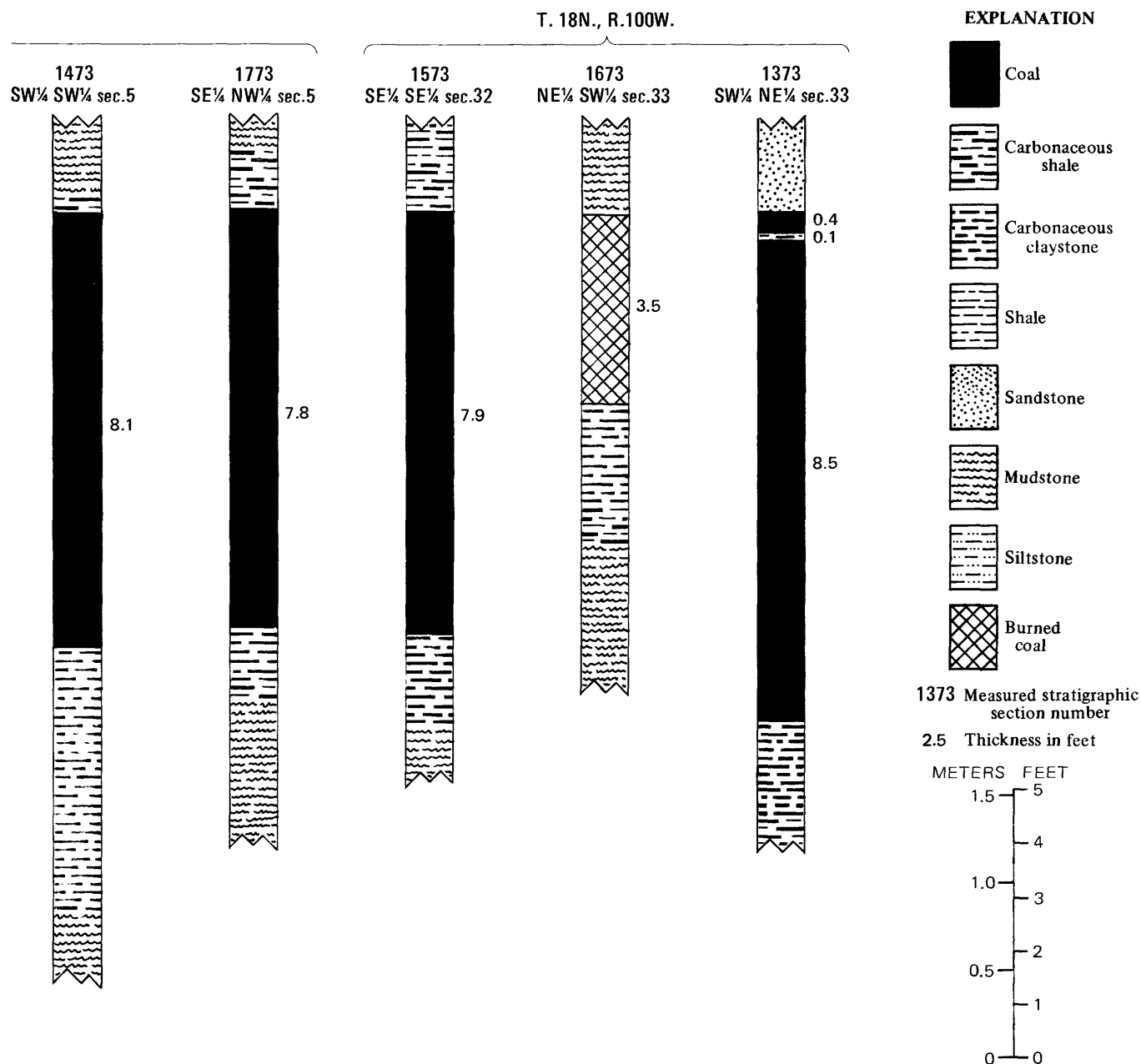


FIGURE 17.—Graphic sections of the Big Burn coal bed in

in the Niland and Cathedral Bluffs Tongues of the Wasatch Formation and in the Sand Butte Bed of the Laney Member of the Green River Formation, but they presently do not have economic importance and are not shown in figure 22.

The oil-shale beds in the quadrangle generally crop out in fairly steep, smooth slopes that are capped by beds of sandstone, algal limestone, or oolitic limestone. Oil shales

that were deposited in fresh-water conditions, which include those in the Luman Tongue, Tipton Shale Member, and Laney Member, have a carbonate content that generally averages less than 25 percent by weight (it may be slightly higher in the Laney Member). These beds weather to drab-brown, flexible, papery flakes. Oil shales deposited in salt-water conditions, mainly those in the Wilkins Peak Member, have a carbonate content that



the Fort Union Formation, Sand Butte Rim NW quadrangle.

usually averages more than 50 percent by weight. These beds weather to brittle, light-chalky-gray flakes and plates. The overall color change from drab-brown-weathering oil shales in the Tipton Shale Member to light-chalky-gray-weathering oil shales in the Wilkins Peak Member, caused by the change in carbonate content, is distinct in outcrops; it marks the contact of the two units.

OIL YIELDS OF OIL SHALES

The color and density of oil-shale beds in the Luman Tongue and the Tipton Shale Member suggest that they will not yield large amounts of oil by Fischer assay. They may yield amounts of oil similar to core samples from the U.S. Bureau of Mines Washakie Basin core hole 1A, 14 mi south of the quadrangle in SW $\frac{1}{4}$ sec. 24, T. 14 N.,

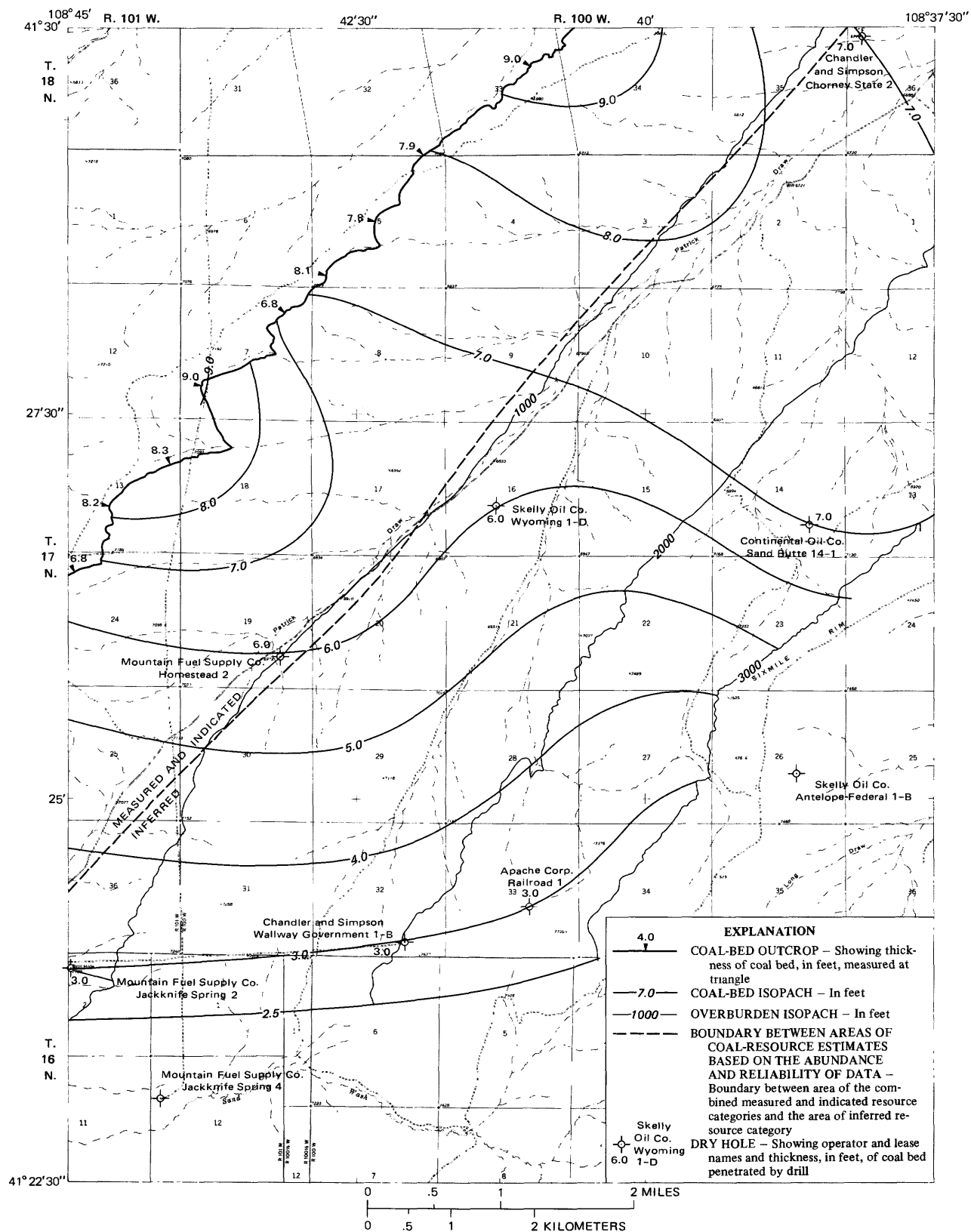


FIGURE 18.—Isopach map of the Big Burn coal bed, Fort Union Formation, showing thickness of overburden. Base from U.S. Geological Survey Sand Butte Rim NW topographic quadrangle, 1968, scale 1:24,000.

Original coal resources of the Hail coal bed

[Leaders (- -), no resources for that category]

Overburden thickness in ft)-----		Measured and indicated resources		Inferred resources								Total coal reserves (million tons) For section For township	
		0-1,000		0-1,000		1,000-2,000		2,000-3,000					
		Bed	Coal	Bed	Coal	Bed	Coal	Bed	Coal				
		thickness (weighted avg. in ft)	reserves (million tons)	thickness (weighted avg. in ft)	reserves (million tons)	thickness (weighted avg. in ft)	reserves (million tons)	thickness (weighted avg. in ft)	reserves (million tons)				
T. 18 N., R. 100 W.													
Sec.	32	8.1	0.079	--	--	--	--	--	--	0.079			
	33	8.8	4.624	--	--	--	--	--	--	4.624			
	34	8.8	10.339	--	--	--	--	--	--	10.339			
	35	8.0	5.207	--	--	7.6	3.401	--	--	8.608			
	36	--	--	--	--	7.0	5.012	--	--	5.012	28.662		
T. 17 N., R. 100 W.													
Sec.	1	--	--	--	--	7.4	5.178	7.3	0.451	5.629			
	2	8.3	0.109	--	--	7.7	8.808	--	--	8.917			
	3	8.4	6.424	7.8	0.305	7.9	2.725	--	--	9.454			
	4	7.8	8.884	--	--	--	--	--	--	8.884			
	5	7.7	4.523	--	--	--	--	--	--	4.523			
	7	7.6	3.858	--	--	--	--	--	--	3.858			
	8	6.9	7.493	--	--	--	--	--	--	7.493			
	9	7.3	6.343	6.9	.618	6.8	1.306	--	--	8.267			
	10	7.6	.222	7.5	.244	7.4	8.055	--	--	8.521			
	11	--	--	--	--	7.5	7.384	7.3	1.187	8.571			
	12	--	--	--	--	7.4	.735	7.3	4.870	5.605			
	13	--	--	--	--	--	--	7.2	4.955	4.955			
	14	--	--	--	--	7.2	1.020	7.2	7.264	8.284			
	15	--	--	--	--	6.3	6.459	5.9	.749	7.208			
	16	6.5	.624	6.4	.521	6.0	5.858	--	--	7.003			
	17	6.7	7.021	6.2	.101	6.1	.596	--	--	7.718			
	18	7.7	8.019	--	--	--	--	--	--	8.019			
	19	6.4	6.874	--	--	5.7	.371	--	--	7.245			
	20	6.5	1.713	--	--	5.7	5.129	--	--	6.842			
	21	--	--	--	--	5.1	5.842	4.4	.072	5.914			
	22	--	--	--	--	5.0	1.326	4.6	4.109	5.435			
	23	--	--	--	--	--	--	5.5	4.198	4.198			
	26	--	--	--	--	--	--	4.0	.029	.029			
	27	--	--	--	--	--	--	3.6	3.837	3.837			
	28	--	--	--	--	4.5	3.112	3.8	1.762	4.874			
	29	--	--	--	--	4.8	5.530	--	--	5.530			
	30	5.4	1.327	4.7	.176	4.9	4.282	--	--	5.785			
	31	--	--	4.3	.028	3.7	4.214	--	--	4.242			
	32	--	--	--	--	3.7	3.787	3.0	.386	4.173			
	33	--	--	--	--	3.8	.266	3.1	3.370	3.636			
	34	--	--	--	--	--	--	2.9	1.015	1.015	185.664		
T. 17 N., R. 101 W.													
Sec.	13	8.0	2.838	--	--	--	--	--	--	2.838			
	24	6.2	5.801	--	--	--	--	--	--	5.801			
	25	4.8	4.390	4.5	0.321	--	--	--	--	4.711			
	36	4.1	.644	3.6	2.033	3.5	0.865	--	--	3.542	16.892		
T. 16 N., R. 100 W.													
Sec.	4	--	--	--	--	--	--	2.5	0.020	0.020			
	5	--	--	--	--	--	--	2.7	.611	.611			
	6	--	--	--	--	2.7	0.589	2.7	.483	1.072	1.703		
T. 16 N., R. 100½ W.													
Sec.	1	--	--	--	--	2.7	0.277	--	--	0.277	0.277		
T. 16 N., R. 101 W.													
Sec.	1	--	--	--	--	2.7	1.406	--	--	1.406			
	2	--	--	2.9	0.415	2.7	.575	--	--	.990	2.396		

Small insignificant areas on the map in this category have overburden exceeding 1,000 ft.

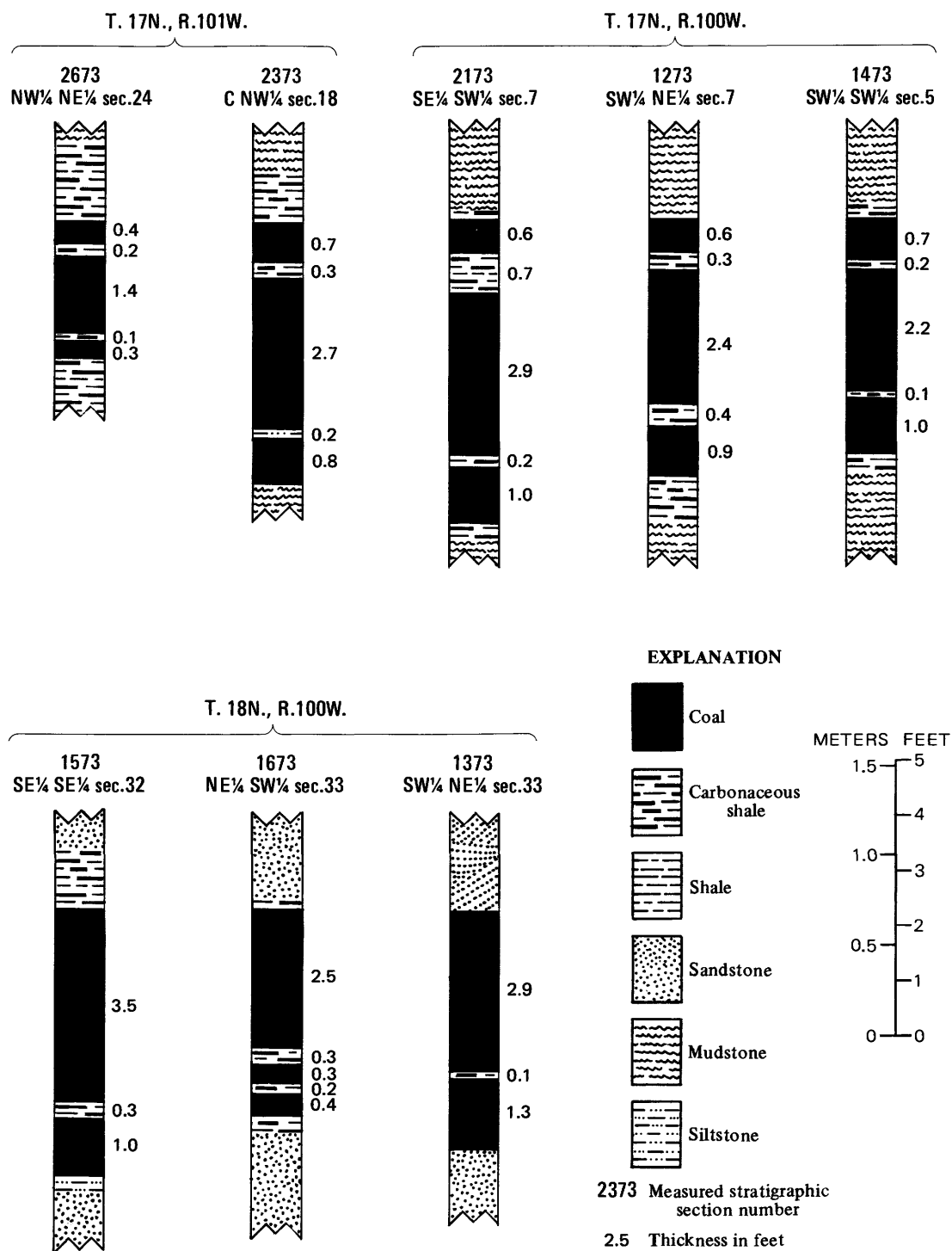


FIGURE 19.—Graphic sections of the Leaf coal bed in the Fort Union Formation, Sand Butte Rim NW quadrangle.

TABLE 6.—*Inferred coal resources in the Almond coal group, in four beds 2.5–5.0 feet thick having an estimated cumulative thickness of 10 feet, under less than 3,000 feet of overburden, in the Sand Butte Rim NW quadrangle*

Location	Area (acres)	Coal resources (million tons)
T. 18 N., R. 100 W.---	2027.9	35.894
T. 18 N., R. 101 W.---	495.5	8.770
T. 17 N., R. 100 W.---	4718.6	83.519
T. 17 N., R. 101 W.---	216.3	38.289
T. 16 N., R. 101 W.---	75.0	1.328
Total-----		167.800

R. 100 W. (Trudell and others, 1973, p. 145–147). Assays of oil shales in the Luman Tongue in the core hole showed 1.2–15.4 gallons of oil per ton of rock and average 6.5 gal/ton. The Tipton Shale Member in the core hole is about 200 ft thick—about four times thicker than in the quadrangle. The Tipton section in the quadrangle is equivalent to the upper part of the member in the core hole, where assays averaged 9.2 gal/ton.

The oil-shale beds in the Wilkins Peak Member yielded slightly more oil than those in the underlying Luman Tongue and Tipton Shale Member. Assays from the U.S. Bureau of Mines core hole ranged from 0.6 to 25.8 gal/ton, and averaged about 9.5 gal/ton.

Fifty-two outcrop channel samples of oil shales in a 190-ft-thick interval in the LaCledde Bed of the Laney Member were collected in the quadrangle area and assayed. A histogram of the amount of oil yielded by Fischer assay of these samples is plotted next to a detailed measured stratigraphic section in figure 6. The average oil yield of the beds is 13.0 gal/ton, but weathering has reduced the yield by at least 10 percent. The beds immediately underlying and overlying the buff marker (fig. 6) yield more oil than other parts of the LaCledde Bed.

RESOURCES

Oil-shale resources were computed for the entire quadrangle by geographic location and stratigraphic unit, and for selected beds in the Laney Member. The total resources for the quadrangle were determined (1) by estimating the average oil yields for each stratigraphic unit on the basis of the physical appearance of the oil shales and on data from core holes outside the quadrangle (table 16), (2) by finding the area, in acres by section, of oil-shale beds in each stratigraphic unit, and (3) by following a U.S. Bureau of Mines computation procedure using the data from (1) and (2) (Stanfield and others, 1960, p. 6–10). The same basic procedure was

used for computing the resources of selected beds in the Laney Member, except that Fischer assays of outcrop samples were substituted for estimations of oil yields. All calculations were rounded to the closest 10,000 bbl of oil and were recorded in millions of barrels. The resource data presented are inferred in all cases, as assay data are not available from unweathered core or mine samples.

The total inferred shale oil in place in the Sand Butte Rim NW quadrangle, in oil-shale beds that have a cumulative thickness of nearly 500 ft, is slightly more than 1,926 million bbl (table 17). Less than 20 ft of the beds will yield oil in amounts greater than 25 gal/ton (not more than 3 percent of the total shale oil in place in the quadrangle). The total resources listed include thick sections of oil shale that yield less than 25 gal/ton, although yields less than that are not presently considered of economic importance.

Two minable intervals in the LaCledde Bed of the Laney Member of the Green River Formation will yield shale oil in amounts greater than 25 gal/ton, are of economic interest, and are worthy of further consideration here. The upper interval is 0–5.6 ft above the top of the buff marker (fig. 6). The oil in place in this bed is estimated to be 7.15 million bbl/mi² (table 18). The lower interval is 12.4–18.9 ft below the base of the buff marker (fig. 6). The oil in place in this bed is estimated to be 7.98 million bbl/mi² (table 18). The total combined oil in place in the two beds in the quadrangle area is more than 30 million bbl. Much of the oil in these beds is recoverable by strip or open-pit mining methods.

ASSAYS

Fifty-two channel samples were collected from the LaCledde Bed in sec. 3, T. 16 N., R. 100 W., and assayed by the Fischer retort method to determine oil yields. The yields ranged from 0 to 41.3 gal/ton, and are listed in table 19 with the thickness of the bed sampled. A few lithologies are included in table 19 to facilitate the identification of the beds shown stratigraphically in figure 6.

A statistical comparison has been made of the assays of weathered and unweathered oil-shale samples from the LaCledde Bed at the U.S. Bureau of Mines Washakie basin core hole 1, in an area 13 miles south of the quadrangle (Trudell and other, 1973, table 4, p. 13). The comparison shows that unweathered core samples yielded 17–60 percent more oil than did the same beds sampled in nearby outcrops. Richer beds that yielded more than 20 gal/ton were consistently less weathered and had less loss of oil than did weathered leaner oil shales.

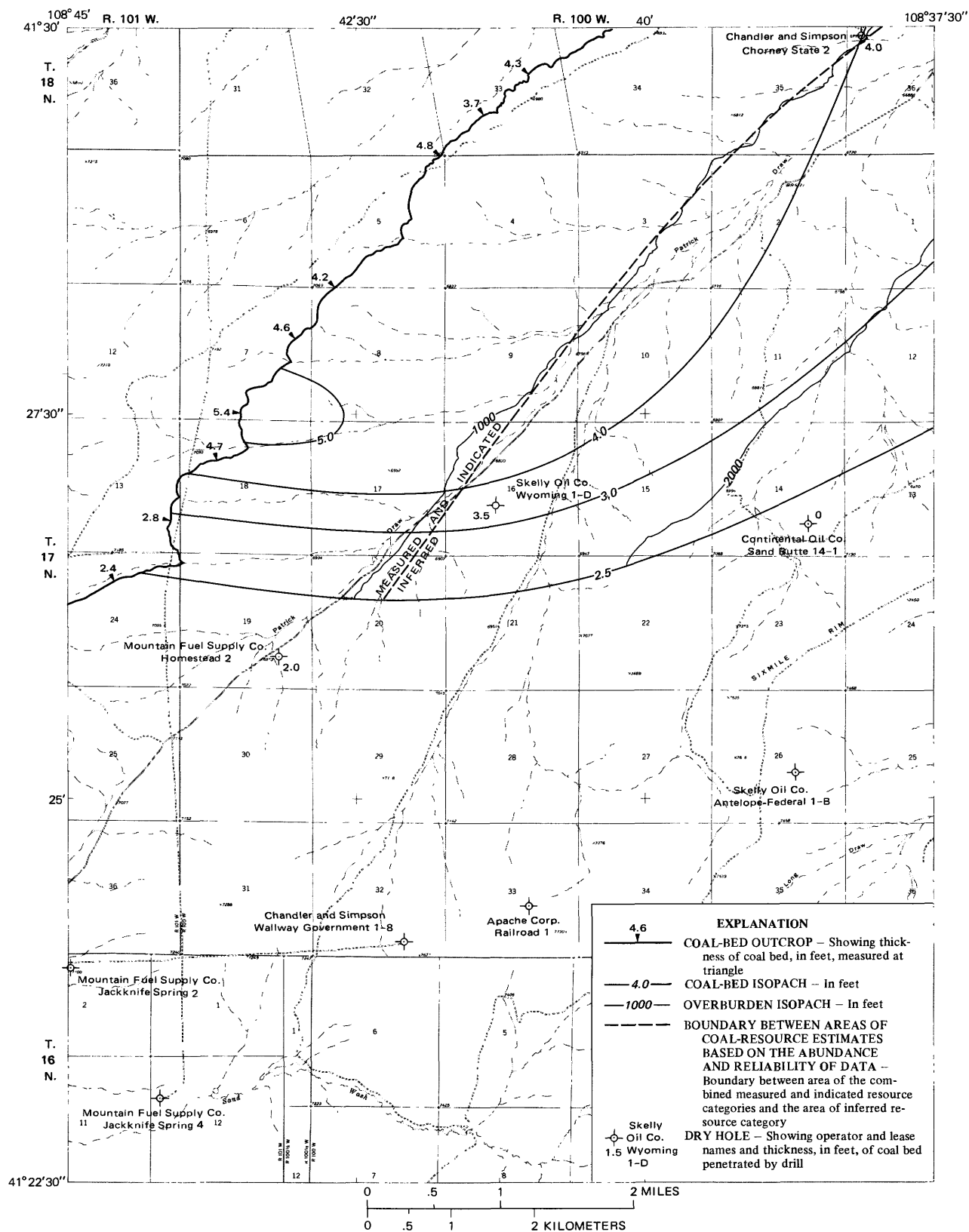


FIGURE 20.—Isopach map of the Leaf coal bed, Fort Union Formation, showing thickness of overburden. Base from U.S. Geological Survey Sand Butte Rim NW quadrangle, 1968, scale 1:24,000.

Original coal resources of the Leaf coal bed

[Leaders (- -), no resources for that category]

Overburden thickness (in ft)-----		Measured and indicated resources		Inferred resources								Total coal reserves (million tons) For section For township	
		0-1,000		0-1,000		1,000-2,000		2,000-3,000					
		Bed	Coal	Bed	Coal	Bed	Coal	Bed	Coal				
		thickness (weighted avg. in ft)	reserves (million tons)	thickness (weighted avg. in ft)	reserves (million tons)	thickness (weighted avg. in ft)	reserves (million tons)	thickness (weighted avg. in ft)	reserves (million tons)				
T. 18 N., R. 100 W.													
Sec.	32	4.8	0.001	--	--	--	--	--	--	0.001			
	33	4.6	2.096	--	--	--	--	--	--	2.096			
	34	4.3	4.828	--	--	--	--	--	--	4.828			
	35	4.2	3.035	4.1	0.119	4.1	1.421	--	--	4.575			
	36	4.0	.130	--	--	3.8	2.591	--	--	2.721	14.221		
T. 17 N., R. 101 W.													
Sec.	1	--	--	--	--	3.4	2.368	3.0	0.181	2.549			
	2	4.2	0.068	--	--	4.0	4.589	--	--	4.657			
	3	4.3	3.337	4.3	0.175	4.2	1.367	--	--	4.879			
	4	4.6	5.239	--	--	--	--	--	--	5.239			
	5	4.8	1.991	--	--	--	--	--	--	1.991			
	7	5.2	1.261	--	--	--	--	--	--	1.261			
	8	4.8	5.428	--	--	--	--	--	--	5.428			
	9	4.5	4.298	4.3	.014	4.2	.792	--	--	5.104			
	10	4.3	.224	4.3	.119	4.1	4.410	--	--	4.753			
	11	--	--	--	--	3.5	3.440	2.8	.447	3.887			
	12	--	--	--	--	3.1	.343	2.8	1.855	2.198			
	13	--	--	--	--	--	--	2.6	.419	.419			
	14	--	--	--	--	2.9	.411	2.7	1.511	1.922			
	15	--	--	--	--	3.0	3.012	2.6	.296	3.308			
	16	4.2	.820	--	--	3.5	3.309	--	--	4.129			
	17	4.0	4.446	--	--	2.9	.123	--	--	4.569			
	18	3.8	3.611	--	--	--	--	--	--	3.611			
	19	2.7	.791	--	--	--	--	--	--	.791			
	20	2.7	.589	--	--	2.7	.343	--	--	.932			
	21	--	--	--	--	2.7	.791	--	--	.791			
	22	--	--	--	--	2.6	.127	2.5	.012	.139	62.557		
T. 17 N., R. 101 W.													
Sec.	13	2.8	0.105	--	--	--	--	--	--	0.105			
	24	2.6	.068	--	--	--	--	--	--	.068	0.173		

¹ Small insignificant areas on the map in this category have overburden exceeding 1,000 feet.

TABLE 7.—Unmapped, inferred coal beds in the Black Butte and Black Rock, Coal groups, more than 2.5 feet thick, under less than 3,000 feet of overburden indicated by resistivity curves on electric logs of oil and gas drill holes in the Sand Butte Rim NW quadrangle

[Leaders (- -), no coal]

Company and drill hole	Location			Electric log depth, Fort Union Formation		Electric log depth, Lance Formation	
	(T.)	(R.)	(sec.)	(ft)		(ft)	
Chandler and Simpson	18 N.	100 W.	36	1,240		1,967	
Chorney State 2.				1,332		1,989	
				2,012			
				2,053			
Continental Oil Co.	17 N.	100 W.	14			2,985	
Sand Butte 14-1							
Skelly Oil Co.	17 N.	100 W.	16	1,523		1,962	
Wyo. 1-D.							
Mountain Fuel Supply Co.	17 N.	100 W.	19	1,223		-----	
Homestead 2.							
Chandler and Simpson	17 N.	100 W.	32	2,314		2,578	
Wallway Govt 1-B.				2,326		2,595	
Apache Corp.	17 N.	100 W.	33	2,662		-----	
Railroad 1				2,782			
Mountain Fuel Supply Co.	16 N.	101 W.	2	1,110		1,384	
Jackknife Spring 2.							

TABLE 8.—Neutron-activation determinations of uranium and thorium (in ppm) of coal-bed channel samples, as received, in the Sand Butte NW quadrangle
 [Samples analyzed by Philip J. Arsavage, Ardith Bartel, Hugh T. Millard, Jr., and Robert A. Zielinski]

Lab. No.	Field No.	Stratigraphic position above formation base (ft)	Bed name	Location			Th	U
				(sec.)	(T.)	(R.)		
Lance Formation								
D165048--	87321----	59	Local bed 15 ft below Little Valley bed.	SW $\frac{1}{2}$ SW $\frac{1}{4}$	12 17 N.	101 W.	<2.0	0.9
D165049--	87323----	64	Unnamed-----	SW $\frac{1}{2}$ NW $\frac{1}{4}$	12 17 N.	101 W.	<2.0	1.1
D165050--	87343----	174	Little Valley-----	SW $\frac{1}{2}$ NW $\frac{1}{4}$	12 17 N.	101 W.	8.3	1.7
Fort Union Formation								
D165051--	10732----	188	Unnamed-----	NE $\frac{1}{2}$ NE $\frac{1}{4}$ NW $\frac{1}{4}$	13 17 N.	101 W.	19.8	6.0
D165052--	107330---	186	-----do-----	NE $\frac{1}{2}$ NE $\frac{1}{4}$ NW $\frac{1}{4}$	13 17 N.	101 W.	2.6	1.7
D165053--	11736----	22	Washout-----	NE $\frac{1}{2}$ SE $\frac{1}{4}$	12 17 N.	101 W.	54.4	75.4
D165054--	117313---	+450	Big Burn-----	SE $\frac{1}{2}$ NW $\frac{1}{4}$ SW $\frac{1}{4}$	7 17 N.	100 W.	3.3	.5
D165055--	127368---	521	Leaf-----	SW $\frac{1}{2}$ SE $\frac{1}{4}$ NE $\frac{1}{4}$	7 17 N.	100 W.	2.8	2.2
D165056--	137374---	408	Hail-----	SW $\frac{1}{2}$ NE $\frac{1}{4}$ NW $\frac{1}{4}$	33 18 N.	100 W.	7.4	3.0
D165057--	137380---	442	Unnamed-----	NW $\frac{1}{2}$ SE $\frac{1}{4}$ NE $\frac{1}{4}$	33 18 N.	100 W.	17.4	6.7
D165058--	137381-T	450	Big Burn	NW $\frac{1}{2}$ SE $\frac{1}{4}$ NE $\frac{1}{4}$	33 18 N.	100 W.	<2.0	.3
D165059--	137381-B	446	-----do-----	NW $\frac{1}{2}$ SE $\frac{1}{4}$ NE $\frac{1}{4}$	33 18 N.	100 W.	9.6	2.5
D165060--	137388---	490	Leaf-----	SE $\frac{1}{2}$ SW $\frac{1}{4}$ NE $\frac{1}{4}$	33 18 N.	100 W.	5.5	1.9
D165061--	147319---	+165	Unnamed-----	NW $\frac{1}{2}$ NE $\frac{1}{4}$ SE $\frac{1}{4}$	6 17 N.	100 W.	7.6	3.9
D165062--	147353---	+420	Hail-----	SW $\frac{1}{2}$ NW $\frac{1}{4}$ SW $\frac{1}{4}$	5 17 N.	100 W.	6.0	3.0
D165063--	147358-T	+450	Big Burn	NW $\frac{1}{2}$ SW $\frac{1}{4}$ SW $\frac{1}{4}$	5 17 N.	100 W.	<2.0	.9
D165064--	147358-B	+446	-----do-----	NW $\frac{1}{2}$ SW $\frac{1}{4}$ SW $\frac{1}{4}$	5 17 N.	100 W.	17.8	3.8
D165065--	147369---	+500	Leaf-----	NE $\frac{1}{2}$ SW $\frac{1}{4}$ SW $\frac{1}{4}$	5 17 N.	100 W.	3.6	2.6
D165066--	157314---	+360	Washout-----	SW $\frac{1}{2}$ SW $\frac{1}{4}$ SE $\frac{1}{4}$	32 18 N.	100 W.	8.3	2.8
D165067--	157323-T	+450	Big Burn-----	SW $\frac{1}{2}$ SE $\frac{1}{4}$ SE $\frac{1}{4}$	32 18 N.	100 W.	2.7	.7
D165068--	157323-B	+446	-----do-----	SW $\frac{1}{2}$ SE $\frac{1}{4}$ SE $\frac{1}{4}$	32 18 N.	100 W.	13.3	4.0
D165069--	157329---	510	Leaf-----	SE $\frac{1}{2}$ SE $\frac{1}{4}$ SE $\frac{1}{4}$	32 18 N.	100 W.	6.8	3.1
D165070--	227312---	+150	Local bed 295 ft below Big Burn.	SE $\frac{1}{2}$ SW $\frac{1}{4}$ NW $\frac{1}{4}$	13 17 N.	101 W.	2.9	2.2
D165071--	227315---	+185	Local bed 255 ft below Big Burn.	SW $\frac{1}{2}$ SE $\frac{1}{4}$ NW $\frac{1}{4}$	13 17 N.	101 W.	15.3	19.4
D165072--	227326---	+358	Washout	SW $\frac{1}{2}$ SE $\frac{1}{4}$ NW $\frac{1}{4}$	13 17 N.	101 W.	14.7	12.4
D165073--	227331-T	+450	Big Burn	NE $\frac{1}{2}$ NE $\frac{1}{4}$ SW $\frac{1}{4}$	13 17 N.	101 W.	<2.0	.8
D165074--	227331-B	+445	-----do-----	NE $\frac{1}{2}$ NE $\frac{1}{4}$ SW $\frac{1}{4}$	13 17 N.	101 W.	5.1	.9
D165075--	227337---	+656	Local bed 50 ft above Leaf bed.	NE $\frac{1}{2}$ SE $\frac{1}{4}$	13 17 N.	101 W.	<2.0	3.8
Lance Formation								
D165076--	277314 --	33	Bluff-----	NW $\frac{1}{2}$ NW $\frac{1}{4}$	31 18 N.	101 W.	2.7	1.7
D165077--	287310 --	03	-----do-----	SE $\frac{1}{2}$ NE $\frac{1}{4}$	36 18 N.	101 W.	<2.0	.6
D165078--	287338-T	265	Little Valley-----	SW $\frac{1}{2}$ NE $\frac{1}{4}$ SW $\frac{1}{4}$	31 18 N.	100 W.	4.0	1.8
D165079--	287338-B	255	-----do-----	SW $\frac{1}{2}$ NE $\frac{1}{4}$ SW $\frac{1}{4}$	31 18 N.	100 W.	4.1	1.0
D165080--	29733-T -	+265	-----do-----	NE $\frac{1}{2}$ NE $\frac{1}{4}$	1 17 N.	101 W.	6.5	2.8
D165081--	29733-B--	+255	-----do-----	NE $\frac{1}{2}$ NE $\frac{1}{4}$	1 17 N.	101 W.	<2.0	.7
D165082--	30733----	+275	Local bed 20 ft above Little Valley	NW $\frac{1}{2}$ SW $\frac{1}{4}$ SE $\frac{1}{4}$	1 17 N.	101 W.	3.7	1.3
D165083--	32734----	+175	Little Valley	SE $\frac{1}{2}$ NW $\frac{1}{4}$ NW $\frac{1}{4}$	12 17 N.	101 W.	3.4	2.3

TABLE 9.—X-ray fluorescence for oxide composition and selenium (in percent of the ash, except for selenium which is in ppm of the sample as received) for coal-bed channel samples in the Sand Butte Rim NW quadrangle

[Samples analyzed by J. S. Wahlberg.]

Lab. No.	Field No.	Stratigraphic position above formation base (ft)	Bed name	Location			SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	CaO	K ₂ O	P ₂ O ₅	SO ₃	Se	
				(sec.)	(T.)	(R.)									
Lance Formation															
D165048-----	87321-----	59	Local bed 115 ft below Little Valley bed.	SW ₁ SW ₁	12	17 N.	101 W.	45	23	8.4	4.1	0.22	1.3	11	1.4
D165049-----	87323-----	64	Unnamed-----	SW ₁ NW ₁	12	17 N.	101 W.	38	23	8.6	6.7	.37	.20	15	.4
D165050-----	87343-----	174	Little Valley--	SW ₁ NW ₁	12	17 N.	101 W.	57	25	3.0	4.2	.13	.05	7.5	1.4
Fort Union Formation															
D165051-----	10732-----	188	Unnamed-----	NE ₁ NE ₁ NW ₁	13	17 N.	101 W.	27	16	25	8.2	0.72	2.1	14	8.6
D165052-----	107330-----	186	-----do.-----	NE ₁ NE ₁ NW ₁	13	17 N.	101 W.	27	17	18	10	.94	.53	15	3.1
D165053-----	11736-----	22	Washout-----	NE ₁ SE ₁	12	17 N.	101 W.	15	9.1	30	12	.79	.36	24	6.8
D165054-----	117313-----	+450	Big Burn-----	SE ₁ NW ₁ SW ₁	7	17 N.	100 W.	36	31	4.3	8.7	.73	.86	11	2.8
D165055-----	127368-----	521	Leaf-----	SW ₁ SE ₁ NE ₁	7	17 N.	100 W.	33	18	21	6.9	.49	.75	13	1.4
D165056-----	137374-----	408	Hail-----	SW ₁ NE ₁ NW ₁	33	18 N.	100 W.	50	23	9.9	3.0	1.1	.24	5.5	4.2
D165057-----	137380-----	442	Unnamed-----	NW ₁ SE ₁ NE ₁	33	18 N.	100 W.	61	23	2.4	.48	1.5	.16	.80	2.5
D165058-----	137381-T--	450	Big Burn-----	NW ₁ SE ₁ NE ₁	33	18 N.	100 W.	40	18	6.5	12	.39	.85	23	.4
D165059-----	137381-B--	446	-----do.-----	NW ₁ SE ₁ NE ₁	33	18 N.	100 W.	34	26	4.3	7.5	.35	8.7	13	2.0
D165060-----	137388-----	490	Leaf-----	SE ₁ NW ₁ NE ₁	33	18 N.	100 W.	28	19	17	8.0	.39	1.00	18	3.2
D165061-----	147319-----	+165	Unnamed-----	NW ₁ NE ₁ SE ₁	6	17 N.	100 W.	26	15	35	5.3	.97	1.2	9.5	3.4
D165062-----	147353-----	+420	Hail-----	SW ₁ NW ₁ SW ₁	5	17 N.	100 W.	50	21	7.0	8.4	1.0	.30	8.8	2.7
D165063-----	147358-T--	+450	Big Burn-----	NW ₁ SW ₁ SW ₁	5	17 N.	100 W.	34	10	19	11	.56	2.0	19	1.7
D165064-----	147358-B--	+446	-----do.-----	NW ₁ SW ₁ SW ₁	5	17 N.	100 W.	46	28	5.3	4.3	1.1	4.1	5.9	3.7
D165065-----	147369-----	+500	Leaf-----	NE ₁ SW ₁ SW ₁	5	17 N.	100 W.	38	17	15	8.5	.59	.47	15	2.0
D165066-----	157314-----	+360	Washout-----	SW ₁ SW ₁ SE ₁	32	18 N.	100 W.	31	9.7	19	11	.87	.08	24	4.0
D165067-----	157323-T--	+450	Big Burn-----	SW ₁ SE ₁ SE ₁	32	18 N.	100 W.	28	20	11	16	.65	.93	14	1.2
D165068-----	157323-B--	+446	-----do.-----	SW ₁ SE ₁ SE ₁	32	18 N.	100 W.	59	24	3.0	1.2	.79	2.6	2.0	5.2
D165069-----	157329-----	510	Leaf-----	SE ₁ SE ₁ SE ₁	32	18 N.	100 W.	36	18	19	7.2	.51	1.2	15	3.4
D165070-----	227312-----	+150	Local bed 295 ft below Big Burn bed.	SE ₁ SW ₁ NW ₁	13	17 N.	101 W.	31	21	21	8.4	.78	.50	11	4.1
D165071-----	227315-----	+185	Local bed 255 ft below Big Burn bed.	SW ₁ SE ₁ NW ₁	13	17 N.	101 W.	52	13	20	2.1	2.0	.74	6.4	9.0
D165072-----	227326-----	+358	Washout-----	SW ₁ SE ₁ NW ₁	13	17 N.	101 W.	33	15	15	7.5	.80	.30	14	8.7
D165073-----	227331-T--	+450	Big Burn-----	NE ₁ NE ₁ SW ₁	13	17 N.	101 W.	30	12	25	9.0	.61	.80	16	4.5
D165074-----	227331-B--	+445	-----do.-----	NE ₁ NE ₁ SW ₁	13	17 N.	101 W.	65	15	6.3	5.5	.64	.54	7.2	1.8
D165075-----	227337-----	+656	Local bed 50 ft above Leaf bed.	NE ₁ SE ₁	13	17 N.	101 W.	29	19	24	6.0	.39	.95	13	1.8
Lance Formation															
D165076-----	277314-----	33	Bluff-----	NW ₁ NW ₁	36	18 N.	100 W.	57	15	5.5	6.4	2.1	0.30	12	1.2
D165077-----	287310-----	03	-----do.-----	SE ₁ NE ₁	31	18 N.	100 W.	28	8.5	8.2	23	.10	.39	29	1.1
D165078-----	287338-T--	265	Little Valley--	SW ₁ NE ₁ SW ₁	31	18 N.	100 W.	53	26	7.3	5.1	1.2	.17	7.6	1.5
D165079-----	287338-B--	255	-----do.-----	SW ₁ NE ₁ SW ₁	31	18 N.	100 W.	50	23	9.2	4.6	3.2	.14	3.2	1.0
D165080-----	29733-T--	+265	-----do.-----	NE ₁ NE ₁	1	17 N.	101 W.	53	25	5.2	4.0	1.0	.12	3.3	1.7
D165081-----	29733-B--	+255	-----do.-----	NE ₁ NE ₁	1	17 N.	101 W.	63	15	7.4	2.7	1.3	.14	4.8	.6
D165082-----	30733-----	+275	Local bed 20 ft above Little Valley bed.	NW ₁ SW ₁ SE ₁	1	17 N.	101 W.	51	15	7.0	10	.76	.08	9.6	1.0
D165083-----	32734-----	+175	Little Valley--	SE ₁ NW ₁ NW ₁	12	17 N.	101 W.	44	15	10	12	.70	.10	12	.5

GEOLOGY OF THE SOUTHEAST PART OF THE ROCK SPRINGS UPLIFT, WYOMING

TABLE 10.—*Semiquantitative six-step spectrographic analysis (in ppm) for trace*

[Elements not listed were not found in measurable amounts]

Lab. No.	Field No.	Stratigraphic position above formation base (ft)	Bed name	Location			Mn	B	Ba	Be	Co	Cr
				(sec.)	(T.)	(R.)						
Lance Formation												
D165048-----	87321-----	59	Local bed 115 ft below Little Valley bed.	SW ₂ SW ₂	12	17 N. 101 W.	100	500	10,000	10	50	100
D165049-----	87323-----	64	Unnamed-----	SW ₂ NW ₂	12	17 N. 101 W.	150	1,000	1,500	30	150	100
D165050-----	87343-----	174	Little Valley--	SW ₂ NW ₂	12	17 N. 101 W.	500	1,500	1,500	7	15	50
Fort Union Formation												
D165051-----	10732-----	188	Unnamed-----	NE ₂ NE ₂ NW ₂	13	17 N. 101 W.	100	50	1,500	3	30	200
D165052-----	107330-----	186	-----do-----	NE ₂ NE ₂ NW ₂	13	17 N. 101 W.	150	150	1,000	7	30	150
D165053-----	11736-----	22	Washout-----	NE ₂ SE ₂	12	17 N. 101 W.	100	50	2,000	5	50	150
D165054-----	117313-----	+450	Big Burn-----	SE ₂ NW ₂ SW ₂	7	17 N. 100 W.	200	300	7,000	15	50	100
D165055-----	127368-----	521	Leaf-----	SW ₂ SE ₂ NE ₂	7	17 N. 100 W.	200	1,000	5,000	5	70	70
D165056-----	137374-----	408	Hail-----	SW ₂ NE ₂ NW ₂	33	18 N. 100 W.	150	300	7,000	5	30	150
D165057-----	137380-----	442	Unnamed-----	NW ₂ SE ₂ NE ₂	33	18 N. 100 W.	50	150	500	--	--	100
D165058-----	137381-T-----	450	Big Burn-----	NW ₂ SE ₂ NE ₂	33	18 N. 100 W.	700	5,000	7,000	--	20	100
D165059-----	137381-B-----	446	-----do-----	NW ₂ SE ₂ NE ₂	33	18 N. 100 W.	200	1,000	15,000	5	20	150
D165060-----	137388-----	490	Leaf-----	SE ₂ SW ₂ NE ₂	33	18 N. 100 W.	700	500	7,000	7	30	150
D165061-----	147319-----	+165	Unnamed-----	NW ₂ NE ₂ SE ₂	6	17 N. 100 W.	100	100	3,000	7	50	150
D165062-----	147353-----	+420	Hail-----	SW ₂ NW ₂ SW ₂	5	17 N. 100 W.	100	200	5,000	7	50	150
D165063-----	147358-T-----	+450	Big Burn-----	NW ₂ SW ₂ SW ₂	5	17 N. 100 W.	150	500	7,000	--	15	100
D165064-----	147358-B-----	+446	-----do-----	NW ₂ SW ₂ SW ₂	5	17 N. 100 W.	100	100	7,000	3	20	150
D165065-----	147369-----	+500	Leaf-----	NE ₂ SW ₂ SW ₂	5	17 N. 100 W.	200	150	10,000	3	100	100
D165066-----	157314-----	+360	Washout-----	SW ₂ SW ₂ SE ₂	32	18 N. 100 W.	100	150	10,000	10	30	70
D165067-----	157323-T-----	+450	Big Burn-----	SW ₂ SE ₂ SE ₂	32	18 N. 100 W.	500	300	5,000	5	30	150
D165068-----	157323-B-----	+446	-----do-----	SW ₂ SE ₂ SE ₂	32	18 N. 100 W.	70	150	3,000	3	20	150
D165069-----	157329-----	510	Leaf-----	SE ₂ SE ₂ SE ₂	32	18 N. 100 W.	300	300	10,000	7	30	150
D165070-----	227312-----	+150	Local bed 295 ft below Big Burn bed.	SE ₂ SW ₂ NW ₂	13	17 N. 101 W.	50	100	7,000	10	30	70
D165071-----	227315-----	+185	Local bed 255 ft below Big Burn bed.	SW ₂ SE ₂ NW ₂	13	17 N. 101 W.	30	70	3,000	3	20	150
D165072-----	227326-----	+358	Washout-----	SW ₂ SE ₂ NW ₂	13	17 N. 101 W.	20	50	70,000	10	50	150
D165073-----	227331-T-----	+450	Big Burn-----	NE ₂ NE ₂ SW ₂	13	17 N. 101 W.	150	300	5,000	3	20	100
D165074-----	227331-B-----	+445	-----do-----	NE ₂ NE ₂ SW ₂	13	17 N. 101 W.	100	200	3,000	3	15	100
D165075-----	227337-----	+656	Local bed 50 ft above Leaf bed.	NE ₂ SE ₂	13	17 N. 101 W.	100	500	3,000	7	50	100
Lance Formation												
D165076-----	277314-----	33	Bluff-----	NW ₂ NW ₂	31	18 N. 100 W.	100	1,500	1,500	3	10	70
D165077-----	287310-----	03	-----do-----	SE ₂ NE ₂	36	18 N. 101 W.	500	2,000	7,000	10	10	70
D165078-----	287338-T-----	265	Little Valley--	SW ₂ NE ₂ SW ₂	31	18 N. 100 W.	200	500	5,000	3	10	100
D165079-----	287338-B-----	255	-----do-----	SW ₂ NE ₂ SW ₂	31	18 N. 100 W.	300	150	2,000	3	20	100
D165080-----	29733-T-----	+265	-----do-----	NE ₂ NE ₂	1	17 N. 101 W.	70	300	2,000	5	10	70
D165081-----	29733-B-----	+255	-----do-----	NE ₂ NE ₂	1	17 N. 101 W.	150	150	3,000	3	10	70
D165082-----	30733-----	+275	Local bed 20 ft above Little Valley bed.	NW ₂ SW ₂ SE ₂	1	17 N. 101 W.	300	300	7,000	15	15	70
D165083-----	32734-----	+175	Little Valley--	SE ₂ NW ₂ NW ₂	12	17 N. 101 W.	500	200	10,000	10	50	100

SAND BUTTE RIM NW QUADRANGLE, SWEETWATER COUNTY, WYOMING

A45

elements in the ash of coal-bed samples in the Sand Butte Rim NW quadrangle
or were not looked for. Samples analyzed by J. C. Hamilton]

Cu	La	Mo	Nb	Ni	Pb	Sc	Sr	V	Y	Zn	Zr	Ce	Ga	Ge	Yb	Pr	Nd	Sm
Lance Formation																		
150	150	20	20	200	70	20	7,000	200	150	--	200	<500	50	<20	10	--	150	--
150	300	20	--	500	50	30	1,000	150	700	700	300	500	30	150	70	<200	700	<200
100	70	7	20	50	70	15	300	700	30	--	300	--	15	--	3	--	--	--
Fort Union Formation																		
500	70	30	20	70	50	50	1,000	300	70	--	300	--	50	--	--	--	150	--
300	150	30	20	150	50	30	700	300	100	<700	200	--	50	<20	--	--	150	--
700	--	30	20	150	30	50	700	150	70	--	200	--	20	--	--	--	--	--
200	100	20	20	100	50	20	2,000	200	70	1,500	150	--	20	--	5	--	150	--
200	100	20	--	200	30	30	2,000	150	100	--	150	--	20	--	--	--	150	--
300	100	20	20	100	50	30	5,000	300	70	--	150	--	30	--	5	--	150	--
100	70	--	30	20	30	15	100	150	20	--	100	--	30	--	2	--	--	--
100	70	10	--	70	30	15	3,000	150	30	--	100	--	20	--	3	--	--	--
300	150	15	--	70	50	50	15,000	500	70	--	100	<500	30	--	7	--	150	--
300	100	15	20	150	30	50	2,000	500	150	--	200	--	30	--	15	--	150	--
200	100	20	20	150	30	50	500	200	100	--	200	--	50	--	15	--	150	--
500	100	15	20	100	30	30	1,000	200	70	--	150	--	30	30	7	--	150	--
150	70	7	20	50	30	15	7,000	150	30	--	150	--	20	--	3	--	--	--
200	150	30	20	100	70	50	5,000	300	70	--	200	<500	30	--	7	--	150	--
300	70	30	20	150	30	30	1,500	200	70	--	150	--	20	--	--	--	--	--
300	70	30	20	200	30	30	1,000	150	70	--	200	--	20	30	--	--	150	--
200	100	15	20	100	30	20	5,000	150	70	--	150	--	30	--	7	--	--	--
200	100	7	20	50	30	30	3,000	200	30	--	200	<500	20	--	3	--	150	--
300	150	20	30	150	30	50	3,000	500	100	--	200	--	30	--	--	--	150	--
200	150	30	20	150	30	20	500	150	100	--	200	--	30	--	--	--	150	--
500	70	50	20	100	50	30	200	200	70	--	200	--	30	20	--	--	150	--
500	300	30	20	200	70	50	1,500	150	200	--	300	700	20	20	20	<200	500	<200
150	70	30	--	70	20	15	1,500	150	30	--	100	--	20	--	--	--	--	--
200	70	10	20	30	30	20	1,000	150	30	--	300	--	15	--	5	--	150	--
300	150	30	20	150	20	50	1,500	700	100	--	200	--	30	--	--	--	150	--
Lance Formation																		
100	70	10	20	70	30	20	700	150	70	--	150	--	30	20	5	--	--	--
70	70	10	20	30	30	30	1,500	100	50	--	150	--	20	30	3	--	--	--
100	150	15	20	30	70	20	1,500	200	50	--	200	<500	30	--	5	--	150	--
70	70	7	20	50	50	20	1,000	150	30	--	150	--	30	--	3	--	--	--
50	70	7	30	30	50	15	500	150	50	--	300	--	30	--	3	--	--	--
70	70	15	20	30	30	15	300	100	30	--	300	--	30	--	5	--	--	--
150	100	10	20	50	50	15	700	100	50	--	300	--	30	--	5	--	--	--
100	100	15	20	150	50	20	1,500	150	70	--	300	--	30	<20	7	--	--	--

TABLE 11.—Quantitative chemical analyses (in percent or ppm, as indicated) of coal-bed samples in the Sand Butte Rim NW quadrangle
[Samples analyzed by A. W. Haubert, Johnnie Gardner, E. J. Fennelly, J. T. Thomas, W. D. Goss, Violet Merritt and G. T. Burrow]

Lab No.	Field No.	Strati- graphic position above formation base (ft)	Bed name	Location			Coal as received					On the ash							
				(sec.)	(T.)	(R.)	Ash (per- cent)	F (ppm)	As (ppm)	Hg (ppm)	Sb (ppm)	MgO (per- cent)	Na ₂ O (per- cent)	Cd (ppm)	Cu (ppm)	Li (ppm)	Pb (ppm)	Zn (ppm)	
Lance Formation																			
D165048--	87321---	59	Local bed 115 ft below Little Valley bed.	SW ₂ SW ₂	12	17 N.	101 W.	5.80	<20	1	0.07	0.2	0.85	0.13	5	122	24	40	320
D165049--	87323---	64	Unnamed-----	SW ₂ NW ₂	12	17 N.	101 W.	5.29	35	1	.05	.1	.55	.19	9	102	18	<25	775
D165050--	87343---	174	Little Valley--	SW ₂ NW ₂	12	17 N.	101 W.	14.4	55	1	.04	.4	3.55	.29	2	74	116	55	80
Fort Union Formation																			
D165051--	10732---	188	Unnamed-----	NE ₂ NE ₂ NW ₂	13	17 N.	101 W.	22.5	60	100	0.43	1.5	2.00	0.46	4	270	50	50	90
D165052--	107330---	186	-----do-----	NE ₂ NE ₂ NW ₂	13	17 N.	101 W.	10.4	60	15	.24	.9	2.55	.34	4	172	16	35	324
D165053--	11736---	22	Washout-----	NE ₂ SE ₂	12	17 N.	101 W.	24.8	60	125	.58	6.4	1.50	.98	5	360	10	35	158
D165054--	117313--	+450	Big Burn-----	SE ₂ NW ₂ SW ₂	7	17 N.	100 W.	7.20	60	2	.07	.3	1.60	.26	5	120	16	<25	1200
D165055--	127368--	521	Leaf-----	SW ₂ SE ₂ NE ₂	7	17 N.	100 W.	8.44	50	15	.14	.4	.95	.49	4	164	32	<25	240
D165056--	137374--	408	Hail-----	SW ₂ NE ₂ NW ₂	33	18 N.	100 W.	26.0	200	60	.34	.7	1.15	.30	5	190	54	35	272
D165057--	137380--	442	Unnamed-----	NW ₂ SE ₂ NE ₂	33	18 N.	100 W.	87.4	760	10	.25	1.5	.90	.30	1	132	100	45	126
D165058--	137381-T	450	Big Burn-----	NW ₂ SE ₂ NE ₂	33	18 N.	100 W.	6.20	60	1	.03	.2	6.90	.70	2	112	72	25	44
D165059--	137381-B	446	Big Burn-----	NW ₂ SE ₂ NE ₂	33	18 N.	100 W.	14.0	245	2	.08	.4	1.45	.19	4	190	56	45	100
D165060--	137388--	490	Leaf-----	SE ₂ SW ₂ NE ₂	33	18 N.	100 W.	16.4	80	15	.18	.4	2.10	1.63	4	206	54	35	160
D165061--	147319--	+165	Unnamed-----	NW ₂ NE ₂ SE ₂	6	17 N.	100 W.	19.0	40	90	.57	1.3	.60	.20	5	140	<10	40	132
D165062--	147353--	+420	Hail-----	SW ₂ NW ₂ SW ₂	5	17 N.	100 W.	23.0	155	8	.14	.7	2.45	.44	4	252	44	40	228
D165063--	147358-T	+450	Big Burn-----	NW ₂ SW ₂ SW ₂	5	17 N.	100 W.	9.98	35	15	.08	.2	1.55	.15	2	110	16	<25	48
D165064--	147358-B	+446	-----do-----	NW ₂ SW ₂ SW ₂	5	17 N.	100 W.	20.7	210	3	.16	.6	.85	.15	4	200	66	40	118
D165065--	147369--	+500	Leaf-----	NE ₂ SW ₂ SW ₂	5	17 N.	100 W.	13.4	45	15	.15	.5	.65	.25	2	192	26	<25	214
D165066--	157314--	+360	Washout-----	SW ₂ SW ₂ SE ₂	32	18 N.	100 W.	19.7	130	80	.38	3.4	2.85	.42	4	174	30	30	230
D165067--	157323-T	+450	Big Burn-----	SW ₂ SE ₂ SE ₂	32	18 N.	100 W.	8.16	95	1	.05	.2	1.75	.20	2	118	12	35	124
D165068--	157323-B	+446	-----do-----	SW ₂ SE ₂ SE ₂	32	18 N.	100 W.	36.6	230	2	.14	.5	.35	.16	5	154	118	35	86
D165069--	157329--	510	Leaf-----	SE ₂ SE ₂ SE ₂	32	18 N.	100 W.	14.1	45	25	.22	.6	1.15	.32	3	208	32	30	120
D165070--	227312--	+150	Local bed 295 ft below Big Burn bed.	SE ₂ SW ₂ NW ₂	13	17 N.	101 W.	13.9	35	20	.28	.5	.50	.20	5	136	16	50	176
D165071--	227315--	+185	Local bed 225 ft below Big Burn bed.	SW ₂ SE ₂ NW ₂	13	17 N.	101 W.	36.9	160	80	.37	2.8	.45	.35	3	242	34	55	48
D165072--	227326--	+358	Washout-----	SW ₂ SE ₂ NW ₂	13	17 N.	101 W.	31.6	120	10	1.00	4.1	1.80	.69	8	370	32	50	186
D165073--	227331-T	+450	Big Burn-----	NE ₂ NE ₂ SW ₂	13	17 N.	101 W.	10.5	45	40	.48	.5	1.00	.17	1	104	<10	<25	70
D165074--	227331-B	+445	-----do-----	NE ₂ NE ₂ SW ₂	13	17 N.	101 W.	14.4	65	5	.06	.4	.95	.22	1	132	48	<25	48
D165075--	227337--	+656	Local bed 50 ft above Leaf bed.	NE ₂ SE ₂	13	17 N.	101 W.	11.4	30	20	.16	.7	.60	.33	3	282	64	<25	180
Lance Formation																			
D165076--	277314--	33	Bluff-----	NW ₂ NW ₂	31	18 N.	100 W.	8.90	60	2	0.07	0.5	1.45	0.12	3	84	34	<25	92
D165077--	287310--	03	-----do-----	SE ₂ NE ₂	36	18 N.	101 W.	8.68	45	2	.09	.2	1.25	.10	3	60	14	35	62
D165078--	287338-T	265	Little Valley--	SW ₂ NE ₂ SW ₂	31	18 N.	100 W.	11.1	80	3	.07	.4	2.25	.10	1	90	62	55	96
D165079--	287338-B	255	-----do-----	SW ₂ NE ₂ SW ₂	31	18 N.	100 W.	14.6	145	2	.05	.3	2.45	.43	1	66	36	45	136
D165080--	29733-T	+265	-----do-----	NE ₂ NE ₂	1	17 N.	101 W.	20.5	75	3	.11	1.0	1.50	.08	<1	42	144	50	76
D165081--	29733-B	+255	-----do-----	NE ₂ NE ₂	1	17 N.	101 W.	11.5	95	1	.05	.4	1.20	.09	<1	62	32	35	70
D165082--	30733---	+275	Local bed 20 ft above Little Valley	NW ₂ SW ₂ SE ₂	1	17 N.	101 W.	11.7	65	5	.08	.4	4.35	.13	1	116	46	45	96
D165083--	32734---	+175	Little Valley--	SE ₂ NW ₂ NW ₂	12	17 N.	101 W.	8.36	90	1	.04	.3	3.90	.17	1	84	18	35	204

SAND BUTTE RIM NW QUADRANGLE, SWEETWATER COUNTY, WYOMING

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TABLE 12.—Amount of trace and minor elements (in ppm) in the ash of samples from coal beds in the Sand Butte Rim NW quadrangle, compared to crustal abundance and to other western coals

[Values in parentheses, percent of volatile elements analyzed in whole coal, but converted arithmetically to parts per million in ash for comparative purposes; 0, element not detected in samples analyzed; leaders (- - -), element not analyzed or not present in enough samples to calculate an average.]

Element	Symbol	Crustal abundance ¹	Ash of coal, average, Western United States ²	Sand Butte Rim NW quadrangle (36 samples)			No. 11 coal, Sweetwater County, Wyo. ³ (1 sample)
				Range		Average	
				Low	High		
Arsenic-----	As--	2	3.6	(5.5)	(504)	(117)	0
Antimony----	Sb--	.2	1.1	(1.4)	(25.8)	(5.1)	-----
Barium-----	Ba--	400	1,467	500	70,000	7,100	3,000
Beryllium----	Be--	2	6	0	30	6.4	80
Bismuth-----	Bi--	.2	1	0	0	0	-----
Boron-----	B---	3	529	50	5,000	550	1,000
Cadmium-----	Cd--	.2	.1	<1	9	3.3	-----
Cerium-----	Ce--	46	238	0	700	<500	-----
Chromium----	Cr--	200	66	50	200	110	100
Cobalt-----	Co--	23	97	0	150	33.6	50
Copper-----	Cu--	45	47	50	700	229.2	30
Flourine----	F---	700	38	(210)	(1,750)	(610)	-----
Gallium-----	Ga--	15	33	15	50	28.3	20
Germanium----	Ge--	2	17	<20	150	-----	50
Lanthanum----	La--	18	128	0	300	105	0
Lead-----	Pb--	15	29	20	70	41.1	10
Lithium-----	Li--	30	168	<10	144	43.4	500
Manganese----	Mn--	1,000	212	20	700	240	200
Mercury-----	Hg--	.5	.11	(.28)	(4.57)	(1.22)	-----
Molybdenum----	Mo--	1	20	0	50	18.9	20
Nickel-----	Ni--	80	54	20	500	111.7	100
Niobium-----	Nb--	24	53	0	30	18.1	0
Rubidium----	Rb--	120	64	-----	-----	-----	200
Scandium----	Sc--	22	52	15	50	29.2	50
Selenium-----	Se--	.09	3.2	(2.9)	(42.8)	(17.6)	50
Strontium----	Sr--	450	1,456	100	15,000	2,240	1,000
Thallium----	Tl--	1	5	0	0	0	-----
Thorium-----	Th--	10	3.3	(17.4)	(219.4)	(41.8)	-----
Tin-----	Sn--	3	17	0	0	0	20
Uranium-----	U---	2	.88	(6.1)	(304)	(26.2)	-----
Vanadium-----	V---	135	152	70	700	215	200
Ytterbium----	Yb--	3	3	0	70	6.2	-----
Yttrium-----	Y---	40	76	20	700	88.1	100
Zinc-----	Zn--	65	258	44	1,200	187	800
Zirconium----	Zr--	160	850	100	300	200	1,000

¹Mason (1958).²Abernethy, Peterson, and Gibson (1969, p. 4, 9); some data are from averages of 125 coal samples listed in Swanson, Huffman, and Hamilton, (1974).³Abernethy, Peterson, and Gibson (1969, p. 29).

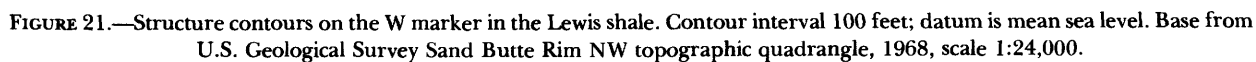
GEOLOGY OF THE SOUTHEAST PART OF THE ROCK SPRINGS UPLIFT, WYOMING

TABLE 13.—Drill-hole data for the Sand Butte Rim NW quadrangle

Company and well	Location (T.) (R.)		(sec.)	Year drilled	Formation and depth (in ft) from surface to top of formation (electric log)	Producing formation and interval (ft)	Initial production potential
Davis Oil Conroy- Federal 1.	16 N.	100 W.	10	1972	Fort Union 3,910----- Lance 5,248----- Fox Hills 5,782----- Lewis 5,988----- Almond 7,115----- Ericson 7,380-----	None	Dry and abandoned
Mountain Fuel Supply Jackknife Spring 2.	16 N.	101 W.	2	1961	Lance 1,210----- Fox Hills 1,497----- Lewis 1,632----- Almond 2,640----- Ericson 3,018----- Rock Springs 4,235--- Blair 5,430----- Baxter 7,145-----	None	Dry and abandoned
Champlin Petroleum Brady 2.	16 N.	101 W.	2	1972-73	Almond 2,843----- Ericson 3,147----- Rock Springs 4,400--- Blair 5,575----- Baxter 7,275----- Frontier 10,480----- Mowry 10,814----- Dakota 11,064----- Morrison 11,250----- Curtis of drillers 11,588----- Entrada of drillers 11,696----- Carmel of drillers 11,792----- Nugget 11,860----- Popo Agie 12,403----- Jelm 12,550----- Red Peak 12,723----- Park City 13,564----- Weber 13,810----- Amsden 14,440?-----	Weber 13,920-14,339	14 million ft ³ /day gas; 3,345 bbl/day condensate; 150 bbl/day water
Champlin Petroleum Brady 8N.	16 N.	101 W.	2	1973	Lance 1,335----- Fox Hills 1,730----- Lewis 1,894----- Almond 2,737----- Ericson 3,066----- Rock Springs 4,334--- Blair 5,485----- Baxter 7,174----- Frontier 10,358----- Mowry 10,691----- Dakota 10,923----- Morrison 11,108----- Curtis of drillers 11,456----- Entrada of drillers 11,570----- Carmel of drillers 11,670----- Nugget 11,788-----	Nugget 11,741-11,808	1,126 bbl/day oil; 1,167,000 ft ³ /day gas
Champlin Petroleum Brady 1.	16 N.	101 W.	11	1972-73	Lewis 1,920?----- Almond 2,810----- Ericson 3,152----- Rock Springs 4,235--- Blair 5,437----- Baxter 7,132----- Frontier 10,290----- Mowry 10,624----- Dakota 10,850----- Morrison 11,038----- Curtis of drillers 11,397----- Entrada of drillers 11,514----- Carmel of drillers 11,590----- Nugget 11,660----- Popo Agie 12,202----- Jelm 12,350----- Red Peak 12,540----- Park City 13,366----- Weber 13,590----- Amsden 14,338----- Madison 15,006----- Gros Ventre 15,703--- Flathead 16,150-----	Weber 13,762-14,184	3,818,000 ft ³ /day gas; 976 bbl/day condensate; 23 bbl/day water
Mountain Fuel Supply Jackknife Spring 4.	16 N.	101 W.	12	1963	Almond 1,805----- Fox Hills 2,055----- Lewis 2,247----- Almond 3,012----- Ericson 3,388----- Rock Springs 4,600--- Blair 5,888----- Baxter 7,580-----	None	Dry and abandoned

TABLE 13.—Drill-hole data for the Sand Butte Rim quadrangle—Continued

Company and well	(T.)	(R.)	(sec.)	Year drilled	Formation and depth (in ft) from surface to top of formation (electric log)	Producing formation and interval (ft)	Initial production potential
Continental Oil Sand Butte 14-1.	17 N.	100 W.	14	1959	Fort Union 1,444?-- Lance 2,985----- Fox Hills 3,314---- Lewis 3,587----- Almond 4,700----- Ericson 4,995----- Rock Springs 6,308-	None	Dry and abandoned
Skelly Oil Wyoming 1-D.	17 N.	100 W.	16	1971	Fort Union 125?--- Lance 1,738----- Fox Hills 2,080---- Lewis 2,176----- Almond 3,140----- Ericson 3,508-----	None	Dry and abandoned
Mountain Fuel Supply Homestead 2.	17 N.	100 W.	19	1963	Fort Union 25?---- Lance 1,429----- Fox Hills 1,670---- Lewis 1,850----- Almond 2,850----- Ericson 3,206----- Rock Springs 4,518- Blair 5,781----- Baxter 7,556-----	None	Dry and abandoned
Skelly Oil Antelope Federal 1-A.	17 N.	100 W.	24	1971	Tipton Member 74?-- Niland Tongue 120?-- Wasatch 565----- Fort Union 2,410?-- Lance 4,075----- Fox Hills 4,586---- Lewis 4,884----- Almond 5,962----- Ericson 6,330-----	Almond 5,963-6,025	Calculated absolute open flow 15,579,000 ft ³ /day gas
Amoco Production Champlin 1-136.	17 N.	100 W.	25	1972	Tipton Member 303-- Niland Tongue 355-- Luman Tongue 709-- Wasatch 880----- Fort Union 2,912-- Lance 4,526----- Fox Hills 5,026---- Lewis 5,303----- Almond 6,415----- Ericson 6,792-----	Almond 6,415-6,418	100,000 ft ³ /day gas
Skelly Oil Antelope B-1.	17 N.	100 W.	26	1971	Luman Tongue 642-- Wasatch 975----- Fort Union 2,260?-- Lance 4,033----- Fox Hills 4,620---- Lewis 4,787----- Almond 5,880----- Ericson 6,250-----	None	Dry and abandoned
Chandler and Simpson Wallway Government 1-B.	17 N.	100 W.	32	1961	Fort Union 1,170?-- Lance 2,430----- Fox Hills 2,755---- Lewis 3,122----- Almond 3,876----- Ericson 4,143-----	None	Dry and abandoned
Apache Railroad 1.	17 N.	100 W.	33	1970	Wasatch 250?----- Fort Union 1957?--- Lance 2,910----- Fox Hills 3,483---- Lewis 2,910----- Almond 4,638----- Ericson 4,965-----	None	Dry and abandoned
Anadarko Production Antelope-Wyoming 1-B.	17 N.	100 W.	36	1971	Wilkins Peak Member 290?----- Tipton Member 540-- Niland Tongue 597-- Luman Tongue 960-- Wasatch 1,115----- Fort Union 3,256--- Lance 4,852----- Fox Hills 5,420---- Lewis 5,677----- Almond 6,810----- Ericson 7,190-----	None	Dry and abandoned
Chandler and Simpson Chorney- State 2.	18 N.	100 W.	36	1963	Almond 1,550----- Fox Hills 2,130---- Lewis 2,262----- Almond 3,295----- Ericson 3,644-----	None	Dry and abandoned
Champlin Petroleum Brady 11W.	17 N.	100 W.	31	1973-74			Drilling
Champlin Petroleum Brady 4.	16 N.	101 W.	4	1973-74			Drilling



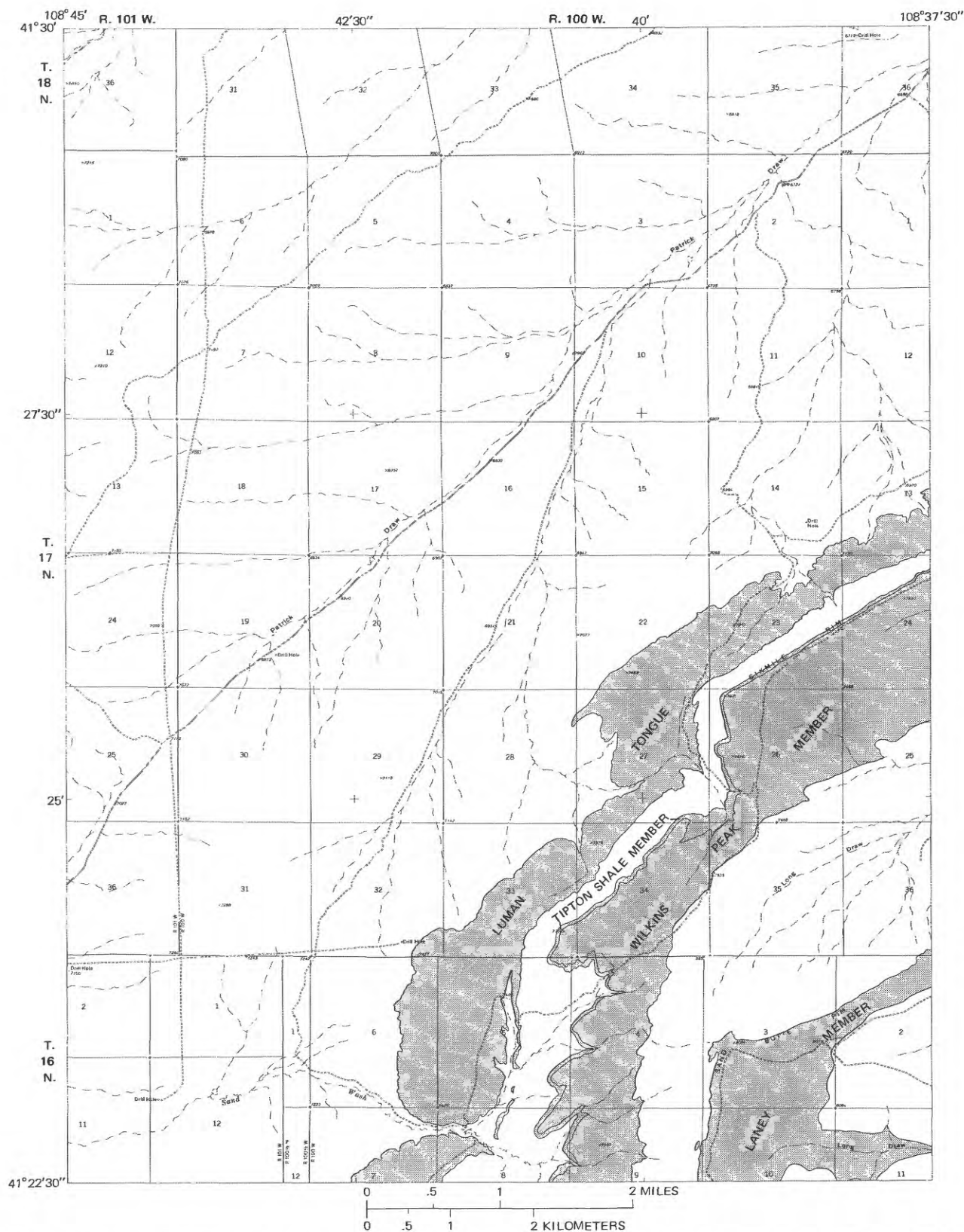


FIGURE 22.—Areas of oil-shale outcrop (patterned); all are in the Green River Formation. Base from U.S. Geological Survey Sand Butte Rim NW topographic quadrangle, 1968, scale 1:24,000.

TABLE 14.—General characteristics of crude oil from producing intervals in Brady Unit 1 well, Brady field
[Depth of interval measured from surface. Tr, trace; Bx, below zero]

	Nugget Sandstone 11,655–11,683 ft	Park City Formation 13,375–13,483 ft	Weber Sandstone 13,750–13,851 ft
Specific gravity at 60/60°F	0.7705	0.7162	0.7714
A.P.I gravity at 60°F-----	52.1	66.1	51.9
Saybolt Universal Viscosity at 70°F, seconds-----	32.0	30.6	30.7
Saybolt Universal Viscosity, at 100°F, seconds-----	30.9	27.3	30.0
Basic sediment and water, percent by volume-----	1.0	0	Tr
Pour point, °F-----	10	Bz	Bz
Total sulfur, percent by weight-----	.02	.26	.22

TABLE 15.—Analyses of gas from producing intervals in Brady Unit 1 well,
Brady field
[Depth of interval measured from surface. All values in volume percent except as noted.
Leaders (- - -), gas not present]

	Dakota Sandstone	Nugget Sandstone	Park City Formation	Weber Sandstone
Interval (ft)-----	Unknown	11,686–11,743	13,375–13,483	13,692–13,750
Hydrogen sulfide-----	---	---	30.11	1.58
Helium-----	0.01	---	---	.11
Carbon dioxide-----	.53	47.97	7.99	28.98
Nitrogen-----	.45	7.04	1.19	3.84
Methane-----	94.34	26.80	52.24	52.46
Ethane-----	3.10	7.71	4.87	7.61
Propane-----	.77	3.70	1.04	2.84
Iso-butane-----	.21	2.18	.42	.68
Normal butane-----	.22	2.57	.66	.93
Iso-pentane-----	.10	.96	.41	.30
Normal pentane-----	.08	.65	.28	.27
Hexanes-----	.10	.42	.79	.18
Heptanes and higher	.09	---	---	.22
Total-----	100.00	100.00	100.00	100.00
Btu/ft ³ -----	1061	738	942	844
Specific gravity-----	0.598	1.231	0.909	0.968

TABLE 16.—Cumulative thicknesses and estimated average oil yields of oil-shale
beds in the Green River Formation in the Sand Butte Rim NW quadrangle

Stratigraphic unit	Cumulative thickness of beds (ft)	Average oil yield (gal/ton)
Luman Tongue-----	175	7
Tipton Shale Member---	44	10
Wilkins Peak Member---	136	12
Laney Member-----	158	15

TABLE 17.—Inferred total shale oil (in millions of barrels) in place in the Sand
Butte Rim NW quadrangle on the basis of thickness and yield data shown on table
15
[Leaders (- - -), tongue or member not present]

Section	Luman Member	Tipton Shale Member	Wilkins Peak Member	Laney Member	Total
T. 16 N., R. 100 W.					
2	52.15	18.26	66.67	70.08	207.16
3	74.04	25.92	94.66	60.74	255.36
4	74.04	23.67	70.79	---	168.50
5	52.15	1.35	2.47	---	55.97
6	9.01	---	---	---	9.01
7	7.08	---	---	---	7.08
8	27.04	.90	1.65	---	29.59
9	35.41	11.95	36.22	2.34	85.92
10	35.41	12.40	45.27	47.89	140.97
11	25.75	9.02	32.92	40.88	108.57
Total---	392.08	103.47	350.65	221.93	1,068.13
T. 17 N., R. 100 W.					
13	8.37	---	---	---	8.37
14	.64	---	---	---	.64
22	19.31	---	---	---	19.31
23	35.41	4.06	2.47	---	41.94
24	45.07	9.92	34.57	---	89.56
25	41.85	14.65	51.85	---	108.35
26	64.38	19.84	49.39	---	133.61
27	35.41	.45	.82	---	36.68
32	2.57	---	---	---	2.57
33	25.75	.90	2.47	---	29.12
34	56.01	15.33	39.51	---	110.85
35	64.38	22.09	79.02	---	165.49
36	42.49	14.88	54.32	0.01	111.70
Total---	441.64	102.12	314.42	0.01	858.19

TABLE 18.—Estimated oil resources, in millions of barrels, for selected oil shales in the LaCade Bed of the Laney Member of the Green River Formation
[See fig. 6 for stratigraphic position of the beds]

Bed interval	Thickness (ft)	Oil yield ¹ gal/ton	Oil in place, bbl/mi ²	Total oil in place secs. 2, 3, 10, and 11, T. 17 N., R. 100 W.
0-5.6 ft above buff marker.	5.6	29.6	7.15	7.62
12.4-18.9 ft below buff marker.	6.5	27.2	7.98	22.80

¹The oil yielded by Fischer assay of channel samples from outcrops (histogram, fig. 5) has been increased by 10 percent to compensate for the loss of oil due to weathering.

TABLE 19.—Oil yields by Fischer assay of channel samples of oil-shale outcrops in the LaCade Bed of the Laney Member of the Green River Formation in the Sand Butte Rim NW quadrangle
[The assays are illustrated by a histogram in fig. 6. NS, no sample; BR, barren rock by visual examination]

Bed thickness (ft)	Oil yield (gal/ton)	Bed thickness (ft)	Oil yield (gal/ton)
2.2-----	41.3	1.3-----	0
1.5-----	12.0	2.7-----	12.7
¹ 1.9-----	23.1	.5-----	.5
⁴ 2.8-----	0	³ 3.4-----	8.7
1.7-----	0	.2-----	0
10.1-----	14.5	6.5-----	10.3
.06-----	0.8	.2-----	0
² 6.5-----	24.7	1.1-----	0
5.7-----	Trace	³ 5.7-----	12.1
.1-----	0	2.3-----	.2
2.0-----	6.9	3.4-----	10.5
1.0-----	Trace	.4-----	0
² .8-----	0	8.3-----	17.3
1.3-----	2.1	10.0-----	15.6
4.8-----	5.8	2.9-----	0
.2-----	Trace	.3-----	0
9.0-----	8.4	4.0-----	NS
.3-----	BR	8.3-----	11.3
2.8-----	8.6	⁴ .2-----	0
.1-----	Trace	.2-----	NS
4.7-----	9.1	.3-----	0
1.2-----	13.5	.5-----	.3
.4-----	0	.1-----	0
1.9-----	3.9	.1-----	NS
.4-----	.4	.2-----	0
.6-----	.5	6.3-----	11.3
⁵ 13.1-----	10.5	.3-----	.4
.3-----		2.0-----	12.2

¹ Buff marker.

² Tuffaceous siltstone.

³ Conglomerate.

⁴ Covered.

⁵ Algal limestone.

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