INTRODUCTION

Purpose and scope

An assessment of the distribution and resources of coal in the Kaiparowits Plateau of southern Utah is presented in this report. Results of the Kaiparowits Plateau study include a preliminary delineation of thick coal deposits and a coal resource estimate that can serve as a baseline for other efforts to further assess the coal resource in terms of its availability and recoverability. The Kaiparowits Plateau project is part of the United States Geological Survey's National Coal Resource Assessment project 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 may be of importance during the first quarter of the next century. The Kaiparowits Plateau is one 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 forty-eight States, if compared to the figures of Averitt (1975).

The assessment of the Kaiparowits Plateau is based on data from geologic mapping, outcrop measurements of stratigraphic sections, and drilling that has been conducted in the region since the late 1960's. Deposits of coal are contained within the John Henry Member of the Straight Cliffs Formation, and although the distribution of coal has been well documented on outcrop, its distribution in the subsurface has remained largely unknown due to the proprietary status of company data. However, recently released company drill-hole data and drilling by the U.S. Geological Survey provide new insight into the subsurface aspects of these coals. We have integrated these recently released data 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 are stored digitally and manipulated in a Geographic Information System to calculate coal resources within a variety of spatial parameters that are useful for land-use planning. Coal resources reported in this investigation are for total in-place coal in the John Henry Member 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 have created digital files for various geologic features within the plateau. These spatial data are stored, analyzed, and manipulated in a Geographic Information System (GIS) using ARC/INFO software developed by the Environmental Systems Research Institute, Inc. Spatial data that require gridding for the generation of contour and isopach maps are processed using Interactive Surface Modeling (ISM) [Dynamics Graphics, Inc.]. Contour lines generated in ISM are then converted into ARC/INFO coverages using a program called ISMARC which we received from the Illinois State Geological Survey. We have also collected and created additional coverages in ARC/INFO that define various geographic boundaries within the vicinity of the Kaiparowits Plateau. Integrating these various coverages allows 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 following paragraphs discuss procedures used to produce the various coverages used in the assessment.

Lithologic and stratigraphic data

Lithologic and stratigraphic data are based on our interpretations of geophysical logs from 139 company coal test holes and 22 oil and gas holes as well as published descriptions from 6 U.S. Geological Survey drill holes and 46 measured stratigraphic sections. Drill hole data have been provided by 5M, Inc., PacificCorp Electric Operations, Andalex Resources, Oryx Energy Company, the Bureau of Land Management, and the Petroleum Information Corp. All data point localities are shown on plate 1 (fig. A). Data are identified in appendix 1, and lithologic and stratigraphic interpretations for each data point are also provided in appendix 1.

Lithologic interpretations on geophysical logs were made from a combination of natural-gamma (gamma ray), density, resistivity, and neutron logs and company descriptions of core and drill-hole cuttings. 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 interpreted from density logs wherever possible and recorded to the nearest 1 foot; coal beds less than 1 foot thick were not included in the assessment. Thicknesses of more than one coal bed have been combined if an intervening parting is thinner than either the overlying or underlying bed of coal according to methods of Wood and others (1983, p. 31, 36) and the thickness of the parting is not included.

Stratigraphic interpretations were based on lithologic stacking patterns in each drill hole and on correlations to cores and outcrops where coeval rocks have been measured and described. Some stratigraphic interpretations were based on lithologic descriptions from published measured sections and from texts in geologic reports. Stratigraphic correlations were difficult using original geophysical log traces because they were recorded using various scales and deflection patterns. In order to make the best correlations, all geophysical logs were digitized and plotted using uniform scales and deflection patterns. Selected digitized log traces are shown in correlation charts on plate 1 (figs. C, D, and E).

Geologic maps

ARC/INFO coverages for geologic features include the locations of stratigraphic boundaries, faults, fold axes, and areas where strata are inclined at various ranges of dip. 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 base of the Drip Tank Member was digitized from a 1:100,000-scale geologic map of Kane county (Doelling and Davis, 1989). The range-of-dip map was compiled at a 1:125,000-scale from structure contour lines and from dip measurements published on 1:24,000-scale geologic maps of the Kaiparowits Plateau.

Geographic boundaries

ARC/INFO coverages for geographic boundaries were imported from existing public domain data bases. 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. Towns and roads were obtained from 1:100,000-scale Digital Line Graphs created by the U.S. Geological Survey EROS Data Center in Sioux Falls, South Dakota. Areas of surface ownership were digitized from 1:100,000-scale quadrangles by the Bureau of Land Management and Geographic Approach to Planning (GAP) in 1993. 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 1:250,000-scale U.S. Geological Survey Digital Elevation Model of the 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 between the towns of Escalante, Henrieville, and Glen Canyon City, in southern Utah (fig. 1). In this report, any further use of the word “plateau” refers to the Kaiparowits Plateau. The northern boundary of the Kaiparowits Plateau merges with the Aquarius Plateau and is arbitrarily delineated by the Paunsaugunt fault, volcanic rocks of Tertiary age, and the 112° line of longitude (fig. 1). Elsewhere, the edge of the Kaiparowits Plateau is defined by the base of Upper Cretaceous strata (fig. 1). The Kaiparowits Plateau covers approximately 1,650 square miles; it extends 65 miles north to south, 20 miles across its northern boundary, and 55 miles across its southern boundary. The plateau is a dissected mesa that rises as much as 6,500 feet above the surrounding terrain. Elevations range from about 4,000 feet above sea level in the south near Lake Powell (fig. 1) to about 9,800 feet above sea level in the north near the Aquarius Plateau; some erosional remnants in the northern part of the plateau are as high as 10,450 feet above sea level. The landscape is defined by four sets of cliffs and benches that form a step-like topography between the Aquarius Plateau and Lake Powell (Sargent and Hansen, 1980). The Straight Cliffs form a prominent escarpment that extends northwest to southeast along the plateau’s eastern flank; the escarpment is as high as 1,100 feet along Fiftymile Mountain (fig. 1). The northern part of the plateau contains lands within Dixie National

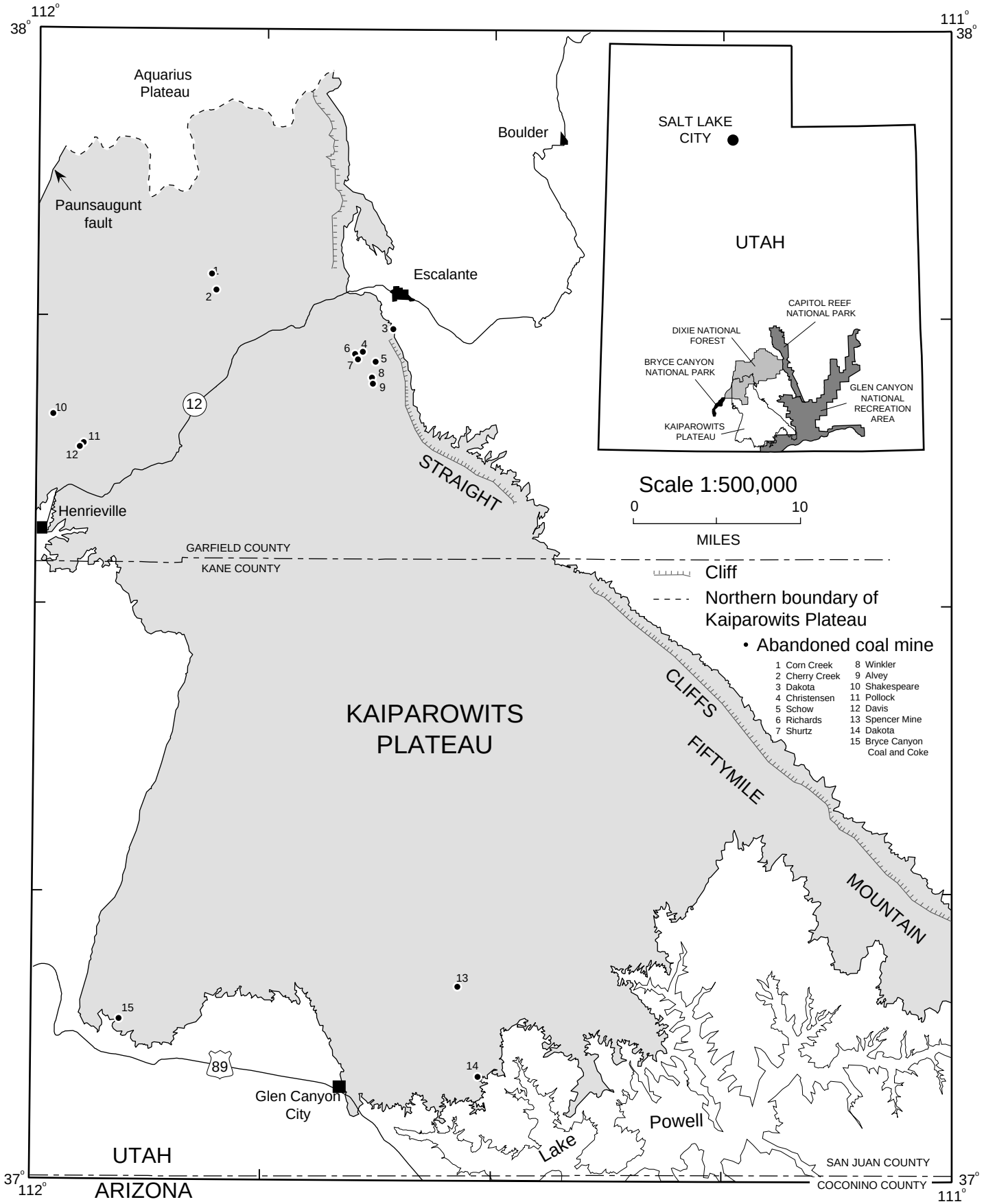

Figure 1. -- Location of Kaiparowits Plateau, Utah, east of 112° of longitude. The plateau is delineated by the base of Upper Cretaceous rocks except along its northern boundary where it merges with the Aquarius Plateau. Inset map shows the location of the Kaiparowits Plateau with respect to nearby National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

Table 1. Coal mining history in the Kaiparowits Plateau, Utah. Total coal production at each mine is estimated from average annual production reported in Doelling and Graham (1972). Mine and 7.5' quadrangle locations (queried where uncertain) are shown on figures 1 and 2, respectively. Table is modified from Doelling and Graham (1972).

Mine	Location quadrangle	7.5' or formation	Producing coal zone of production	Years production (short tons)	Estimated total
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

Forest, and the southern boundary of the plateau contains lands within the Glen Canyon National Recreation area (fig. 1). Bryce Canyon and Capitol Reef National Parks are located west and east of the plateau, respectively (fig. 1).

Previous geologic studies and mining activity

Coal in the Kaiparowits Plateau region 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 early 1960's. Locations of the abandoned mines and adits are shown on figure 1. Production figures from Doelling and Graham (1972, p. 71) shown on table 1 indicate that less than 50,000 short tons of coal have been mined from the Kaiparowits Plateau.

Although coal investigations were first reported in the Kaiparowits Plateau by Gregory and Moore (1931), it was not until the early 1960's that energy companies expressed an interest to commercially develop coal in the region. Since then, coal leases have been held by at least 23 companies (Doelling and Graham, 1972, p. 98-99), and about 1,000 company coal test holes have been drilled in the plateau (Jim Kohler, U.S. Bureau of Land Management, 1991, oral communication). 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 generating plant after controversy over environmental issues (Sargent, 1984, p. 8). Construction plans were finally discontinued because of government action and pending lawsuits over environmental concerns (Sargent, 1984). Currently, only a few companies retain coal leases in the area.

The U.S. Geological Survey conducted investigations to study the geology and assess the region's coal resources. Stratigraphic investigations resulted in formal divisions of some Upper Cretaceous and Tertiary strata (Peterson, 1969b; Bowers, 1972, respectively). Other sedimentological investigations demonstrated the detailed relationships between coal-bearing continental and related marine strata and provided sequence stratigraphic divisions for the Upper

Cretaceous rocks (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 scales of 1:24,000 for twenty-five 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 Escalante 1x2 degree quadrangle (Hackman and Wyant, 1973).

The U.S. Geological Survey has also published a series of 1:125,000 scale maps that address geologic factors that may affect coal mining within the Kaiparowits Plateau. Results of these studies were summarized by Sargent (1984). These maps show drainage patterns and stream-flow data (Price, 1978), water quality (Price, 1977a, 1979), ground-water availability (Price, 1977b), scenic features and landforms (Carter and Sargent, 1983; Sargent and Hansen, 1980, respectively), surficial and bedrock geology (Williams, 1985; Sargent and Hansen, 1982, respectively), geologic cross sections (Lidke and Sargent, 1983), and total coal thickness and overburden (Hansen, 1978a, b, respectively).

Geologic investigations by the Utah Geological and Mineralogical Survey have also resulted in significant publications. Seven 7.5' quadrangles in the southern part of the plateau were published by the Utah Geological and Mineralogical Survey at a 1:31,680 scale as a result of cooperative investigations with the U.S. Geological Survey (fig. 2). A comprehensive assessment of geology and coal resources in the Kaiparowits Plateau was published by Doelling and Graham (1972); that report includes geologic maps, published at a scale of 1:42,240, and measured coal thicknesses in twenty-seven 7.5' quadrangles in the plateau (fig. 2). The geology of Kane County, Utah, was reported by Doelling and Davis (1989) and includes a 1:100,000 scale geologic map that covers the southern part of the Kaiparowits Plateau. Coal resources for the southern part of the plateau are described by Blackett (1995).

Coal resources of the Kaiparowits Plateau have been estimated by Averitt (1961), Peterson (1969b), and Doelling and Graham (1972) and include coals in the John Henry and Smoky Hollow Members of the Straight Cliffs Formation as well as the Dakota Formation. Initially, Averitt (1961) estimated that the Kaiparowits Plateau contained 3 billion tons of coal. Coal discoveries made during the 1960's resulted in higher estimates, and Peterson (1969a, p. 219) estimated the potential coal resource for the plateau to be about 40 billion tons for beds greater than 1 foot thick and less than 3,000 feet deep. Doelling and Graham (1972, p. 102-106) stated that most of the coal in the plateau is minable only by underground methods, and they reported a coal reserve of about 15 billion tons for all beds greater than 4 feet thick and less than 3,000 feet deep. Both Peterson (1969a, p. 221) and Doelling and Graham (1972, p. 102) estimated that about 4 billion tons of coal could be mined. Coal resource estimates were also reported in 12 of the 7.5' quadrangles in the plateau (appendix 2) by Doelling and Graham (1972) and by the U.S. Geological Survey. These resource estimates total only about 11 billion short tons of coal, but they are generally determined for limited bed thicknesses and limited areas in each quadrangle.

Acknowledgments

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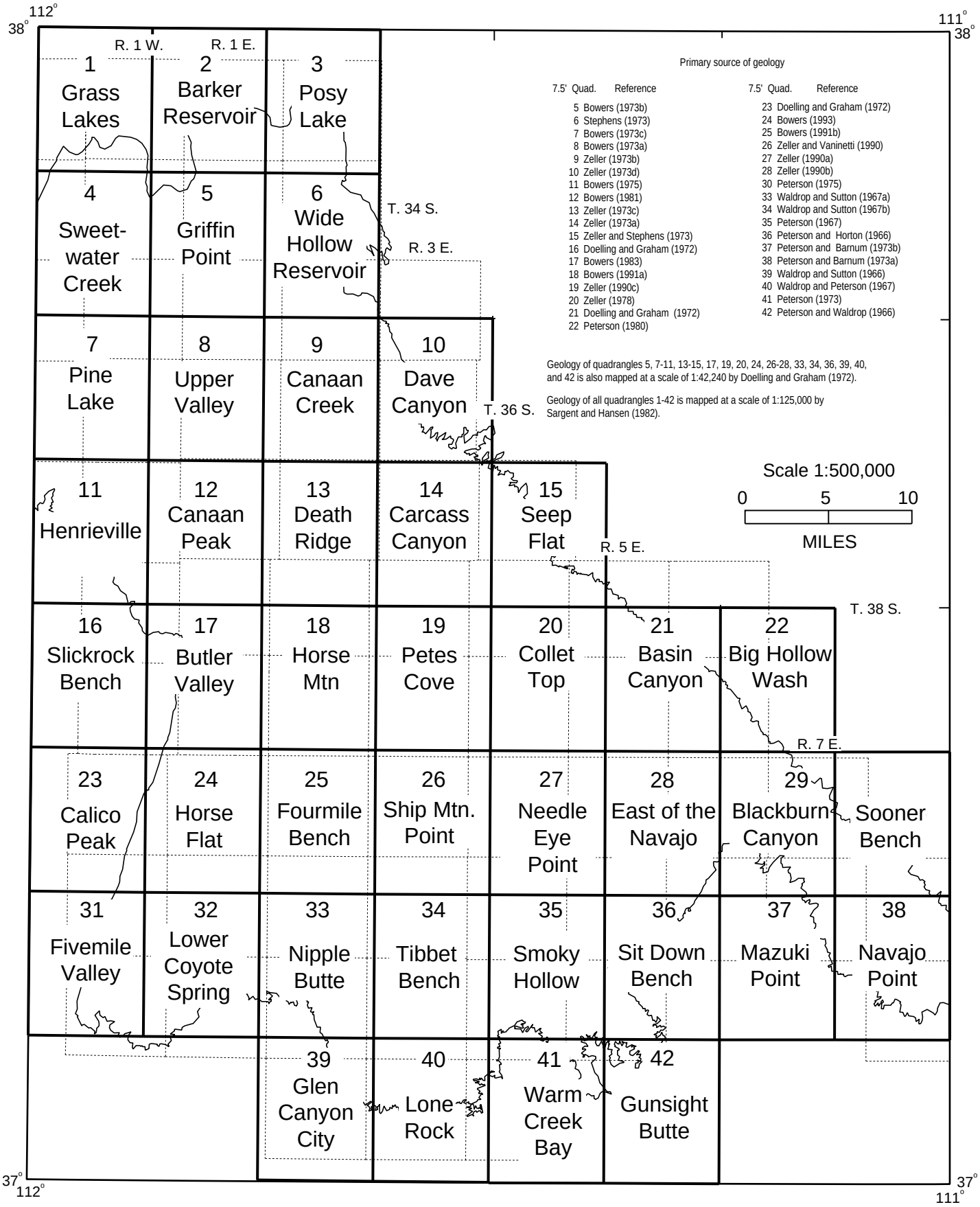

Figure 2. -- Index map for 7.5' quadrangles and townships in the Kaiparowits Plateau. Published geologic maps for each quadrangle are referenced in the inset.