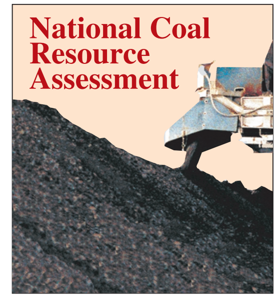
Chapter T

Geologic Overview and Resource Assessment of Coal in the Kaiparowits Plateau, Southern Utah



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Chapter T *of*

Geologic Assessment of Coal in the Colorado Plateau: Arizona, Colorado, New Mexico, and Utah

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Appendix 6—ArcView Project

[The digital files used for the coal resource assessment of the Kaiparowits Plateau are presented as views in the ArcView project. The ArcView project and the digital files are stored on both discs of this CD-ROM set—Appendix 6 of chapter T resides on both discs. Persons who do not have ArcView 3.1 may query the data by means of the ArcView Data Publisher on disc 1. Persons who do have ArcView 3.1 may utilize the full functionality of the software by accessing the data that reside on disc 2. An explanation of the ArcView project and data library —and how to get started using the software—is given by Biewick and Mercier (chap. D, this CD-ROM). Metadata for all digital files are also accessible through the ArcView project]

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Geologic Overview and Resource Assessment of Coal in the Kaiparowits Plateau, Southern Utah

By Robert D. Hettinger, Laura N.R. Roberts, Laura R.H. Biewick, *and* Mark A. Kirschbaum

Abstract

This report on the coal resources of the Kaiparowits Plateau, Utah, is a contribution to the U.S. Geological Survey's National Coal Resource Assessment, a 5-year effort to identify and characterize coal beds and coal zones that could potentially provide energy resources for the Nation during the 21st century. The Kaiparowits Plateau was evaluated because coal companies have expressed an interest in developing this coal resource since the early 1960's and because the potential for coal development has created many land-use and environmental issues. This report provides a geologic overview of the plateau and assesses the distribution and abundance of its coal resource. The results are reported within a variety of spatial parameters that might be useful for potential future energy exploration and land-use planning. Coal quantities reported as resources represent, as accurately as data allow, all coal in the ground in beds greater than 1 ft thick and under less than 6,000 ft of overburden. The term "original resource" refers to coal in the ground prior to mining. More deeply buried coal is reported as other occurrences of non-resource coal. This study does not attempt to estimate coal *reserves* for the Kaiparowits Plateau. Reserves are that subset of the resource that can be economically produced at the present time. Some factors that might significantly affect the amount of coal that can be recovered include: (1) bed thickness, (2) bed continuity, (3) inclination (dip) of strata, (4) coal that must be left in the ground for roof support, (5) coal that might be bypassed or destroyed while mining adjacent beds, and (6) coal that might not be mined because of land-use or environmental restrictions.

The Kaiparowits Plateau occupies about 1,650 mi^2 in southern Utah. It extends across the Grand Staircase–Escalante National Monument, and is adjacent to the Glen Canyon National Recreation Area and Bryce Canyon National Park. The plateau contains large quantities of subbituminous and bituminous coal in the John Henry Member of the Upper Cretaceous Straight Cliffs Formation. The coal is less than 2,000 ft deep throughout much of the plateau and is as much as 8,500 ft deep in the plateau's central region. The coal developed from peat that accumulated in coastal-plain mires that were located immediately inland (southwest) of shorelines of the Western Interior Seaway. The coastal-plain strata grade into shoreface deposits to the northeast and fluvial strata to the southwest, and these collective facies are contained in highstand systems tracts of the Calico and A-sequences. The highstand deposits are generally progradational in the Calico sequence and aggradational in the overlying A-sequence. The combined sequences contain 1 to 164 ft of net coal in 1 to 30 beds and individual coal-bed thicknesses range from 1 to 59 ft. More than 100 ft of net coal are found near the plateau's northern boundary and in three areas located 8–15 mi southwest of the plateau's eastern flank.

The Calico and A-sequences contain about 28 billion short tons of coal that are favorable for current underground mining technology. These resources are in beds that are more than 3.5 ft thick, less than 3,000 ft deep, and inclined by less than 12°. Less than 50,000 short tons have been mined from this resource, and all of the remaining coal would have to be mined by underground methods. Although some of this resource is currently feasible to mine economically, much of it might not be minable because of additional geological, technological, land-use, or environmental restrictions. A significant amount of the coal may remain undeveloped because it is within the Grand Staircase–Escalante National Monument. The Calico and A-sequences contain an additional 34 billion short tons of coal that are not likely to be mined in the foreseeable future because, in addition to their proximity to the National Monument, they (1) are in beds that are too thin (< 3.5 ft), (2) cannot be extracted from beds that are more than 14 ft thick, (3) are too deep (> 3,000 ft), or (4) are steeply inclined (>12°).

Introduction

Purpose and Scope

An overview of the geology and the assessment of coal resources in the Kaiparowits Plateau of southern Utah is presented in this report. Included are maps and charts that show the distribution of coal. These diagrams can serve as a baseline to further assess the coal resource in terms of its availability and recoverability. The Kaiparowits Plateau is part of the U.S. Geological Survey's (USGS) National Coal Resource Assessment that was initiated in 1994. The goal of the National Assessment is to characterize the resource potential and quality of coal for the entire Nation, with emphasis on those coals that might be of importance during the first quarter of the 21st century. The Kaiparowits Plateau is one of six priority areas within the Rocky Mountains and Colorado Plateau region. The Kaiparowits Plateau contains about 1.5 percent of the Nation's total coal resource in the lower 48 States, if compared to the figures of Averitt (1975). Coal resources of the Kaiparowits Plateau are a source of ongoing controversy because of coal mining, environmental, and land-use issues. These issues became paramount in 1996 when about 75 percent of the plateau was included in the Grand Staircase–Escalante National Monument. A preliminary coal-resource investigation by Hettinger and others (1996) made geologic and coal-resource data available to the public and land-use agencies for decisions regarding the newly established National Monument. Coal-resource figures presented in this report supersede those in the preliminary assessment by Hettinger and others (1996).

The assessment of the Kaiparowits Plateau is based on data from geologic mapping, outcrop measurements, and drilling that has been conducted in the region since the late 1960's. Deposits of coal are contained in the Smoky Hollow and John Henry Members of the Upper Cretaceous Straight Cliffs Formation, and although the distribution of coal is well documented on outcrop, its distribution in the subsurface has remained largely unknown because of the proprietary status of company data. However, recently acquired company drill-hole data and drilling conducted by the USGS have provided new insight into the subsurface aspects of these coals. These recently released data have been integrated with additional published geologic data to construct coal correlation charts and maps that show various aspects of coal distribution in the Kaiparowits Plateau. These data have been stored digitally and were manipulated in a geographic information system (GIS) to calculate coal resources within a variety of spatial parameters that are useful for land-use planning. Original coal resources reported in this investigation are for total in-place coal in the Smoky Hollow and John Henry Members and do not indicate the amount of coal that can be economically mined from the Kaiparowits Plateau.

Methods

In order to assess the coal resources of the Kaiparowits Plateau, we created digital files for various geologic features within the plateau. These spatial data were stored, analyzed, and manipulated in GIS using ARC/INFO software developed by the Environmental Systems Research Institute, Inc. Spatial data that required gridding (such as coal thicknesses from individual data points) for the generation of contour and isopach maps were processed using Interactive Surface Modeling (ISM—Dynamics Graphics, Inc.). Contour lines generated in ISM were then converted into ARC/INFO coverages using a program called ISMARC, which we received from the Illinois State Geological Survey. We also collected and created additional coverages in ARC/INFO that define various geographic boundaries in the vicinity of the Kaiparowits Plateau. Integrating these various coverages has allowed us to calculate coal resources and characterize coal distribution within a variety of geologic and geographic parameters that can be selected according to an individual's needs. The digital coverages used in this report are available in the Arc/View project in Appendix 6, and they are explained by Biewick and Mercier (chap. D, this CD-ROM). The following paragraphs discuss procedures used to produce the various coverages used in the assessment.

Lithologic and Stratigraphic Data

Lithologic and stratigraphic data are derived from our interpretations of the geophysical logs from 139 company coal-exploration drill holes and 22 oil and gas holes as well as published descriptions from 6 USGS drill holes and 46 measured stratigraphic sections. Drill-hole data were provided by 5M, Inc., PacificCorp Electric Operations, Andalex Resources, Oryx Energy Company, the U.S. Bureau of Land Management (BLM), and the Petroleum Information Corp. All data point localities are shown on figure A of plate 1. Data are identified, and lithologic and stratigraphic interpretations for each data point are provided, in Appendix 1. Depths of lithologic and stratigraphic intervals from 155 selected drill holes are shown in Appendix 5 (disc 2, this CD-ROM). The selected drill holes are a subset from appendix 1, and they include all coal exploration and oil and gas holes that penetrate significant portions of the coal-bearing interval assessed in this report.

Lithologic interpretations of geophysical logs are based on a combination of responses from natural gamma or gamma ray, density, resistivity, and neutron logs, and were modified by core and cutting descriptions when available. Examples of geophysical log responses to lithologies are provided by Wood and others (1983, their figs. 26–31). Sandstone was interpreted from a moderate response on natural gamma and resistivity logs. Mudrock was interpreted from a high natural gamma and a low resistivity response. Coal was interpreted from a low natural gamma and density response and a high resistivity and neutron response. Coal-bed thicknesses were measured between the midpoints on density or natural-gamma log curves wherever possible, and measurements were rounded to the nearest foot. Coal beds less than 1 ft thick were not included in the assessment. The minimum thickness of 1 ft was a modification from the 14 in cutoff for coals of bituminous rank as suggested by Wood and others (1983). The thicknesses of coal benches were combined and reported as a single bed if an intervening parting was thinner than both of the underlying and overlying benches; the thickness of the partings was not included in the reported thickness of the coal bed (Wood and others, 1983, p. 31, 36).

Stratigraphic interpretations are based on lithologic stacking patterns in each drill hole and on correlations to nearby cores and outcrops. Some stratigraphic interpretations are based on lithologic descriptions from published measured sections and geologic reports. Many of the original geophysical logs were recorded at various scales and deflection patterns and, therefore, were not well suited for the purpose of stratigraphic correlations. We resolved the log-scale problems by digitizing all geophysical logs and plotting them at uniform scales. Selected digitized log traces are shown in cross sections on figures C, D, and E of plate 1.

Geologic Maps

ARC/INFO coverages for geologic features include the locations of stratigraphic boundaries, faults, fold axes, and areas where strata are variably inclined (dipping). These data were digitized using ARC/INFO. Geologic contacts, fold axes, and faults were digitized at a 1:125,000-scale from a geologic map of the Kaiparowits coal-basin area (Sargent and Hansen, 1982). The upper contact of the coal-bearing John Henry Member was digitized from a 1:100,000-scale geologic map of Kane County (Doelling and Davis, 1989). The ranges-of-dip map was compiled at a 1:125,000 scale from structure contour lines and dip measurements shown on published 1:24,000-scale geologic maps.

Geographic Boundaries

ARC/INFO coverages for geographic boundaries were imported from existing public-domain databases. Township boundaries were obtained from a 1:24,000-scale Public Land Survey System (PLSS) coverage produced by the Automated Geographic Reference Center (AGRC) in Salt Lake City, Utah. The locations of towns and roads were obtained from 1:100,000-scale digital line graphs created by the USGS EROS Data Center in Sioux Falls, South Dakota. Areas of surface ownership were digitized from 1:100,000-scale maps that were compiled in 1993 for the Utah Geographic Approach to Planning Analysis Project (GAP). The ownership data were then updated in 1999 using information provided by the Utah School and Institutional Trust Lands Administration (SITLA) to show changes associated with the establishment of the Grand Staircase–Escalante National Monument. Areas of coal ownership were obtained from 1:100,000-scale digital compilations from the former U.S. Bureau of Mines Inventory of Land Use Restraints program and the PLSS coverage. County and State lines were obtained from 1:100,000-scale Topologically Integrated Geographic Encoding and Referencing (TIGER) files produced by the U.S. Bureau of the Census in 1990. Surface topography was obtained from a USGS digital elevation model (DEM) of the 1:250,000-scale Escalante quadrangle.

Location

The Kaiparowits Plateau is located in the southwestern part of the Colorado Plateau province and occupies parts of Kane and Garfield Counties near the towns of Escalante, Henrieville, and Glen Canyon City, in southern Utah (fig. 1). In this study, the boundary of the Kaiparowits Plateau is placed at the base of Upper Cretaceous rocks where they are exposed between lat 37°N. and 38°N. and long 111°W. and 112°W. The Kaiparowits Plateau merges to the north with the Aquarius Plateau (fig. 1), and the boundary between the two is defined by the Paunsaugunt fault and exposures at the base of Tertiary volcanic rocks. Further use of the word "plateau" in this report refers only to the Kaiparowits Plateau. The plateau covers an area of approximately 1,650 mi^2 and extends about 65 mi from north to south and 20 to 55 mi from east to west. The northern part of the plateau is in the Dixie National Forest, a few small areas along the plateau's southern boundary are in the Glen Canyon National Recreation Area, and about 75 percent of the plateau is in the Grand Staircase–Escalante National Monument (inset on fig. 1). Bryce Canyon and Capitol Reef National Parks are located west and east of the plateau, respectively.

The Kaiparowits Plateau is a dissected mesa that rises as much as 6,500 ft above the surrounding terrain. Elevations range from about 4,000 ft in the south near Lake Powell (fig. 1) to 10,450 ft in the northern part of the plateau. The landscape is dominated by four sets of cliffs and benches that form a step-like topography between the Aquarius Plateau and Lake Powell (Sargent and Hansen, 1980). One set includes the Straight Cliffs, which form a prominent escarpment extending along most of the plateau's eastern flank; the escarpment is as much as 1,100 ft high at Fiftymile Mountain (fig. 1).

Previous Mining Activity and Geologic Studies

Coal in the Kaiparowits Plateau was first mined by settlers in the late 1800's near the town of Escalante, and small mines produced coal for local needs until the 1960's. Locations of the abandoned mines are shown on figure 1. Production figures from Doelling and Graham (1972) are shown on table 1 and indicate that less than about 50,000 short tons of coal have been mined from the region.

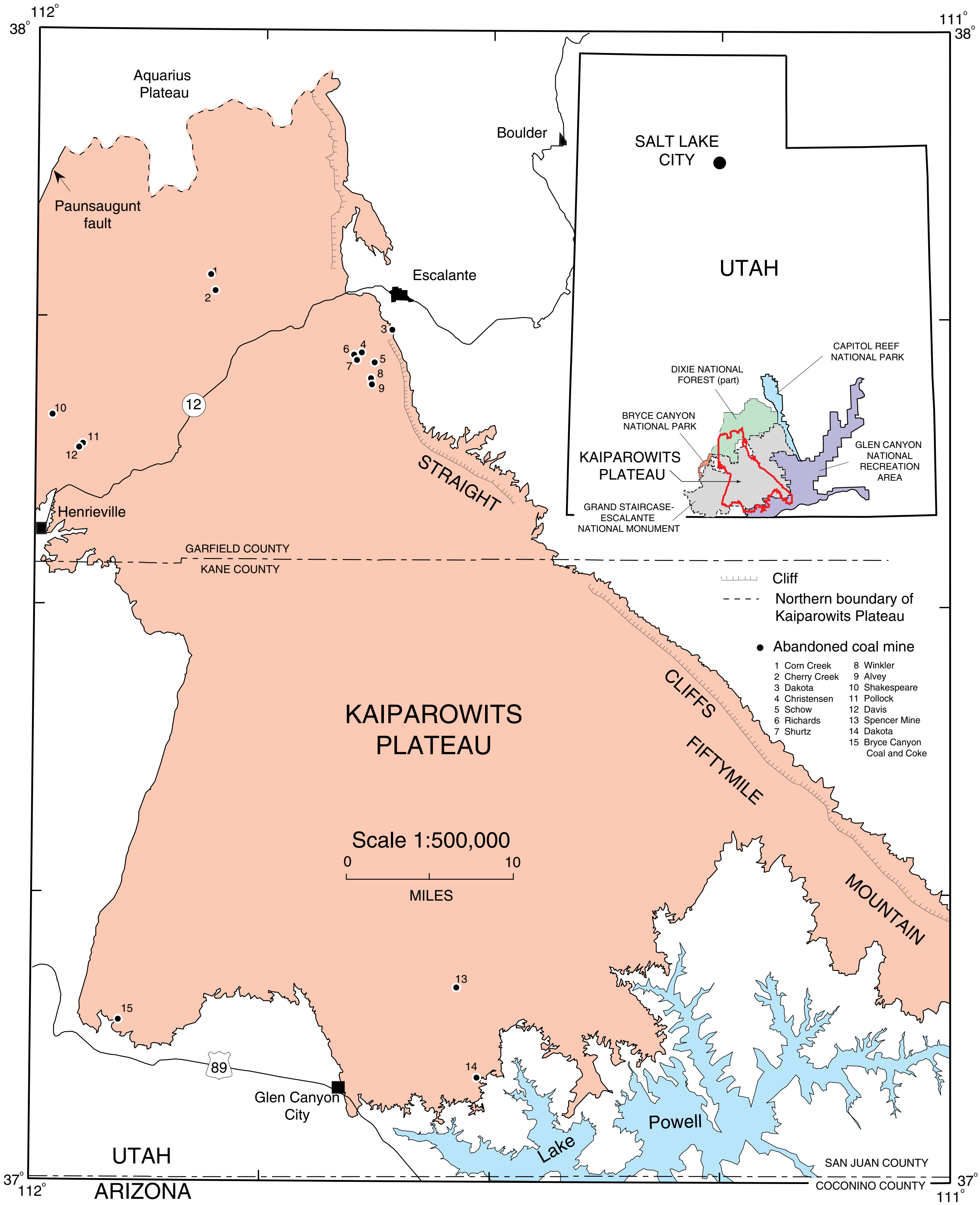

Figure 1. Location of Kaiparowits Plateau, Utah, east of long 112°W. The plateau is delineated by the base of Upper Cretaceous rocks except along its northern boundary where it merges with the Aquarius Plateau. Inset map shows the location of the Kaiparowits Plateau with respect to nearby National Monuments, Forests, Parks, and Recreation Areas.

Table 1. Coal mining history in the Kaiparowits Plateau, Utah.

[Total coal production from each mine is estimated from average annual production reported in Doelling and Graham (1972). Mine and quadrangle locations are shown on figures 1 and 2, respectively. Table is modified from Doelling and Graham (1972)]

Mine	Location	7.5' quadrangle	Producing horizon	Years of production	Estimated total production (short tons)
Alvey	NW1/4 sec. 12, T. 36 S., R. 2 E.	Canaan Creek	Alvey coal zone	1952-1962	12,000
Bryce Canyon Coal and Coke	NE1/4 sec. 21, T.42 S., R. 1 W.	Fivemile Valley	Dakota Formation	1939-1970? (Intermittent)	1,000
Cherry Creek	SE1/4 sec. 8, T. 35 S., R. 1 E.	Griffin Point	Alvey coal zone	1962-1964	420
Christensen	SW1/4 sec. 36, T. 35 S., R. 2 E.	Canaan Creek	Christensen coal zone	1893-1930	100
Corn Creek	SE1/4 sec. 5, T. 35 S., R. 1 E.	Griffin Point	Rees coal zone?	unknown	unknown
Davis	NE1/4 sec. 36, T. 36 S., R. 2 W.	Pine Lake	Henderson coal zone	1952-1953	100
Dakota Coal mine	NE1/4 sec. 30, T. 35 S. R. 3 E.	Dave Canyon	Dakota Formation	unknown	unknown
Dakota Coal mine	NW1/4, sec. 7, T. 43 S., R. 4 E.	Lone Rock	Dakota Formation	Abandoned, 1913	145
Pollock	SE1/4 sec. 25?, T. 36 S., R. 2 W.	Pine Lake	Henderson coal zone	1920-1925	unknown
Richards	SE1/4 sec. 35, T. 35 S., R. 2 E.	Canaan Creek	Christensen coal zone	1913-1928	15,000
Shakespeare	NW1/4 sec. 23, T. 36 S., R. 2 W.	Pine Lake	Henderson coal zone	1952-1964	5,800
Shurtz	SW1/4 sec. 35, T. 35 S., R. 2 E.	Canaan Creek	Christensen coal zone	1913-1928	1,500
Schow	SW1/4 sec. 36, T. 35 S., R. 2 E.	Canaan Creek	Christensen coal zone	unknown	unknown
Spencer	SW1/4 sec. 3, T. 42 S., R. 3 E.	Tibbet Bench	Christensen coal zone ?	1910-1913	115
Winkler	NW1/4 sec. 12, T. 36 S., R. 2 E.	Canaan Creek	Alvey coal zone	1920's	unknown

Although coal investigations in the Kaiparowits Plateau were first reported by Gregory and Moore (1931), it was not until the early 1960's that energy companies expressed an interest to develop the region's coal resource. Since then, coal leases have been held by at least 23 companies (Doelling and Graham, 1972), and about 1,000 coal exploration holes have been drilled in the plateau (Jim Kohler, BLM, oral commun., 1991). Plans were made in 1965 to develop a 5,000-megawatt coal-burning power plant but were revised in the mid 1970's to a 3,000-megawatt plant because of controversy over environmental issues (Sargent, 1984, p. 8). Construction plans were finally discontinued because of government action and pending lawsuits over environmental issues (Sargent, 1984). By 1996, only a few companies retained coal leases and Preference Right Lease Applications (PRLA), and most of these expired shortly thereafter. Finally, in late 1996, about 1,250 mi^2 of the plateau was included in the Grand Staircase–Escalante National Monument. The few Federal coal leases that remained were suspended prior to the establishment of the Monument and remain in suspension as of this publication (Jim Kohler, BLM, oral commun., 1999). Currently, only one PRLA remains in the plateau, and it is located near the abandoned Shakespeare mine (fig. 1).

The USGS has conducted numerous investigations to assess the geology and coal resources of the Kaiparowits Plateau. Stratigraphic investigations resulted in formal divisions of some Upper Cretaceous and Tertiary strata (Peterson, 1969b; Bowers, 1972, respectively). Other sedimentological and stratigraphic studies demonstrated the relations between marine and coal-bearing continental strata and provided sequence stratigraphic divisions for Upper Cretaceous rocks in the region (Shanley and McCabe, 1991; Shanley and others, 1992; McCabe and Shanley, 1992; Hettinger and others, 1994; Hettinger, 1995). Information obtained from coal drilling projects was reported by Zeller (1976, 1979) and Hettinger (1993, 1995). Geologic maps were published at a 1:24,000 scale for 25 7.5′ quadrangles within the plateau (fig. 2), at 1:125,000 for the entire Kaiparowits Plateau (Sargent and Hansen, 1982), and at 1:250,000 for the 1°×2° Escalante quadrangle (Hackman and Wyant, 1973). Seven 7.5′ quadrangles in the southern part of the plateau were also mapped by the USGS and published at a 1:31,680 scale by the Utah Geological and Mineralogical Survey (fig. 2).

The USGS also published a series of 1:125,000-scale maps that addressed geologic factors related to potential coal mining within the Kaiparowits Plateau. Results of these studies were summarized by Sargent (1984). Drainage patterns and stream-flow data were shown by Price (1978), water quality was reported by Price (1977a, 1979), and ground-water availability was reported by Price (1977b). Scenic features and landforms were mapped by Carter and Sargent (1983) and Sargent and Hansen (1980), respectively. Surficial geology was mapped by Williams (1985), and landslide deposits were mapped by Fuller and others (1981). Bedrock geology was mapped by Hansen (1982). Geologic cross sections were provided by Lidke and Sargent (1983) and maps of total coal and overburden were provided by Hansen (1978a, 1978b).

Geologic investigations by the Utah Geological and Mineralogical Survey have also resulted in significant publications. A comprehensive assessment of the geology and coal

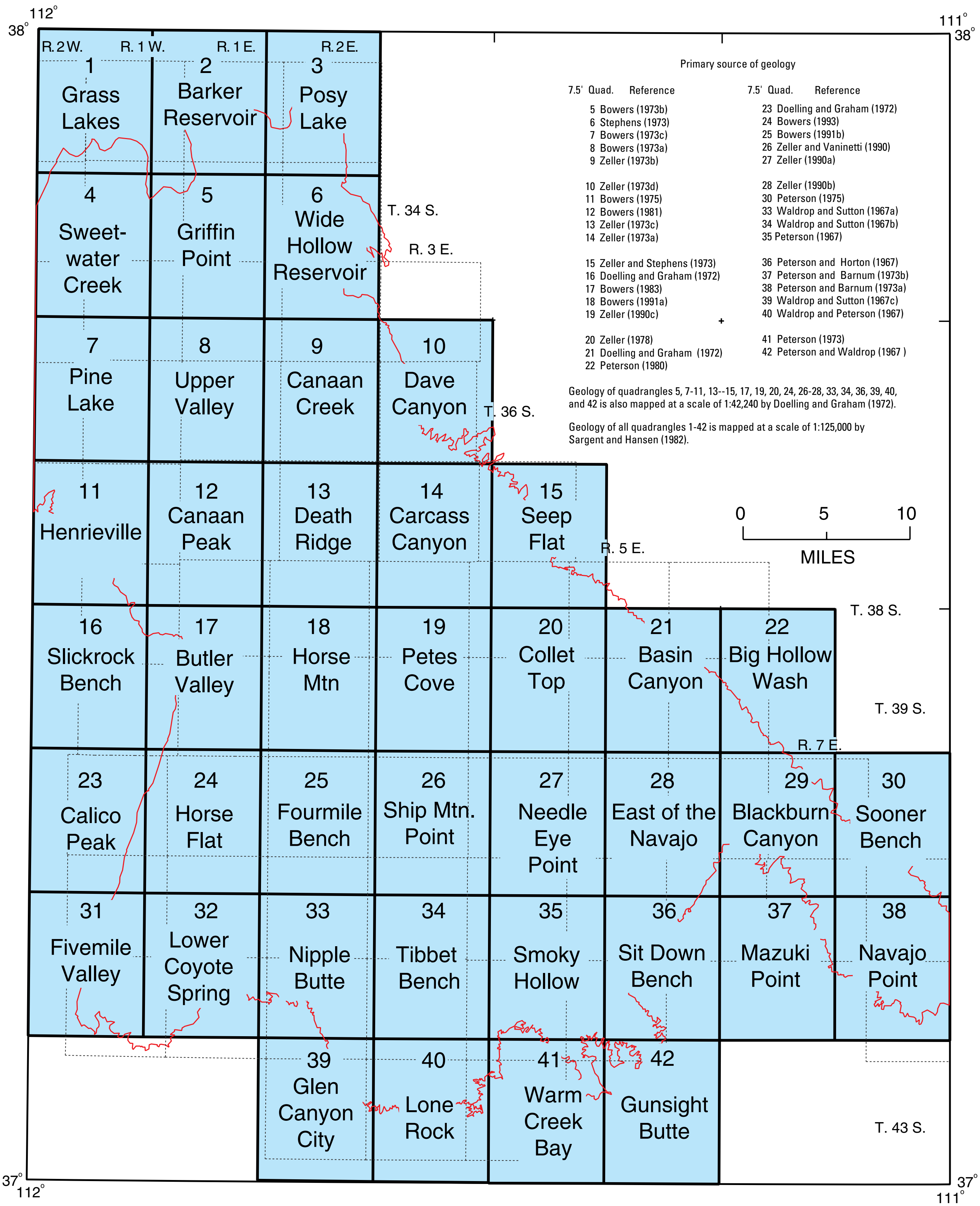

Figure 2. Index map of 7.5′ quadrangles and townships in the Kaiparowits Plateau. Published geologic maps of quadrangles are referenced in inset. The outline of the plateau is shown in red, township lines are dashed, and 7.5′ quadrangles are numbered and shown in blue.

resources in the Kaiparowits Plateau was published by Doelling and Graham (1972). This report included geologic maps, at a scale of 1:42,240, and measured coal thicknesses in 27 7.5′ quadrangles in the plateau (fig. 2). The geology of Kane County, Utah, was reported by Doelling and Davis (1989) and included a 1:100,000-scale geologic map of the southern part of the Kaiparowits Plateau. Coal resources for the southern part of the plateau were also described by Blackett (1995).

Coal resources of the Kaiparowits Plateau were previously estimated by Averitt (1961), Peterson (1969b), and Doelling and Graham (1972), and the reported tonnages included coal in both the Dakota and Straight Cliffs Formations. Initially, Averitt (1961) estimated that the Kaiparowits Plateau contained 3 billion short tons of coal. Coal discoveries made during the 1960’s resulted in higher estimates, and Peterson (1969a, p. 219) estimated that the plateau contained about 40 billion short tons of coal in beds that were more than 1 ft thick and less than 3,000 ft deep. Doelling and Graham (1972, p. 102–106) reported that the plateau contained about 15 billion short tons of coal in beds more than 4 ft thick and less than 3,000 ft deep and stated that most of the coal in the plateau was minable only by underground methods. Both Peterson (1969a, p. 221) and Doelling and Graham (1972, p. 102) estimated that about 4 billion short tons of coal could be mined. Coal resource estimates have also been made by Doelling and Graham (1972) and the USGS for 12 quadrangles in the plateau, and those estimates are included in Appendix 3.

Acknowledgments

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Geologic Setting

General Stratigraphy of Cretaceous and Tertiary Strata of the Kaiparowits Plateau

Geologic cross sections by Lidke and Sargent (1983) indicate that as much as 7,500 ft of Upper Cretaceous strata and 3,000 ft of Tertiary strata underlie the Kaiparowits Plateau (table 2). Upper Cretaceous rocks include, in ascending order, the Dakota Formation, Tropic Shale, and Straight Cliffs, Wahweap, Kaiparowits, and Canaan Peak (lower part) Formations. Paleocene strata are in the Canaan Peak (upper part), Pine Hollow, and Wasatch (lower part) Formations. The middle and upper parts of the Wasatch Formation are Eocene in age, and the Osiris Tuff is Miocene in age. The Dakota, Tropic, and Straight Cliffs Formations are exposed along the margins of the plateau but are buried by younger strata in the plateau’s central region (fig. 3). Thicknesses, lithologies, and depositional settings for these Cretaceous and Tertiary formations are summarized in table 2, and additional sedimentological, stratigraphic, paleontological, and palynological data are provided in the publications cited in table 3.

Coal is found in the Dakota Formation and the Smoky Hollow and John Henry Members of the Straight Cliffs Formation (table 2). Coal beds in the Dakota Formation and lower part of the Smoky Hollow Member are generally thin, lenticular, or too deep to be mined in the foreseeable future, so they are described only briefly in the following paragraph. The Smoky Hollow (upper part) and John Henry Members contain coal beds that are generally thicker, and they have been the focus of company exploration; therefore, they are described in detail throughout the remainder of this report.

Coal has been found in most areas where the Dakota Formation is exposed along the periphery of the plateau (fig. 3). The Dakota has as many as seven lenticular beds of coal that are generally less than 2 ft thick; however, 4- to 6-ft-thick beds have been reported in the Dave Canyon quadrangle (Zeller, 1973d), Henrieville quadrangle (Bowers, 1975), and Wide Hollow Reservoir quadrangle (Stephens, 1973) (fig. 2). The quality of coal in the Dakota Formation is not well known, but proximate and ultimate analyses of a sample from the Dakota Coal mine (fig. 1, table 1) yielded 11,370 Btu/lb on a moist, mineral-matter-free basis (Waldrop and Peterson, 1967), and it has an apparent rank of subbituminous A using the Parr formula described in American Society for Testing and Materials (1995). The basal 25 ft of the Smoky Hollow Member contains as many as four coal beds that are generally less than 2 ft thick; additionally, 3-ft-thick beds have been reported in the Wide Hollow Reservoir quadrangle (Stephens, 1973), and 4- to 5-ft-thick beds have been reported in the Lone Rock quadrangle (Waldrop and Peterson, 1967) and Smoky Hollow quadrangle (Peterson, 1967) (fig. 2).

Detailed Stratigraphy of the Upper Cretaceous Straight Cliffs Formation

During the Late Cretaceous, the region now occupied by the Kaiparowits Plateau was located at a paleolatitude of about 41°N. (Irving, 1979; Beeson, 1984), on the western margin of the Western Interior Seaway (fig. 4). Shorelines were oriented about N. 45° W. to S. 45° E., (Peterson, 1969b; Shanley, 1991; Roberts and Kirschbaum, 1995), and sediment was supplied from the Sevier Highlands (Peterson, 1969a). Approximately 1,100–1,600 ft of strata were assigned to the Straight Cliffs Formation by Gregory and Moore (1931). The Straight Cliffs Formation was initially divided by Waldrop and

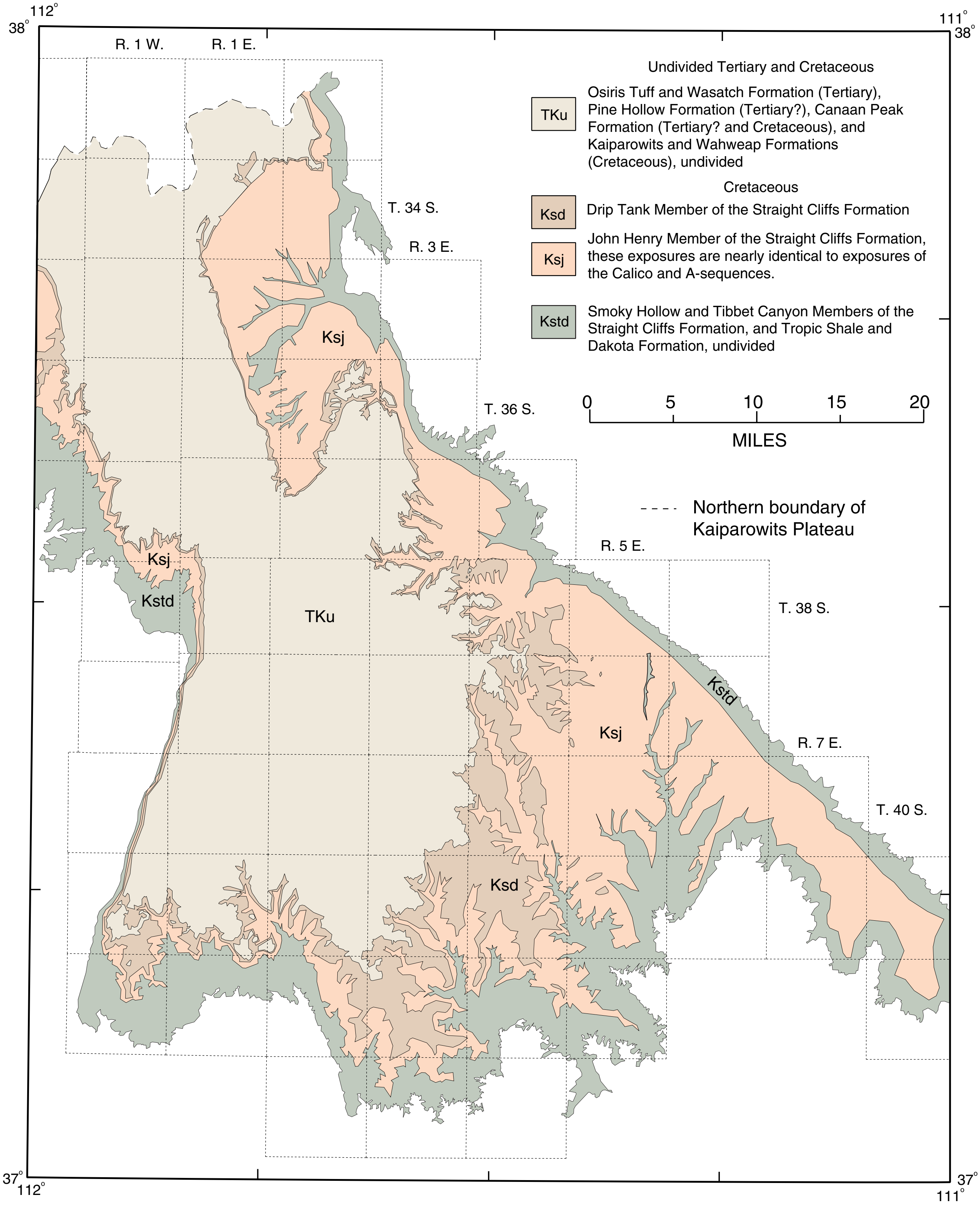

Figure 3. Generalized geologic map showing outcrops of Upper Cretaceous and Tertiary rocks in the Kaiparowits Plateau. At the mapped scale, outcrops of the John Henry Member of the Straight Cliffs Formation are nearly identical with outcrops of the Calico and A-sequences. Geologic map is modified from Sargent and Hansen (1982).

Table 2. Stratigraphic summary of Upper Cretaceous and Tertiary strata in the Kaiparowits Plateau, Utah.

[Lithologic descriptions and depositional interpretations are based on Sargent and Hansen (1982), Bowers (1972), Peterson (1969a, 1969b) and Shanley and McCabe (1991)]

Age	Formation	Thickness (ft)	Description and depositional interpretation
Miocene	Osiris Tuff	0-600	Gray, purplish-gray and red-brown welded ash-flow tuff. Volcanic.
Eocene and Paleocene	Wasatch Formation	1,350-1,650	**Variegated sandstone member** (0-600 ft) Red, pink, and purplish-gray, very fine to coarse-grained sandstone, mudrock and minor conglomerate. Fluvial. **White limestone member** (0-600 ft) Light-gray to white, crystalline limestone and minor mudrock. Lacustrine. **Pink limestone member** (0-900 ft) Gray, tan, white, pink or red, fine-grained clastic limestone, mudrock, sandstone, and minor conglomerate. Fluvial.
Paleocene?	Pine Hollow Formation	0-450	Lavender to red and gray mudrock and limestone with coarse-grained, pebbly sandstone in lower part. Low-energy fluvial and lacustrine.
Paleocene? and Late Cretaceous	Canaan Peak Formation	0-900	Gray, tan, and brown conglomerate, conglomeratic sandstone, and minor gray and red mudstone. High- energy fluvial.
Late Cretaceous	Kaiparowits Formation	600-3,000	Greenish- and bluish-gray, fine-grained, silty sandstone with subordinate beds of mudrock and limestone. Low-energy fluvial (meandering river) and floodplain.
	Wahweap Formation	900-2,600	Light-gray and brownish-orange, fine- to medium-grained sandstone interbedded with gray mudrock and shale. Upper part is dominantly sandstone. Fluvial and floodplain.
	Straight Cliffs Formation	1,000-2,000	**Drip Tank Member** (140-400 ft) Light-gray, medium- to coarse-grained sandstone, conglomeratic sandstone, and minor mudrock. Braided river. **John Henry Member** (600 *-1,500 ft) Light-gray to brown, very fine to medium-grained sandstone; minor coarse-grained and conglomeratic sandstone; olive-gray, brown, and black mudrock, and coal. Nearshore marine, estuarine, paludal, and alluvial. * Thickness based on subsurface data. **Smoky Hollow Member** (20-300 ft) Lower part is fine-grained sandstone, mudrock, and coal. Upper part contains light-gray, medium- to coarse-grained and pebbly sandstone in the informally named Calico bed, and coal locally overlies the Calico bed. Coastal plain, paludal, and braided river (Calico bed). **Tibbet Canyon Member** (60-185 ft) Yellowish-gray and grayish-orange, fine- to medium-grained sandstone with siltstone and mudrock in lower part. Estuarine and nearshore marine.
	Tropic Shale	600-900	Gray shale with thin beds of siltstone and fine-grained sandstone in upper part. Offshore marine.
	Dakota Formation	15-250	**Upper member** (0-68) Light-brown, very fine- to fine-grained sandstone interbedded with gray mudrock. Coastal plain, brackish water, and nearshore marine. **Middle member** (4-76) Gray to brown, very fine grained to fine-grained sandstone interbedded with yellowish-green mudrock, carbonaceous mudrock, and coal. Low-energy fluvial, flood basin, and paludal. **Lower member** (0-66) Gray to brown conglomerate and fine- to coarse-grained, pebbly sandstone and minor carbonaceous mudrock. High-energy fluvial.

Table 3. Summary of publications regarding the stratigraphy, sedimentology, paleontology, and palynology of Upper Cretaceous and Tertiary rocks in the Kaiparowits Plateau, Utah.

Formation	Authors of investigation and references
Wasatch, Pine Hollow, and Canaan Peak Fms.	Bowers (1972)
Kaiparowits Fm.	Lohrengel (1969)
Wahweap Fm.	Peterson (1969a), Eaton (1991)
Straight Cliffs Fm.	Peterson (1969a, 1969b), Orlansky (1971), Doelling and Graham (1972), Vaninetti (1978), Johnson and Vaninetti (1982), Eaton (1991), Shanley (1991), Shanley and McCabe (1991), Shanley and others (1992), McCabe and Shanley (1992), Hettinger and others (1994), Hettinger (1995), Nichols (1995)
Tropic Shale and Dakota Fm.	Lawrence (1965), Peterson (1969a), May and Traverse (1973), Gustason (1989), Eaton (1991), Kirschbaum and McCabe (1992)

Peterson (1967) into lower, middle, and upper sandstone members that were mapped along the plateau's southern flank (fig. 5). The middle member contained a minor coal zone, a white sandstone marker bed, a major coal zone, and an upper barren zone.

Peterson (1969b) formally divided the Straight Cliffs Formation, in ascending order, into the Tibbet Canyon, Smoky Hollow, John Henry, and Drip Tank Members (table 2, fig. 5). Peterson interpreted the Tibbet Canyon and Smoky Hollow as middle and late Turonian-age deposits that accumulated along the regressive shorelines of the Western Interior Seaway. He also interpreted the Tibbet Canyon as consisting of shallow-marine and beach deposits and the Smoky Hollow as consisting of coal-bearing coastal-plain strata in its lower part and braided-river deposits in its upper part; the braided-river deposits were informally named the Calico bed. Peterson further interpreted the Calico bed as being truncated by an unconformity of late Turonian to early Coniacian age. However, the unconformity has not been recognized on the western flank of the plateau, and Shanley and others (1992) reinterpreted it as a ravinement surface that was cut during a marine transgression. The John Henry is early Coniacian to late Santonian in age (Eaton, 1991) and consists of coal-bearing continental beds that grade eastward into a vertical stack of near-shore marine strata (Peterson, 1969a, 1969b). Shoreface sandstones in the marine strata form the dominate lithology along the Straight Cliffs escarpment (fig. 1) and were informally named A through G (fig. 5) by Peterson. Coal in the John Henry was assigned to the lower, Christensen, Rees, and Alvey zones (fig. 5) by Peterson. The Drip Tank is constrained to a late Santonian or early Campanian age (Eaton, 1991) and consists of sandstone that is interpreted to have been deposited in a fluvial environment (Peterson, 1969a, 1969b).

The stratigraphic divisions and nomenclature of Peterson (1969b) have been used to map most areas in the southeastern and eastern parts of the plateau. However, the Straight Cliffs Formation was simply divided by Bowers (1973c) into lower and upper parts (fig. 5) that were mapped along the western flank of the plateau. The lower part contains a basal marine sandstone that is equivalent to the Tibbet Canyon and a white marker sandstone that is equivalent to the Calico bed. The upper part contains the Henderson coal zone (defined by Robison, 1966) at its base and is capped by a thick, massive sandstone that is equivalent to the Drip Tank. Strata between the white marker sandstone and thick, massive sandstone are equivalent to the John Henry. Correlations between the various units and members shown in figure 5 are based on Doelling and Graham (1972) and Bowers (1973c, 1975, 1983, 1991a, 1991b, 1993). In this report, all further references to the nomenclature of Peterson (1969b) include equivalent strata throughout the Kaiparowits Plateau. Outcrops of the John Henry and Drip Tank and their laterally equivalent strata are shown in figure 3.

Sequence Stratigraphy of the Straight Cliffs Formation

Recent stratigraphic and sedimentological investigations by Shanley and McCabe (1991) have resulted in the identification of four unconformity-bounded sequences in the Straight Cliffs Formation. The unconformities are located (1) in the Tibbet Canyon Member, (2) near the base of the Calico bed, (3) within the A-sandstone, and (4) near the base of the Drip Tank Member, and these are named the Tibbet, Calico, A-, and Drip Tank sequence boundaries, respectively (fig. 5, fig. 6). Each overlying sequence is named after its basal unconformity. The sequence-boundary unconformities are recognized by facies that have abruptly shifted basinward over regional surfaces of erosion. The basinward facies shifts are characterized by fluvial and estuarine strata that are juxtaposed over finer grained coastal-plain and shoreface strata (fig. 6); these relationships have been documented by Shanley (1991), Shanley and others (1992), and Hettinger and others (1994).

Deposition in each of the sequences is interpreted to have been controlled by base-level fluctuations, in that each sequence-boundary unconformity was cut during a fall in base

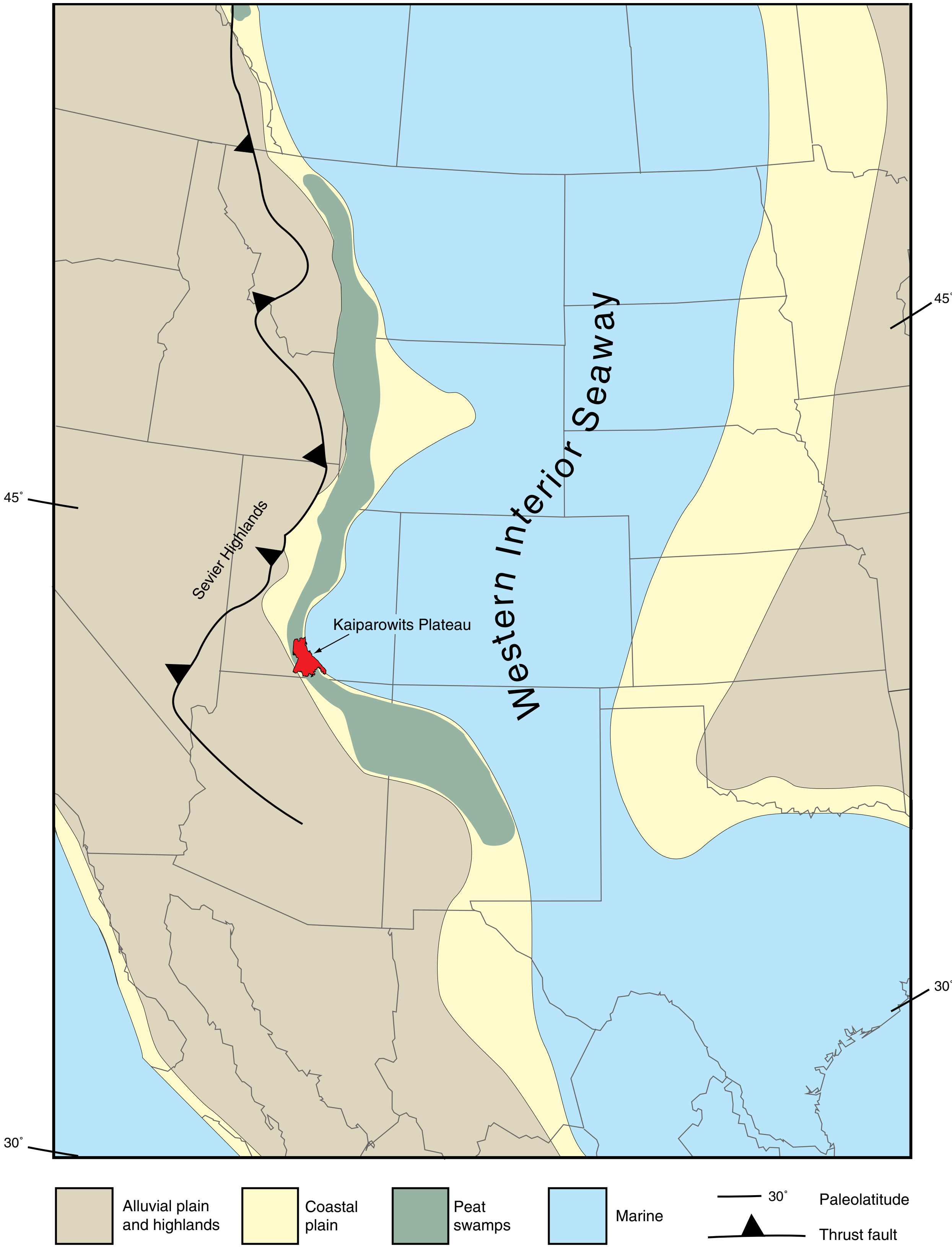

Figure 4. Paleogeographic map of the central part of North America during the Coniacian and Santonian Stages (88.5–83.5 Ma) of the Cretaceous Period. The Kaiparowits Plateau is shown in relation to shorelines, coastal plains, and peat swamps associated with the Western Interior Seaway; strata from these depositional systems are preserved in the Straight Cliffs Formation. Map is modified from Roberts and Kirschbaum (1995).

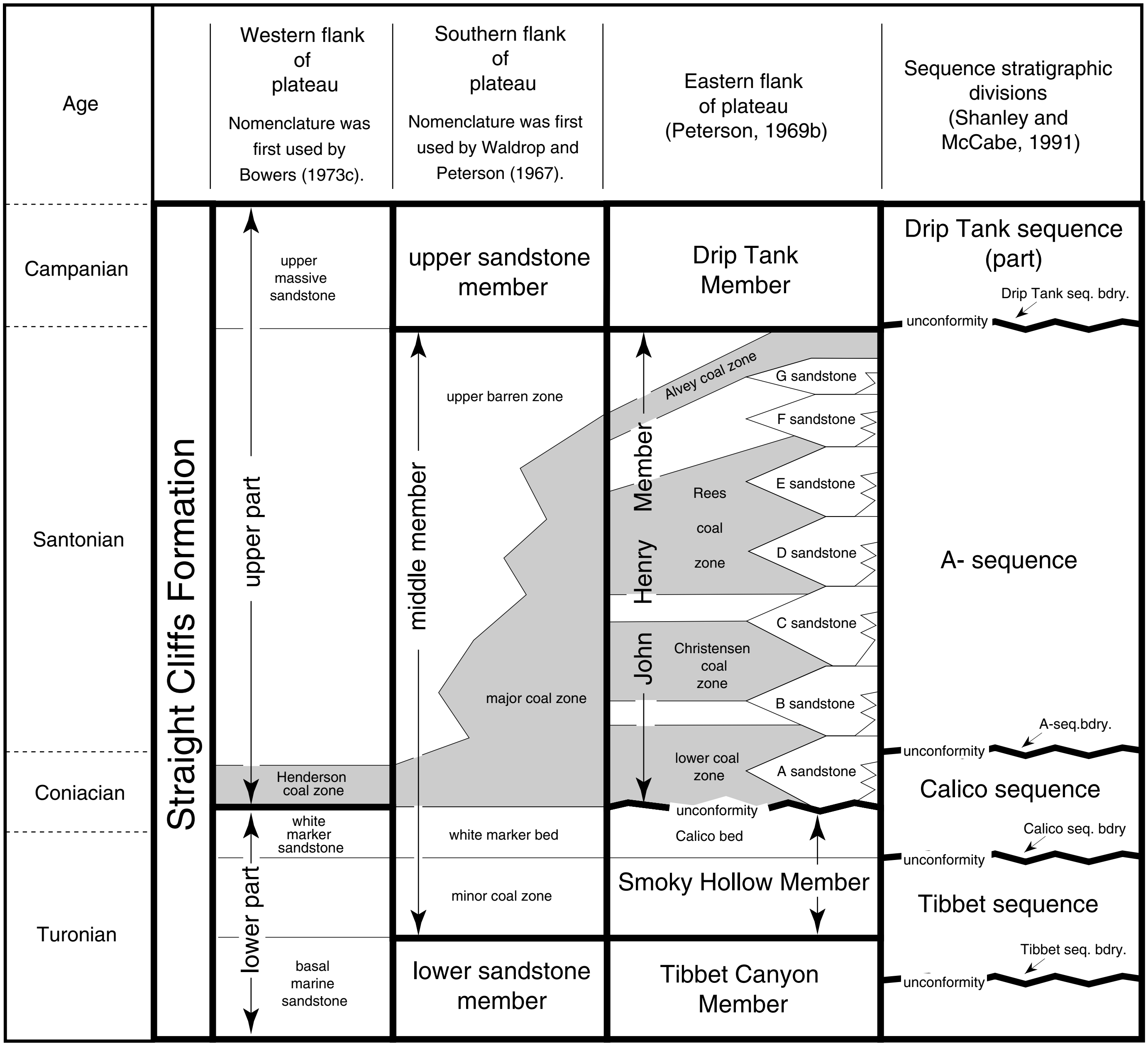

Figure 5. Stratigraphic divisions of the Straight Cliffs Formation used for geologic mapping and stratigraphic studies in various parts of the Kaiparowits Plateau. Age boundaries are approximately located.

level and each overlying sequence was deposited during a subsequent rise in base level (Shanley and McCabe, 1991). Valleys were incised during lowering base levels and were subsequently backfilled by upward-deepening stratal successions during the initial stage of base-level rise; the deepening-upward successions are interpreted to be within transgressive systems tracts (fig. 6). Overlying aggradational and progradational deposits of marine and coal-bearing continental strata are interpreted to have been deposited in highstand systems tracts during slower rates of base-level rise (fig. 6).

The Calico and A-sequences contain all of the coal that is in the Smoky Hollow (upper part) and John Henry Members. These two sequences underlie approximately 1,300 mi^2 of the plateau, and their outcrops are nearly identical to those shown for the John Henry at the scale shown in figure 3. Criteria used to recognize the Calico and A-sequences on geophysical logs were provided by Hettinger (1995), and examples of core and log characteristics from that report are shown on figure 7. The Calico sequence boundary was recognized by a high natural-gamma response that corresponds to a thick and widespread paleosol located below the Calico bed (Hettinger, 1995). The Drip Tank sequence boundary was placed near the base of

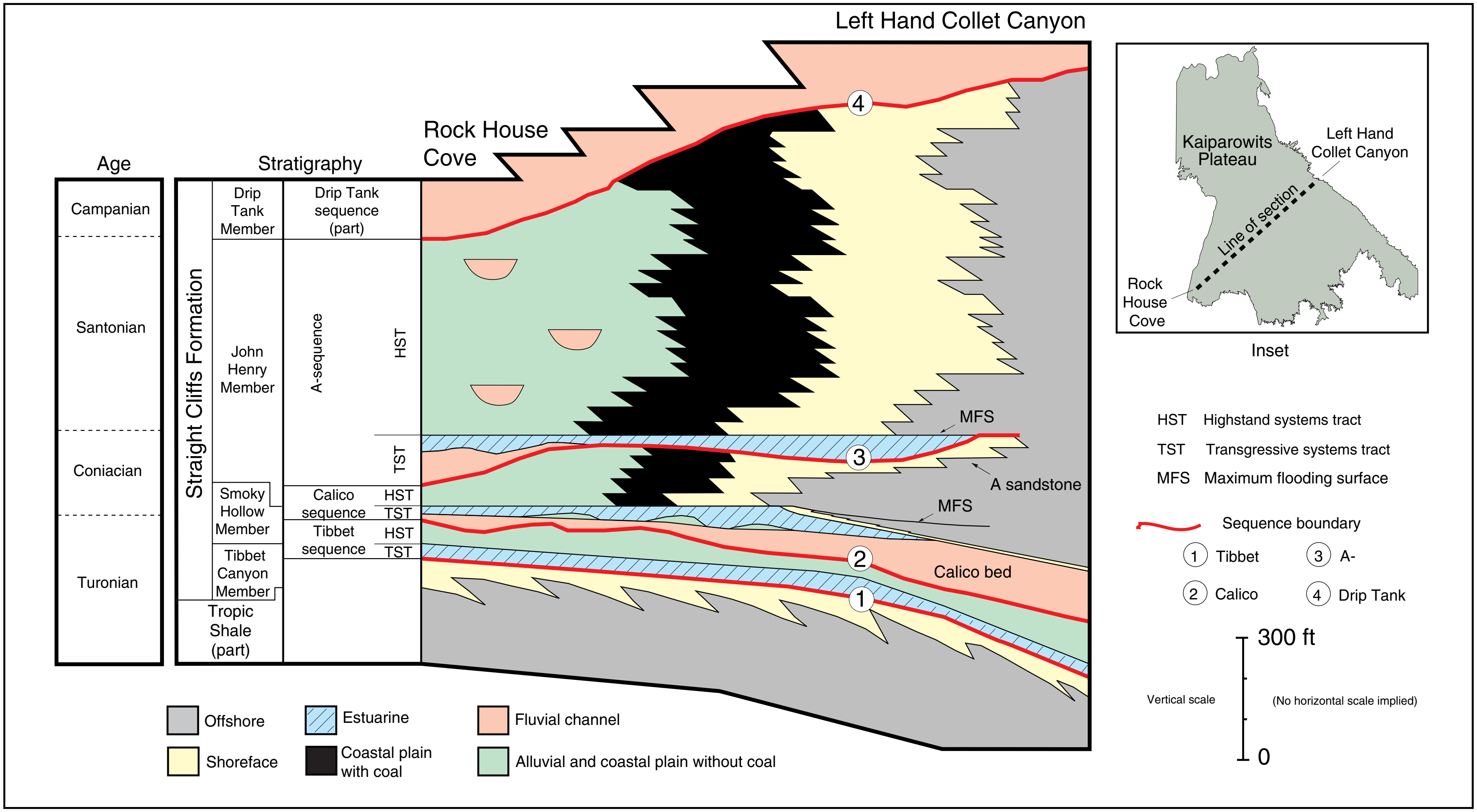

Figure 6. Sequence stratigraphy and facies relations in the Straight Cliffs Formation and upper part of the Tropic Shale. Line of section extends from Left Hand Collet Canyon to Rock House Cove (inset) and is perpendicular to paleoshoreline. Sequence-stratigraphic divisions are compared to formal stratigraphic nomenclature. Diagram is modified from Shanley (1991). Position of age boundaries are approximate.

blocky log signatures that correspond to thick sandstones in the Drip Tank Member (Hettinger, 1995). We have used this criteria to identify the Calico and Drip Tank sequence boundaries on the geophysical logs from about 166 drill holes, and the boundaries' down-hole elevations are listed in Appendix 1. These data were used in conjunction with outcrop data to construct isopach maps that show the thickness and deformation of the coal-bearing strata across the plateau.

The Calico and A-sequences have a combined thickness of approximately 600–1,600 ft (fig. 8); about 75–400 ft of strata are in the Calico sequence and 525–1,200 ft of strata are in the A-sequence. The combined sequences are 750–850 ft thick throughout much of the southwestern and south-central parts of the plateau and gradually thicken in the northern part of the plateau. The sequences are thickest along the Straight Cliffs escarpment (fig. 1), where they contain thick aggradational stacks of shoreface sandstone and mudrock. Conversely, they are thinnest in the central part of the plateau, where they are dominated by mudrock and coal (Hettinger, 1995). The variations in thickness probably result from the differential compaction of sandstone, mudrock, and peat. Trends in thickness of the combined sequences are based on our interpretations from the 192 data points listed in Appendix 1. The thickness of the combined sequences was determined from geophysical logs using the criteria described by Hettinger (1995). The thickness of the combined sequences from measured sections utilize the stratigraphic interval between the base of the Calico bed and base of the Drip Tank Member. The thicknesses of the combined sequences at the control points were based on texts from published geologic maps.

Structure

Strata within the Kaiparowits Plateau are inclined along numerous northerly trending folds that plunge into a deep central basin containing the Table Cliffs, Last Chance, and Coyote Creek–Billie Wash synclines (fig. 9). The eastern flank of the central basin is defined by the westwardly dipping limb of the Dutton monocline, and its western flank is defined by eastwardly dipping limbs of the Johns Valley anticline and East Kaibab monocline. Strata are inclined by less than 6° throughout most of the plateau (fig. 9). However, strata are inclined by as much 25° along a westwardly dipping homocline near the town of Escalante, 30° on the eastern limb of the Johns Valley anticline, 45° along the Dutton monocline, and 80° along the East Kaibab monocline. Areas where strata are inclined from 0°–6°, 6°–12°, 12°–25°, and more than 25° are shown in figure 9 and are based on inclination and structure-contour data shown on published geologic maps (fig. 2) and photogeologic maps by Detterman (1956), McQueen and Ray (1958), and McQueen (1958).

There are relatively few faults in the Kaiparowits Plateau, and most of these are located around its peripheral areas (fig. 9). Displacements are generally insignificant in regard to the potential mining of coal (Doelling and Graham, 1972). Faults having significant displacement include the northeast-trending Paunsaugunt fault and the bounding faults of the Jake Hollow graben, both located along the plateau's northern margin. The Paunsaugunt fault has as much as 2,000 ft of displacement and truncates all coal-bearing strata along the northwestern flank of the plateau (Doelling and Graham, 1972). The Jake Hollow graben is about 6 mi long, 0.5–1.0 mi wide, and has as much as 500 ft of displacement (Bowers, 1973b). Northeast-trending faults on the west-central flank of the plateau near Henrieville have a strong right-lateral strike-slip component and 200–250 ft of vertical displacement (Bowers, 1983). Farther south, the East Kaibab monocline is cut by numerous southeast-trending faults that have only minor displacements (Bowers, 1983, 1993). The southern margin of the plateau contains several additional northwest-trending faults that extend less than 10 mi and have less than 50 ft of displacement (Peterson, 1967; Waldrop and Sutton, 1967a; Zeller, 1990a).

Deformation of coal-bearing strata in the Calico and A-sequences is shown on a structure contour map of the Calico sequence boundary (fig. 10). The sequence boundary is 4,500–9,000 ft above sea level on outcrop but only 2,000 ft above sea level in the Table Cliffs syncline (figs. 9 and 10). The structure of the Calico sequence boundary reflects most of the major folds in the plateau and indicates that the folds are not related to the compaction of the overlying rock. Figure 10 was made using measured and estimated elevations of the sequence boundary from 166 drill holes (Appendix 1) as well as numerous elevations recorded 50 to 100 ft below the mapped base of the John Henry Member (see maps referenced in figure 2).

Coal Distribution, Quality, and Resources in the Calico and A-Sequences

The Calico and A-sequences contain coal in the Henderson coal zone, the lower coal zone, and the Christensen, Rees, and Alvey coal zones (fig. 5). The Henderson and lower coal zones are in the Calico sequence, and the Christensen, Rees, and Alvey coal zones are in the A-sequence. We describe these coals in sequence-stratigraphic context because, unlike the formational contacts of the John Henry Member, the Calico and Drip Tank sequence boundaries provide marker horizons that can be traced on geophysical logs throughout the plateau.

Coal Distribution

Coal-bearing strata in the Calico and A-sequences extend as much as 60 mi from north to south and 30 mi from east to west. Outcrop investigations show that the coal is confined within several distinct zones that are exposed along the flanks of the plateau. On the eastern flank of the plateau,

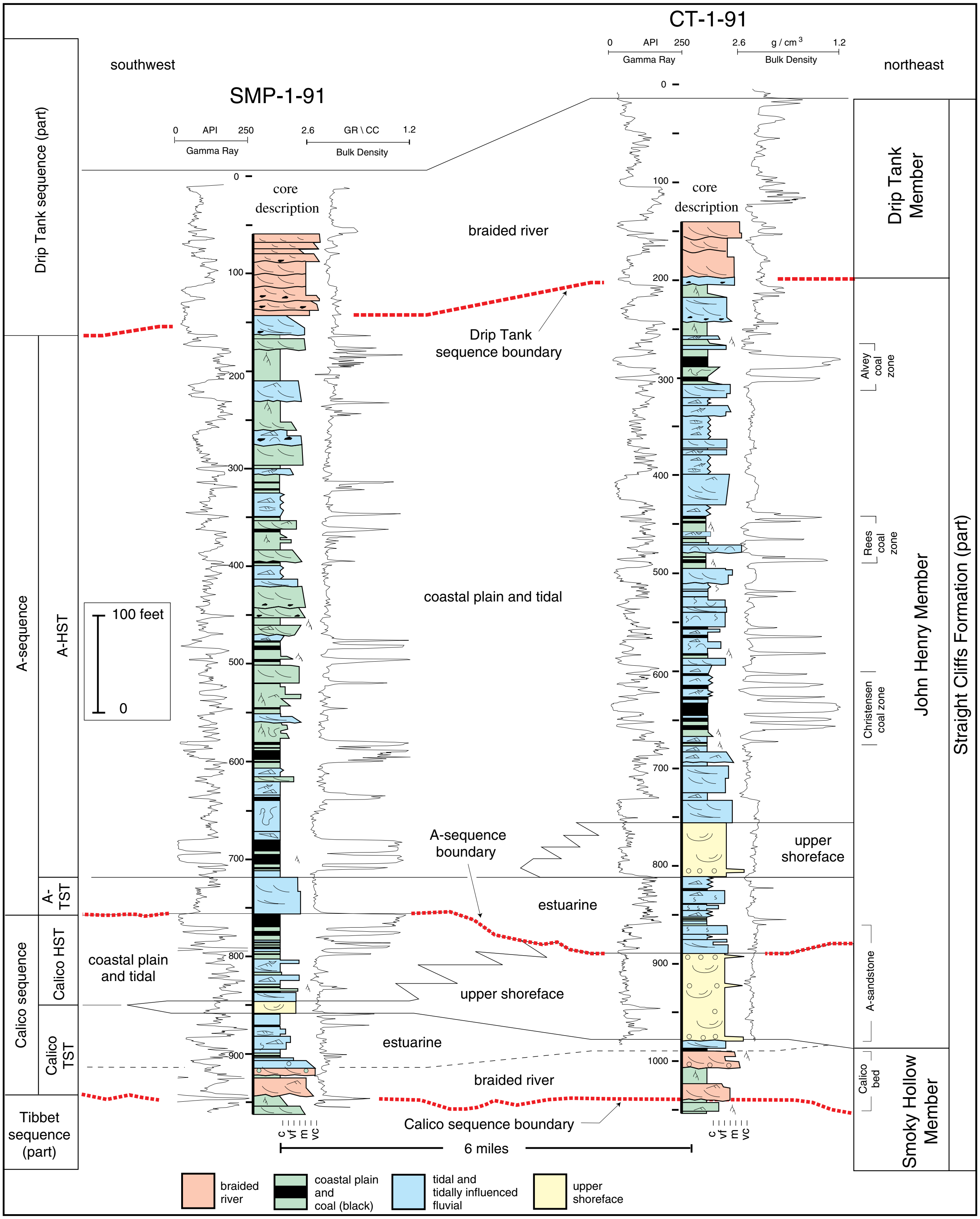

Figure 7. Responses of gamma ray and bulk density curves to lithologies in the Calico and A-sequences. Geophysical logs are from drill holes CT-1-91 and SMP-1-91 (localities 5 and 6, fig. A on plate 1). Lithologies are from core descriptions in Hettinger (1995). Explanations for grain size abbreviations (c, vf, m, vc) and symbols used for sedimentary structures are given on plate 1. Highstand systems tract (HST), transgressive systems tract (TST). Diagram is modified from Hettinger (1995).

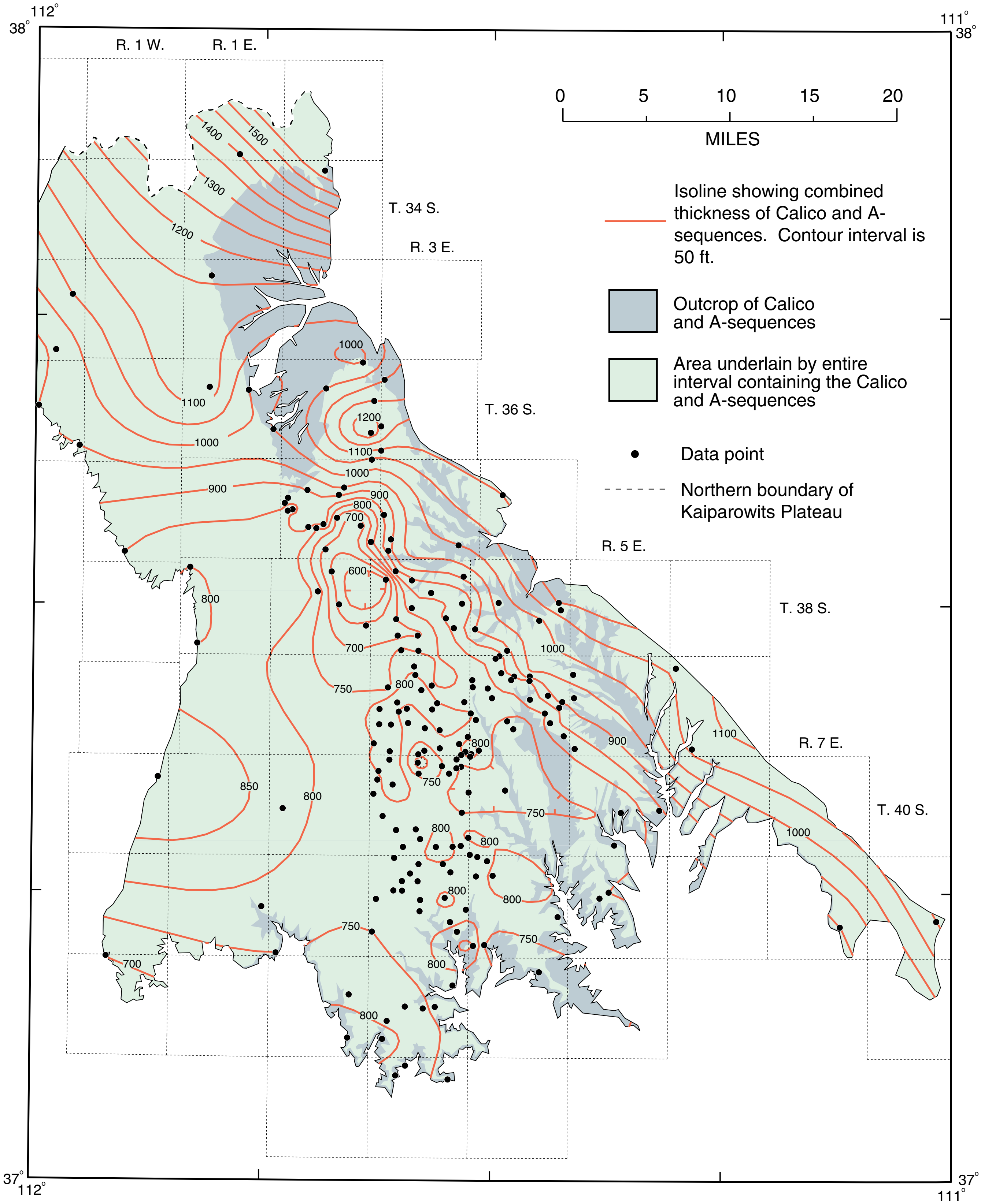

Figure 8. Isopach map showing the combined thickness of the Calico and A-sequences. Thicknesses are based on 192 data points. Data points are identified on figure A of plate 1, and the thickness of the combined sequences at each data point is given in Appendix 1. Isolines over outcrop areas represent restored thicknesses.

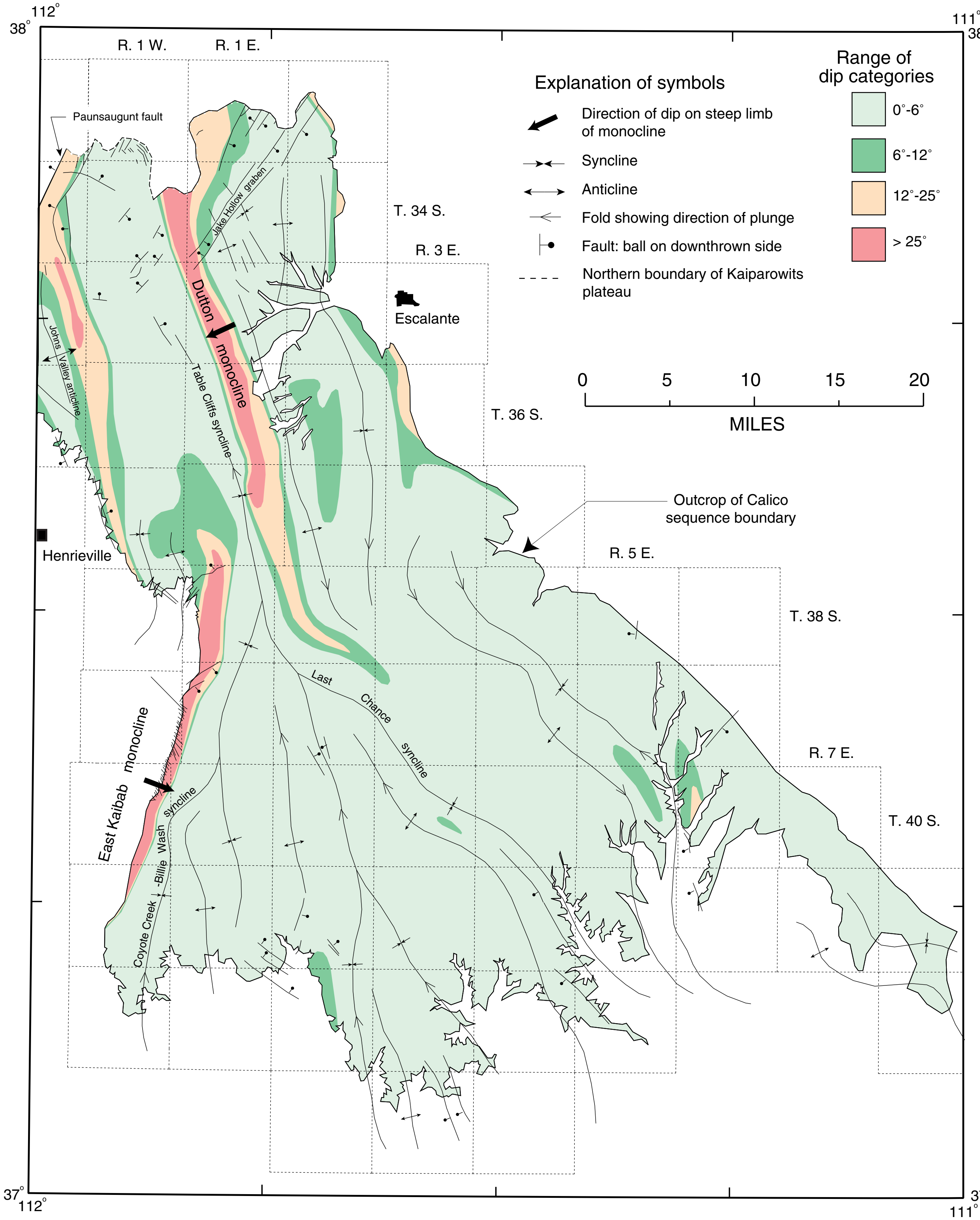

Figure 9. Structural features and inclination of strata within the Kaiparowits Plateau. Inclinations of strata are based on geologic mapping referenced in figure 2 and are shown in categories that range from 0–6, 6–12, 12–25, and >25 degrees. Fold axes and faults are from Sargent and Hansen (1982).

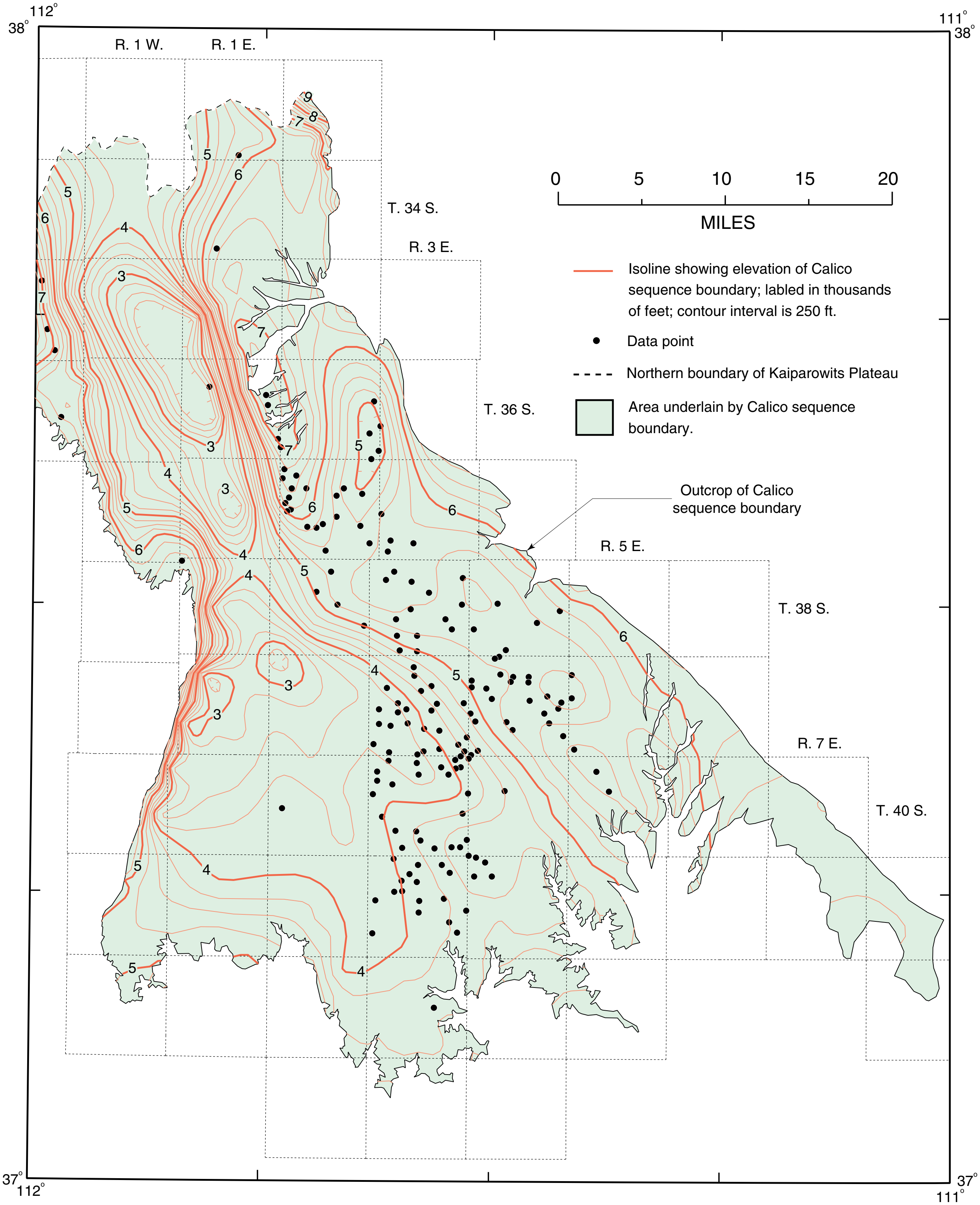

Figure 10. Structure contour map of the Calico sequence boundary. Sequence-boundary elevations are based on 166 drill holes. The Calico sequence boundary occurs from 50 to 100 ft below the John Henry Member; therefore, an inferred elevation of the sequence boundary was used at numerous locations along the outcrop where the base of the John Henry Member was mapped. Data points are identified on figure A of plate 1 and sequence-boundary elevations are provided in Appendix 1.

the coal-bearing interval is 500–700 ft thick and coal beds are concentrated into the lower, Christensen, Rees, and Alvey coal zones, which intertongue with, and pinch out into, shoreface deposits in the A-sequence (fig. 5). The coal-bearing interval thins to less than 50 ft on the plateau's western flank, where the only remaining coal is in the Henderson zone of the Calico sequence. Southwestward thinning of the coal-bearing strata is observed in exposures along the plateau's southern flank. The full extent of the coal-bearing interval is revealed on geophysical logs and in core collected from the plateau's interior region where the net coal accumulation is greatest. These drill-hole data show that the coal zones exposed on the plateau's flanks merge and lose their identity in the subsurface. The following section of this report provides a brief summary of coal distribution in outcrops and is followed by a detailed summary of coal distribution in the subsurface.

Coal Distribution in Outcrops

Thicknesses for coal beds exposed along the flanks of the Kaiparowits Plateau are provided in coal geologic maps cited in figure 2. Coal outcrop data from each 7.5′ quadrangle are summarized in Appendix 3, and a brief summary of coal beds in each zone is given below. In general, the coal beds are reported to split and pinch out over short distances on outcrop and are difficult to trace because they are commonly burned and covered by slope wash and talus. Coals are extensively burned and are still burning in parts of the East of Navajo, Needle Eye Point, Smoky Hollow, and Sit Down Bench quadrangles (fig. 2), and baked rocks in these areas can extend 200–300 ft into the subsurface (Peterson and Horton, 1967; Peterson, 1967).

Henderson coal zone.—The Henderson coal zone is 5–50 ft thick on outcrop and contains as much as 29 ft of net coal on the northwestern flank of the plateau in the Pine Lake quadrangle (fig. 2). The Henderson zone thins to the south and pinches out completely on the southwestern flank of the plateau in the Horse Flat quadrangle.

Lower coal zone.—This zone is exposed on the southern flank of the plateau, where it is as much as 40 ft thick and contains as many as four beds of coal that are 1–7 ft thick. The lower zone is split by the A-sandstone (fig. 5), and the upper split is exposed in the East of Navajo and Needle Eye Point quadrangles.

Christensen coal zone.—Outcrops of the Christensen coal zone are 70–130 ft thick and contain as many as six beds of coal that are 1–30 ft thick.

Rees coal zone.—This zone is 70–200 ft thick in outcrops and contains as many as seven beds of coal that are 1–20 ft thick.

Alvey coal zone.—Outcrops of the Alvey coal zone are 40–160 ft thick and have as many as eight beds of coal that are 1–20 ft thick.

Coal Distribution in the Subsurface

A broad overview of coal distribution in the Calico and A-sequences is shown on a net coal isopach map (fig. 11) and on cross sections A-A′, B-B′, and C-C′ (figs. C, D, and E on pl. 1). The net coal isopach map is based on coal measurements from 209 data points (Appendix 1). Cross sections A-A′ and B-B′ are perpendicular to paleoshorelines, and C-C′ is nearly parallel to paleoshorelines. A-A′ extends northeast 25 mi from Tibbet Canyon to Left Hand Collet Canyon; B-B′ extends southwest 11 mi from Alvey Wash; and C-C′ is located about 10 mi southwest of the Straight Cliffs and trends parallel to the escarpment for 19 mi (fig. B on pl. 1). Stratigraphic control was provided from cores CT-1-91 and SMP-1-91 (Hettinger, 1995) and measured sections at Alvey Wash (Zeller, 1973d), Left Hand Collet Canyon (Peterson, 1969a; Shanley, 1991), and Tibbet Canyon (Shanley, 1991); the respective localities are 5, 6, 177, 196, and 211 (fig. A on pl. 1).

The distribution of net coal in the Calico and A-sequences is related to the distance that peat accumulated inland from the shoreline of the Western Interior Seaway. McCabe and Shanley (1992) demonstrated that coal in the A-sequence developed in a wide belt immediately inland (southwest) from a stillstand of the shoreline; the belt was several miles wide and was bordered to the southwest by a large crevasse-splay and fluvial system. McCabe and Shanley proposed that the coal formed in mires that were elevated several meters above the coastal plain and suggested that the raised mires acted to stabilize the position of the shoreline.

Details of relations between the coal-bearing and shoreface strata are viewed in the dip-oriented cross sections A-A′ and B-B′ (fig. C and D, pl. 1). The cross sections show that beds of coal are located in close proximity to localities where the shoreface sandstones pinch out. The shoreline reached a maximum landward position in the central part of the plateau during the Coniacian Stage and then moved to the northeast and reached a stillstand near the Straight Cliffs escarpment during the Santonian Stage. As a result, highstand deposits of the Coniacian-age Calico sequence are dominated by progradational stacks of shoreface sandstone and mudrock in the central and eastern parts of the plateau and contain coal-bearing coastal-plain and fluvial strata along the western part of the plateau. The mostly Santonian-age A-sequence is dominated by aggradational stacks of shoreface sandstone along the Straight Cliffs escarpment, and it rapidly grades southwest into thick deposits of coal-bearing coastal-plain strata. Measured sections in Alvey Wash (Zeller, 1973d) and Left Hand Collet Canyon (Shanley, 1991) show that, within 2.5 mi of the escarpment, the A-sequence contains about 30 ft of net coal that is in the Christensen, Rees, and Alvey coal zones. The zones are separated by thick wedges of shoreface strata that thin to the southwest, and their thinning is accompanied by an increase in net coal. Eventually, the coal zones merge and their boundaries become indistinct. Core collected at CT-1-91 reveals that the

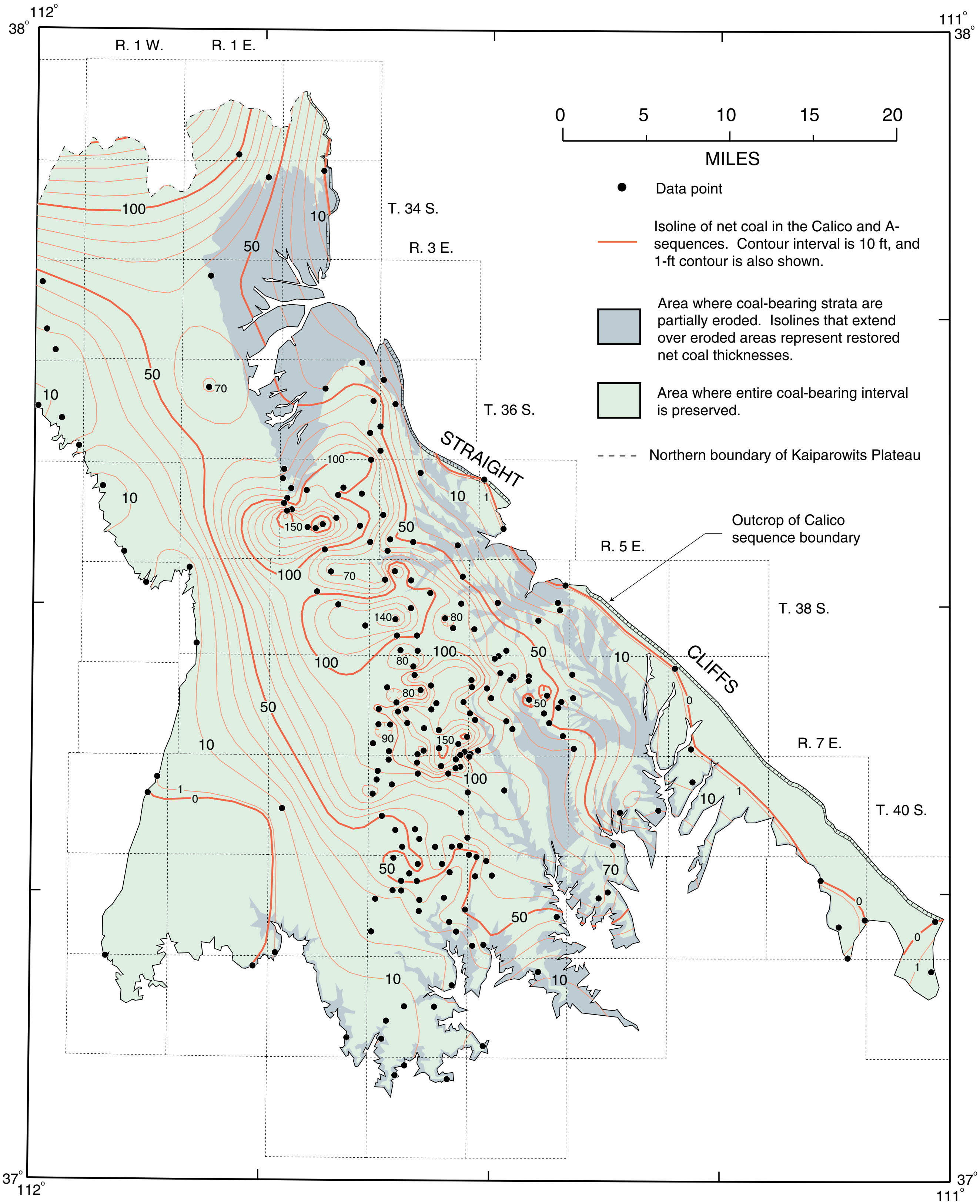

Figure 11. Isopach map of net coal in the Calico and A-sequences. Net coal values represent all coal beds that are more than 1 ft thick and are determined from 209 data points listed in Appendix 1; data points are identified on figure A of plate 1.

A-sequence contains 61 ft of net coal 5 mi southwest from the escarpment; the coal beds are as much as 11 ft thick, and intervening strata are dominantly tidal and coastal plain in origin (Hettinger, 1995).

Areas where net coal accumulations exceed 100 ft are located about 8–15 mi southwest of the Straight Cliffs escarpment (fig. 11) and are shown along depositional strike in cross section C-C′ (fig. E on pl. 1). As much as 160 ft of net coal is contained in a 500- to 600-ft-thick interval, and coal beds are as thick as 59 ft. Net coal accumulations of 150–160 ft have been drilled at localities 8, 9, 12, 13, 101, and 108 (fig. A on pl. 1), which are located about 10–12 mi southwest of the escarpment. Core SMP-1-91 reveals that Calico and A-sequences both contain thick coal beds in these areas and that intervening strata are mostly tidal and fluvial in origin (Hettinger, 1995). Coal beds in areas of maximum accumulation are concentrated in pods that extend laterally for about 1–3 mi. The pods eventually split into distinct coal zones that can be traced for several miles. Examples are seen at locality 13 (figs. D and E on pl. 1) between the depths of 1,595 and 1,670 ft and at locality 22 (fig. D on pl. 1) between the depths of 1,315 and 1,472 ft. Within the areas of overall thick coal accumulation, several localities have a relative paucity of coal. For example, as few as 70 ft of net coal were drilled at localities 15, 87, 94, and 152 (fig. A on pl. 1). Geophysical logs from these localities show a marked increase in sandstone as compared to nearby areas, and coal beds appear to be discontinuous. The increased sandstone content and decreased amount of coal might indicate that northeast-flowing fluvial systems prevailed in the area.

The net coal isopach map (fig. 11) and cross section A-A′ (fig. C on pl. 1) show that net coal accumulations and coal-bed thicknesses decrease southwest of the areas of maximum accumulation. A measured section described in Tibbet Canyon, located 22 mi southwest of the Straight Cliffs escarpment, shows that the A-sequence contains about 20 ft of net coal in beds that are all less than 3 ft thick, and only a few minor beds of coal remain in the Calico sequence (Shanley, 1991). The measured section also reveals that clastic deposits of both sequences are predominantly alluvial and, to a lesser degree, tidally influenced (Shanley, 1991). Still farther southwest, at Rock House Cove (fig. B on pl. 1), both highstand deposits are entirely alluvial in origin and contain no coal (Shanley, 1991).

The profile of net coal distribution in the Calico and A-sequences is shown on two diagrams in figure 12. The diagram in figure 12*A* demonstrates the net coal distribution perpendicular to the shoreline, and the diagram in figure 12*B* shows the net coal distribution parallel to the shoreline. The diagrams were constructed with the same drill-hole data used in their respective cross sections, A-A′ and C-C′ (figs. C and E on pl. 1). The vertical axis of each diagram shows the net coal recorded in holes drilled along the transect, and the horizontal axis shows the distance between the drill holes. In addition, the diagrams show the net coal accumulations within bed-thickness categories of 1–3.4, 3.5–14.0, and greater than 14.0 ft. The diagram in figure 12*A* shows that, perpendicular to the shoreline, the coal distribution takes on the shape of a simple curve, whereby thin coal beds and low values of net coal (less than 20 ft) are located along the flanks of the curve and thick coal beds and maximum values of net coal (as much as 150 ft) are found near the center of the curve. These relations suggest that the thickest peat accumulated on the coastal plain in areas that were nearly equidistant from shoreface and alluvial realms and that these areas of thick peat were least affected by clastic influx from either marine or fluvial sources. The diagram in figure 12*B* shows that, parallel to the shoreline, areas of maximum net coal (120–160 ft) are found at three distinct localities and are separated by areas where the net coal has decreased (60–70 ft) and thick beds are absent. These areas of decreased net coal might have been affected by clastic debris supplied from through-flowing streams that reached the coast.

Coal Quality

Coals in the Kaiparowits Plateau have been reported to be subbituminous C to high-volatile A bituminous in apparent rank (Doelling and Graham, 1972, p. 93). Proximate and ultimate analyses were provided by Doelling and Graham (p. 123–127) for about 100 coal samples collected from outcrops and abandoned mines. The ranges of proximate and ultimate analyses from these samples are summarized in Appendix 4. Additional coal-quality data have been reported for samples collected from four cores. The cores are from holes K-1-DR, CT-1-91, SMP-1-91, and DH-1. Drill holes K-1-DR, CT-1-91, SMP-1-91 are at localities 4, 5, and 6, respectively (fig. A on pl. 1), and information by Bowers (1973c) indicates that DH-1 is about 150 ft from locality 151 (fig. A on pl. 1). Analyses from DH-1 were reported by Doelling and Graham (p. 126), analyses from K-1-DR were reported by Zeller (1979) and Affolter and Hatch (1980), and analyses from CT-1-91 and SMP-1-91 were provided by Brenda Pierce (USGS, unpub. data, 1996).

The ranges in proximate and ultimate analyses and moist, mineral-matter-free BTU/lb are provided for core samples in table 4, and the arithmetic mean of proximate and ultimate analyses and moist, mineral-matter-free BTU/lb for outcrop and mine samples are provided in table 5. Apparent rank determined from these values are also provided in tables 4 and 5, respectively. These data show that the apparent ranks of samples collected from outcrops and mines range from subbituminous B to high-volatile C bituminous coal and that the apparent ranks of samples collected from core range from subbituminous B to high-volatile A bituminous coal (tables 4 and 5).

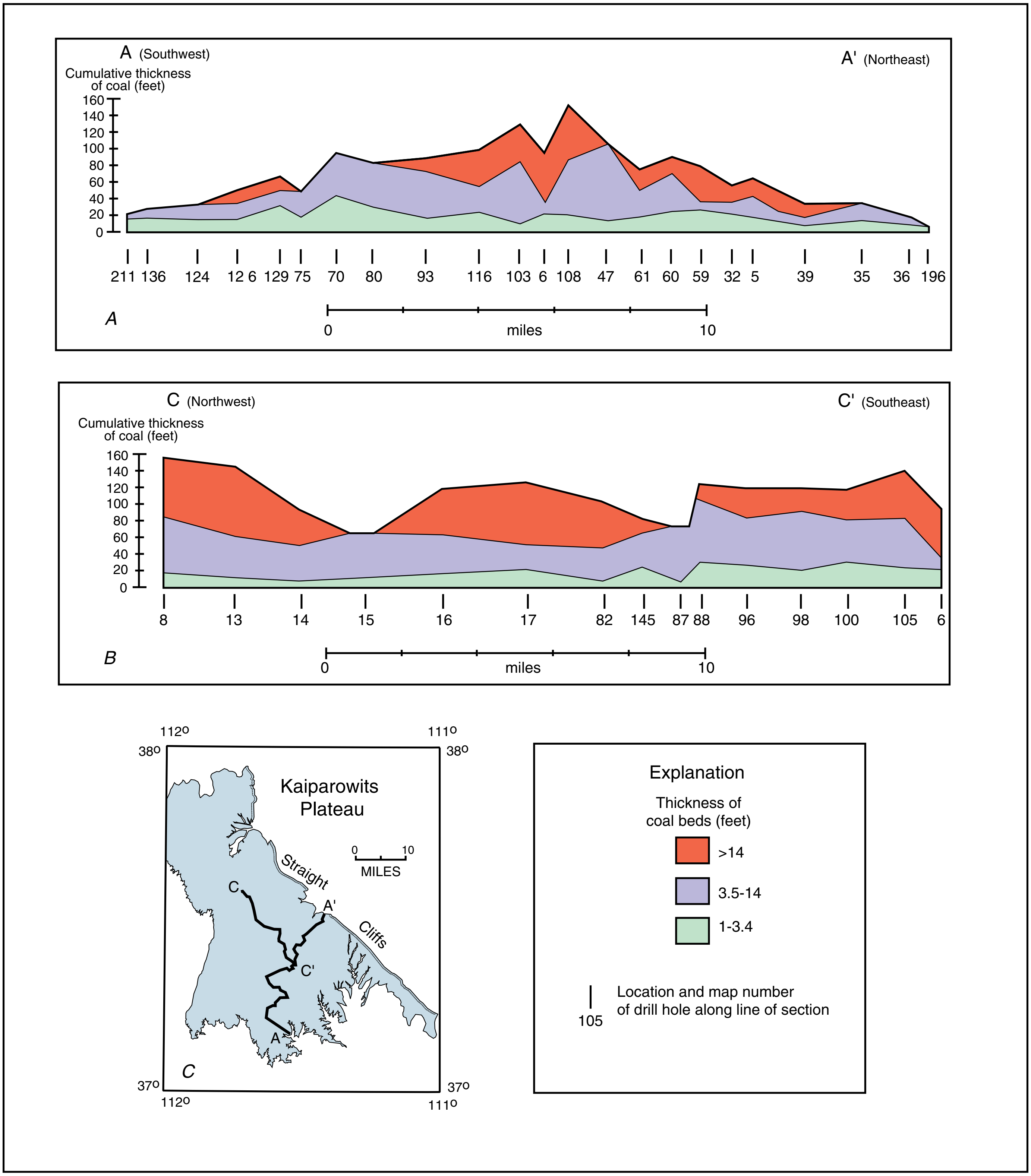

Figure 12. Coal distribution in the Calico and A-sequences. *A*, Coal distribution along A-A′, which trends perpendicular to the paleoshorelines. *B*, Coal distribution along C-C′, which trends parallel to the paleoshorelines. *C*, Locations of A-A′ and C-C′. Horizontal axes in *A* and *C* show distance between drill holes, and vertical axes show the cumulative coal thicknesses for beds that range from 1–3.4, 3.5–14.0, and greater than 14 ft in thickness. Drill-hole locations are shown on figure A of plate 1, and coal-bed thicknesses within each drill hole are listed in Appendix 1.

Table 4. Coal-quality summary for samples collected from cores from the Calico and A-sequences in the Kaiparowits Plateau, Utah.

[Coal zones are queried where uncertain. Apparent rank was calculated using the Parr formula (American Society for Testing and Materials, 1995)]

Coal zone	Moisture %	Volatile matter %	Fixed carbon %	Ash yield %	Sulfur content %	Heating value Btu/lb	Moist, mineral-matter-free heating value Btu/lb	Apparent rank
Coal samples collected from core K-DR-1 (map no. 4, fig. A on pl. 1)								
Alvey (2 samples)	19.7-20.4	34.7-35.1	37.0-37.7	7.2-8.2	1.0	9,440-9,510	10,240-10,440	Subbituminous B
Rees (3 samples)	15.6-18.4	29.6-35.0	29.9-36.3	10.3-24.9	0.6-0.7	7,640-9,280	10,450-10,460	Subbituminous B
Christensen (3 samples)	19.7-21.1	33.3-34.7	39.8-40.9	4.4-5.8	0.5-0.6	9,830-9,860	10,320-10,520	Subbituminous A and B
Coal samples collected from core SMP-1-91 (map no. 6, fig. A on pl. 1)								
Rees ? (6 samples)	8.2-9.7	41.7-43.9	41.8-44.7	2.7-8.2	0.4-0.7	11,490-12,380	12,390-12,760	High-volatile C Bituminous
Rees (17 samples)	0.7-7.8	27.9-50.7	24.9-45.4	4.3-42.5	0.5-2.3	6,960-12,390	12,700-13,710	High-volatile B and C Bituminous
Christensen (13 samples)	5.5-7.9	35.3-44.5	34.6-48.0	2.3-24.7	0.3-1.0	9,460-12,480	12,360-13,590	High-volatile B and C Bituminous
lower (15 samples)	4.5-7.1	35.4-46.5	32.1-45.5	3.5-26.4	0.4-2.3	9,000-12,620	12,610-16,720	High-volatile A, B, and C Bituminous
Coal samples collected from core CT-1-91 (map no. 5, fig. A on pl. 1)								
Christensen (23 samples)	8.5-15.5	34.5-41.1	34.8-4.6	3.7-17.6	0.4-2.2	9720-11720	11,110-12,590	Subbituminous A to high-volatile C Bituminous
Coal samples collected from core DH-1 [Information by Bowers (1973c) indicates that DH-1 is located 150 ft northwest of map number 151 (fig. A on pl. 1)].								
Henderson (5 samples)	9.4-18.9	32.4-38.2	26.4-35.6	8.4-29.9	NR	9,740-10,300	11,010-11,350	Subbituminous A

Table 5. Coal-quality summary of samples collected from mines and outcrops in the Calico and A-sequences in the Kaiparowits Plateau, Utah.

[Arithmetic means are reported for moisture, volatile matter, fixed carbon, ash yield, sulfur content, and heating value, and are based on proximate and ultimate analyses from about 100 samples reported in Doelling and Graham (1972, p. 123-127). Apparent ranks and moist and mineral-matter-free heating values were determined from these average values. Apparent rank was calculated using the Parr formula (American Society for Testing and Materials, 1995)]

Coal zone	Moisture %	Volatile matter %	Fixed carbon %	Ash yield %	Sulfur content %	Heating value Btu/lb	Moist, mineral-matter-free heating Value Btu/lb	Apparent rank
Coal collected from mines								
Alvey	16.4	38.4	38.0	7.3	0.6	9,350	10,150	Subbituminous B
Rees	5.0	41.4	48.7	5.0	0.7	11,600	12,270	High-volatile C Bituminous
Christensen	6.7	39.2	44.2	7.3	2.1	11,600	12,640	High-volatile C Bituminous
Henderson	18.7	39.1	36.5	8.6	1.0	9,260	10,210	Subbituminous B
Coal collected from outcrops								
Alvey	11.3	40.2	41.7	6.6	0.9	10,310	11,110	Subbituminous A
Rees	10.3	41.0	39.3	9.2	1.1	9,250	10,280	Subbituminous B
Christensen	10.9	38.8	43.1	7.2	0.9	10,390	11,280	Subbituminous A
Henderson	20.5	36.1	37.1	8.3	0.9	9,000	9,890	Subbituminous B

Coal Resources

The Kaiparowits Plateau contains an original coal resource of 61 billion short tons (table 6*A*) within the Calico and A-sequences. That tonnage is reported for all beds of coal that are greater than 1 ft thick and under less than 6,000 ft of overburden. The beds are distributed across a 825-mi^2 area where the entire coal-bearing interval is preserved (fig. 11). Production records reported by Doelling and Graham (1972, p. 71) indicate that less than 50,000 short tons of coal have been mined from the original resource (table 1). The plateau contains an additional 1.7 billion short tons of non-resource coal in the Calico and A-sequences that are covered by 6,000 to 8,500 ft of overburden (table 6*B*). Those coals are located in a 25-mi^2 area in the northern part of the plateau along the axis of the Table Cliffs syncline (fig. 9 , fig. 13). Coal beds deeper than 6,000 ft are not considered to be a resource, using criteria of Wood and others (1983, p. 30). Coal tonnages were calculated using the methodology of Wood and others and were determined by multiplying the volume of coal by its average density. The volume of coal in the Calico and A-sequences was determined as the product of its net thickness and areal extent as shown in figure 11. A bituminous rank was assumed for coal in the Calico and A-sequences based on analyses from mines and cores summarized in tables 4 and 5 and Appendix 4, and the average density of bituminous coal was determined to be 1,800 short tons per acre-foot by Wood and others (p. 22). The area containing the original resource includes most areas where State and Federal coal leases and Federal coal prospect permits were issued prior to 1972, as shown in Doelling and Graham (p. 100–101). Doelling and Graham (p. 106) state that underground mining is the most likely method for extracting coal in the plateau, and, although all localities in the reported resource area would have to be mined by underground methods, much of the coal is too deep to be economically mined in the foreseeable future.

Additional coal resources underlie the eastern and southern flanks of the Kaiparowits Plateau where the coal-bearing interval has been partially eroded (fig. 11). The eroded areas were not assessed because the coal tonnage would have to have been determined for each bed of coal based on their individual outcrop patterns and bed thicknesses, and these data were generally unavailable for individual coal beds in eroded areas. In many areas, coal measurements were shown in stratigraphic columns but could not be related to individual mapped beds, and in other areas individual coal beds were not mapped. In contrast, resources in non-eroded areas were calculated using the net thickness of all coal beds, and outcrop patterns were not a factor because all of the beds occupied the same area. Coal-tonnage estimates have been previously reported for many 7.5′ quadrangles where the eroded areas are located, and those estimates are provided in Appendix 3.

Original resources of coal and non-resource coal are reported in identified and hypothetical reliability categories (table 6). The categories are based on the distance that the calculated coal tonnage is from a data point. The identified category refers to coal tonnage that is within 3 mi of a data point, and the hypothetical category refers to coal that is more than 3 mi from a data point (Wood and others, 1983). Although confidence levels have not been established for these reliability categories, they reflect decreased levels of accuracy for the calculated coal tonnage based on their increased distance from a data point. About 47 billion short tons of coal (about 78 percent of the original resource) are less than 3 mi from a data point and are therefore considered to be an identified resource (table 6*A*). About 13 billion short tons of coal (about 22 percent of the original resource) are in areas farther than 3 mi from a data point and are therefore considered to be a hypothetical resource (table 6*A*). Nearly all of the non-resource coal is hypothetical (table 6*B*). Areas of identified and hypothetical resource are shown in figure 13 and are based on the distribution of 209 data points listed in Appendix 1. The hypothetical areas generally indicate where the coal was too thin or too deep to have been drilled.

Coal resources and non-resource coal are also reported for areas of coal ownership and for each county, quadrangle, and township in the plateau. County locations are shown in figure 1, township and quadrangle locations are shown in figure 2, and areas of coal ownership are shown in figure 14. Coal tonnages in 7.5′ quadrangles and townships are reported in Appendix 2 and can be used to estimate resources within specific areas. Of the 61 billion short tons of original-resource coal, about 57 percent is in Kane County and the remainder is in Garfield County (table 6*A*); Garfield County also contains an additional 1.7 billion short tons of non-resource coal that is more than 6,000 ft deep (table 6*B*). Approximately 99 percent of the coal in the Calico and A-sequences is federally owned, and 1 percent is either State or privately owned. Prior to the establishment of the Grand Staircase–Escalante National Monument in 1996, about 92 percent of the coal was federally owned, and the areas of previous Federal ownership are shown in Hettinger and others (1996).

Geologic Restrictions to Coal Availability

In order to better quantify the original coal resource of the Calico and A-sequences, various aspects of coal distribution were investigated, including overburden, coal-bed thickness, and dip of strata.

Overburden

Maximum overburden on coal in the Calico and A-sequences was determined using the topography of the Calico sequence boundary shown in figure 10 and surface elevations imported from a 1:250,000 digital elevation model constructed by the USGS. Overburden isolines were shown on the resultant map (fig. 15) at 0-; 1,000-; 2,000-; 3,000-; and 6,000-ft intervals in accordance with methodology of Wood and others (1983). Overburden on the Calico sequence boundary (fig. 15)

Table 6. Original coal resources (*A*) and other occurrences of coal (*B*) in the Calico and A-sequences in the Kaiparowits Plateau, Utah.

[Original coal resources and other occurrences of coal are reported in millions of short tons; tonnages are rounded to two significant figures, and the subtotal and total categories might not equal the sum of the components because of independent rounding. According to Wood and others (1983), coal that is deeper than 6,000 ft is not considered to be a resource and is reported as other occurrences of coal. Reported coal tonnages were calculated for beds more than 1 ft thick, using an average density of 1,800 short tons per acre-ft, and represent areas of the plateau where the entire coal-bearing section was preserved (fig. 11). Coal tonnage is reported by reliability and overburden categories and by county]

A.—Original coal resources (in millions of short tons) in the Calico and A-sequences.

County	Reliability	Original coal resource (in millions of short tons*) Overburden (thickness in ft) 0-1,000	1,000-2,000	2,000-3,000	3,000-6,000	Total
Garfield	Identified	2,800	6,600	3,100	4,400	17,000
	Hypothetical	61	360	1,300	7,300	9,000
	Subtotal	2,800	7,000	4,500	12,000	26,000
Kane	Identified	13,000	9,200	7,700	77	30,000
	Hypothetical	300	150	3,300	620	4,400
	Subtotal	14,000	9,400	11,000	700	35,000
Total		16,000	16,000	15,000	12,000	61,000

* Coal tonnages were rounded to two significant figures, and categories showing subtotal and total tonnages might not equal the sum of the components because of independent rounding.

B.—Other occurrences of non-resource coal (in millions of short tons*) at depths greater than 6,000 ft in the Calico and A-sequences.

County	Reliability	Other occurrences of non-resource coal (in millions of short tons*) Total coal in areas where overburden > 6,000 ft
Garfield	Identified	76
	Hypothetical	1,700
	Subtotal	1,700
Kane	Identified	0
	Hypothetical	0
	Subtotal	0
Total		1,700

* Coal tonnages were rounded to two significant figures, and categories showing subtotal and total tonnages might not equal the sum of the components because of independent rounding.

was checked for accuracy by comparing it to an overburden map previously constructed on the base of the Christensen coal zone by Hansen (1978b). The two maps compared favorably throughout most of the plateau, and minor differences were attributed to generalities in the digital elevation model and different stratigraphic horizons used to construct the two maps. However, local discrepancies of 500 and 1,000 ft were found along the northeastern margin of the plateau in the Jake Hollow graben (fig. 9) and in the Posy Lake quadrangle (fig. 2), respectively. The discrepancies were attributed to a lack of structural control in the area of the graben, and a thick wedge of shoreface strata that overlies the Calico sequence boundary in the Posy Lake quadrangle. Both areas were limited in aerial extent, and the discrepancies had no appreciable effect on resources reported within overburden categories.

The maximum overburden map shows that coal in the Calico and A-sequences is less than 2,000 ft deep in all areas of the plateau except along its northern boundary and in its central basin, where overburden ranges from 2,000 to 8,500 ft (fig. 15). Coal tonnages have been determined for overburden categories of 0–1,000; 1,000–2,000; 2,000–3,000; 3,000–6,000; and greater than 6,000 ft by integrating the overburden map (fig. 15) with the net coal isopach map (fig. 11). The coal tonnage in each category is reported in table 6. About 33 billion short tons of coal are under less than 2,000 ft of overburden, 15 billion short tons are under 2,000–3,000 ft of overburden, and 14 billion short tons of coal are under more than 3,000 ft of overburden (table 6).

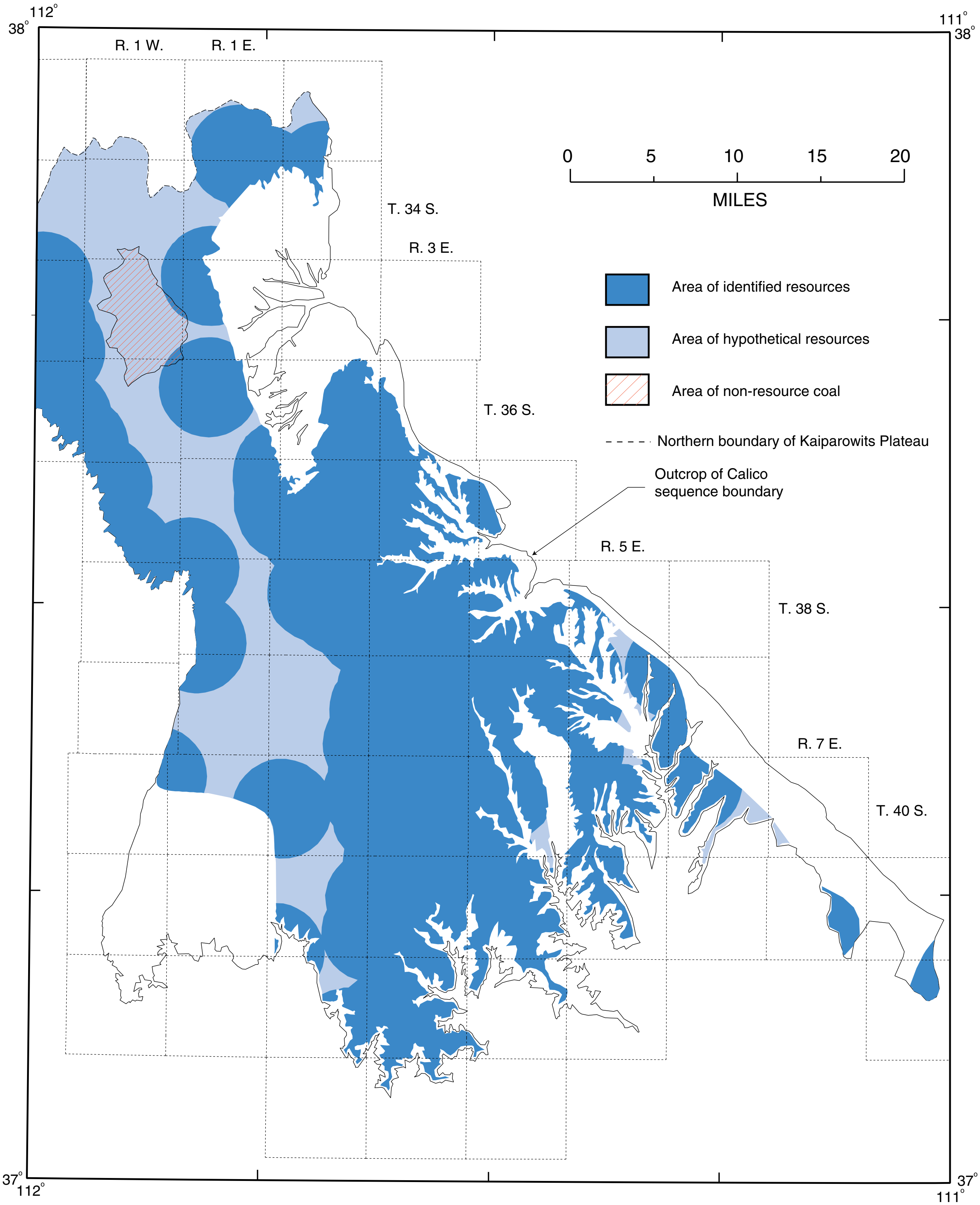

Figure 13. Map showing areas of reliability for coal resources in the Calico and A-sequences. Areas with identified resources are less than 3 mi from a data point, and areas with hypothetical resources are more than 3 mi from a data point. Identified and hypothetical areas of non-resource coal are also shown; non-resource coal is under more than 6,000 ft of overburden. Areas of reliability are based on 209 data points shown in figure 11 and apply only to localities underlain by the total coal-bearing interval where coal beds are greater than 1 ft thick.

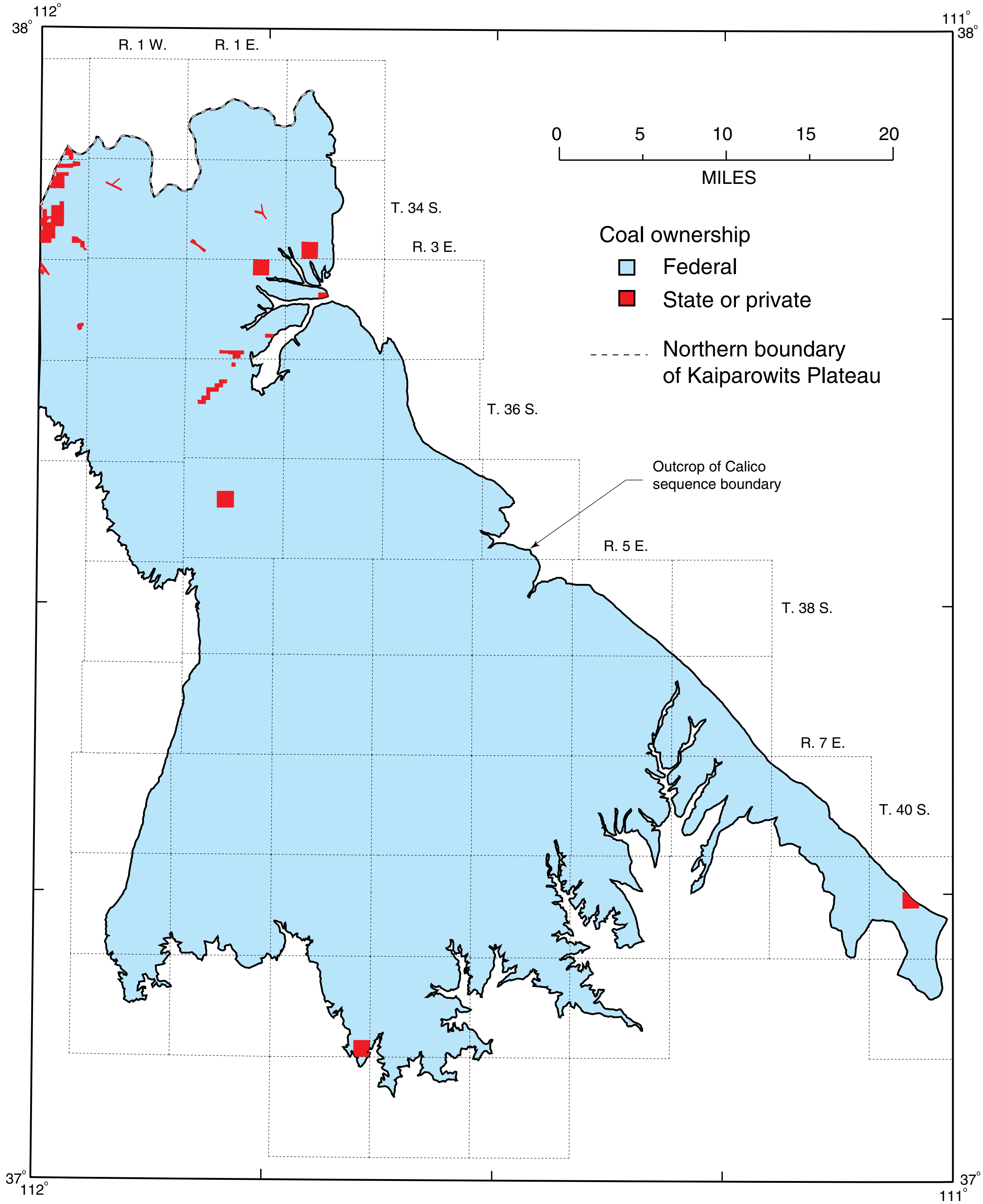

Figure 14. Mineral ownership for areas underlain by the Calico and A-sequences in the Kaiparowits Plateau, Utah.

Coal-Bed Thickness

The Calico and A-sequences contain as many as 30 beds of coal that range from 1 to 59 ft in thickness (Appendix 1). In order to better understand the distribution of these coal beds, we have constructed a series of isopach maps that show net coal in range-of-thickness categories of 1.0 to 2.4, 2.5 to 3.4, 3.5 to 7.4, 7.5 to 14.0, 14.1 to 20.0, and greater than 20.0 ft (figs. 16*A*, 17*A*, 18*A*, 19*A*, 20*A*, 21*A*), respectively. The number of beds in each range-of-thickness category are shown in figures 16*B*, 17*B*, 18*B*, 19*B*, 20*B*, and 21*B*. We calculated the coal tonnage in category by multiplying the volume of coal, as determined from the respective isopach map (figs. 16*A*–21*A*), by an average density of 1,800 short tons per acre-foot. The resultant tonnage in each range-of-thickness category was then normalized so that the sum of the categories would equal the total net coal reported for the Calico and A-sequence in tables 6*A* and 6*B*; the normalized tonnages are listed in table 7.

Coal beds less than 3.4 ft thick are widely distributed throughout the entire plateau. As many as 22 beds range from 1 to 2.4 ft in thickness and have a maximum net thickness of 30 ft (figs. 15*A*, 15*B*). As many as nine beds range from 2.5 to 3.4 ft in thickness and have a maximum net thickness of 27 ft (figs. 17*A*, 17*B*). About 12 billion short tons of coal are in beds that range from 1 to 3.4 ft in thickness (table 7).

Coal beds that are 3.5 to 14.0 ft in thickness are also widely distributed throughout the plateau but occupy a smaller area than the thinner coals. As many as nine beds of coal range from 3.5 to 7.4 ft in thickness, and these beds have a maximum net thickness of 65 ft (figs. 18*A*, 18*B*). As many as seven beds of coal are from 7.5 to 14.0 ft thick, and these beds have a maximum net thickness of 66 ft (figs. 19*A*, 19*B*). About 32 billion short tons of coal are in beds that range from 3.5 to 14.0 ft in thickness (table 7).

Coal beds that exceed 14.1 ft in thickness are found in several pods that are located along an elongated belt that trends northwest-southeast through the plateau's central region (figs. 20*A*, 21*A*). The pods are 1 to 11 mi wide in the plateau's central and southern regions and contain one to four beds that are 14.1 to 20.0 ft thick (fig. 20*B*) and one to three beds that are more than 20 ft thick (fig. 21*B*). Examples include an area near data point 8 (T. 37 S., R. 2 E.; Appendix 2) that has as much as 71 ft of net coal in four beds that are 14.1 to 20 ft thick (figs. 20*A*, 20*B*) and an area near data point 64 (T. 39 S., R. 4 E.; Appendix 2) that has as much as 76 ft of net coal in three beds that are more than 20 ft thick (figs. 21*A*, 21*B*). One large area along the plateau's northern boundary might contain one to three beds of coal that are more than 14.1 ft thick (figs. 20*B*, 21*B*); however, the continuity and lateral extent of these coal beds are unknown because of a paucity of data.

Approximately 18 billion short tons of coal are estimated to be in beds that are more than 14.1 ft thick (table 7). However, current longwall mining technology can economically extract no more than 14 ft of coal even if the bed is of greater thickness (Timothy J. Rohrbacher, USGS, oral commun., 1996). We estimate, therefore, that only about 6 billion short tons of coal would be available for mining from these thicker beds; the estimate was made by treating each bed mapped in figures 20*B* and 21*B* as if it were only 14 ft thick. Furthermore, the estimated tonnage does not account for any additional restriction to mining other than bed thickness.

Table 7. Estimated coal tonnage (in billions of short tons) for beds ranging from 1-2.4, 2.5-3.4, 3.5-7.4, 7.5-14.0, 14.1-20.0, and greater than 20.0 ft in thickness in the Calico and A-sequences, Kaiparowits Plateau, Utah.

[Tonnage estimates include only areas where the entire coal-bearing section is preserved]

Coal-bed thickness in ft	Estimated tonnage (in billions of short tons)
1-2.4	8
2.5-3.4	4
3.5-7.4	17
7.5-14.0	15
14.1-20.0	9
> 20.0	9

Dip of Strata

Based on studies conducted by the U.S. Bureau of Mines between 1985 and 1993, current underground mining is (1) most efficient where strata are inclined by less than 6°, (2) difficult where strata are inclined between 6° and 12°, and (3) not feasible where strata are inclined by more than 12° (Timothy J. Rohrbacher, USGS, oral commun., 1996). Areas where strata are inclined from 0°–6°, 6°–12°, 12°–25°, and greater than 25° are shown in figure 9. Coal resources within each category of inclination were calculated by integrating the dip-of-strata map (fig. 9) with the net coal isopach map (fig. 11). About 50 billion short tons of coal are in areas where strata are inclined by less than 6°; about 5.6 billion short tons are in areas where strata are inclined from 6° to 12°; and about 6.9 billion short tons of coal are in areas where strata are inclined by more than 12°. These tonnages respectively comprise about 80, 9, and 11 percent of the coal in the Calico and A-sequences.

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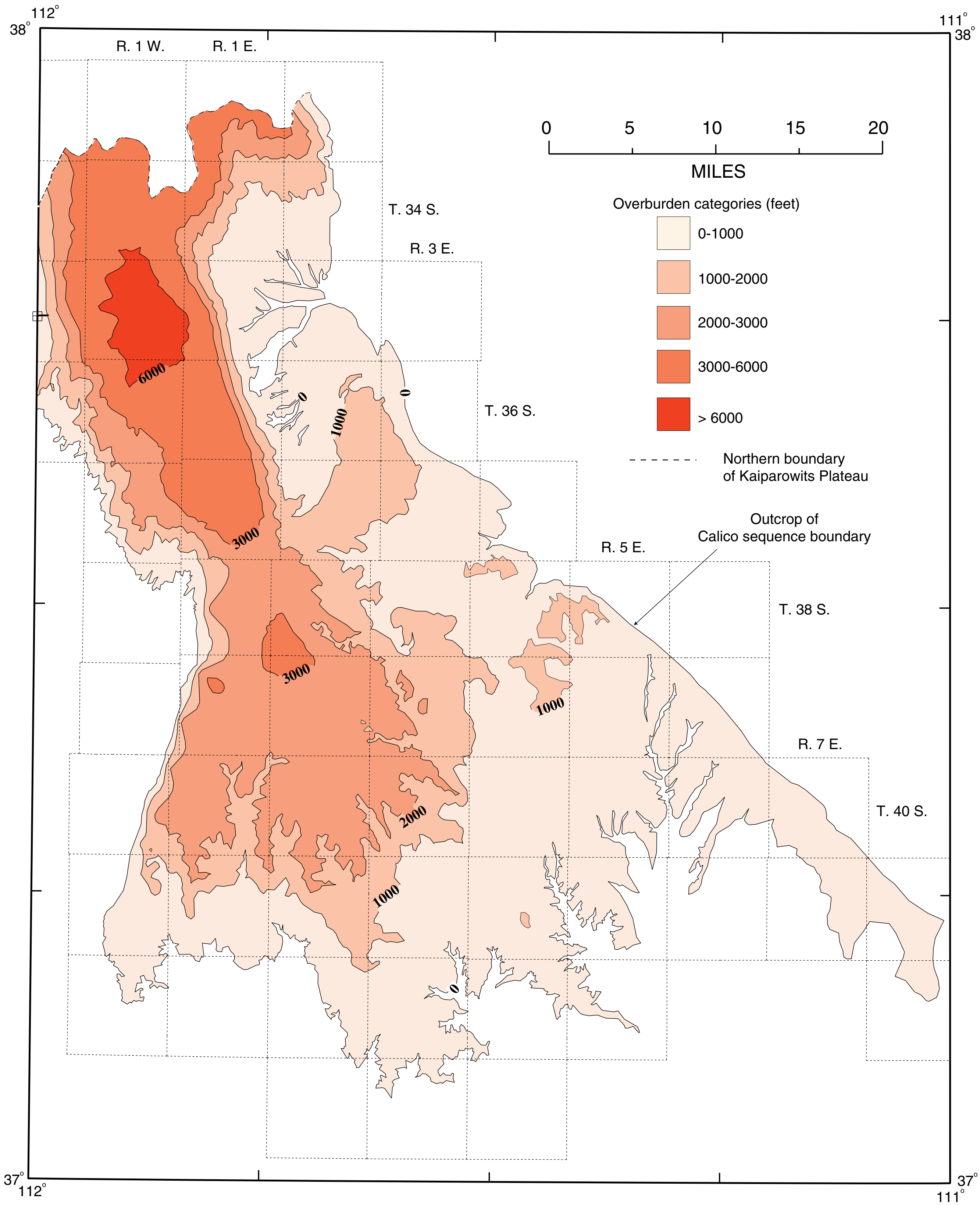

Figure 15. Overburden on the Calico sequence boundary. Thickness categories show range of maximum overburden on coal in the Calico and A-sequences. Isolines are labled at 0-, 1,000-, 2,000-, 3,000-, and 6,000-ft intervals.

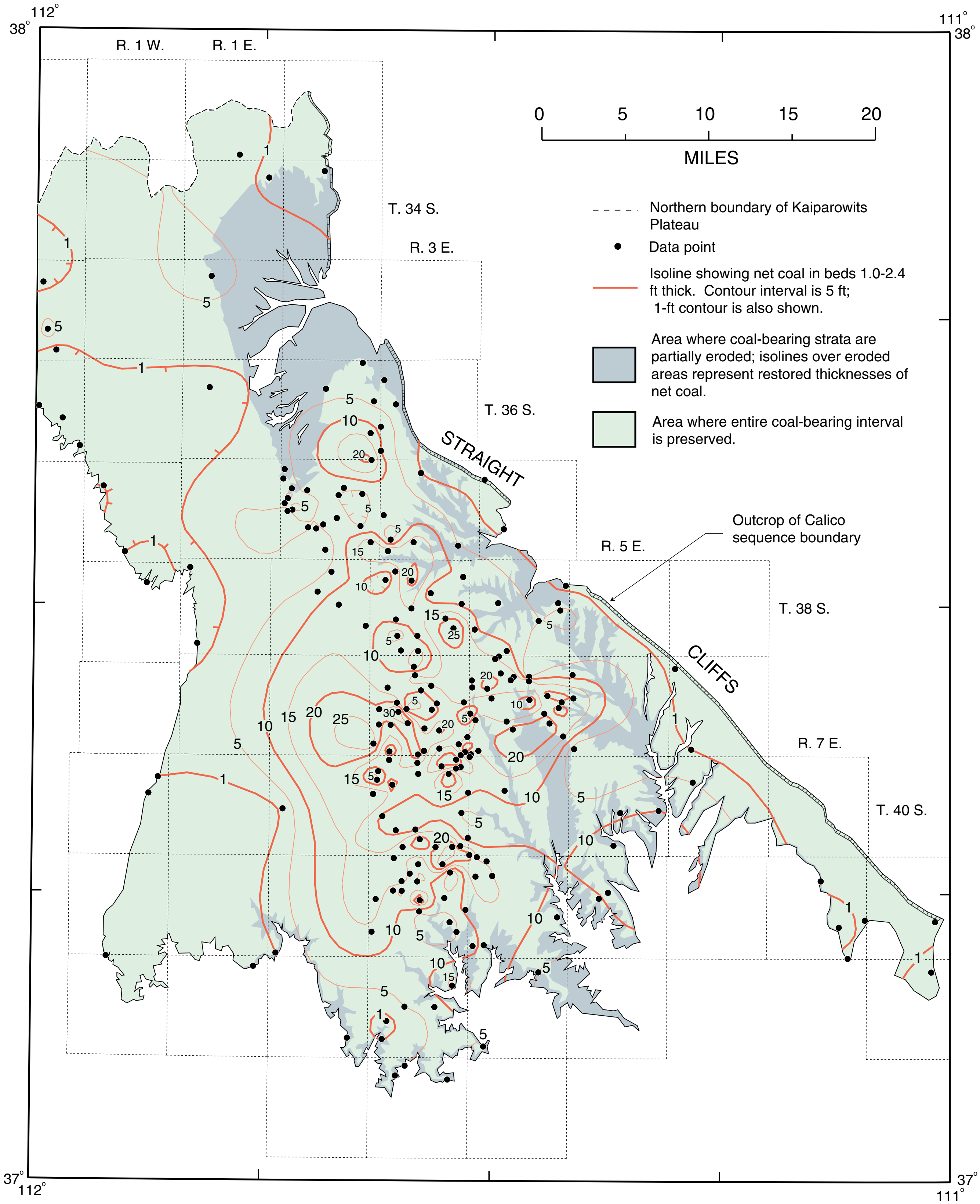

Figure 16*A*. Distribution of net coal in beds 1.0 to 2.4 ft thick in the Calico and A-sequences.

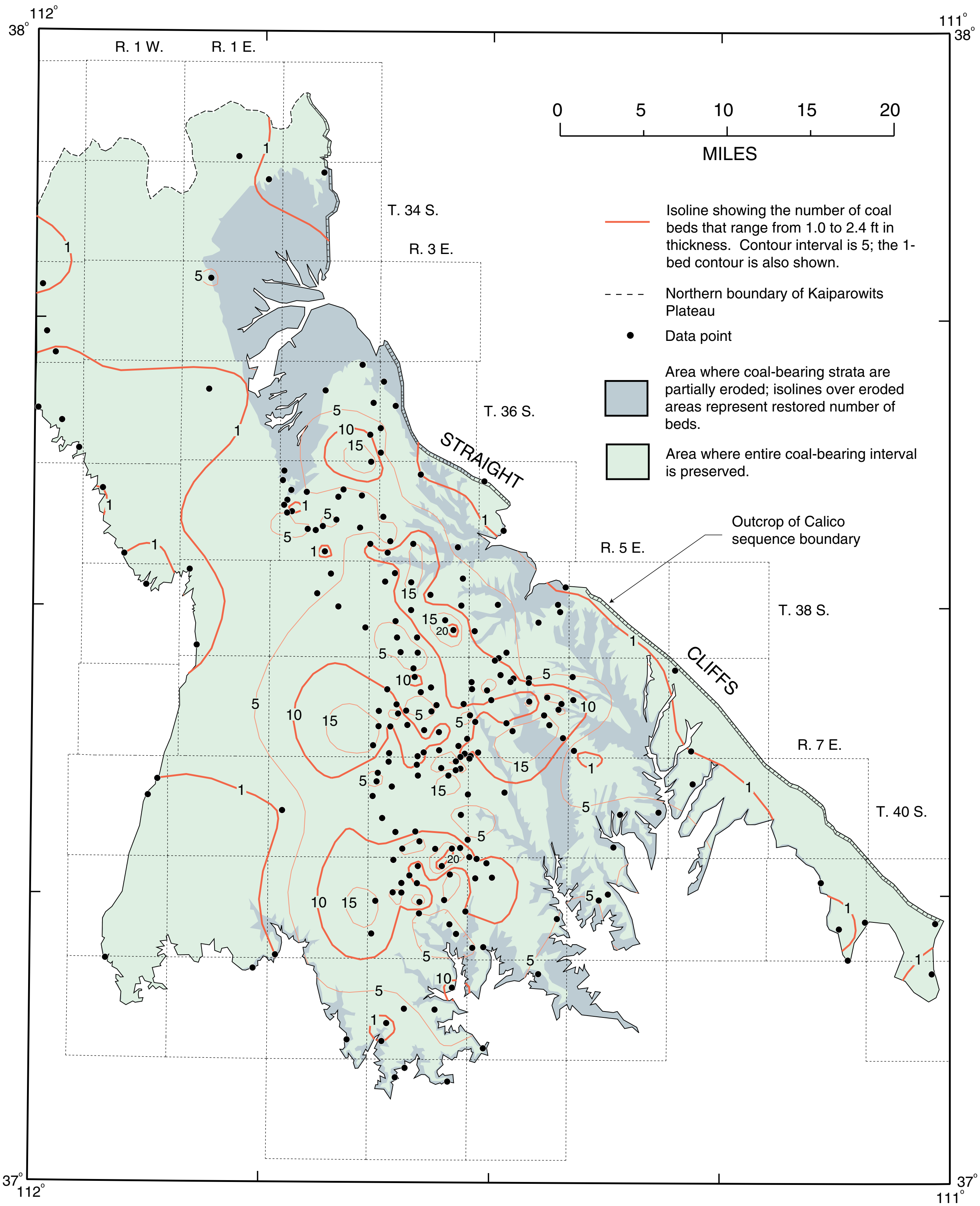

Figure 16*B*. Distribution of the number of coal beds that are 1.0 to 2.4 ft thick in the Calico and A-sequences.

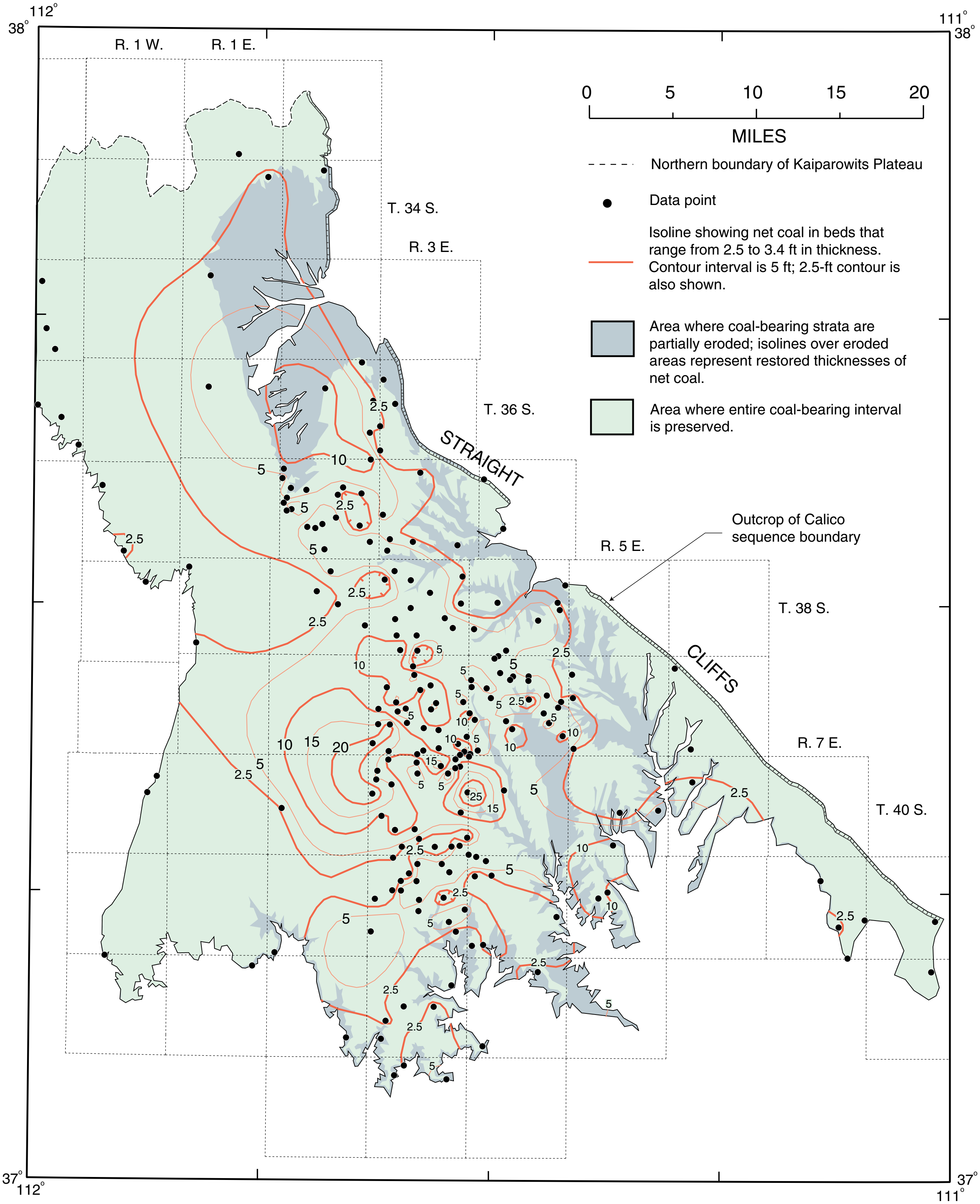

Figure 17*A*. Distribution of net coal in beds 2.5 to 3.4 ft thick in the Calico and A-sequences.

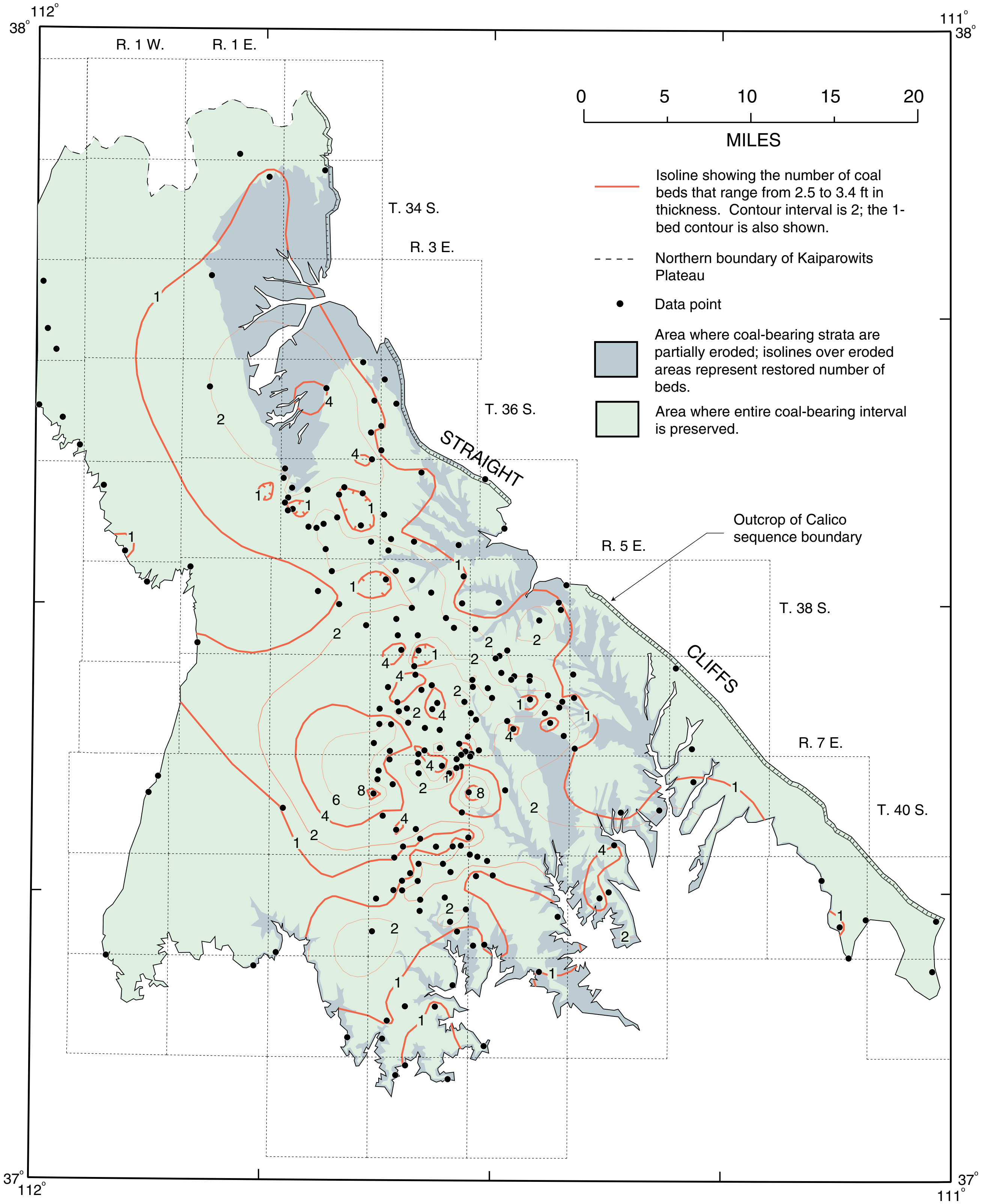

Figure 17*B*. Distribution of the number of coal beds that are 2.5 to 3.4 ft thick in the Calico and A-sequences.

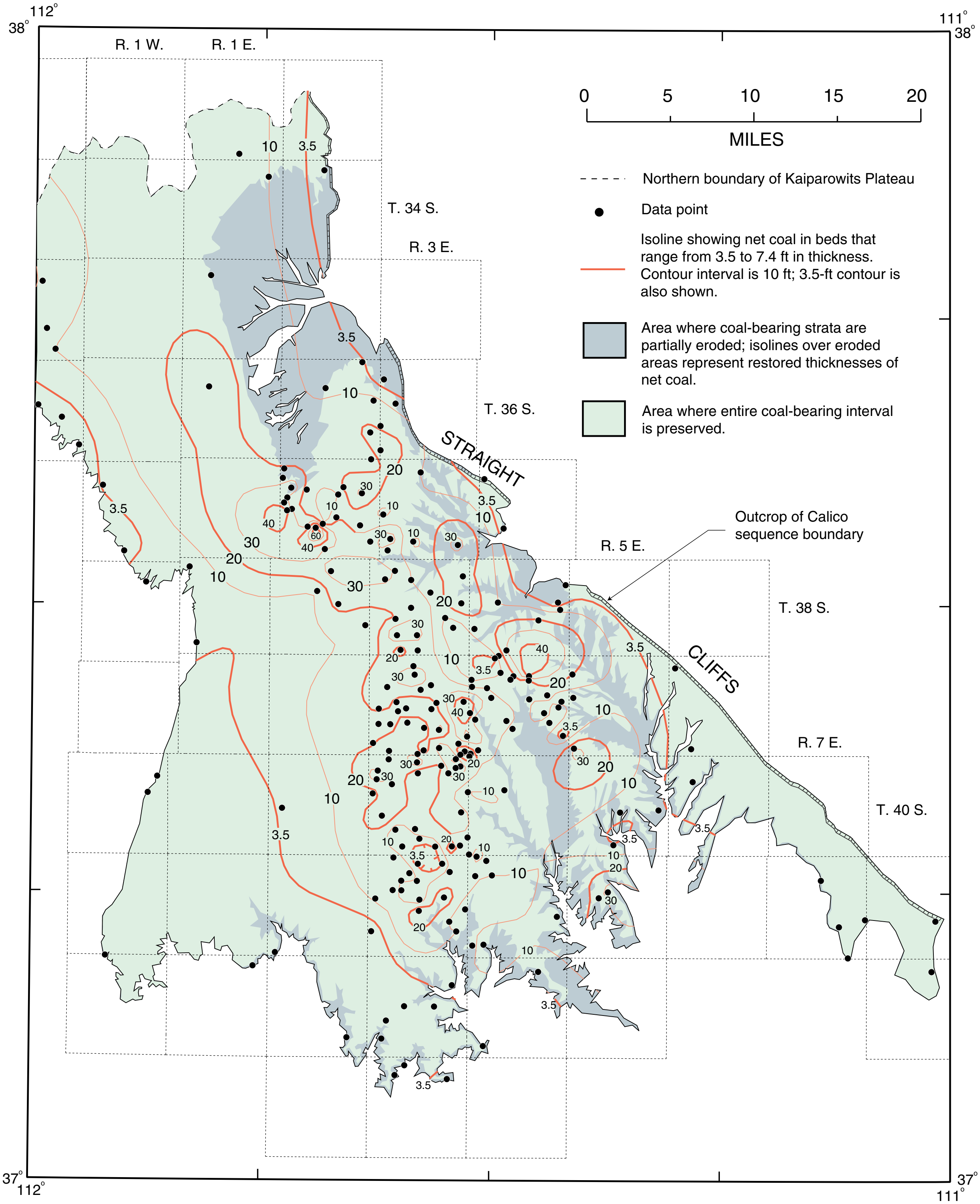

Figure 18*A*. Distribution of net coal in beds 3.5 to 7.4 ft thick in the Calico and A-sequences.

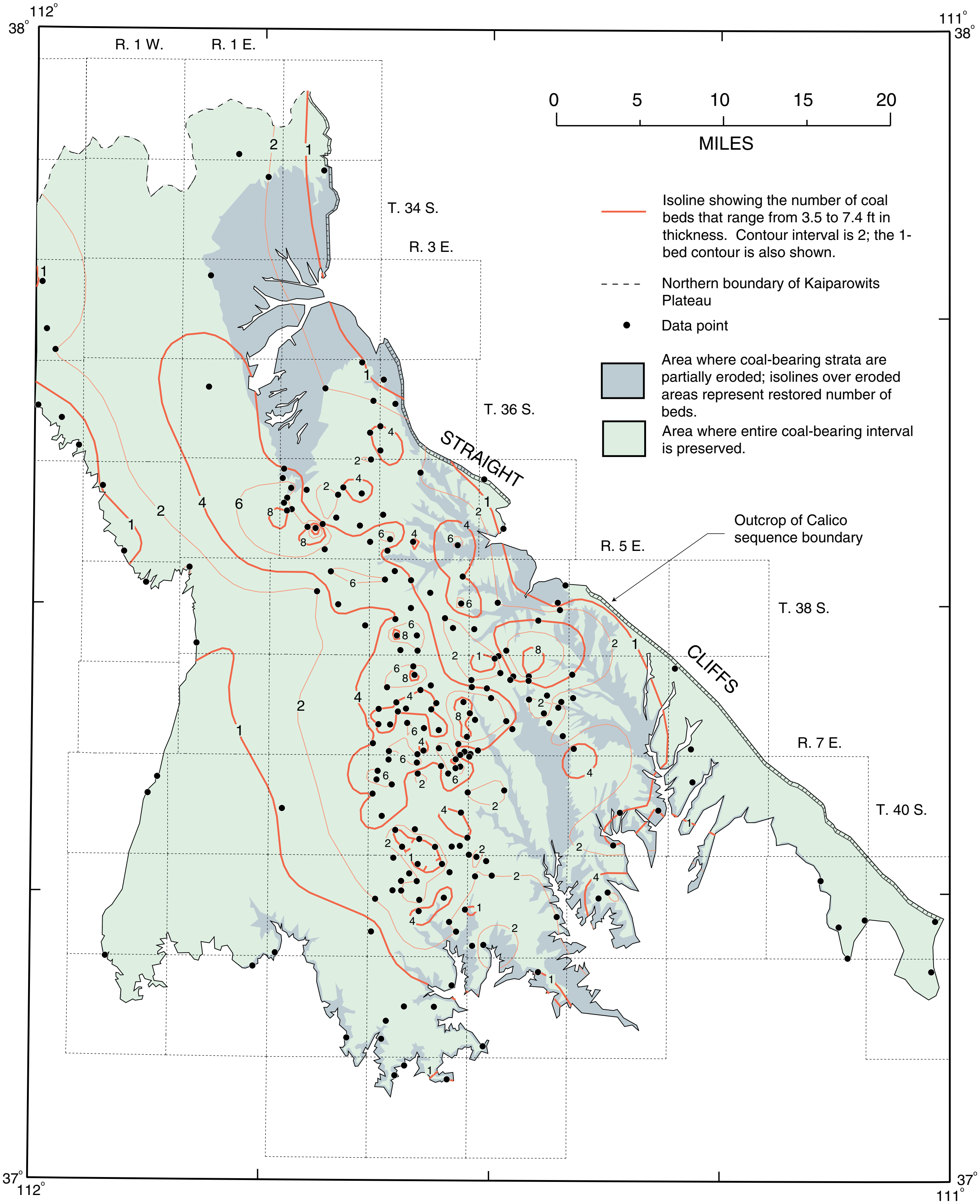

Figure 18*B*. Distribution of the number of coal beds that are 3.5 to 7.4 ft thick in the Calico and A-sequences.

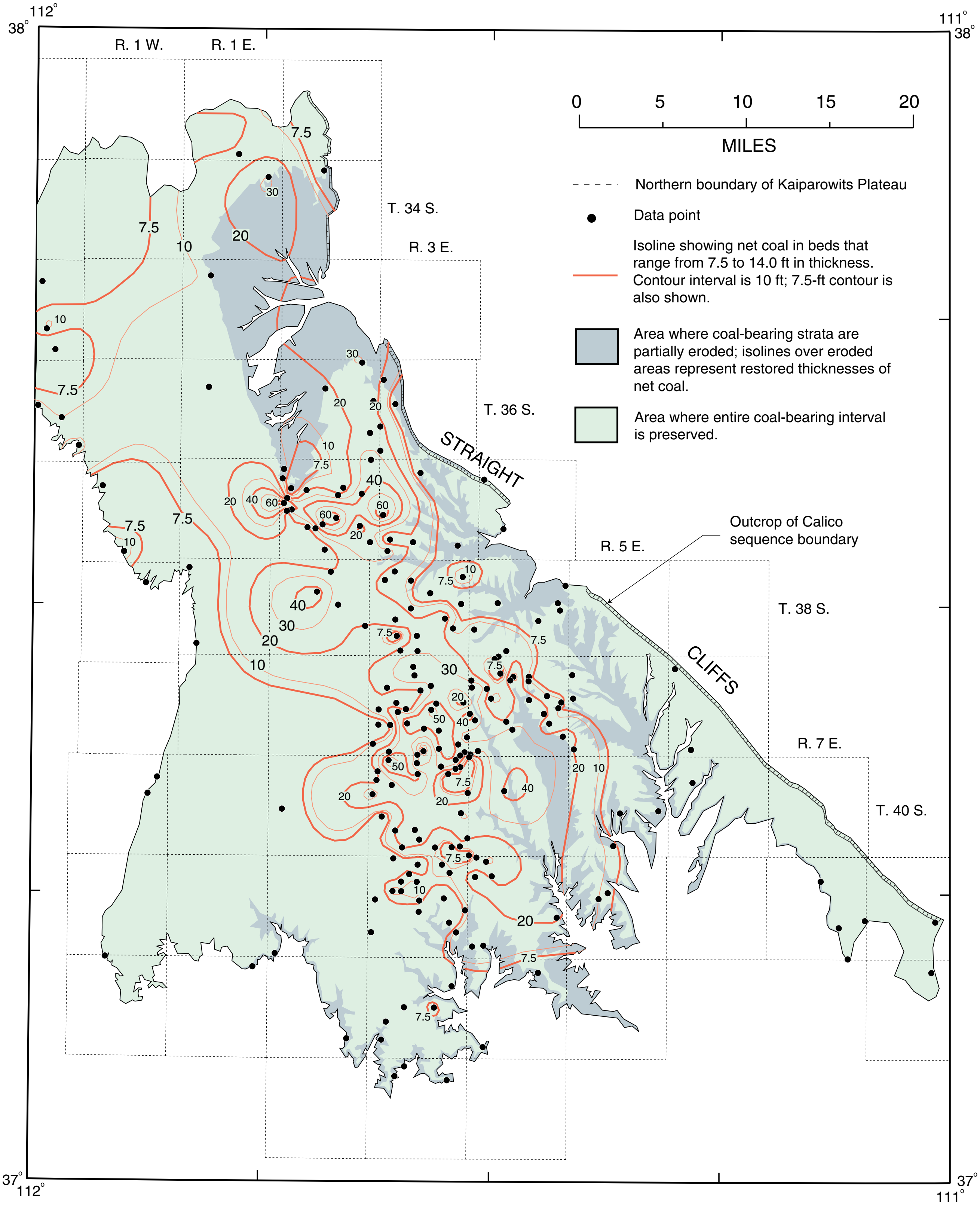

Figure 19*A*. Distribution of net coal in beds 7.5 to 14.0 ft thick in the Calico and A-sequences.

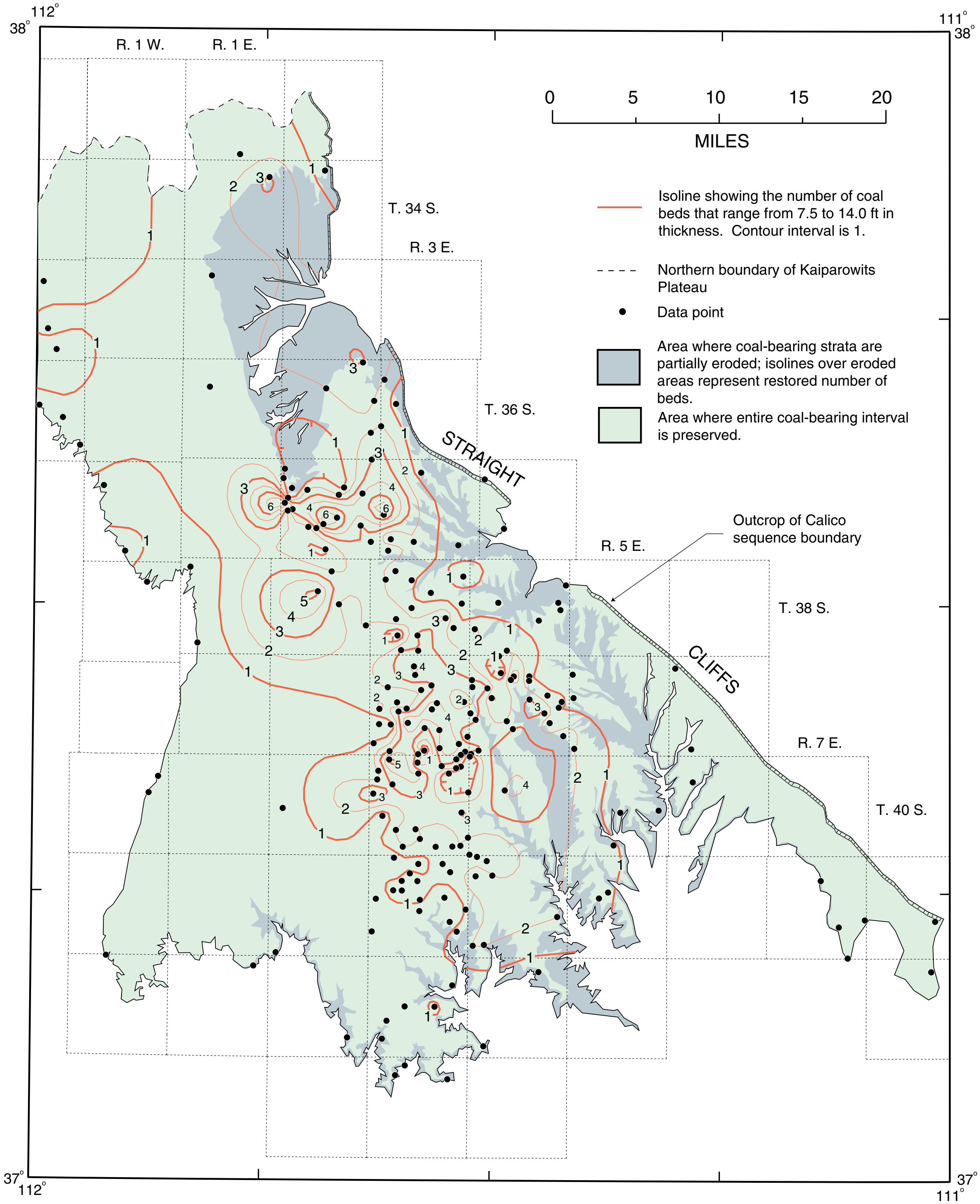

Figure 19*B*. Distribution of the number of coal beds that are 7.5 to 14.0 ft thick in the Calico and A-sequences.

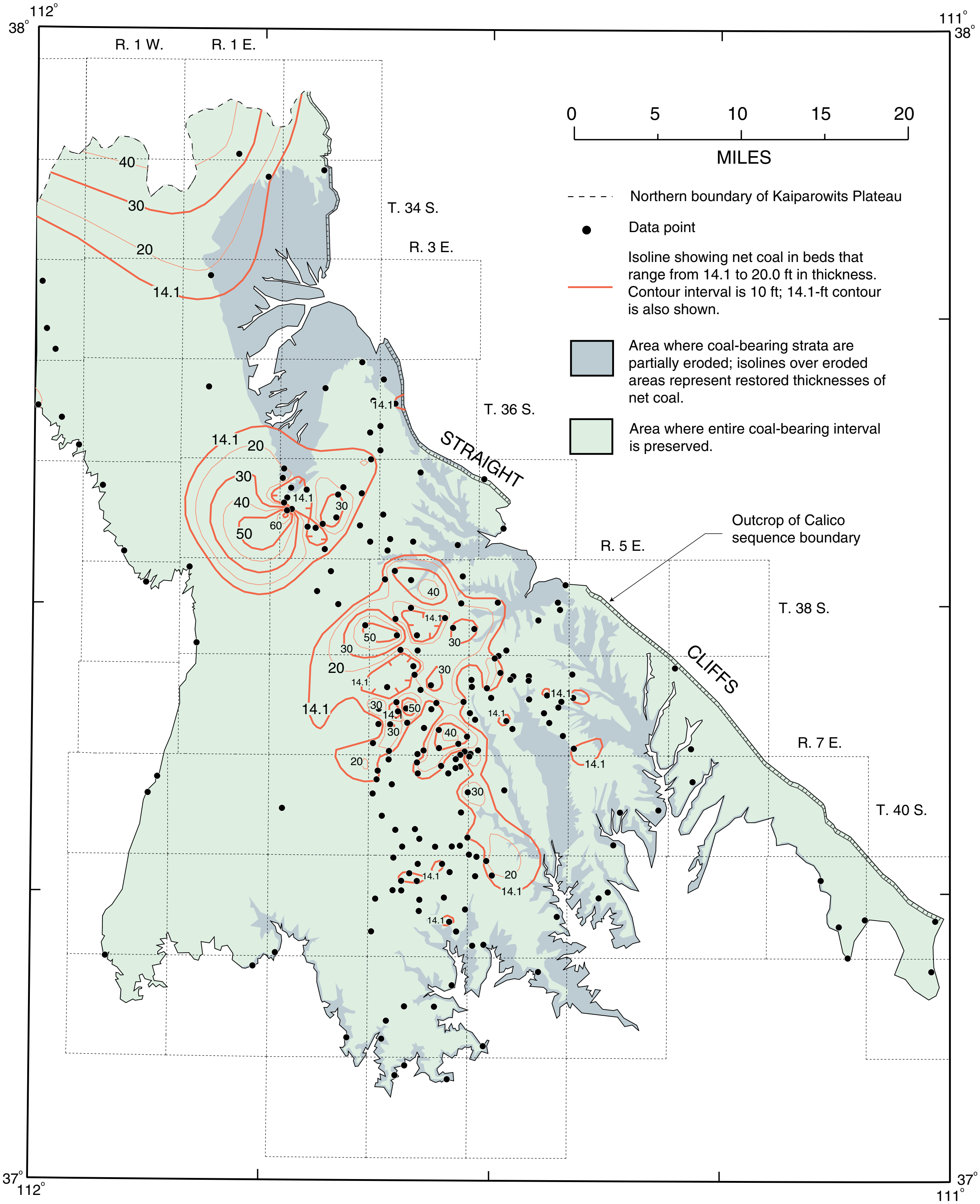

Figure 20*A*. Distribution of net coal in beds 14.1 to 20.0 ft thick in the Calico and A-sequences.

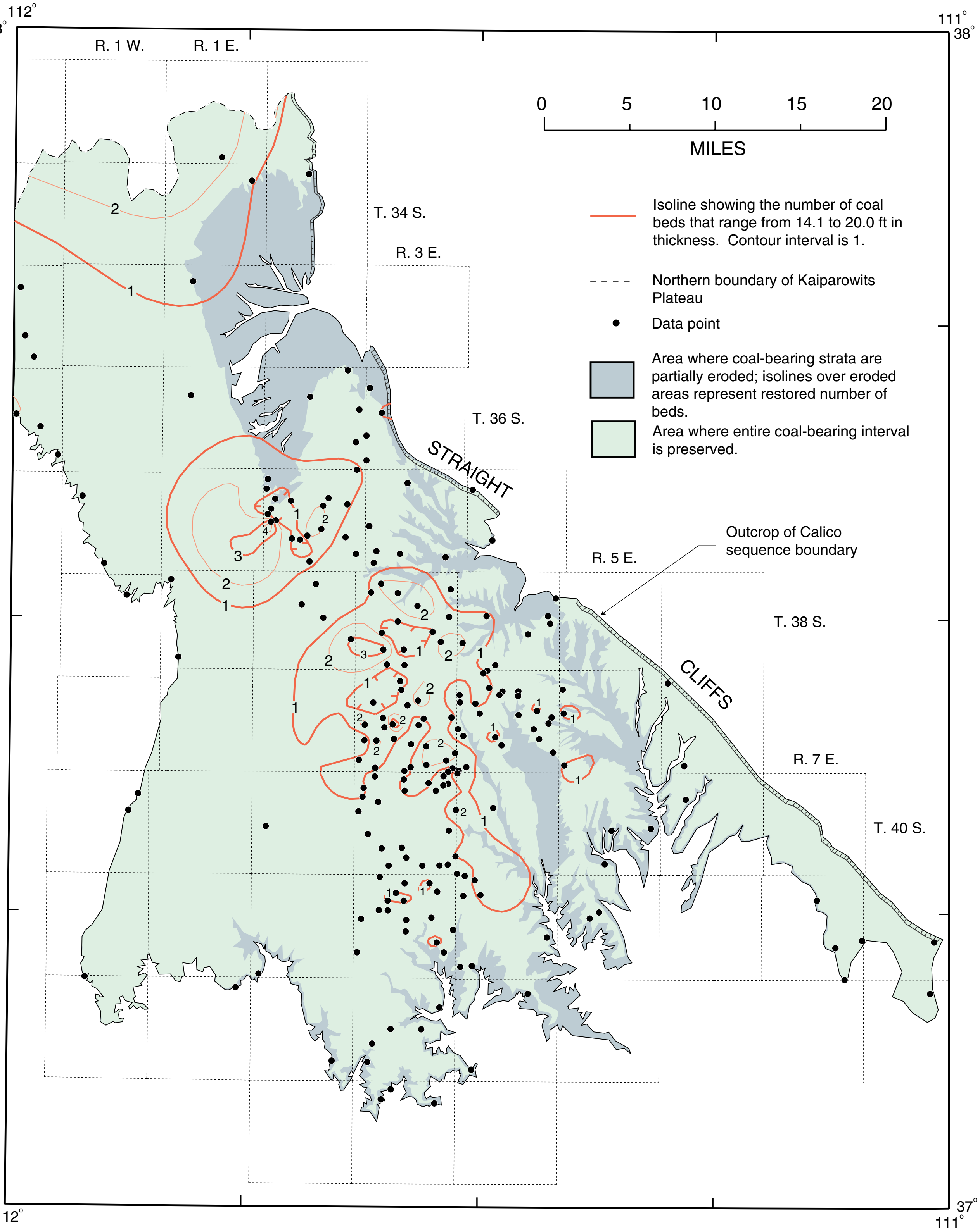

Figure 20*B*. Distribution of the number of coal beds that are 14.1 to 20.0 ft thick in the Calico and A-sequences.

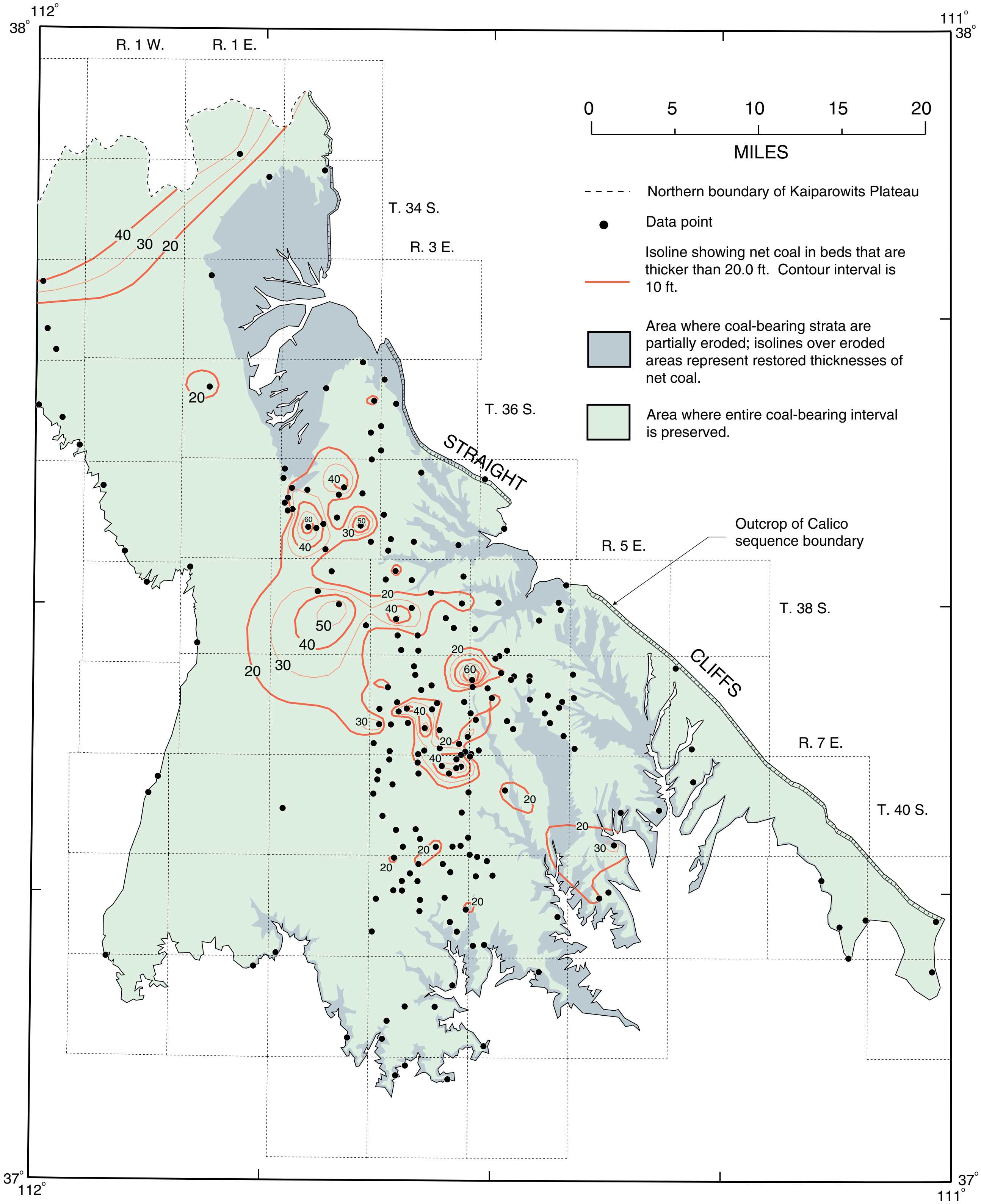

Figure 21*A*. Distribution of net coal in beds greater than 20.0 ft thick in the Calico and A-sequences.

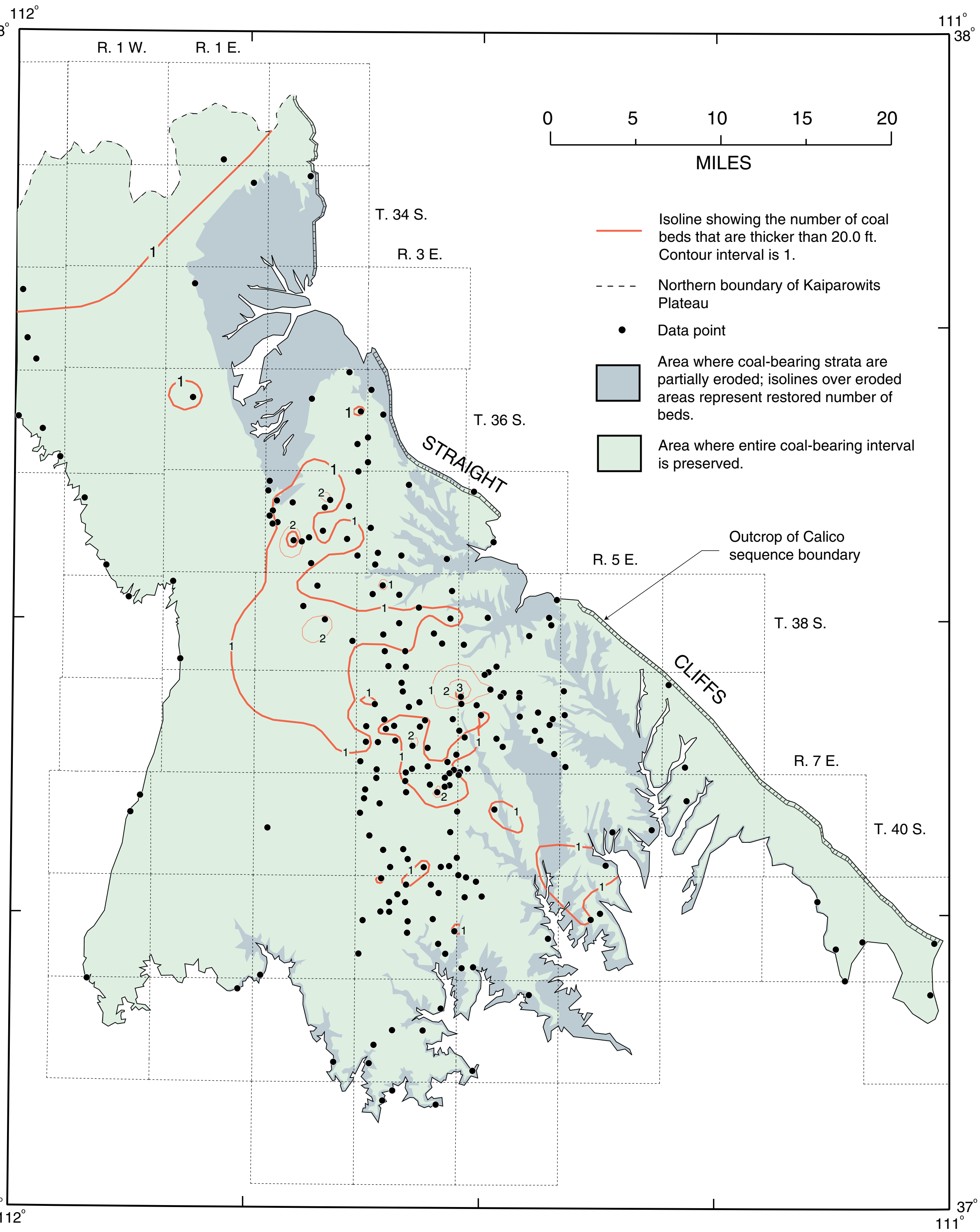

Figure 21*B*. Distribution of the number of coal beds that are greater than 20.0 ft thick in the Calico and A-sequences.

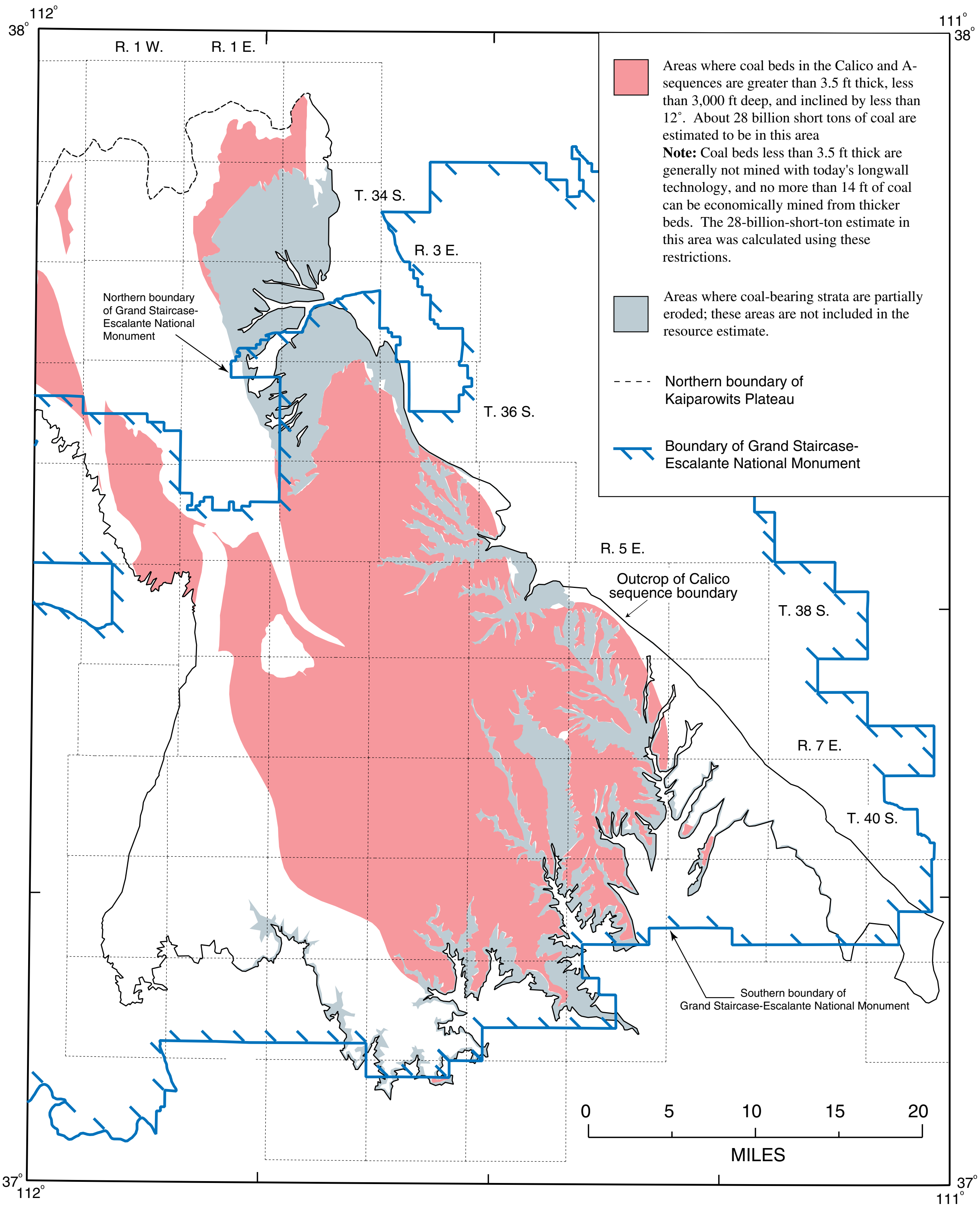

Figure 22. Map of the Kaiparowits Plateau showing areas (pink stipple) where coal beds are (1) greater than 3.5 ft thick, (2) under less than 3,000 ft of overburden, and (3) inclined by less than 12° of dip. Areas where coal-bearing strata are partially eroded (gray stipple) are not addressed in this investigation.

Coal Resource Summary

Significant deposits of coal are contained in the Calico and A-sequences of the Upper Cretaceous Straight Cliffs Formation in the Kaiparowits Plateau, Utah. The Calico and A-sequences have an original coal resource of about 61 billion short tons that are in beds more than 1 ft thick and less than 6,000 ft deep. The sequences contain an additional 1.7 billion short tons of non-resource coal that are 6,000 to 8,500 ft deep. The coal is in a 50- to 700-ft-thick stratigraphic interval that covers an area of 850 mi^2. Fewer than 50,000 short tons of coal have been mined to date, and most of the remaining resource would have to be mined using underground methods.

Although the Calico and A-sequences contain an original coal resource of 61 billion short tons, this large resource figure must be regarded with caution because it does not reflect the geological, technological, economical, environmental, or land-use constraints that might affect its availability and recoverability. Technological and economic constraints generally limit current longwall methods to depths of less than 3,000 ft, beds that are more than 3.5 ft thick, and strata that are inclined by less than 12°; additionally, only about 14 ft of coal can be mined from beds that exceed that thickness (Timothy J. Rohrbacher, USGS, oral commun., 1996). These overburden and bed-thickness limits are supported by a summary given for 81 current longwalls operated in the United States by 30 companies (Merritt and Fiscor, 1995, p. 32–38). Peterson (1969a) estimated that only 10 percent of the coal in the plateau could be recovered with the technology of that time. For the purpose of comparison, coal-production studies by Rohrbacher and others (1994) indicated that less than 10 percent of the original coal resource in many areas of the central Appalachian region of the Eastern United States could be mined and marketed at a profit.

Land-use and environmental considerations that might affect the availability of coal in the Kaiparowits Plateau include the impact that mining and coal utilization might have on the overlying surface area as well as on air and water quality in nearby grazing areas, regional populations, and National Parks and Recreational Areas (Sargent, 1984). Those issues have been significant—in 1976, several companies dropped their plans to construct a coal-burning power plant in the region because of Government actions and pending lawsuits over environmental issues (U.S. Bureau of Land Management, 1976; Sargent, 1984). Finally, in 1996, about 75 percent of the plateau was included in the Grand Staircase–Escalante National Monument. The only remaining Federal coal leases were suspended prior to the establishment of the Monument, and they remain in suspension as of this publication date (Jim Kohler, BLM, oral commun., 1999).

Of the total 62 billion short tons of coal (resource and non-resource coal) in the Calico and A-sequences, an estimated 34 billion short tons of coal are not likely to be mined in the foreseeable future because of geologic and technological restrictions that include overburden, dip of strata, and coal bed thickness. About 18 billion short tons of coal are not likely to be mined because they are more than 3,000 ft deep or because they are in strata that are inclined by more than 12°. Coal tonnage in these areas was estimated by integrating the dip-of-strata map (fig. 9) with the net coal isopach map (fig. 11) and overburden map (fig. 15). An additional 16 billion short tons of coal are not likely to be mined from areas where coal is less than 3,000 ft deep and strata are inclined by less than 12° because the coal is in beds that are less than 3.4 ft thick (12 billion short tons) or cannot be extracted from beds that are more than 14 ft thick (4 billion short tons). These amounts were determined by integrating the overburden and dip-of-strata maps with coal isopach maps (figs. 16*A*, 17*A*) and bed maps (figs. 20*B*, 21*B*).

An estimated 28 billion short tons of coal are in areas of the Kaiparowits Plateau where geologic conditions might be favorable for current underground mining technology (fig. 22). These coal resources are in areas where overburden is less than 3,000 ft thick and strata dip less than 12°. The coal tonnage was estimated for all coal beds more than 3.5 ft thick, and tonnage from beds more than 14 ft thick was calculated for the recovery of 14 ft. About 11 billion short tons are in beds that are 3.5–7.0 ft thick, about 11 billion short tons are in beds that are 7.1–14.0 ft thick, and about 6 billion short tons are in beds more that 14 ft thick. These estimates do not account for additional coal that cannot be mined (1) because of the discontinuity of coal beds, (2) because coal might be destroyed while mining of adjacent strata, or (3) because some coal must be left in the ground for roof support. Nor do the estimates account for coal that might not be mined because of potential land-use or environmental restrictions. Additionally, a significant part of the resource might remain undeveloped because it is now within the Grand Staircase–Escalante National Monument (fig. 22).

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Appendix 1—Database Tables

Appendix 1 provides the database developed for this report. The database contains the identification number and location of each data point used for the assessment and provides stratigraphic and lithologic interpretations used at each locality. Down-hole depths of lithologic and stratigraphic intervals are shown for 155 selected drill holes in Appendix 5 (disc 2 of this 2-CD-ROM set).

Data point identification.—The map number identifies the data point on the location map (figure A of plate 1) and cross sections (figures C, D, and E of plate 1). The point ID number is the original name of each data point. Map numbers 1-6 are USGS drill holes, 7-145 are company coal test holes, 146-167 are oil and gas holes, 168-213 are published stratigraphic sections; and 214-226 are control points where information is based on published geologic descriptions.

Data point information.—Data point information includes the latitude and longitude of each data point and the surface elevation and total depth of each drill hole.

Stratigraphic interpretations.—Stratigraphic interpretations include the elevation of the Calico sequence boundary (Csb.), elevation of the Drip Tank sequence boundary (Dsb.), and thickness of the combined Calico and A-sequences (Thk. C-A). An elevation with an asterisk indicates that the hole was not drilled deep enough to penetrate the sequence boundary, but the inferred depth of the sequence boundary was estimated by correlation to nearby drill holes. The thickness of the combined Calico and A-sequences was determined in drill holes by measuring the stratigraphic interval between the Calico and Drip Tank sequence boundaries. In measured sections, the thickness of the combined Calico and A-sequences was based on the stratigraphic interval between the base of the Calico bed and base of the Drip Tank Member, and an asterisk indicates that the thickness was estimated from a partial measured section.

Lithologic interpretations.—Lithologic interpretations include the thickness of net coal and total number of coal beds in the Calico and A-sequences; the depths to the upper and lowermost coal bed in the Calico and A-sequences were also provided. Lithologic interpretations also include the net coal thickness and number of coal beds within several bed-thickness categories. Following Wood and others (1983), the thickness of two or more coal benches were recorded as a single bed if intervening partings were thinner than the overlying or underlying benches and the thickness of partings were not included as part of the bed.

The net coal in the Calico and A-sequences was estimated at eight drill-hole localities where the entire coal-bearing interval was not drilled. At these localities, measured coal thicknesses in the drill hole were added to potential coal thicknesses in undrilled parts of the Calico or A-sequences and the estimated coal thicknesses were based on stratigraphic correlations to nearby drill holes. The data points, measured coal thicknesses and estimated net coal thicknesses are shown in the table below.

Appendix 1, table 1. Estimated total coal in drill holes used in the assessment that did not penetrate the entire coal-bearing interval.

Map number	Point identification	Actual coal measured from geophysical logs (ft)	Estimated net coal in Calico and A-sequences based on correlations to nearby drill holes (ft)
4	K-1-DR	88	110
8	73-37-19	147	157
83	G-24-1	81	86
93	L-41-1	81	89
95	N-35-3	88	105
119	DH-203	39	44
130	DH-324	39	45
139	DH-365	62	70

Appendix 1, table 2.

Data point identification		Data point information				Stratigraphic interpretations			Lithologic interpretations															
									Net coal in Calico and A-sequences (values in ft)				Net coal thickness (in ft) and number of coal beds in bed-thickness categories											
Map no.	Point ID	Longitude	Latitude	Surface elev (ft)	Total depth (ft)	Elev Csb. (ft)	Elev Dsb. (ft)	Thk C-A seq (ft)	Total coal	# beds	Depth top coal	Depth bottom coal	1.0-2.4	# beds	2.5-3.4	# beds	3.5-7.4	# beds	7.5-14.0	# beds	14.1-20.0	# beds	> 20.0	# beds
1	KP-1-BR	111.77917	37.89109	7676	1095	5776*	7176	1400*	100	9	614	1028	3	2	0	0	14	3	12	1	35	2	36	1
2	KP-5-SC	111.99306	37.77930	7790	675	6960*	-----	-----	44	2	438	563	0	0	0	0	4	1	0	0	0	0	40	1
3	KP-4-PL	111.97040	37.66105	6880	220	6460*	-----	-----	10	1	166	176	0	0	0	0	0	0	10	1	0	0	0	0
4	K-1-DR	111.70249	37.59981	7360	804	6250*	7150	900*	110*	14	317	799	6	5	6	2	17	3	19	2	15	1	25	1
5	CT-1-91	111.49186	37.45609	6370	1057	5329	6164	835	64	16	278	889	12	9	6	2	14	3	11	1	0	0	21	1
6	SMP-1-91	111.52324	37.36871	5247	963	4303	5107	804	95	19	316	905	13	10	9	3	14	3	0	0	36	2	23	1
7	73-37-10	111.66252	37.60202	6680	1220	5160*	6110	950*	106	13	694	1172	6	4	3	1	21	4	14	1	15	1	47	2
8	73-37-19	111.72372	37.58157	7250	1040	6060*	6910	850*	157*	22	529	981	9	6	6	2	41	8	20	2	71	4	0	0
9	73-37-21	111.68451	37.57020	7620	1925	5650*	6510	860*	164	21	1232	1868	8	5	9	3	19	4	56	6	32	2	40	1
10	73-37-22	111.67005	37.57580	7420	1872	5470*	6215	745*	133	18	1314	1793	8	5	6	2	19	3	65	6	35	2	0	0
11	73-37-23	111.64399	37.56888	6485	1205	5255*	5935	680*	108	11	666	1088	5	3	0	0	16	3	28	3	0	0	59	2
12	73-37-28	111.69221	37.56674	7685	1903	5725*	6535	810*	157	21	1265	1894	2	2	6	1	65	12	32	3	0	0	52	2
13	73-37-29	111.70131	37.56751	7790	1927	5840*	6705	865*	146	21	1311	1860	6	6	6	2	32	7	18	2	15	1	69	3
14	73-37-33	111.68224	37.54815	6470	900	5480*	6170	690*	94	11	348	849	2	1	6	2	30	5	13	1	17	1	26	1
15	73-38-10	111.67531	37.52903	6550	1180	5290*	5935	645*	66	13	683	1150	6	3	6	2	33	6	21	2	0	0	0	0
16	73-38-14	111.66691	37.50029	6480	1164	5270*	5905	635*	119	18	634	1083	14	8	3	1	24	5	23	2	0	0	55	2
17	73-38-25	111.63755	37.48219	6190	1104	5010*	5670	660*	127	18	566	1045	13	7	9	3	10	2	20	2	51	3	24	1
18	U5	111.66811	37.59554	6750	1180	5320*	6230	910*	98	11	638	1120	5	3	3	1	10	2	23	2	31	2	26	1
19	EP-6	111.64231	37.59694	6725	1415	5025*	-----	-----	92	14	919	1366	4	3	3	1	31	5	38	4	16	1	0	0
20	EP-7	111.58590	37.55498	6810	878	5700*	-----	-----	50	20	257	811	18	15	3	1	9	2	20	2	0	0	0	0
21	EP-8	111.61871	37.57849	6738	945	5538*	6393	855*	90	16	443	904	10	6	6	2	8	2	66	6	0	0	0	0
22	EP-20	111.63026	37.67739	6230	720	5040*	6190	1150*	65	8	138	661	4	2	3	1	12	2	24	2	0	0	22	1
23	EP-21	111.63351	37.64969	6384	1035	4894*	6124	1230*	59	17	404	954	13	10	3	1	22	4	21	2	0	0	0	0
24	EP-22	111.62225	37.65534	6420	1092	4960*	6140	1180*	51	13	332	1061	8	6	3	1	18	4	22	2	0	0	0	0
25	EP-23	111.62220	37.63444	6440	1112	4900*	5990	1090*	63	15	509	1015	10	7	0	0	26	5	27	3	0	0	0	0
26	EP-24	111.63236	37.62645	6580	1307	4930*	5970	1040*	101	26	697	1268	20	16	12	4	14	2	36	3	19	1	0	0
27	EP-26	111.63278	37.55471	6360	1027	5335	6120	785	88	21	374	992	18	10	9	3	26	5	35	3	0	0	0	0
28	EP-27	111.61356	37.54729	6780	1002	5680*	6560	880*	66	21	303	891	18	12	9	3	26	3	35	3	0	0	0	0
29	EP-28	111.60558	37.52955	6710	880	5610*	6450	840*	124	19	357	861	12	7	9	3	29	5	14	1	33	2	27	1
30	EP-30	111.61617	37.52214	6720	830	5720*	6318	598*	71	16	447	827	8	7	0	0	31	6	17	2	15	1	0	0
31	EP-32	111.58788	37.52176	6650	1040	5610*	6450	840*	94	28	266	973	22	18	9	3	20	4	9	1	34	2	0	0
32	77-KP-1	111.49590	37.45407	6360	1073	5323*	6140	817*	56	16	269	817	16	11	6	2	4	1	10	1	20	1	0	0
33	77-KP-2	111.45891	37.43873	6410	805	5290*	6225	935*	57	11	333	789	2	1	3	1	43	8	9	1	0	0	0	0
34	77-KP-3	111.41145	37.44014	6340	850	5250*	6220	970*	28	9	168	741	8	5	0	0	20	4	0	0	0	0	0	0
35	77-KP-4	111.44883	37.48718	6540	803	5490*	6480	990*	35	11	147	675	5	4	9	3	21	4	0	0	0	0	0	0
36	77-KP-5	111.42491	37.49652	6820	853	5730*	6800	1070*	17	7	100	713	6	4	3	1	8	2	0	0	0	0	0	0
37	77-KP-6	111.55053	37.48894	6460	1243	5328	6135	807	77	27	371	900	19	19	6	2	10	2	27	3	15	1	0	0
38	77-KP-7	111.53319	37.50179	6340	843	5270*	6075	805*	89	15	355	758	9	7	0	0	30	6	0	0	19	1	31	1
39	77-KP-8	111.49313	37.50237	6340	861	5270*	6240	970*	34	9	198	750	8	6	0	0	10	2	0	0	16	1	0	0
40	77-KP-9	111.53159	37.52516	6390	851	5260*	6170	910*	48	13	313	804	10	7	3	1	22	4	13	1	0	0	0	0
41	77-KP-10	111.51858	37.47951	6430	851	5300*	6200	900*	78	17	347	737	11	8	6	2	14	3	15	2	32	2	0	0
42	77-KP-11	111.58776	37.49766	6684	1385	5479	6254	775	114	22	517	1016	15	12	6	2	29	5	13	1	16	1	35	1
43	77-KP-12	111.56679	37.51100	6610	851	5570*	6380	810*	104	17	320	839	7	7	9	3	17	3	0	0	50	3	21	1
44	77-KP-13	111.54175	37.48041	6450	852	5320*	6130	810*	81	27	388	830	26	20	9	3	4	1	9	1	33	2	0	0
45	DH-73	111.48326	37.46097	6439	881	5339*	6229	890*	67	18	311	771	12	8	6	2	30	6	19	2	0	0	0	0

Appendix 1, table 2—*Continued.*

Map no. (Data point identification)	Point ID	Longitude (Data point information)	Latitude	Surface elev (ft)	Total depth (ft)	Elev Csb. (ft) (Stratigraphic interpretations)	Elev Dsb. (ft)	Thk C-A seq (ft)	Total coal (Lithologic interpretations: Net coal in Calico and A-sequences (values in ft))	# beds	Depth top coal	Depth bottom coal	1.0-2.4 (Net coal thickness (in ft) and number of coal beds in bed-thickness categories)	# beds	2.5-3.4	# beds	3.5-7.4	# beds	7.5-14.0	# beds	14.1-20.0	# beds	> 20.0	# beds
46	DH-23	111.52170	37.37074	5267	970	4311	5142	831	82	15	318	840	8	5	12	4	11	2	34	3	17	1	0	0
47	DH-28	111.52286	37.40633	5878	1120	4786	5588	802	106	18	421	952	2	1	12	4	48	9	44	4	0	0	0	0
48	DH-44	111.43663	37.39827	6481	810	5501*	6331	830*	51	24	221	678	22	18	3	1	16	4	10	1	0	0	0	0
49	DH-172	111.45921	37.43499	6340	796	5290*	6130	840*	60	21	248	736	19	12	12	4	18	4	11	1	0	0	0	0
50	DH-176	111.43900	37.42204	6280	798	5250*	6130	880*	67	23	196	715	21	16	6	2	13	3	11	1	16	1	0	0
51	DH-180	111.41059	37.42010	6180	793	5140*	6060	920*	45	16	158	694	20	13	3	1	5	1	0	0	17	1	0	0
52	DH-182	111.42350	37.41666	6160	796	5145*	6060	915*	38	18	155	692	20	15	3	1	4	1	11	1	0	0	0	0
53	DH-189	111.45833	37.41859	6280	793	5270*	6100	830*	43	9	249	689	6	4	0	0	11	2	26	3	0	0	0	0
54	DH-193	111.44226	37.40658	6360	793	5420*	6220	800*	59	22	186	633	19	15	9	3	5	1	26	3	0	0	0	0
55	DH-194	111.42666	37.41155	6250	717	5280*	6135	855*	45	15	151	642	11	8	9	3	17	3	8	1	0	0	0	0
56	DH-202	111.42137	37.38680	6556	786	5656*	6481	825*	56	19	192	665	16	12	12	4	0	0	28	3	0	0	0	0
57	DH-223	111.47584	37.43852	6350	889	5270*	6120	850*	78	24	283	848	19	14	6	2	17	4	36	4	0	0	0	0
58	DH-224	111.47896	37.43555	6325	703	5255*	6085	830*	69	22	306	696	19	13	6	2	18	4	26	3	0	0	0	0
59	DH-227	111.48976	37.44147	6285	800	5205*	6045	840*	79	20	317	756	18	13	9	3	10	2	0	0	18	1	24	1
60	DH-232	111.50453	37.42822	6230	992	5150*	5935	785*	90	26	358	900	22	17	3	1	20	4	25	3	20	1	0	0
61	DH-235	111.49987	37.41979	6170	797	5200*	5990	790*	75	19	452	793	12	10	6	2	23	5	9	1	0	0	25	1
62	DH-241	111.48321	37.39962	6170	903	5280*	6020	740*	88	21	312	770	15	10	6	2	28	6	21	2	18	1	0	0
63	DH-247	111.47663	37.39273	6160	805	5290*	5990	700*	80	28	255	765	22	18	12	4	14	3	32	3	0	0	0	0
64	DH-254	111.52139	37.43507	6110	846	5090*	5855	765*	130	19	369	843	15	10	3	1	9	2	27	3	0	0	76	3
65	DH-255	111.52092	37.42923	6040	851	5030*	5810	780*	110	24	356	836	17	12	9	3	19	4	43	4	0	0	22	1
66	DH-258	111.52980	37.41613	5865	856	4855*	5635	780*	99	26	361	829	16	13	3	1	46	9	16	2	18	1	0	0
67	DH-259	111.51717	37.40051	5780	850	4840*	5630	790*	108	22	311	819	16	12	6	2	23	4	35	3	0	0	28	1
68	DH-263	111.51385	37.37419	5435	852	4515*	5305	790*	96	20	323	823	16	11	3	1	27	4	31	3	19	1	0	0
69	A-34-1	111.62844	37.37990	6050	2344	3730	4530	800	94	30	1689	2280	27	17	21	7	19	4	9	1	18	1	0	0
70	A-46-1	111.62832	37.33600	6235	2391	3915	4685	770	95	26	1742	2280	20	10	24	8	16	4	35	4	0	0	0	0
71	C-25-3	111.62196	37.40972	5976	2697	3521	4346	825	102	23	1830	2408	21	12	9	3	21	4	16	2	35	2	0	0
72	C-29-3	111.62230	37.39653	5940	2383	3557	4380	823	91	26	1705	2266	22	16	15	5	17	4	0	0	0	0	37	1
73	C-40-3	111.62286	37.35597	6210	2236	3900*	4710	810*	91	19	1750	2181	8	5	15	5	31	6	22	2	15	1	0	0
74	C-42-3	111.62402	37.34838	6245	2350	3965	4740	775	83	17	1758	2192	4	2	15	5	32	7	17	2	15	1	0	0
75	D-51-3	111.61801	37.31682	6268	2370	3988	4748	760	49	15	1713	2163	9	6	9	3	31	6	0	0	0	0	0	0
76	E-20-3	111.61336	37.42863	6140	2340	3890	4630	740	93	22	1720	2209	12	10	9	3	27	6	24	2	0	0	21	1
77	E-36-1	111.61067	37.37296	5989	2375	3589*	4429	840*	98	19	1767	2320	6	4	15	5	29	6	30	3	18	1	0	0
78	E-38-1	111.61112	37.36564	6059	2435	3714	4549	835	98	19	1750	2299	14	7	9	3	20	4	55	5	0	0	0	0
79	F-29-3	111.60943	37.39628	5970	2325	3540*	4390	850*	87	21	1814	2294	16	9	21	7	15	3	0	0	35	2	0	0
80	F-44-1	111.60745	37.34406	6265	2263	3945*	4795	850*	83	23	1639	2179	15	9	15	5	29	6	24	3	0	0	0	0
81	G-4-3	111.60457	37.48790	6720	1357	5430	6130	700	145	19	748	1187	12	6	9	3	20	4	33	3	20	1	51	2
82	G-8-1	111.60287	37.47377	6117	1200	5112	5797	685	104	14	380	851	2	1	6	2	40	8	0	0	56	3	0	0
83	G-24-1	111.60274	37.41564	6106	2200	3756*	4596	840*	86*	22	1714	2180	18	11	15	5	18	4	11	1	19	1	0	0
84	G-26-1	111.60129	37.40762	6075	2446	3690	4485	795	124	26	1834	2341	30	17	3	1	19	4	33	3	0	0	39	1
85	I-25-4	111.59252	37.41012	5454	1800	3834	4614	780	135	15	1075	1573	7	4	6	2	12	3	16	2	51	3	43	1
86	J-29-2	111.59099	37.39775	6072	2342	3737	4512	775	123	28	1759	2293	25	14	6	2	26	6	49	5	17	1	0	0
87	K-15-4	111.58477	37.44677	5987	1646	4602	5397	795	74	14	741	1256	4	3	3	1	28	6	39	4	0	0	0	0
88	K-17-4	111.58357	37.43940	5670	1298	4450	5250	800	125	28	573	1174	16	10	15	5	37	8	40	4	17	1	0	0
89	L-8-1	111.58106	37.47382	6615	1460	5235	5930	695	101	22	772	1255	11	8	9	3	33	7	26	3	0	0	22	1
90	L-11-4	111.58006	37.46065	6327	1400	4993	5737	744	90	13	725	1244	4	2	0	0	26	6	28	3	32	2	0	0

Appendix 1, table 2—*Continued.*

Data point identification		Data point information				Stratigraphic interpretations			Lithologic interpretations															
									Net coal in Calico and A-sequences (values in ft)				Net coal thickness (in ft) and number of coal beds in bed-thickness categories											
Map no.	Point ID	Longitude	Latitude	Surface elev (ft)	Total depth (ft)	Elev Csb. (ft)	Elev Dsb. (ft)	Thk C-A seq (ft)	Total coal	# beds	Depth top coal	Depth bottom coal	1.0-2.4	# beds	2.5-3.4	# beds	3.5-7.4	# beds	7.5-14.0	# beds	14.1-20.0	# beds	> 20.0	# beds
91	L-36-4	111.57968	37.37066	6020	2315	3690*	4405	715*	120	30	1758	2307	23	16	12	4	27	6	29	3	0	0	29	1
92	L-38-4	111.58042	37.36312	6074	2380	3679*	4359	680*	118	23	1870	2376	16	10	6	2	36	7	20	2	18	1	22	1
93	L-41-1	111.57925	37.35355	6028	2280	3648*	4388	740*	89*	16	1802	2197	11	8	3	1	11	2	40	4	16	1	0	0
94	M-21-2	111.57668	37.42618	5585	1400	4315	5165	850	77	16	679	1169	10	6	9	3	25	4	18	2	15	1	0	0
95	N-35-3	111.57324	37.37388	6022	2118	3772*	4502	730*	105*	19	1672	2081	17	10	12	4	15	3	0	0	16	1	28	1
96	O-20-1	111.56559	37.43048	5727	1297	4542	5297	755	120	23	626	1251	15	9	12	4	26	5	31	3	36	2	0	0
97	O-30-1	111.57276	37.39326	5297	1375	4007	4777	770	142	20	726	1217	12	7	9	3	24	5	38	3	0	0	59	2
98	P-25-3	111.56499	37.40958	5650	1400	4170*	5010	840*	120	19	860	1370	7	4	15	5	17	4	53	5	0	0	28	1
99	Q-24-2	111.55948	37.41504	5761	1396	4361*	5161	800*	129	21	825	1315	11	6	15	5	20	4	42	4	17	1	24	1
100	Q-30-4	111.55654	37.39156	5505	1397	4115	4905	810	118	24	810	1339	21	13	9	3	8	2	44	4	36	2	0	0
101	Q-35-1	111.55629	37.37599	5198	1191	3968*	4743	775*	154	24	646	1168	11	8	6	2	34	7	40	4	32	2	31	1
102	R-39-3	111.55381	37.36035	5153	1335	3843	4593	750	145	17	723	1273	4	2	18	6	21	4	33	3	17	1	52	1
103	U-37-4	111.53778	37.36625	5180	1100	4110	4875	765	129	16	461	995	1	1	9	3	40	8	35	3	0	0	44	1
104	U-40-1	111.53795	37.35861	5090	1060	4050	4810	760	122	17	511	1027	10	5	6	2	32	7	20	2	0	0	54	1
105	V-34-1	111.53534	37.37977	5312	1198	4247	5032	785	141	22	488	981	12	6	12	4	24	5	36	4	36	2	21	1
106	W-36-3	111.53292	37.37003	5214	1265	4191	4964	773	104	16	406	931	9	8	6	2	11	2	32	3	0	0	46	1
107	W-39-3	111.53294	37.35976	5081	935	4111*	4856	745*	122	16	415	900	6	3	12	4	35	7	10	1	0	0	59	1
108	X-32-4	111.52584	37.38591	5680	1182	4490*	5280	790*	152	24	625	1086	15	8	6	2	41	9	25	2	32	2	33	1
109	X-36-2	111.52857	37.37291	5295	1097	4265	5095	830	116	27	407	943	25	15	15	5	11	2	28	3	15	1	22	1
110	DH-1	111.52471	37.33768	5091	998	4061*	4786	725*	88	22	490	975	11	8	27	9	11	2	9	1	30	2	0	0
111	DH-2	111.53201	37.32004	5076	843	4236	4986	750	70	14	337	798	5	3	12	4	23	4	30	3	0	0	0	0
112	DH-5	111.51483	37.28180	5571	814	4711*	5501	790*	45	15	298	678	13	9	9	3	7	1	16	2	0	0	0	0
113	DH-6	111.50425	37.27787	5531	810	4691*	5481	790*	67	20	212	652	14	12	9	3	16	3	9	1	19	1	0	0
114	DH-7	111.51626	37.26494	5400	798	4600*	5365	765*	57	18	273	668	19	13	0	0	11	2	27	3	0	0	0	0
115	DH-12	111.49818	37.26538	5549	903	4659	5474	815	61	18	291	827	15	12	3	1	10	2	18	2	18	1	0	0
116	DH-13	111.54597	37.35376	5104	1380	3864	4629	765	99	22	701	1189	24	14	0	0	31	6	0	0	0	0	44	2
117	DH-115	111.52688	37.23580	5249	759	4359*	5149	790*	52	15	397	734	12	10	6	2	4	1	8	1	0	0	22	1
118	DH-201	111.53659	37.21645	5167	653	4287*	-----	-----	26	7	454	626	5	4	0	0	10	2	11	1	0	0	0	0
119	DH-203	111.54389	37.22500	5125	710	4255*	5040	785*	44*	9	429	620	3	3	9	3	9	2	0	0	18	1	0	0
120	DH-231	111.54390	37.26806	5220	665	4420*	5190	770*	35	10	354	640	3	3	9	3	13	3	10	1	0	0	0	0
121	DH-245	111.54993	37.24592	5087	635	4217*	5027	810*	32	10	425	595	6	5	0	0	26	5	0	0	0	0	0	0
122	DH-301	111.57736	37.23423	5000	1400	4110	4900	790	36	11	515	664	6	5	3	1	27	5	0	0	0	0	0	0
123	DH-304	111.57688	37.24388	4975	750	4075*	4860	785*	41	23	302	691	22	19	6	2	4	1	9	1	0	0	0	0
124	DH-310	111.59625	37.25193	4970	815	4000*	4790	790*	33	14	403	754	9	9	6	2	8	2	10	1	0	0	0	0
125	DH-311	111.60590	37.25218	5000	850	3980*	4750	770*	38	13	415	790	13	9	0	0	14	3	11	1	0	0	0	0
126	DH-314	111.57952	37.26030	4980	746	4100*	4860	760*	51	15	391	732	10	9	6	2	9	2	10	1	16	1	0	0
127	DH-316	111.59657	37.26040	4970	800	4000*	4760	760*	53	20	421	760	17	15	3	1	10	2	8	1	15	1	0	0
128	DH-319	111.58779	37.26693	4880	705	4080*	4840	760*	53	15	230	654	14	10	0	0	15	3	9	1	15	1	0	0
129	DH-322	111.55249	37.27511	5220	1015	4375	5165	790	67	27	262	811	26	22	6	2	4	1	14	1	17	1	0	0
130	DH-324	111.57861	37.27515	5170	885	4170*	4950	780*	45*	11	537	856	10	8	6	2	0	0	0	0	0	0	23	1
131	DH-334	111.54161	37.29038	5470	975	4585	5400	815	52	25	378	850	26	20	3	1	23	4	0	0	0	0	0	0
132	DH-336	111.55995	37.29000	5325	800	4395*	5235	840*	63	16	314	795	19	13	0	0	4	1	12	1	0	0	28	1
133	DH-340	111.59573	37.29012	5110	870	4090*	4860	770*	48	20	417	822	18	16	3	1	7	1	20	2	0	0	0	0
134	DH-346	111.58188	37.30536	5420	970	4250*	5030	780*	54	16	597	957	9	8	9	3	14	3	22	2	0	0	0	0
135	DH-348	111.60338	37.30471	5300	1055	4060*	4830	770*	45	13	654	1026	8	6	12	4	5	1	20	2	0	0	0	0

Appendix 1, table 2—*Continued.*

Data point identification		Data point information				Stratigraphic interpretations			Lithologic interpretations															
									Net coal in Calico and A-sequences (values in ft)				Net coal thickness (in ft) and number of coal beds in bed-thickness categories											
Map no.	Point ID	Longitude	Latitude	Surface elev (ft)	Total depth (ft)	Elev Csb. (ft)	Elev Dsb. (ft)	Thk C-A seq (ft)	Total coal	# beds	Depth top coal	Depth bottom coal	1.0-2.4	# beds	2.5-3.4	# beds	3.5-7.4	# beds	7.5-14.0	# beds	14.1-20.0	# beds	> 20.0	# beds
136	DH-354	111.62448	37.24456	4910	905	3880*	4650	770*	28	18	525	803	17	16	0	0	11	2	0	0	0	0	0	0
137	DH-362	111.60525	37.28051	5080	960	3990*	4745	755*	54	17	625	889	16	12	3	1	13	3	0	0	0	0	22	1
138	DH-364	111.53311	37.29105	5510	1100	4660*	5405	745*	52	21	369	789	15	14	6	2	14	3	17	2	0	0	0	0
139	DH-365	111.52483	37.29820	5580	699	4710*	5520	810*	70*	13	420	696	8	6	0	0	18	4	21	2	15	1	0	0
140	DH-378	111.62864	37.21634	4960	925	3870*	4620	750*	23	17	532	904	14	14	9	3	0	0	0	0	0	0	0	0
141	DH-381	111.52279	37.28339	5570	769	4730*	5520	790*	48	20	352	719	22	14	9	3	17	3	0	0	0	0	0	0
142	DH-383	111.57712	37.29689	5460	965	4310*	5070	760*	58	21	541	923	23	17	3	1	7	1	25	2	0	0	0	0
143	Diamanti-1	111.56020	37.15117	5240	658	4420*	5180	760*	18	9	486	606	7	7	3	1	0	0	8	1	0	0	0	0
144	DH-211	111.48485	37.33938	5340	770	4500*	5230	730*	97	18	279	766	12	8	9	3	11	2	41	4	0	0	24	1
145	DH-6-72	111.59883	37.46090	5880	1200	4870*	5630	760*	83	18	394	891	10	5	15	5	17	4	24	3	17	1	0	0
146	BF-1-33	111.80330	37.80912	7218	7974	6408	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----
147	Byrd-Oil	111.38419	37.35681	6150	10044	5850	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----
148	Cleary-Pet	111.37071	37.33943	5941	6465	5781	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----
149	Fed-Sky-1	111.83749	37.53743	7128	7094	6698	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----
150	JV-1	111.97818	37.72016	8110	11180	6930	7890	960	10	2	908	952	0	0	0	0	10	2	0	0	0	0	0	0
151	JV-41-27	111.98795	37.73796	7912	8702	7132	----	----	22	5	378	554	5	3	0	0	7	1	10	1	0	0	0	0
152	Liston	111.81000	37.68878	7070	5010	2345	3470	1125	71	10	3769	4435	0	0	6	2	23	5	20	2	0	0	22	1
153	LV-2-18	111.72709	37.58845	7606	7921	6236	7091	855	107	17	605	1260	2	2	3	1	36	7	66	7	0	0	0	0
154	Rees-Can-2	111.40932	37.37589	6594	9015	5774	6594	820	70	11	62	670	2	2	3	1	30	5	20	2	15	1	0	0
155	Skyline-A	111.61073	37.55733	6860	7450	5695	6585	890	52	12	351	870	4	3	3	1	36	7	9	1	0	0	0	0
156	Tibbet-Can-1	111.72638	37.32307	6167	4243	3887	4717	830	9	3	1874	1962	2	1	3	1	4	1	0	0	0	0	0	0
157	Trap-Can	111.71875	37.58261	7387	7636	6197	7037	840	114	12	549	1085	0	0	0	0	28	6	44	4	15	1	27	1
158	UV-1	111.72361	37.59280	7560	-------	6342	7210	868	91	14	470	1118	6	3	6	2	30	6	12	1	15	1	22	1
159	UV-2	111.74778	37.68256	7701	6655	7421	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----
160	UV-2a	111.71373	37.61226	7095	6521	6555	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----
161	UV-3	111.74472	37.67359	7671	6648	7351	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----
162	UV-11	111.73371	37.64331	7519	7125	7064	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----
163	UV-12	111.72722	37.61788	7294	7220	6714	----	----	65	11	140	433	4	2	9	3	21	4	12	1	19	1	0	0
164	UV-17x	111.73131	37.63770	7508	7025	6996	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	---
165	UV-21	111.72866	37.60978	7230	9951	6580	----	----	74	11	110	435	4	2	3	1	23	5	12	1	32	2	0	0
166	UV-27	111.71942	37.60117	7380	7321	6572	----	----	78	13	5	702	4	2	9	3	38	7	0	0	0	0	27	1
167	UV-South-1	111.69049	37.51163	6861	3208	5071	5851	780	97	12	1080	1700	7	4	0	0	12	2	44	5	0	0	34	1
168	BV4	111.82122	37.46618	-----	----	----	----	800	7	2	----	----	0	0	3	1	4	1	0	0	0	0	0	0
169	C1	111.64269	37.71058	-----	----	----	----	1000	36	5	-----	----	2	1	0	0	4	1	30	3	0	0	0	0
170	C2	111.68270	37.68808	-----	----	----	----	1050	40	10	----	-----	3	2	12	4	8	2	17	2	0	0	0	0
171	CC1	111.57820	37.61543	-----	----	----	----	----	14	4	----	----	1	1	3	1	10	2	0	0	0	0	0	0
172	CC2	111.53702	37.55266	-----	----	----	----	1000	37	9	----	----	5	3	0	0	32	6	0	0	0	0	0	0
173	CM9	111.02006	37.18240	-----	----	----	----	----	2	2	----	---	2	2	0	0	0	0	0	0	0	0	0	0
174	CMNW1	111.14038	37.26174	-----	----	----	-----	-----	0	0	-----	-----	0	0	0	0	0	0	0	0	0	0	0	0
175	CP15	111.82971	37.53214	-----	----	----	-----	800	5	1	-----	-----	0	0	0	0	5	1	0	0	0	0	0	0
176	DC1	111.61901	37.69599	-----	----	----	-----	1100	23	6	-----	-----	5	4	0	0	0	0	18	2	0	0	0	0
177	DC2	111.60590	37.67489	-----	----	----	-----	-----	26	5	-----	-----	4	3	0	0	7	1	0	0	15	1	0	0
178	GB7	111.44759	37.18193	-----	----	----	-----	725	13	6		-----	5	4	3	1	5	1	0	0	0	0	0	0
179	GB19	111.42726	37.22998	-----	----	----	-----	790	43	9	-----	-----	8	5	0	0	14	2	21	2	0	0	0	0
180	GP1	111.80898	37.78553	-----	----	----	-----	1160	56	11	-----	-----	6	5	3	1	17	3	11	1	19	1	0	0

Appendix 1, table 2—*Continued.*

Data point identification		Data point information				Stratigraphic interpretations			Lithologic interpretations															
									Net coal in Calico and A-sequences (values in ft)				Net coal thickness (in ft) and number of coal beds in bed-thickness categories											
Map no.	Point ID	Longitude	Latitude	Surface elev (ft)	Total depth (ft)	Elev Csb. (ft)	Elev Dsb. (ft)	Thk C-A seq (ft)	Total coal	# beds	Depth top coal	Depth bottom coal	1.0-2.4	# beds	2.5-3.4	# beds	3.5-7.4	# beds	7.5-14.0	# beds	14.1-20.0	# beds	> 20.0	# beds
181	H5	111.92516	37.60241	-----	-----	-----	-----	-----	5	2	-----	-----	1	1	0	0	4	1	0	0	0	0	0	0
182	H17	111.90134	37.54537	-----	-----	-----	-----	850	16	3	-----	-----	1	1	3	1	0	0	12	1	0	0	0	0
183	H26	111.87681	37.51877	-----	-----	-----	-----	-----	13	6	-----	-----	4	4	0	0	9	2	0	0	0	0	0	0
184	HF7	111.86294	37.35016	-----	-----	-----	-----	890	1	1	-----	-----	1	1	0	0	0	0	0	0	0	0	0	0
185	NB7	111.61219	37.13881	-----	-----	-----	-----	720	3	1	-----	-----	0	0	3	1	0	0	0	0	0	0	0	0
186	NB8	111.59264	37.15122	-----	-----	-----	-----	720	5	4	-----	-----	5	4	0	0	0	0	0	0	0	0	0	0
187	NB12	111.51907	37.20443	-----	-----	-----	-----	850	32	7	-----	-----	8	4	0	0	7	1	17	2	0	0	0	0
188	NBNW4	111.73344	37.19761	-----	-----	-----	-----	750	1	1	-----	-----	1	1	0	0	0	0	0	0	0	0	0	0
189	NBSE1	111.61743	37.12282	-----	-----	-----	-----	800	1	1	-----	-----	1	1	0	0	0	0	0	0	0	0	0	0
190	NBSE8	111.54597	37.08804	-----	-----	-----	-----	790	17	8	-----	-----	6	5	6	2	5	1	0	0	0	0	0	0
191	NBSE12	111.50682	37.11676	-----	-----	-----	-----	-------	4	3	-----	-----	4	3	0	0	0	0	0	0	0	0	0	0
192	NBSW1	111.65514	37.12404	-----	-----	-----	-----	775	3	3	-----	-----	3	3	0	0	0	0	0	0	0	0	0	0
193	PL1	111.99657	37.67165	-----	-----	-----	-----	950	27	2	-----	-----	0	0	0	0	0	0	11	1	16	1	0	0
194	PL11	111.95158	37.63706	-----	-----	-----	-----	950	22	2	-----	-----	0	0	0	0	0	0	22	2	0	0	0	0
195	RHC	111.91823	37.19414	-----	-----	-----	-----	702	-----	-----	-----	-----	----	----	----	----	----	----	----	----	----	----	----	----
196	S6	111.42748	37.50258	-----	-----	-----	-----	1100*	6	3	-----	-----	3	2	3	1	0	0	0	0	0	0	0	0
197	S7	111.60248	37.09128	-----	-----	-----	-----	700	4	2	-----	-----	4	2	0	0	0	0	0	0	0	0	0	0
198	S8	111.59205	37.09985	-----	-----	-----	-----	700	8	4	-----	-----	5	3	3	1	0	0	0	0	0	0	0	0
199	S17	111.50703	37.20509	-----	-----	-----	-----	750	46	14	-----	-----	12	8	3	1	16	3	15	2	0	0	0	0
200	S21	111.38188	37.24611	-----	-----	-----	-----	790*	78	17	-----	-----	9	5	15	5	23	5	10	1	0	0	21	1
201	S22	111.37197	37.25121	-----	-----	-----	-----	800*	64	19	-----	-----	13	9	9	3	34	6	8	1	0	0	0	0
202	S23	111.36592	37.29192	-----	-----	-----	-----	780*	67	16	-----	-----	13	9	12	4	4	1	8	1	0	0	30	1
203	S24	111.35909	37.32031	-----	-----	-----	-----	760	14	8	-----	-----	9	7	0	0	5	1	0	0	0	0	0	0
204	S25	111.31725	37.32245	-----	-----	-----	-----	840*	20	9	-----	-----	10	6	6	2	4	1	0	0	0	0	0	0
205	S26	111.28034	37.34722	-----	-----	-----	-----	-----	8	4	-----	-----	5	3	3	1	0	0	0	0	0	0	0	0
206	S27	111.28200	37.37577	-----	-----	-----	-----	1060*	1	1	-----	-----	1	1	0	0	0	0	0	0	0	0	0	0
207	S28	111.29987	37.44613	-----	-----	-----	-----	1060*	0	0	-----	-----	0	0	0	0	0	0	0	0	0	0	0	0
208	S30	111.12097	37.22158	-----	-----	-----	-----	900*	6	3	-----	-----	3	2	3	1	0	0	0	0	0	0	0	0
209	S32	111.09251	37.22743	-----	-----	-----	-----	-----	0	0	-----	-----	0	0	0	0	0	0	0	0	0	0	0	0
210	S34	111.01593	37.22609	-----	-----	-----	-----	1100*	0	0	-----	-----	0	0	0	0	0	0	0	0	0	0	0	0
211	TC1	111.54110	37.16979	-----	-----	-----	-----	770	22	12	-----	-----	16	11	0	0	6	1	0	0	0	0	0	0
212	WHR1	111.68559	37.87749	-----	-----	-----	-----	1580	0	0	-----	-----	0	0	0	0	0	0	0	0	0	0	0	0
213	WHR2	111.74660	37.87126	-----	-----	-----	-----	-----	58	7	-----	-----	0	0	3	1	10	2	30	3	15	1	0	0
214	--------	111.76739	37.68632	-----	-----	-----	-----	1000	-----	-----	-----	-----	----	----	----	----	----	----	----	----	----	----	----	----
215	--------	111.74013	37.65241	-----	-----	-----	-----	1000	-----	-----	-----	-----	----	----	----	----	----	----	----	----	---	----	----	----
216	--------	111.50868	37.60964	-----	-----	-----	-----	-----	0	0	-----	-----	0	0	0	0	0	0	0	0	0	0	0	0
217	--------	111.48949	37.59624	-----	-----	-----	-----	1100	-----	-----	-----	-----	----	----	----	----	----	----	----	----	----	----	----	---
218	--------	111.48724	37.56715	-----	-----	-----	-----	-----	0	0	-----	-----	0	0	0	0	0	0	0	0	0	0	0	0
219	--------	111.41923	37.51808	-----	-----	-----	-----	-----	0	0	-----	-----	0	0	0	0	0	0	0	0	0	0	0	0
220	--------	111.11067	37.19458	-----	-----	-----	-----	-----	0	0	-----	-----	0	0	0	0	0	0	0	0	0	0	0	0
221	--------	111.57336	37.14957	-----	-----	-----	-----	740	-----	-----	-----	-----	----	----	----	----	----	----	----	----	----	----	----	----
222	--------	111.65367	37.16162	-----	-----	-----	-----	740	-----	-----	-----	-----	----	----	----	----	----	----	----	----	----	----	----	----
223	--------	111.74949	37.23766	-----	-----	-----	-----	780	-----	-----	-----	-----	----	----	----	----	----	----	----	----	----	----	----	----
224	--------	111.75791	37.18605	-----	-----	-----	-----	-----	0	0	-----	-----	0	0	0	0	0	0	0	0	0	0	0	0
225	--------	111.87301	37.33589	-----	-----	-----	-----	-----	0	0	-----	-----	0	0	0	0	0	0	0	0	0	0	0	0
226	--------	111.96056	37.76837	-----	-----	-----	-----	1050	-----	-----	-----	-----	----	----	----	----	----	----	----	----	----	----	----	----

Appendix 2—Coal Tonnage Tables for Quadrangles and Townships

Appendix 2 contains tables that report the original coal resources (coal < 6,000 ft deep) and other occurrences of non-resource coal (coal > 6,000 ft deep) (in millions of short tons) for each 7.5′ quadrangle and township in the Kaiparowits Plateau. Total coal tonnage reported in each table is for original coal resources as well as other occurrences of non-resource coal. Tonnage was calculated for all coal beds greater than 1 ft thick in the Calico and A-sequences and was reported in reliability and overburden categories; coal tonnage was calculated only for areas in the plateau where the entire coal-bearing interval has been preserved (fig. 11). The reported tonnages were rounded to two significant figures, and some categories in the tables do not equal the sum of their components because of independent rounding. The locations of quadrangles and townships are provided in figure 2.

Appendix 2, table 1, 1 of 3. Original coal resources and other occurrences of non-resource coal in the Calico and A-sequences by 7.5-minute quadrangle (in millions of short tons).

[Original coal resources are < 6,000 ft deep, and other occurrences of non-resource coal are > 6,000 ft deep]

7.5' quadrangle name	Reliability	Overburden categories (thickness in ft)					
		0-1000	1000-2000	2000-3000	3000-6000	>6000	Total
Barker Reservoir	Identified	0	230	630	1,100	0	**2,000**
	Hypothetical	0	0	0	220	0	**220**
	Total	**0**	**230**	**630**	**1,300**	**0**	**2,200**
Basin Canyon	Identified	170	0.5	0	0	0	**170**
	Hypothetical	39	0	0	0	0	**39**
	Total	**210**	**0.5**	**0**	**0**	**0**	**210**
Blackburn Canyon	Identified	18	0	0	0	0	**18**
	Hypothetical	20	0	0	0	0	**20**
	Total	**38**	**0**	**0**	**0**	**0**	**38**
Butler Valley	Identified	36	80	240	12	0	**370**
	Hypothetical	3.9	9	760	7.5	0	**780**
	Total	**40**	**89**	**1,000**	**19**	**0**	**1,200**
Canaan Creek	Identified	580	920	0	0	0	**1,500**
	Total	**580**	**920**	**0**	**0**	**0**	**1,500**
Canaan Peak	Identified	88	190	610	650	0	**1,500**
	Hypothetical	0	0	590	930	0	**1,500**
	Total	**88**	**190**	**1,200**	**1,600**	**0**	**3,100**
Carcass Canyon	Identified	2,100	530	0	0	0	**2,600**
	Total	**2,100**	**530**	**0**	**0**	**0**	**2,600**
Collet Top	Identified	1,800	560	0	0	0	**2,400**
	Hypothetical	0	0	0	0	0	**0**
	Total	**1,800**	**560**	**0**	**0**	**0**	**2,400**
Dave Canyon	Identified	110	210	0	0	0	**320**
	Total	**110**	**210**	**0**	**0**	**0**	**320**
Death Ridge	Identified	1,100	4,100	1,400	0.1	0	**6,600**
	Hypothetical	0	0	130	0	0	**130**
	Total	**1,100**	**4,100**	**1,500**	**0.1**	**0**	**6,700**
East of the Navajo	Identified	470	0	0	0	0	**470**
	Hypothetical	33	0	0	0	0	**33**
	Total	**500**	**0**	**0**	**0**	**0**	**500**
Fourmile Bench	Identified	0	320	1,800	0	0	**2,200**
	Hypothetical	2.8	110	300	0	0	**410**
	Total	**2.8**	**430**	**2,100**	**0**	**0**	**2,600**

Appendix 2, table 1, 2 of 3. Original coal resources and other occurrences of non-resource coal in the Calico and A-sequences by 7.5-minute quadrangle (in millions of short tons)—*Continued.*

[Original coal resources are < 6,000 ft deep, and other occurrences of non-resource coal are > 6,000 ft deep]

7.5' quadrangle name	Reliability	Overburden categories (thickness in ft)					
		0-1000	1000-2000	2000-3000	3000-6000	>6000	Total
Glen Canyon City	Identified	6.3	0	0	0	0	**6.3**
	Total	**6.3**	**0**	**0**	**0**	**0**	**6.3**
Grass Lakes	Hypothetical	0	0	130	1,100	120	**1,400**
	Total	**0**	**0**	**130**	**1,100**	**120**	**1,400**
Griffin Point	Identified	39	520	400	560	30	**1,500**
	Hypothetical	0	76	230	1,000	150	**1,500**
	Total	**39**	**600**	**630**	**1,600**	**180**	**3,000**
Henrieville	Identified	74	80	90	0	0	**240**
	Hypothetical	0	0	1.2	0	0	**1.2**
	Total	**74**	**80**	**91**	**0**	**0**	**250**
Horse Flat	Identified	4.5	20	48	0	0	**72**
	Hypothetical	0	8.2	86	0	0	**94**
	Total	**4.5**	**28**	**130**	**0**	**0**	**170**
Horse Mountain	Identified	100	840	2,700	65	0	**3,700**
	Hypothetical	0	2.6	1,700	610	0	**2,300**
	Total	**100**	**840**	**4,400**	**680**	**0**	**6,000**
Lone Rock	Identified	83	0	0	0	0	**83**
	Total	**83**	**0**	**0**	**0**	**0**	**83**
Mazuki Point	Identified	3.7	0	0	0	0	**3.7**
	Total	**3.7**	**0**	**0**	**0**	**0**	**3.7**
East of the Navajo	Identified	45	0	0	0	0	**45**
	Total	**45**	**0**	**0**	**0**	**0**	**45**
Needle Eye Point	Identified	3,100	0	0	0	0	**3,100**
	Hypothetical	170	0	0	0	0	**170**
	Total	**3,200**	**0**	**0**	**0**	**0**	**3,200**
Nipple Butte	Identified	140	230	0	0	0	**370**
	Hypothetical	33	24	0	0	0	**57**
	Total	**170**	**250**	**0**	**0**	**0**	**420**
Petes Cove	Identified	1,700	4,500	890	0	0	**7,000**
	Total	**1,700**	**4,500**	**890**	**0**	**0**	**7,000**
Pine Lake	Identified	190	180	270	160	0	**800**
	Hypothetical	0	0	59	410	380	**850**
	Total	**190**	**180**	**330**	**570**	**380**	**1,700**
Posy Lake	Identified	11	140	190	73	0	**410**
	Hypothetical	42	41	27	7.7	0	**120**
	Total	**53**	**190**	**210**	**81**	**0**	**530**
Seep Flat	Identified	45	20	0	0	0	**65**
	Total	**45**	**20**	**0**	**0**	**0**	**65**
Ship Mountain Point	Identified	2,100	1,700	1,100	0	0	**4,800**
	Total	**2,100**	**1,700**	**1,100**	**0**	**0**	**4,800**
Sit Down Bench	Identified	90	0	0	0	0	**90**
	Total	**90**	**0**	**0**	**0**	**0**	**90**
Smoky Hollow	Identified	680	22	0	0	0	**700**
	Total	**680**	**22**	**0**	**0**	**0**	**700**
Sooner Bench	Identified	0.1	0	0	0	0	**0.1**
	Total	**0.1**	**0**	**0**	**0**	**0**	**0.1**

Appendix 2, table 1, 3 of 3. Original coal resources and other occurrences of non-resource coal in the Calico and A-sequences by 7.5-minute quadrangle (in millions of short tons)—*Continued*.

[Original coal resources are < 6,000 ft deep, and other occurrences of non-resource coal are > 6,000 ft deep]

7.5' quadrangle name	Reliability	Overburden categories (thickness in ft)					
		0-1000	1000-2000	2000-3000	3000-6000	>6000	Total
Sweetwater Creek	Identified	74	220	220	380	0	**890**
	Hypothetical	0	190	560	2,900	650	**4,300**
	Total	**74**	**410**	**780**	**3,300**	**650**	**5200**
Tibbet Bench	Identified	1,100	40	0	0	0	**1,100**
	Total	**1,100**	**40**	**0**	**0**	**0**	**1,100**
Upper Valley	Identified	93	230	250	1,400	47	**2,100**
	Hypothetical	19	55	76	720	350	**1,200**
	Total	**110**	**290**	**330**	**2,200**	**400**	**3,300**
Wide Hollow Reservoir	Identified	1.2	25	0	0	0	**26**
	Total	**1.2**	**25**	**0**	**0**	**0**	**26**
Total (parts 1, 2, and 3)		**16,000**	**16,000**	**15,000**	**12,000**	**1,700**	**62,000**

Appendix 2, table 2, 1 of 3. Original coal resources and other occurrences of non-resource coal in the Calico and A-sequences by township (in millions of short tons).

[Original coal resources are < 6,000 ft deep, and other occurrences of non-resource coal are > 6,000 ft deep]

Township and Range	Reliability	Overburden categories (thickness in ft)					
		0-1000	1000-2000	2000-3000	3000-6000	>6000	Total
33S 1W	Hypothetical	0	0	0	510	110	**620**
	Total	**0**	**0**	**0**	**510**	**110**	**620**
33S 2W	Hypothetical	0	0	34	90	0	**120**
	Total	**0**	**0**	**34**	**90**	**0**	**120**
33S 1E	Identified	0	95	660	1,000	0	**1,800**
	Hypothetical	0	0	0	220	0	**220**
	Total	**0**	**95**	**660**	**1,300**	**0**	**2,000**
33S 2E	Identified	11	49	93	7.3	0	**160**
	Hypothetical	42	41	27	6.9	0	**120**
	Total	**53**	**90**	**120**	**14**	**0**	**280**
34S 1W	Identified	0	0	45	50	0	**95**
	Hypothetical	0	0	31	3,300	99	**3,400**
	Total	**0**	**0**	**76**	**3,400**	**99**	**3,500**
34S 2W	Identified	7.5	120	110	74	0	**320**
	Hypothetical	0	190	660	560	0	**1400**
	Total	**7.5**	**310**	**770**	**630**	**0**	**1700**
34S 1E	Identified	33	590	280	280	0	**1200**
	Hypothetical	0	76	200	250	0	**530**
	Total	**33**	**670**	**480**	**530**	**0**	**1700**
34S 2E	Identified	1.4	45	0	0	0	**46**
	Total	**1.4**	**45**	**0**	**0**	**0**	**46**
35S 1W	Identified	0	0	6	410	54	**470**
	Hypothetical	0	0	0	380	1,300	**1,700**
	Total	**0**	**0**	**6**	**780**	**1,400**	**2,200**
35S 2W	Identified	110	150	170	250	0	**680**
	Total	**110**	**150**	**170**	**250**	**0**	**680**
35S 1E	Identified	20	190	190	360	6.9	**760**
	Hypothetical	2.8	28	22	99	24	**180**
	Total	**23**	**220**	**210**	**460**	**31**	**940**
35S 2E	Identified	2.1	0	0	0	0	**2.1**
	Total	**2.1**	**0**	**0**	**0**	**0**	**2.1**
36S 1W	Identified	19	45	200	300	15	**590**
	Hypothetical	0	0	94	630	120	**850**
	Total	**19**	**45**	**300**	**930**	**140**	**1,400**
36S 2W	Identified	130	85	16	0.3	0	**230**
	Total	**130**	**85**	**16**	**0.3**	**0**	**230**
36S 1E	Identified	100	220	190	950	0	**1,500**
	Hypothetical	16	27	24	310	0	**380**
	Total	**120**	**240**	**210**	**1,300**	**0**	**1,800**
36S 2E	Identified	540	880	0	0	0	**1,400**
	Total	**540**	**880**	**0**	**0**	**0**	**1,400**
36S 3E	Identified	100	170	0	0	0	**270**
	Total	**100**	**170**	**0**	**0**	**0**	**270**
37S 1W	Identified	93	110	110	0	0	**310**
	Hypothetical	0	0	85	91	0	**180**
	Total	**93**	**110**	**190**	**91**	**0**	**490**
37S 1E	Identified	28	290	940	660	0	**1,900**
	Hypothetical	0	0	150	850	0	**1,000**
	Total	**28**	**290**	**1,100**	**1,500**	**0**	**2,900**
37S 2E	Identified	910	3,100	130	0	0	**4,200**
	Total	**910**	**3,100**	**130**	**0**	**0**	**4,200**
37S 3E	Identified	640	450	0	0	0	**1,100**
	Total	**640**	**450**	**0**	**0**	**0**	**1,100**

Appendix 2, table 2, 2 of 3. Original coal resources and other occurrences of non-resource coal in the Calico and A-sequences by township (in millions of short tons)—*Continued.*

[Original coal resources are < 6,000 ft deep, and other occurrences of non-resource coal are > 6,000 ft deep]

Township and Range	Reliability	Overburden categories (thickness in ft)					
		0-1000	1000-2000	2000-3000	3000-6000	>6000	Total
37S 4E	Identified	20	1.6	0	0	0	**21**
	Total	**20**	**1.6**	**0**	**0**	**0**	**21**
38S 1W	Identified	32	0	0	0	0	**32**
	Total	**32**	**0**	**0**	**0**	**0**	**32**
38S 1E	Identified	54	160	300	0	0	**510**
	Hypothetical	0	0	750	55	0	**800**
	Total	**54**	**160**	**1,000**	**55**	**0**	**1,300**
38S 2E	Identified	170	1,400	1,800	65	0	**3,500**
	Hypothetical	0	0	71	290	0	**360**
	Total	**170**	**1,400**	**1,900**	**360**	**0**	**3,800**
38S 3E	Identified	2,200	1,300	1	0	0	**3,600**
	Total	**2,200**	**1,300**	**1**	**0**	**0**	**3,600**
38S 4E	Identified	780	210	0	0	0	**990**
	Total	**780**	**210**	**0**	**0**	**0**	**990**
38S 5E	Identified	30	18	0	0	0	**48**
	Hypothetical	9.2	0	0	0	0	**9.2**
	Total	**39**	**18**	**0**	**0**	**0**	**57**
39S 1W	Identified	3.2	2.3	0	0	0	**5.5**
	Hypothetical	1	0.5	0	0	0	**1.5**
	Total	**4.2**	**2.8**	**0**	**0**	**0**	**7**
39S 1E	Identified	8.3	22	95	12	0	**140**
	Hypothetical	2.9	13	680	33	0	**730**
	Total	**11**	**35**	**780**	**45**	**0**	**870**
39S 2E	Identified	0	17	1,500	0	0	**1,500**
	Hypothetical	0	3.1	1,500	240	0	**1,800**
	Total	**0**	**20**	**3,000**	**240**	**0**	**3,300**
39S 3E	Identified	83	3,200	1,300	0	0	**4,600**
	Total	**83**	**3,200**	**1,300**	**0**	**0**	**4,600**
39S 4E	Identified	1,700	650	0	0	0	**2,400**
	Total	**1,700**	**650**	**0**	**0**	**0**	**2,400**
39S 5E	Identified	2,500	2.4	0	0	0	**2,500**
	Hypothetical	180	0	0	0	0	**180**
	Total	**2,700**	**2.4**	**0**	**0**	**0**	**2,700**
39S 6E	Identified	28	0.5	0	0	0	**28**
	Total	**28**	**0.5**	**0**	**0**	**0**	**28**
40S 1W	Identified	3.3	2.9	0	0	0	**6.2**
	Total	**3.3**	**2.9**	**0**	**0**	**0**	**6.2**
40S 1E	Identified	0.2	24	58	0	0	**82**
	Hypothetical	0	11	63	0	0	**73**
	Total	**0.2**	**35**	**120**	**0**	**0**	**160**
40S 2E	Identified	0	110	1,500	0	0	**1,600**
	Hypothetical	0	35	170	0	0	**210**
	Total	**0**	**140**	**1,700**	**0**	**0**	**1,800**
40S 3E	Identified	560	1,400	1,100	0	0	**3,100**
	Total	**560**	**1,400**	**1,100**	**0**	**0**	**3,100**
40S 4E	Identified	240	0	0	0	0	**240**
	Hypothetical	1.5	0	0	0	0	**1.5**
	Total	**250**	**0**	**0**	**0**	**0**	**250**
40S 5E	Identified	870	0	0	0	0	**870**
	Hypothetical	11	0	0	0	0	**11**
	Total	**890**	**0**	**0**	**0**	**0**	**890**
40S 6E	Identified	88	0	0	0	0	**88**
	Hypothetical	29	0	0	0	0	**29**
	Total	**120**	**0**	**0**	**0**	**0**	**120**

Appendix 2, table 2, 3 of 3. Original coal resources and other occurrences of non-resource coal in the Calico and A-sequences by township (in millions of short tons)—*Continued*.

Original coal resources are < 6,000 ft deep, and other occurrences of non-resource coal are > 6,000 ft deep]

Township and Range	Reliability	Overburden categories (thickness in ft)					
		0-1000	1000-2000	2000-3000	3000-6000	>6000	Total
40S 7E	Identified	0	0	0	0	0	**0**
	Hypothetical	3.8	0	0	0	0	**3.8**
	Total	**3.8**	**0**	**0**	**0**	**0**	**3.8**
41S 2E	Identified	63	290	49	0	0	**400**
	Hypothetical	20	88	46	0	0	**150**
	Total	**83**	**370**	**96**	**0**	**0**	**550**
41S 3E	Identified	1,100	270	3.6	0	0	**1,400**
	Total	**1,100**	**270**	**3.6**	**0**	**0**	**1,400**
41S 4E	Identified	1,500	22	0	0	0	**1,600**
	Hypothetical	27	0	0	0	0	**27**
	Total	**1,600**	**22**	**0**	**0**	**0**	**1,600**
41S 5E	Identified	570	0	0	0	0	**570**
	Total	**570**	**0**	**0**	**0**	**0**	**570**
41S 6E	Hypothetical	2.4	0	0	0	0	**2.4**
	Total	**2.4**	**0**	**0**	**0**	**0**	**2.4**
41S 7E	Identified	28	0	0	0	0	**28**
	Total	**28**	**0**	**0**	**0**	**0**	**28**
41S 8E	Identified	3.1	0	0	0	0	**3.1**
	Total	**3.1**	**0**	**0**	**0**	**0**	**3.1**
42S 2E	Identified	61	12	0	0	0	**72**
	Hypothetical	16	0	0	0	0	**16**
	Total	**77**	**12**	**0**	**0**	**0**	**88**
42S 3E	Identified	330	4.2	0	0	0	**340**
	Total	**330**	**4.2**	**0**	**0**	**0**	**340**
42S 4E	Identified	70	0	0	0	0	**70**
	Total	**70**	**0**	**0**	**0**	**0**	**70**
42S 5E	Identified	0.1	0	0	0	0	**0.1**
	Total	**0.1**	**0**	**0**	**0**	**0**	**0.1**
42S 8E	Identified	19	0	0	0	0	**19**
	Total	**19**	**0**	**0**	**0**	**0**	**19**
43S 2E	Identified	0.5	0	0	0	0	**0.5**
	Total	**0.5**	**0**	**0**	**0**	**0**	**0.5**
43S 3E	Identified	21	0	0	0	0	**21**
	Total	**21**	**0**	**0**	**0**	**0**	**21**
Total (parts 1, 2, and 3)		**16,000**	**16,000**	**15,000**	**12,000**	**1,700**	**62,000**

Appendix 3—Summary of Coal Measurements and Resource Estimates from Previous Studies

Appendix 3 contains summaries of coal-bed measurements (4 tables), and coal resource estimates (1 table) from previously published geologic investigations of 7.5′ quadrangles in the Kaiparowits Plateau, Utah. Quadrangle locations are shown in figure 2 in the text.

Appendix 3, table 1, 1 of 4. Summary of coal beds for each 7.5' quadrangle in the Kaiparowits Plateau.

Summary of coals exposed in outcrops of the John Henry Member of the Straight Cliffs Formation along the eastern and southeastern parts of the Kaiparowits Plateau				
[1] Quadrangle	[2] Thickness data for coal in outcrops (in feet)			Comments
	Christensen coal zone	[3] Rees coal zone	Alvey coal zone	
Basin Canyon (Doelling and Graham, 1972)	3.0	1.0	2.0	Coal is found only in southwest part of quadrangle.
Blackburn Canyon	------	------	------	Coal data is not available for this quadrangle, however, data in surrounding areas indicate that significant coal deposits are unlikely in this area.
Canaan Creek (Zeller, 1973b)	25.0 25.0 1 bed	11.3 8.0 3 beds	26.0 20.5 3 beds	A lower local zone is 30 ft thick and has 10 ft of coal in 2 beds. Christensen zone is 110 ft thick. Rees equivalent coal zone is 30 ft thick. Alvey zone is 170 ft thick. Strata dip as much as 20 degrees in southwest part of quadrangle.
Carcass Canyon (Zeller, 1973a)	30.0 11.0 6 beds	14.0 10.0 2 beds	19.0 17.0 2 beds	Christensen zone is 120 ft thick. Rees equivalent coal zone is 50 ft thick. Alvey zone is 70 ft thick.
Collet Top (Zeller, 1978)	18.4 12.6 2 beds	8.2 6.2 2 beds	21.3 11.8 3 beds	Christensen zone is 80 ft thick. Rees coal zone is 120 ft thick. Alvey zone is 100 ft thick.
Dave Canyon (Zeller, 1973d)	26.9 15.0 5 beds	1.8 1.8 1 bed	13.0 13.0 1 bed	Christensen zone is 100 ft thick. Rees equivalent coal zone is 20 ft thick. Alvey zone is 160 ft thick. Coals are in western most part of quadrangle .
Death Ridge (Zeller, 1973c)	Only upper 20 ft exposed (see comment)	32.5 7.0 8 beds	18.2 12.0 2 beds	Only upper 20 ft of Christensen zone is exposed; zone has at least 80 ft of coal in a 115 ft interval in drill hole. Rees equivalent zone is 160 ft thick. Alvey zone is 120 ft thick. Coals are exposed in northwestern part of quadrangle and underlie remainder of area. Coal-bearing strata dip as much as 22 degrees in western part of quadrangle.
East of the Navajo (Zeller, 1990b)	51.4 29.6 7 beds	5.2 1.7 4 beds	7.0 6.0 2 beds	Lower coal zone has 7.6 ft coal in 2 beds that are 3.8 ft thick. Christensen zone is 75 ft thick. Rees zone is 175 ft thick. Alvey zone is 40 ft thick. Very little coal in eastern half of quadrangle. Most coal outcrops in western half of quadrangle are burned. Coals are still burning in southeast part of quadrangle.
Griffin Point (Bowers, 1973b)	16.5 12.0 2 beds	27.2 19 6 beds	27.3 17.9 5 beds	Coals are in zones a through e. Zone a is 100 ft thick and correlates to Christensen zone. Zones b and c are 140 ft thick and are reported in the Rees zone in this table. Zones d and e are 130 ft thick and correlate to the Alvey zone. Coal outcrops in eastern half of quadrangle but dips steeply into subsurface and is deeply buried in western half of quadrangle. Strata in western areas are inclined by as much as 40 degrees. Northern coal-bearing areas are faulted.

[1] Source of data is shown in parentheses.
[2] Top figure is maximum net coal in beds >1 ft thick. Middle figure is thickest coal bed in the zone in the entire quadrangle. Lower figure is number of coal beds at the locality of maximum net coal. Bed thicknesses were determined according to Wood and others (1983).
[3] Includes local unnamed coals between the Christensen and Alvey coal zones.

Appendix 3, table 1, 2 of 4. Summary of coal beds for each 7.5' quadrangle in the Kaiparowits Plateau—*Continued.*

Summary of coals exposed in outcrops of the John Henry Member of the Straight Cliffs Formation along the eastern and southeastern parts of the Kaiparowits Plateau

[1] Quadrangle	[2] Thickness data for coals in outcrops (in feet)			Comments
	Christensen coal zone	[3] Rees coal zone	Alvey coal zone	
Horse Mountain (Bowers, 1991a)	------	------	------	Coals are in subsurface only at depths from 500-3,500 feet. Beds dip 7-24 degrees in northern part of quadrangle. Christensen, Rees, and Alvey zones contain coal in the eastern quadrangle but the coals are likely to be thin and pinch out to west.
Mazuki Point (Peterson and Barnum, 1973b)	6.5 3.0 3 beds	------	------	Christensen coal zone is 210 ft thick and is the only coal zone in the John Henry Member in this quadrangle.
Navajo Point (Peterson and Barnum, 1973a)	6.5 3.7 3 beds	------	------	Christensen coal zone is 210 ft thick and is the only coal zone in the John Henry Member in this quadrangle.
Needle Eye Point (Zeller, 1990a)	33.4 23.3 2 beds	29.9 19.3 6 beds	5.7 5.7 1 bed	A local zone below the Christensen zone has 7.4 ft of coal in one bed. Christensen zone is 80 ft thick. Rees zone is 190 ft thick. Alvey zone is 40 ft thick. Coals are burned on outcrop over much of quadrangle and are still burning in many places.
Petes Cove (Zeller, 1990c)	not exposed	10.3 5.0 3 beds	16.5 11.5 2 beds	Most coals are in subsurface. Drill-hole data show that the Christensen zone is 150 ft thick, and has 50.5 ft total coal in 4 beds and the thickest bed is 15.5 ft thick. Rees zone is about 120 ft thick. Alvey zone is 90 ft thick. Total coal in subsurface is about 100 ft.
Ship Mountain Point (Zeller and Vaninetti, 1990)	------	------	-----	There are no significant outcrops of coal in this quadrangle. However, the quadrangle is entirely underlain by coal in the John Henry Member.
Sooner Bench (Peterson, 1975)	------	------	------	John Henry Member is in southwest part of quadrangle only and has no coal in outcrops.
Seep Flat (Zeller and Stephens, 1973)	22.0 12.9 7 beds	3.0 3.0 1 bed	9.2 5.0 4 beds	Christensen zone is 120 ft thick. Rees zone is about 10 ft thick. Alvey zone is 70 ft thick. The only significant coal bed is in the Christensen coal zone in the southwest corner of the quadrangle.
Upper Valley (Bowers, 1973a)	17.8+ 6.0+ 4 beds	8.6 6.1 2 beds	23.5 15.5 3 beds	Coals are in zones a through e. Zone a is 70 ft thick and correlates to the Christensen zone . Zones b and c are 60 ft thick and are described as the Rees zone in this table. Zones d and e are 150 ft thick and correlate to the Alvey zone. Coals are steeply inclined where exposed in eastern part of quadrangle and are deeply buried (> 3000 ft) in rest of quadrangle.
Wide Hollow Reservoir (Stephens, 1973)	15.5* 10.6* 2 beds*	15.6* 5.5* 6 beds*	1.5* 1.5* 1 bed*	A local zone below the Christensen zone has 2.0 ft of coal in one bed*. Christensen zone is 130 ft thick. Rees equivalent zones is 70 ft thick. Alvey zone is 30 ft thick. Coals are in small erosional remnants scattered throughout western part of quadrangle and are generally burned. Coals are thickest in western and southern parts of quadrangle but thin and pinch out to northeast. *Additional coal thicknesses are reported by Stephens (1973) but are not included in table because they are impure.

[1] Source of data is shown in parentheses.
[2] Top figure is maximum total coal in beds >1 ft thick. Middle figure is thickest coal bed in these zone in entire quadrangle. Lower figure is number of coal beds at locality of maximum coal. Bed thicknesses are determined according to Wood and others (1983).
[3] Includes local unnamed coals between the Christensen and Alvey coal zones.

Appendix 3, table 1, 3 of 4. Summary of coal beds for each 7.5' quadrangle in the Kaiparowits Plateau—*Continued*.

Summary of coals exposed in outcrops of the upper part of the Straight Cliffs Formation along the western margin of the Kaiparowits Plateau		
[1] Quadrangle	[2] Thickness data for coals in outcrops (in feet) Henderson coal zone	Comments
Butler Valley (Bowers, 1983)	7.6 4.3 2 beds	Henderson zone is about 15 ft thick. Coals contain numerous partings. Coal-bearing outcrops dip as much as 62 degrees and are faulted throughout much of the quadrangle.
Canaan Peak (Bowers, 1981)	16.2 8.5 2 beds	Henderson zone is about 40 ft thick. Coals contain many partings. In the southern part of the quadrangle, coals are faulted in outcrops and dip as much as 30 degrees in the subsurface.
Calico Peak (Doelling and Graham, 1972)	------	Coals are located along eastern margin of quadrangle only. Coal-bearing strata dip >45 degrees. Coal thicknesses are not available but are probably < 2.5 ft thick.
Five Mile Valley (Doelling and Graham, 1972)	------	No significant coal is in the upper part of the Straight Cliffs Formation in this quadrangle.
Four Mile Bench (Bowers, 1991b)	------	All coals are in the subsurface between depths of 1,000-2,500 ft.
Henrieville (Bowers, 1975)	15.4 12.4 2 beds	Henderson zone is about 40 ft thick. Coals are lenticular, split abruptly, and have many partings. Coal-bearing rocks of the Straight Cliffs Formation underlie eastern half of quadrangle only. Coal beds are inclined between 6-20 degrees in outcrops.
Horse Flat (Bowers, 1993)	3.5 2.3 2 beds	Henderson zone is about 10 ft thick. Coals outcrop only in northwest part of quadrangle, are highly faulted, and dip >45 degrees. Coals are deeply buried throughout remainder of quadrangle at depths from 1,000-2,400 ft.
Pine Lake (Bowers, 1973c)	27.0 13.9 3 beds	Henderson zone is about 35 ft thick. Core from the Henderson zone in the northwest part of the quadrangle contains as much as 29 ft of coal in a 36-ft-thick interval. Local coal beds as thick as 3.5 ft are found above Henderson coal zone. Coals dip as much as 20 degrees in subsurface in central part of quadrangle and are at depths > 5,000 ft in northeastern part of quadrangle.

[1] Source of data is shown in parentheses.
[2] Top figure is maximum total coal in beds >1 ft thick. Middle figure is thickest coal bed in coal zone. Lower figure is number of coal beds at locality of maximum coal. Bed thicknesses are determined according to Wood and others (1983).

Appendix 3, table 1, 4 of 4. Summary of coal beds for each 7.5' quadrangle in the Kaiparowits Plateau—*Continued*.

Summary of coals exposed in the Middle member of the Straight Cliffs Formation along the southern margin of the Kaiparowits Plateau		
[1] Quadrangle	[2] Major coal zone	Comment
Glen Canyon City (Waldrop and Sutton, 1967c)	Contains 1-3 coal beds that are < 2 ft thick.	Major coal zone is 250 ft thick. Coals are in northeastern most part of quadrangle only.
Lone Rock (Waldrop and Peterson, 1967)	Contains 1 to 8 beds that are 1-6.9 ft thick and average 2.5 ft thick.	Major coal zone is as much as 375 ft thick. Coal beds are lenticular.
Lower Coyote Springs	--	No coal data is available and no significant coals are likely to be in the quadrangle.
Nipple Butte (Waldrop and Sutton, 1967a)	Contains lenticular coals < 2.3 ft thick. Coal beds average 0.6 ft thick.	Major coal zone is 250 ft thick. Coal beds are lenticular.
Sit Down Bench (Peterson and Horton, 1967)	Contains several coal beds > 5 ft thick. One coal bed is 14.2 ft thick.	Major coal zone is 500 ft thick. Coal are generally burned as far back as 200-300 ft from outcrop. Coals in southwest part of quadrangle may be entirely burned.
Smoky Hollow (Peterson, 1967)	Contains several coals from 5-15 ft thick and numerous coals < 5 ft thick.	Major coal zone is 550 ft thick. Coal are generally burned as far back as 200-300 ft from outcrop.
Tibbet Bench (Waldrop and Sutton, 1967b)	Contains numerous coals > 4 ft thick and several coals that are 10-17.3 ft thick Coals average 2.7 ft thick.	Major coal zone is 450 ft thick. Coals increase in thickness to northeast. Individual beds are lenticular and are not in well-defined zones.

[1] Sources of data are shown in parentheses.
[2] Bed thicknesses are determined according to Wood and others (1983).

Appendix 3, table 2. Previous coal resource estimates for 7.5′ quadrangles in the Kaiparowits Plateau, Utah.

Quadrangle	Coal resources (millions of short tons) Doelling and Graham (1972)	Coal resources (millions of short tons) USGS	Comments
Butler Valley	0.5	not determined	Lenticular coal beds in the quadrangle made resources difficult to determine; the area has low potential for coal development due to the thin and discontinuous coal beds, steep dips, and numerous faults (Bowers, 1983). Figures reported by Doelling and Graham (1972) include areas in adjoining Slickrock Bench quadrangle.
Canaan Creek	398	600 (Zeller, 1973b)	Total coal resources estimated for beds > 4 feet thick and < 2,000 ft deep (Zeller, 1973b).
Carcass Canyon	629	700 Zeller (1973a)	Estimate made for total coal in beds > 4 ft thick and having < 2,000 ft of overburden; precise resource appraisal was not made for individual coals because of limited exposures, lenticular coal beds, and lack of subsurface data (Zeller, 1973a).
Collet Top	470	920 Zeller (1978)	Total coal resources calculated for coal beds > 4.8 ft thick. All coals in quadrangle have < 1,000 ft of overburden (Zeller, 1978).
Dave Canyon	170	200 Zeller (1973d)	Estimate made for total coal in beds > 4 ft thick and having < 2,000 ft of overburden; precise resource appraisal was not made for individual coals because of limited exposures, lack of coal quality, and lenticular coal beds (Zeller, 1973d).
Death Ridge	1,060	1,500 (Zeller, 1973c)	Total coal resources was estimated for beds > 4 ft thick and < 2,000 ft deep (Zeller, 1973c). Much of the resource is 1,000-1,500 ft deep, and the lower part of Christensen coal zone was not included in the estimate because bed continuity was unknown (Zeller, 1973c).
East of the Navajo	28	60 (Zeller, 1973c	Estimate was made for coal beds > 4 ft thick; sufficient data was not available for precise resource appraisal (Zeller, 1990b).
Griffin point	449	178 (Bowers, 1973b)	Estimated inferred resources of total coal were made for coals > 1 ft thick and <2,000 ft deep; considerable coal is likely to be at greater depths (Bowers, 1973b).
Henrieville	43	16 (Bowers, 1975).	Inferred resources calculated for coal beds > 4 ft thick and <1,200 ft deep; additional coal is probably at depths between 800-2,500 ft in the northeastern part of the quadrangle (Bowers, 1975).
Lone Rock	38	not determined	
Needle Eye Point	683	800 Zeller (1990a)	Resources were estimated by Zeller (1990a) for coal beds > 4 ft thick; precise resource appraisal was not made due to exposures, lack of coal quality, lenticular coal beds, and extensive burning.
Petes Cove	809	3,500 Zeller, 1990c)	Estimate of total coal in beds > 4 ft thick (Zeller, 1990c).
Pine Lake	611	216 (Bowers, 1973c)	Inferred resources calculated for coal beds > 4 ft thick and < 2,500 ft deep; additional coal is probably at depths between 1,500-7,000 ft in the eastern part of the quadrangle (Bowers, 1973c).
Seep Flat	28	2 Zeller and Stephens (1973)	Estimate by Zeller and Stephens (1973) was made for total coal in beds > 4 ft thick. Zeller and Stephens did not make a precise resource appraisal because of limited exposures, lack of coal-quality data, and lenticular nature of coal beds.
Ship Mountain Point	1,266	not determined	
Sit Down Bench	18	not determined	Formerly called Gunsight Butte NE.
Smoky Hollow	430	not determined	Formerly called Gunsight Butte NW.
Tibbet Bench	272	not determined	Formerly called Nipple Butte NE.
Upper Valley	147	169 (Bowers, 1973a)	Estimated inferred resources of total coal were made for coals > 1 ft thick and at depths < 2,500 ft. Additional coal is likely at greater depths (Bowers, 1973a).

Appendix 4—Summary of Coal Quality

Appendix 4 contains summaries of coal-quality data from the John Henry Member. Samples were collected from core, mines, and outcrops. Quadrangle locations are shown in figure 2 in the text, and mine locations are shown in figure 1 in text. Core locations are shown in figure A on plate 1; K-DR-1 is at locality 4, CT-1-91 is at locality 5, SMP-1-91 is at locality 6, and DH-1 is 150 ft northwest of locality 151.

Appendix 4, table 1. Coal quality of samples collected from core of the John Henry Member, Kaiparowits Plateau, Utah.

Core collected from drill hole CT-1-91

Sample interval	Down hole depth (ft)	M %	VM %	FC %	S %	A %	Btu/ lb	Coal zone	Moist, mineral-matter-free Btu and apparent rank
CT-J (5 samples)	613.4-617.6	8.5-14.3	35.2-40.0	34.8-41.6	1.0-2.0	6.4-17.6	9,720-10,830	Christensen	11,110-12,590 Subbituminous A and High volatile C Bituminous
CT-L (9 samples)	633.3-643.7	11.1-15.6	34.5-41.1	41.5-44.6	0.4-1.5	3.7-6.8	10,460-11,720	Christensen	11,220-12,580 Subbituminous A and High volatile C Bituminous
CT-M (5 samples)	648.1-652.8	11.0-13.8	35.0-37.7	37.7-44.0	0.7-2.2	5.3-16.4	9,730-10,970	Christensen	11,560-11,830 High volatile C Bituminous
CT-N (4 samples)	655.8-662.2	10.7-12.5	37.8-40.4	39.0-44.5	0.7-1.4	4.8-12.5	10,340-11,380	Christensen	11,790-12,060 High volatile C Bituminous

Apparent rank determined from proximate and ultimate analyses and gross calorific values (Btu/lb) of coals collected from core hole CT-1-91 located in sec. 5, T. 39 S., R. 4 E. Core hole CT-1-91 is listed as data point 5 in this report. Ranges of proximate and ultimate analyses and gross calorific values are based on unpublished data provided by Brenda Pierce (USGS, 1996). Apparent rank was calculated using the Parr formula (American Society for Testing and Materials, 1995). Moisture (M), volatile matter (VM), fixed carbon (FC), sulfur content (S), ash yield (A), gross calorific value (Btu/lb).

Appendix 4, table 2. Coal quality of samples collected from core of the John Henry Member, Kaiparowits Plateau, Utah.

Core collected from drill hole SMP-1-91

Sample number	Down hole depth (ft)	M %	VM %	FC %	S %	A %	Btu/ lb	Coal zone	Moist, mineral-matter-free Btu and apparent rank
SMP-E (3 samples)	483.0-486.8	8.2-9.7	42.6-43.8	42.5-44.4	0.5-0.7	3.3-5.5	11,940-11,980	Rees ?	12,390-12,750 High volatile C Bituminous
SMP-F (3 samples)	497.6-501.2	8.3-9.3	41.6-43.9	41.8-44.7	0.4-0.6	2.7-8.2	11,490-12,380	Rees ?	12,470-12,760 High volatile C Bituminous
SMP-H (17 samples)	581.2-603.0	0.7-7.8	27.9-50.7	24.9-45.4	0.5-2.3	4.3-42.5	6,960-12,390	Rees	12,700-13,710 High volatile B and C Bituminous
SMP-J (13 samples)	682.4-712.3	5.5-7.9	35.3-44.5	34.6-48.0	0.3-1.0	2.3-24.6	9,460-12,480	Christensen	12,360-13,590 High volatile B and C Bituminous
SMP-K (15 samples)	759.0-781.0	4.5-7.1	35.3-46.5	32.1-45.5	0.4-2.3	3.4-26.4	9,000-12,620	lower	12,610-16,720 High volatile A, B, and C Bituminous

Apparent rank determined from proximate and ultimate analyses and gross calorific values (Btu/lb) of coals (queried where uncertain) collected from core hole SMP-1-91 located in sec. 6, T. 40 S., R. 4 E. Core hole SMP-1-91 is listed as data point 6 in this report. Coal zones are queried where uncertain. Ranges of proximate and ultimate analyses and gross calorific values are based on unpublished data by Brenda Pierce (USGS, 1996). Apparent rank was calculated using the Parr formula (American Society for Testing and Materials, 1995). Moisture (M), volatile matter (VM), fixed carbon (FC), sulfur content (S), ash yield (A), gross calorific value (Btu/lb).

Appendix 4, table 3. Coal quality of samples collected from core of the John Henry Member, Kaiparowits Plateau, Utah.

Core collected from drill hole K-DR-1

Sample number	Down hole depth (ft)	M %	VM %	FC %	S %	A %	Btu/ lb	Coal zone	Moist, mineral-matter-free Btu and apparent rank
D204048	313-319	20.4	34.7	37.7	1.0	7.2	9,440	Alvey	10,240 subbituminous B
D204049	336-351	19.7	35.1	37.0	1.0	8.2	9,510	Alvey	10,440 subbituminous B
D204050	547-555	18.4	35.0	36.3	0.6	10.3	9,280	Rees	10,450 subbituminous B
D204051	603-608	15.6	29.6	29.9	0.7	24.9	7,640	Rees	10,460 subbituminous B
D204052	617-625	17.2	33.4	34.8	0.8	14.6	8,990	Rees	10,680 subbituminous A
D204053	702-713	21.1	34.7	39.8	0.5	4.4	9,830	Christensen	10,320 subbituminous B
D204054	713-727	20.1	33.3	40.9	0.5	5.7	9,840	Christensen	10,490 subbituminous B
D204055	775-780	19.7	34.6	39.9	0.6	5.8	9,860	Christensen	10,520 subbituminous A

Apparent rank determined from proximate and ultimate analyses and gross calorific values (Btu/lb) of coals collected from core hole K-DR-1 located in sec. 8, T. 37 S., R. 2 E. Core hole K-DR-1 is listed as data point 4 in this report. Proximate and ultimate analyses and gross calorific values are from as-received samples reported in Zeller (1979) and Affolter and Hatch (1980). Apparent rank was calculated using the Parr formula (American Society for Testing and Materials, 1995). Moisture (M), volatile matter (VM), fixed carbon (FC), sulfur content (S), ash yield (A), gross calorific value (Btu/lb).

Appendix 4, table 4. Coal quality of samples collected from core of the John Henry Member, Kaiparowits Plateau, Utah.

Core collected from drill hole DH-1

Sample number	Down hole depth (ft)	M %	VM %	FC %	S %	A %	Btu/ lb	Coal zone	Moist, mineral-matter-free Btu and apparent rank
DH-1 core	289-292	9.7	32.4	28.3	NR	29.9	NR	Henderson	---------------
DH-1 core	292-298	17.6	34.4	26.4	NR	21.7	NR	Henderson	---------------
DH-1 core	298-304	18.0	38.3	33.1	NR	10.6	9,740	Henderson	11,010 Subbituminous A
DH-1 core	304-307	19.8	37.2	35.1	NR	7.9	10,130	Henderson	11,080 Subbituminous A
DH-1 core	310-317	17.8	37.8	30.6	NR	13.8	NR	Henderson	---------------
DH-1 core	318-324	18.9	36.7	36.0	NR	8.4	10,300	Henderson	11,350 Subbituminous A

Analyses from core of the Henderson coal zone collected from drill hole DH-1 located in the SWNE1/4, sec. 22, T. 35 S., R. 2 W. (Doelling and Graham, 1972, p. 126). DH-1 is located 150 ft northwest of data point 151 (fig. A on pl. 1). Proximate and ultimate analyses and gross calorific values are from as-received values reported in Doelling and Graham (1972, p. 126). Apparent rank was calculated using the Parr formula (American Society for Testing and Materials, 1995), and assumes a sulfur value of 1.0 percent. Value unknown (NR), moisture (M), volatile matter (VM), fixed carbon (FC), sulfur content (S), ash yield (A), gross calorific value (Btu/lb).

Appendix 4, table 5. Coal quality of samples collected from mines in the John Henry Member, Kaiparowits Plateau, Utah.

Mine / no. of samples analyzed	Analyses	Moisture %	Volatile matter %	Fixed carbon %	Ash %	Sulfur %	Heating value Btu/lb
Alvey coal zone							
Canaan Creek quadrangle							
Alvey mine	as received	16.6-17.7	36.9-38.3	37.5-38.9	6.6-7.8	0.4-1.2	9,910-10,460
(5)	dry	----------	44.6-45.9	46.1-46.8	7.9-8.6	0.6-1.5	12,170-12,540
Griffin Point quadrangle							
New Cherry	as received	15.1	41.1	39.1	4.7	0.9	10,120
Creek mine	dry	----------	48.4	46.0	5.6	1.1	11,920
(1)							
Cherry Creek	as received	7.6-24.8	33.3-46.0	32.9-40.0	5.3-10.5	0.4-0.7	7,420- 9,960
mine (6)	dry	----------	41.2-49.8	40.7-47.3	6.8-12.4	0.6-0.8	9,880-11,720
Corn Creek	as received	6.2	45.0	42.0	6.8	NR	9,070
mine (1)	dry	----------	48.0	44.8	7.2	-------	9,660
Rees coal zone							
Tibbet Bench quadrangle							
Spencer mine	as received	3.7-5.9	38.1-45.5	47.4-51.0	3.8-5.7	0.5-1.1	10,610-12,300
(3)	dry	----------	40.2-46.8	49.3-54.0	3.9-6.0	0.6-1.1	11,210-12,760
Christensen coal zone							
Canaan Creek quadrangle							
Schow mine	as received	3.8-8.6	35.3-42.3	39.6-46.3	3.5-16.1	0.5-3.2	11,060-12,280
(6)	dry	--------	37.5-46.1	42.1-50.1	3.8-17.1	2.3-3.4	11,870-13,070
Shurtz mine	as received	7.4-12.2	39.4-39.6	44.2-49.3	3.7-4.3	0.8	11,110-11,160
(2)	dry	---------	42.8	53.2	4.0	NR	12,060
Tibbet Bench quadrangle							
Warm Creek prospect (1)	as received	4.7	40.7	48.6	6.0	0.7	12,190
Henderson coal zone							
Pine Lake quadrangle							
Davis mine	as received	11.3	41.3	39.2	8.5	0.9	10,130
(1)	dry	-----	46.1	44.1	9.5	1.0	11,360
Pollock mine	as received	16.3-22.0	37.2-40.4	30.6-36.0	7.2-10.2	0.8-1.3	8,540-9,600
(3)	dry	----------	46.6-48.3	39.3-44.5	8.9-13.0	1.0-1.6	10,990-11,470
Tropic mine	as received	20.2-20.9	NR	NR	NR	NR	8,910-9,240
(3)	dry	---------	42.0-42.6	44.9-47.0	11.0-12.5	0.7-1.0	11,270-11,680

Proximate analyses are from Doelling and Graham (1972, p. 123-127). Value unknown (NR), moisture (M), volatile matter (VM), fixed carbon (FC), sulfur content (S), ash yield (A), gross calorific value (Btu/lb).

Appendix 4, table 6. Coal quality of samples collected from outcrops of the John Henry Member, Kaiparowits Plateau, Utah.

Quadrangle / no. of samples analyzed	Analyses	Moisture %	Volatile matter %	Fixed carbon %	Ash %	Sulfur %	Heating value Btu/lb
Alvey coal zone							
Canaan Creek (6)	as-received	3.6-17.4	30.8-44.3	40.4-59.1	3.0-11.2	0.8-1.0	8,730-11,210
	dry	---------	32.0-46.8	42.9-61.3	3.2-11.9	0.9-1.0	9,260-12,650
Carcass Canyon (9)	as-received	6.6-18.4	37.5-43.1	34.4-47.6	3.4-8.9	0.4	NR
	dry	---------	42.0-50.5	42.0-51.0	4.2-10.5	0.4	9,930-10,860
Collet Top (1)	as-received	16.7	38.0	29.7	15.7	1.0	8,940
	dry	---------	45.6	35.6	18.8	1.3	10,740
Dave Canyon (2)	as-received	8.1-11.6	41.5-44.4	36.1-42.1	5.4-9.5	1.3	10,230-10,800
	dry	---------	46.9-48.3	40.8-45.8	5.9-10.7	1.5	11,130-12,220
Death Ridge (1)	as-received	7.2	38.3	50.0	4.5	NR	10,410
	dry	---------	41.3	53.9	4.8	NR	11,220
Griffin Point (1)	as-received	16.5	41.5	34.0	6.7	1.3	9,980
	dry	---------	49.8	40.8	8.0	1.6	11,890
Ship Mountain Point (1)	as-received	9.8	41.4	43.8	5.0	0.8	10,230
Upper Valley (1)	as-received	6.6	41.1	46.3	6.0	NR	9,740
	dry	---------	44.0	49.6	6.4	NR	10,430
Rees coal zone							
Canaan Creek (2)	as-received	5.6-8.3	36.3-44.9	35.9-38.9	7.9-22.2	NR	7,570-9,740
	dry	---------	38.5-49.0	38.0-42.4	8.6-23.5	NR	8,020-10,620
Death Ridge (1)	as-received	7.1	45.8	41.2	4.9	NR	9,230
	dry	---------	49.3	44.4	5.3	NR	9,930
East of the Navajo (1)	as-received	9.1	34.7	50.1	7.1	0.9	10,220
	dry	---------	38.2	55.1	7.8	0.9	11,240
Needle Eye Point (2)	as-received	12.3-23.7	37.6-40.8	29.5-38.6	7.3-9.2	1.1-1.2	8,450-10,140
	dry	---------	46.4-49.2	38.6-45.3	8.3-12.2	1.5-1.6	11,060-11,560
Upper Valley (1)	as-received	5.7	46.8	41.2	5.6	NR	9,380
	dry	---------	49.6	44.5	5.9	NR	9,950
Christensen coal zone							
Canaan Creek (2)	as-received	4.6-6.3	43.8-46.1	40.9-44.7	4.6-9.0	NR	9,740-9,870
	dry	---------	46.7-48.3	43.7-46.9	4.8-9.6	NR	10,200-10,540
Carcass Canyon (7)	as-received	4.4-25.4	35.6-52.5	28.9-49.1	3.4-10.1	0.4	NR
	dry	---------	44.6-54.9	37.6-51.7	3.7-13.5	0.4	9,780-11,230
Death Ridge (2)	as-received	5.4-6.0	41.0	46.6-48.3	5.3-6.4	NR	10,960-11,240
	dry	---------	43.3-43.6	49.6-51.1	5.6-6.8	NR	11,660-11,890
Needle Eye Point (7)	as-received	6.7-14.6	20.3-51.7	20.5-66.2	4.6-17.8	0.4-1.3	9,780-11,780
	dry	NR	NR	NR	NR	NR	NR
Seep Flat (1)	as-received	10.4	36.0	47.5	6.1	0.9	11,100
	dry	---------	40.2	53.0	6.8	1.0	12,390
Tibbet Bench (4)	as-received	11.2-24.2	35.9-42.6	33.9-38.1	6.0-10.1	0.9-1.2	8,780-9,860
	dry	---------	45.3-48.0	40.6-45.7	7.9-11.5	1.1-1.4	11,110-11,580
Henderson coal zone							
Henrieville (2)	as-received	17.7-22.7	34.6-35.6	32.5-37.8	8.6-9.6	0.6-0.7	7,770-9,510
	dry	---------	43.6-44.7	42.1-46.0	10.4-12.4	0.8	10,050-11,550
Pine Lake (2)	as-received	13.1-28.6	37.8	40.9	6.7	1.5	7,370-11,370
	dry	---------	43.5-45.0	41.1-44.5	7.7-10.5	0.9-1.7	10,360-13,080

Values are based on Doelling and Graham (1972, p. 123-127).

Appendix 5—Lithologic and Stratigraphic Data for Selected Drill Holes in the Kaiparowits Plateau Database

Appendix 5 contains location, lithologic, and stratigraphic data from 155 drill holes selected from the Kaiparowits Plateau database shown in Appendix 1. The data is available in ASCII format, .dbf, and Excel spreadsheet files on disc 2 of this CD-ROM. Appendix 5 does not include additional data shown in Appendix 1 that are from outcrops, control points, or drill holes that do not penetrate coal-bearing strata.

Appendix 6—ArcView project for the Coal Assessment of the Kaiparowits Plateau, Utah

The digital files used for the coal resource assessment of the Kaiparowits Plateau are presented as views in the ArcView project.

The ArcView project and the digital files are stored on both discs of this CD-ROM set—Appendix 6 of chapter T resides on both discs. Persons who do not have ArcView 3.1 may query the data by means of the ArcView Data Publisher on disc 1. Persons who do have ArcView 3.1 may utilize the full functionality of the software by accessing the data that reside on disc 2. An explanation of the ArcView project and data library—and how to get started using the software—is given by Biewick and Mercier (chap. D, this CD-ROM). Metadata for all digital files are also accessible through the ArcView project.

Click on image below to bring up high-resolution image of plate 1.

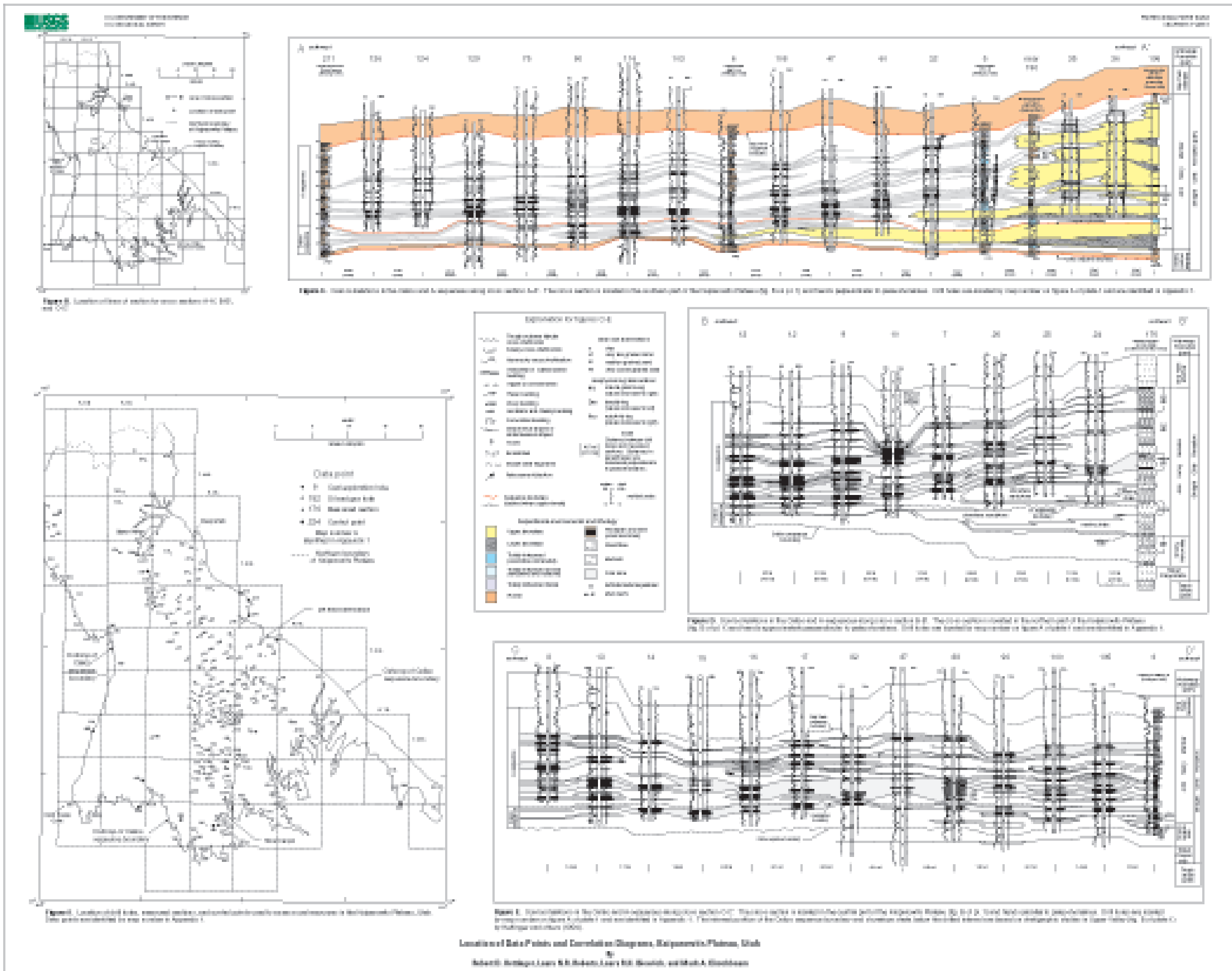
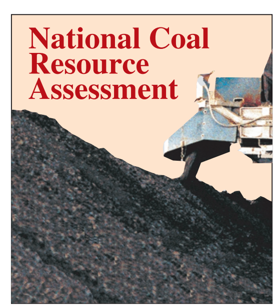


Plate 1. Locations of data points and correlation diagrams, Kaiparowits Plateau, Utah.



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