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GEOLOGIC OVERVIEW, COAL DEPOSITS, AND POTENTIAL FOR METHANE RECOVERY FROM COALBEDS UINTA BASIN, UTAH AND COLORADO

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TABLE OF CONTENTS

TABLE OF CONTENTS (CONT'D)

LIST OF FIGURES (CONT'D)

LIST OF FIGURES (CONT'D)

LIST OF FIGURES (CONT'D)

LIST OF TABLES

LIST OF TABLES (CONT'D)

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1. SUMMARY

This report on the Uinta Basin compiles presently available data needed to determine the coalbed methane resource and to provide a framework for the U.S. Department of Energy's Methane Recovery from Coalbeds Project (MRCP) resource delineation effort in that basin. A primary target area having the highest potential for coalbed methane production has been designated covering most of Carbon County, and parts of Emery and Grand Counties, Utah (Figure l-l). This target was determined by evaluating desorption data from the Utah Geological and Mineral Survey (UGMS), mine emission data from the U.S. Bureau of Mines (USBM), and desorption data from Mountain Fuel Resources, Inc. On the basis of UGMS and Mountain Fuel data, an estimated 368.2 to 1,211.8 billion cubic feet of gas is contained in the Book Cliffs coal field. This estimate applies to the primary target area because of that coal field's inclusion within the area. Based on available UGMS data, ranges for the expected in-place methane resource have been made for the seven coal fields of the Uinta Basin. The low value of 230.8 billion cubic feet and the high value of 832.3 billion cubic feet of gas are estimated to be present, based on available coal resource estimates. The geology, coal resources, and methane potential of the basin are summarized below.

The Uinta Basin is an east-west asymmetrical syncline located in the Colorado Plateau Province, which is structurally and topographically a basin. For purposes of this report, the area discussed will include the Wasatch Plateau, a southwestern appendage of the basin. The area covers an estimated 11,550 square miles in northeastern Utah and northwestern Colorado. Lying within a semi-arid region where vegetation is sparse, the topography is generally rugged because of erosional dissection. The Green River flows southeastward, and is the principal river draining the basin. Semi-arid climate, sparse vegetation, and rugged topography have restricted the area's population to concentration in a few major towns. Major transportation routes are a limited number of major highways, secondary roads, and the Denver and Rio Grande Railroad.

The Uinta Basin contains comparatively minor structural deformation in the form of folding and faulting. Structurally, the Wasatch Plateau is more complex, with four major normal fault zones traversing north to south over the plateau.

Sedimentary deposition in the area occurred from late Precambrian to Quaternary. The basement Precambrian rocks are composed of a thick sequence of schistose and gneissic rocks. With the exception of a hiatus during Ordovician and Silurian time, the basin was a stable peneplain with continuous deposition from Cambrian to Pennsylvanian time. Major coal-bearing strata were deposited during Late Mesozoic time. The Tertiary Age was marked by the deposition of shales, sandstones, conglomerates, and limestones. Pleistocene glacial drift covered the northern edge of the basin, and alluvium was deposited along streams and river channels.

Major coal-bearing strata of the Uinta Basin and Wasatch Plateau are contained in the Upper Cretaceous Mancos Shale, and Mesaverde Group. The area is divided into seven coal fields and regions: Vernal coal field, Tabby Mountain coal field, Sevier-Sanpete region, Wasatch Plateau coal field, Emery coal field, Book Cliffs coal field, and Sego coal field. The Wasatch Plateau, and Book Cliffs coal fields are the most extensively developed. Their major coal deposits are found in the Mesaverde Group Blackhawk and Price River Formations along the basin's southern perimeter. The Wasatch Plateau coal field contains 22 coalbeds greater than 4 feet thick, the most important being the Hiawatha, Castlegate "A", Blind Canyon, and Wattis coalbeds, ranging in rank from high-volatile B to C bituminous. The Book Cliffs coal field is subdivided into four areas containing seven important coalbeds or zones which are widely traceable over the majority of the field. Coal contained within these zones and beds is ranked as high-volatile B bituminous rank. The remaining five coal fields have not been extensively developed. Thin and split coalbeds are prevalent in a few of these coal fields, and in many instances top quality coals are scattered, making it difficult to justify development. Little is known about the coal resource at depth in the basin.

In addition to its coal resources, the basin contains significant oil and gas resources in Mesozoic and Cenozoic rocks. The Jurassic Morrison

Formation, and Tertiary Wasatch, Green River and Uinta Formations have been extensively developed for oil production. Gas is being produced from the Jurassic Morrison Formation., Cretaceous Dakota and Ferron Sandstones, and the Tertiary Green River Formation.

The potential methane resource for the Wasatch Plateau, Emery, Book Cliffs, and Sego coal fields has been estimated using UGMS desorption data from the Survey's Special Study Series of August 1979. Additional desorption data for the Book Cliffs coal field was obtained from Mountain Fuel Resources, Inc. Whitmore Park Well Sites No. 1 and 2 in Carbon County, Utah. Supportive data from USBM includes mine emission data available for mines emitting at least 100,000 cfd of gas, and information from Kaiser Steel Company's long-hole degasifying test on Sunnyside No. 1 Mine. There is an absence of available gas data for the Vernal, Tabby Mountain, and Sevier-Sanpete coal areas and the deeper, central parts of the basin.

The area considered in this report as the prime methane resource target within the Uinta Basin is discussed below. It includes the majority of Carbon County, and parts of Emery and Grand Counties in Utah. The reasons for the target area's choice are:

- Of the four coal fields tested by UGMS for their methane content, the data show significantly higher gas yields from Carbon County.
- Wells drilled by Mountain Fuel Resources, Inc. indicate high gas content within Carbon County coals.
- Numerous mines within the target area provide emission data indicating the release of large amounts of methane gas.

A program for investigating the methane recovery potential of the Uinta Basin would include the following additional activities:

- Obtain geophysical logs and gas information from oil and gas wells penetrating coal-bearing zones in the basin.
- Cooperate with the U.S. and Utah geological surveys and other private organizations to collect coal core, coal chip, and gas samples to perform methane desorption tests, and analyses.
- Collect other pertinent information through logs, personal contacts, reports, and mine data, and from personnel working within the basin area.

- Construct a lineation map of the basin, concentrating in the primary target area shown on Figure 6-1 to better define areas for further testing.

- Participate in a detailed study of the target area to help pinpoint test sites for methane exploration.

- Perform drilling, logging, sampling, and flow testing of test sites chosen by the detailed study.

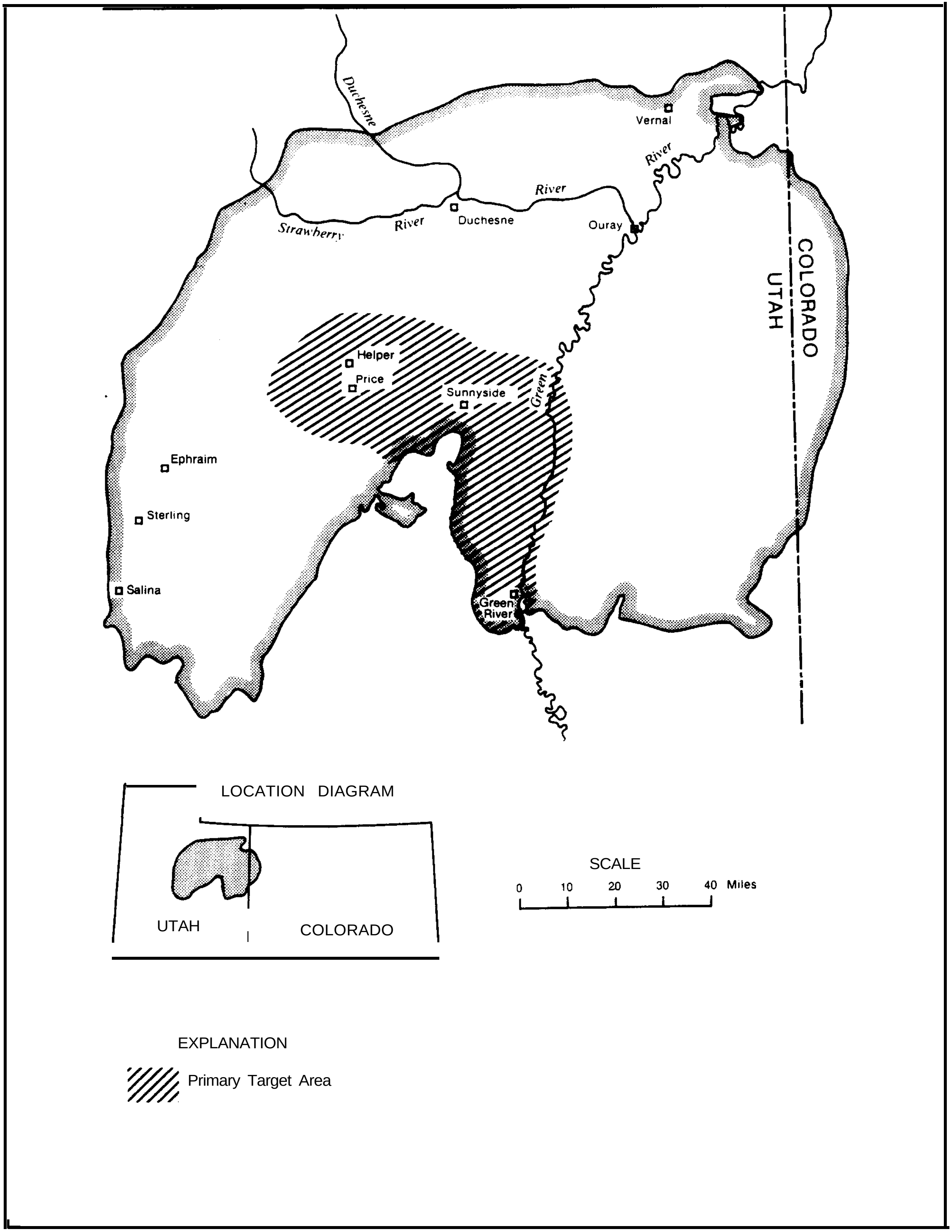


Figure I-l. Primary Methane Target Area of the Uinta Basin

2. INTRODUCTION

Methane, the major component of natural gas, is generated during the natural process of coal formation and frequently is trapped in the coal and associated strata. The total magnitude of the U.S. coal-associated methane resource has been estimated as much as 700 trillion cubic feet. Given current and conservatively projected economic and technological factors, the recovery of some 300 trillion cubic feet of this natural gas resource appears to be feasible.

The objective of this report is to provide a data base on what is presently known about the coalbed methane resource in the Uinta Basin of Utah and Colorado. Various sections of the report detail the basin's general geographical, cultural and geological setting and give an overview of its coal resources and associated coalbed methane gas. This analysis was performed under the Department of Energy's Methane Recovery from Coalbeds Project (MRCP). The MRCP consists of a planned sequence of resource characterization, research and development, and technology systems tests, designed to evaluate and test the technical and economical extraction and utilization of gas associated with coalbeds. Resource delineation of the methane content of the nation's coalbeds has been done on a very limited basis, mostly in conjunction with active mining. Previous work includes only a very small percentage of the coal resource and does not provide the knowledge needed to locate recovery and utilization projects in the coalbeds with the greatest potential for methane production.

This report is organized into four main sections with three appendices. Following the Summary and Introduction, Section 3 discusses the basin setting of the Uinta Basin including the geography/physiography, cultural features, climate, structural geology, stratigraphy, basin hydrology, and a subsection describing energy resources other than coal. Principal coal fields and coalbeds are described in Section 4. Section 5 concerns the potential methane resource, where known existing and relevant data on methane occurrence in coalbeds are compiled, including an estimate of the potential magnitude of the coalbed methane resource of the Uinta Basin. Section 6, Conclusions and Recommendations, identifies potential methane exploration target areas, and outlines an approach for further study. Appendix A includes topographic maps, and Appendix B contains geologic maps covering the Uinta Basin. Water Resources Investigations of Utah and Colorado are presented in Appendix C.

NOTE

All geologic terms in this report conform to the standards of the American Geological Institute (AGI). All engineering and petroleum terms conform to the standards of the Society of Petroleum Engineers (SPE).

3. BASIN SETTING

3.1 GEOGRAPHY/PHYSIOGRAPHY

The Uinta Basin is one of the six major physiographic sections that comprise the Colorado Plateau province. Located in the northernmost part of the province, the basin covers 9,750 square miles in the northeastern corner of Utah and a small part of northwest Colorado (Figure 3-1) (Thornbury, 1965).

For purposes of this report, the Wasatch Plateau, located in the High Plateau section of the Colorado Plateau province, makes up the southwest corner of the Uinta Basin. The plateau covers an estimated 1,800 square miles, and contains gently rolling to flat-lying strata with rugged terrain dissected by canyons.

The basin is an east-west asymmetrical syncline lying immediately south of the Uinta Mountains. To the west lie the Wasatch Mountains and the majority of the High Plateau section. The White River Plateau and West Elk Mountain are on the region's east side, and the Uncompahgre Plateau is southeast of the basin. The basin's southern terminus is a double escarpment called the Tavaputs Plateau, also referred to as the Book and Roan Cliffs. This escarpment descends 3,000 feet to the Canyon Lands section (Thornbury, 1965).

The Uinta Basin is both structurally and topographically a basin, with an average elevation of over 5,000 feet. Near its southern margin, in the Tavaputs Plateau, elevations exceed 10,000 feet (Thornbury, 1965). Much of the area has rugged topography as a result of erosional dissection, although numerous broad benches believed to be pediments are located near the south base of the Uinta Mountains. In the central portion of the basin, badland topography has developed extensively.

3.2 CULTURAL FEATURES

Counties wholly or partially contained within the Uinta Basin include: Uintah, Duchesne, Wasatch, Utah, Sanpete, Sevier, Emery, Carbon, Juab, and Grand in Utah; and Rio Blanco, Moffat, Mesa, and Garfield in Colorado (Figure 3-2). Populations within the region, according to the 1970 census, are concentrated principally in towns such as: Vernal (population 3,908), Richfield (4,471), Ephraim (2,127), Price (6,128), and Helper (1,964), Utah. Just outside the region to the south in Utah are the towns of Green River (1,033), Moab (4,793) and Salina (1,494). The remaining scattered communities generally have populations of less than 1,000; many have less than 100.

The Uinta and Ouray Indian Reservation covers approximately 2,000 square miles of the east central part of the Uinta Basin. The Dinosaur National Monument lies northeast of Vernal on the Utah side of the Utah-Colorado state line.

Regional transportation relies primarily upon highways and secondary roads. The principal roads are U.S. Highways 40, 50, and I-70 and State Highway 33. The only railroad, Denver and Rio Grande Western, runs along the southern boundary of the region and passes through the Utah towns of Price, Green River, and Springville. The Utah cities of Vernal, Price, and Green River also have modern airports.

Mineral and mining industries employ the majority of the population, together with agriculture, tourism, forestry, and trade. The region has oil and gas fields and pipelines which cross the basin (Figure 3-3). Main pipelines include a gas line (mainline trends northeast-southwest) of the Mountain Fuel Supply Company, and an oil line (northwest-southeast) of the Northwest Pipeline Company.

3.3 CLIMATE

The Uinta Basin is characterized by a semiarid climate and averages less than 12 inches of precipitation annually. In the bordering mountains and plateaus, however, a range of 20 to 30 inches is considered normal (Figure 3-4). Precipitation in the eastern portion of the state results primarily from moist air masses moving northwest from the Gulf of Mexico and releasing their water either as cyclonic storms of late winter or thunderstorms of late summer, Streams reach their highest level in May and June following the melting of mountain snow (NOAA, 1974).

Regional temperatures vary in accordance with altitude and season. A temperature decrease of 30°F occurs for each 1,000-foot increase in altitude. Surrounding mountains act as a barrier to much of the moisture, leaving the lower interior areas dry and hot during summer days. Nocturnal cooling is common in elevated valleys where, often accompanied by fog, cool air collects and causes a temperature drop of as much as 30°F from the daily peak. The average July temperature ranges from a low of 75°F at the base of Book Cliffs to a high of 100°F in lowlands of the region (NOAA, 1974).

In winter, the mountains receive moderately heavy snowfall while the valleys and basins remain relatively snow-free. In some areas, the dryness causes cooler than expected weather at those elevations and latitude. The city of Vernal, situated at the bottom of Ashley Valley in the northern part of the basin, has an average winter temperature 10°F cooler than comparable locations (Doelling and Graham, 1972). However, protected from arctic air currents by mountains to the north and east, the region as a whole has rather moderate winters. The average regional temperature for the month of January is 15°F, but this is highly dependent upon location. A winter temperature of -20°F is not uncommon at Green River, Utah near the Book Cliffs coal field (Doelling, 1972). Winds travel from the west across the basin.

Vegetation in the lowlands is sparse, and many crops require irrigation. Big sagebrush, shadscale, blackbush, greasewood, grassland, saltbush, and summer-cyprus are the major vegetation types in the basin's low-lying areas. Vegetation of the region's mountainous areas is characterized by alpine meadow, subalpine forest, mountain forest, mountain brush, and pinyon-juniper (Doelling, 1972).

3.4 STRUCTURAL GEOLOGY

3.4.1 Uinta Basin Structure

Compared to other areas of the Colorado Plateau Province, the Uinta Basin is not structurally complex (Figure 3-5). It is a broad, east-west trending syncline, asymmetrical on the north side (Figure 3-6). The area has a broad, gentle south flank with comparatively shallow dips which range from 3" to 12" north along the Tavaputs Plateau. On the northern edge of the basin, a sharp increase in dip occurs where the strata turn upward against the south flank of the Uinta Mountains (Figure 3-7). Dips range from 20" to 75" south to southwest in the Tabby Mountain and Vernal areas. Faulting within the basin is limited primarily to the northern boundary where the Uinta Mountains uplift caused high-angle normal faults. Displacement along these faults is generally less than 250 feet of throw (Doelling and Graham, 1972).

3.4.2 Wasatch Plateau Structure

The Wasatch Plateau, a southwest-trending appendage from the Uinta Basin, is structurally more complex. The plateau, which belongs to the High Plateau section of the Colorado Plateau Province, is located between the San Rafael Swell on the east and the Great Basin on the west, and carries characteristics of both areas. The strata of the eastern area dip gently westward as an extension of the west flank of the San Rafael Swell (Spieker, 1931). The western part of the area is a monoclinal fold more characteristic of the Great Basin (Childs, 1950). Faulting, which is common in the Great Basin, is the major structural disturbance in the plateau. Normal faults, which resulted from post-Cretaceous tensional stresses, are found in four major north-to-south-trending fault zones: Musinia, Joe's Valley, Pleasant Valley, and North Gordon (Figure 3-8). The Musinia fault zone, located in the southwest corner of the plateau, is 50 miles long and 2 miles wide, with a maximum displacement of 2,500 feet. The Joe's Valley fault zone in the central part of the plateau is 75 miles long north to south, 2 miles wide, and has faults with a maximum displacement of 2,500 feet. The Pleasant Valley fault zone, located on the plateau's north end, is 35 miles long and 4 miles wide, with displacements of up to 1,500 feet. The North Gordon fault zone is the boundary which separates the Wasatch Plateau coal field in the northeast section of the plateau from the Book Cliffs coal field in the southwest part of the basin. The system is 22 miles long, 4 miles wide, and has displacements up to a maximum of 800 feet. These four fault zones have produced prominent ridges and valleys in the plateau, and have altered the paths of many minor streams (Doelling, 1972).

3.4.3 Uinta Basin -- Structural History

The Uinta Basin was positioned on a stable crustal block throughout the Paleozoic Era. No major orogenic events are recorded in rocks of this era, and except for a hiatus during the Silurian and Devonian, continuous sedimentation occurred throughout the era. Crustal movement during the era was mainly epiorogenic rather than orogenic. However, during the Carboniferous, the uplift of the ancestral Rockies to the southeast of the basin affected sedimentation in the basin (Childs, 1950).

There is no orogenic break between the Paleozoic and Mesozoic Eras. The orogenic sequence of the basin possibly began with the Nevadan orogeny and continued through the Larimide orogeny. These orogenies affected the sedimentary environment with the highlands west of the basin being the principal source of sediments. The "Early Larimide" orogenic period is concurrent with the broad downwarp of the Uinta Basin--along with the final uplift of the Uinta Mountain Arch (Childs, 1950). The Triassic period was also characterized by the forming of the Douglas Creek Arch in northwest Colorado, the eastern margin of the basin.

The Tertiary Period was marked mainly by differential uplift between the basin and the surrounding mountain systems (Osmond, 1965). At the close of early Eocene, the upthrust of the Uinta Mountain block on the northern edge of the basin caused sharp asymmetrical folding of the Tertiary basin fill. The collapse of the eastern end of the Uinta Mountain arch at the close of the Miocene Epoch marked the final structural event in the Uinta Basin (Childs, 1950).

3.4.4 Wasatch Plateau -- Structural History

The Wasatch Plateau underwent two major periods of structural deformation. In Late Cretaceous, after coal-bearing sediments were deposited, the plateau was elevated along with the majority of the High Plateau section (Spieker and Reeside, 1925). Erosion was a key occurrence during this time with sediments being transported to the east. This major mountain-building period died down and sedimentation again regained dominance. In late Tertiary, the second uplift of the region occurred with erosion again a key factor. During the last stages of this uplift, the plateau was broken by normal faults displacing 800 to 2,500 feet of strata (Doelling, 1972).

3.5 STRATIGRAPHY

Geologic formations in the Uinta Basin range in age from late Precambrian to Quarternary (Table 3-l and Figure 3-9). Sequence thickness is approximately 40,000 in the east portion of the basin, and approximately 48,000 feet in the west. Exposed strata are composed primarily of quartzite, limestone, shale, and conglomerate.

Precambrian*

The Uinta Basin is underlain at depth by a thick sequence of schistose and gneissic rocks. These basement rocks are similar to the Precambrian Uncompahgre suite of the Uncompahgre Plateau (Crittenden, 1950).

North of the basin, the Uinta Mountains contain 12,000 to 20,000 feet of Precambrian deposits--some of which are exposed in the mountain's core (Crittenden, 1950). The deposits consist of quartzite, conglomerate, and argillite referred to as the Uinta Mountain Group. The Colorado River and the Uncompahgre Plateau, southeast of the basin, are underlain by members of the Uncompahgre suite, including schistose and gneissic rocks intruded by granite dikes.

The Wasatch Mountains, to the west of the basin, contain three units, older than the Cambrian Tintic Formation, which are referred to as late Precambrian deposits. The basal unit is the 12,000- to 16,000-foot-thick Big Cottonwood Formation, composed of white or green quartzite and varicolored shales (Crittenden, 1950). The middle unit is an unnamed black tillite, ranging from 0 to 4,000 feet thick, with boulders and cobbles in a sandy matrix (Crittenden, 1950). The upper unit is an unnamed formation composed of quartzite and shale which ranges in thickness from 0 to 1,500 feet. The core of the Uinta Mountains contains about the same thickness and sequence as these units, so it is highly probable that they are related (Crittenden, 1950).

*The information for the Precambrian to Triassic stratigraphy discussion within this report was extracted from the work of J. C. Osmond in Geologic History of Site of Uinta Basin, Utah, 1965, unless otherwise noted.

Paleozoic

The Uinta Basin was a stable, broad peneplain from Cambrian to Pennsylvanian time.

Cambrian

The Cambrian Period was marked by the Cambrian seas trangressing eastward across Utah. Sandstone, shale, and carbonate were deposited across the basin in sequences thinning to the east. The deposits are approximately 2,000 feet thick near the Wasatch Plateau thinning to 1,000 near the Douglas Creek Arch in northwestern Colorado.

The Cambrian Tintic Formation is a basal quartzite unit present in the southern and central portions of the Wasatch Mountains to the west of the basin. A similar unit also has been located in the San Rafael Swell (Crittenden, 1950).

To the north of the basin, in the Uinta Mountains, the oldest Cambrian unit is a green shale. This unit is 3,000 feet thick on the mountain's south flank, and appears to extend as far east as the Colorado-Utah state line (Crittenden, 1950).

Ordovician and Silurian

There is an abscence of identifiable Ordovician and Silurian age deposits within the Uinta Basin.

Devonian

During the Devonian Period, seas transgressed westward covering the southern half of the Uinta Basin, resulting in dolomite, sandstone, and shale deposits. The sequence thickness increases eastward, reaching a maximum of 200 feet on the east side of the basin at the Douglas Creek Arch, and on the basin's south. The northern half of the basin is thought to have been elevated slightly above sea level during this time.

Mississippian

The Mississippian Age deposits near the Uinta Basin contain two distinctive lithologic units: the lower, with massive dolomite and limestone referred to as the Redwall, Leadville, Madison, and Deseret

Formations; and the upper unit, consisting of interbedded shale, limestone, and sandstone of the Manning Canyon, Humbug, Great Blue, Molas, and Doughnut Formations.

Pennsylvanian

The Pennsylvanian sequence is composed of the Morgan Formation and Weber Sandstone (Figure 3-10).

The basal Morgan Formation is composed of varicolored shale, limestone, and sandstone that vary in thickness from less than 400 to greater than 1,200 feet. The formation averages 445 feet in thickness along the Duchesne River in the central basin, and 1,266 feet along Green River in Uintah County, Utah (Bissell, 1950).

The Weber Sandstone, also referred to as the Weber Quartrite, is the upper unit, and consists of massive sandstone ranging from 1,000 to 1,600 feet in thickness in the basin. Along the Duchesne River, the unit's thickness averages 1,500 to 1,600 feet, and near Dinosaur National Monument, northeast of Vernal, Utah, it is 1,200 feet thick (Bissell, 1950).

Late Paleozoic and Early Mesozoic

Permian and Triassic

Permian and Triassic Age deposits originated from erosion of the Uncompahgre Uplift. Debris from the uplift was deposited to the north and south. Eastward-trending Permian to Cretaceous Age sediments also were deposited, in some instances overlapping the Uncompahgre Uplift sediments. This sequence of deposits thickens westward across the basin. The Park City Formation, consisting of argillaceous sandy limestone and dolomite with shale, was deposited during Permian time. The unit ranges from 80 to 1,500 feet thick.

In the Uinta Basin the Chinle and Moenkopi Formations are the principal Triassic Age units. The Moenkopi Formation is the basal Triassic unit and consists of brown-to-green silty shale up to 800 feet thick. The formation grades west into the Mahogany, Thaynes, and Woodside Formations. The Chinle Formation consists of red-brown and green silty shale, 200 to 300 feet thick.

Middle and Late Mesozoic

Jurassic*

The Jurassic system in the Uinta Basin which includes the Morrison Formation outcrops on the south flank of the Uinta Mountains, and averages from 780 to 800 feet thick over the basin. The Morrison Formation includes varicolored shales interbedded with sandstones of fluvial origin. This formation contains dinosaur fossils found in Dinosour National Monument near Jensen, Utah.

Upper Cretaceous

The Dakota Sandstone defines the base of the Upper Cretaceous in the Uinta Basin. In the western portion of the basin, the Dakota Sandstone is a coarse-grained, cross-bedded, tan sandstone, 30 to 50 feet thick. The sandstone coarsens and thickens to the east, and splits into numerous sandstone beds separated by sandy shale. Near the Colorado border, the sandstone is greater than 300 feet thick, and contains a pebble conglomerate.

The valley forming Mancos Shale conformably overlies the Dakota Sandstone. The thickness of this gray, marine shale ranges from 800 feet at Currant Creek to 6,000 at the Utah-Colorado state line. The shale intertongues with the upper boundary of the Mesaverde Group sandstone. Five members are included in the Mancos Shale. The lowest stratigraphic member is a 50- to 100-foot-thick, black, fissile shale found near the Colorado border; farther west it transforms to a gray shale greater than

*The Jurassic to Recent stratigraphy description within this section was extracted from the work of Paul T. Walton in Geology of the Cretaceous of the Uinta Basin, 1944, except where otherwise noted.

300 feet thick. The overlying Aspen shale is a dark gray, siliceous, fine-grained member, ranging from 15 to 95 feet in thickness, and possibly originated as water-laid volcanic ash. The middle member is a gray shale, 42 to 108 feet thick. This shale becomes thicker and more carbonaceous toward the Colorado border to the east.

The overlying Frontier Sandstone member is greater than 750 feet thick in the western portion of the basin, and thins to approximately 160 feet at the Colorado border. Thinning of the Frontier Sandstone to the east is caused by intertonguing of beds and a change of facies. This member is generally composed of thin sandstones, sandy shales, coal, and small tongues of Mancos Shale. Eastward, the sandstone becomes finer-grained, more thinly bedded, calcareous, and argillaceous. The sandstones form prominent hogbacks within the basin.

The upper shale member includes marine gray shale with a few sandstone beds at the top. The member is homogeneous through the Uinta Basin, although it ranges in thickness from 800 to 6,000 feet.

Mesaverde Group

The overlying Mesaverde Group, exposed in the Tabby Mountain and Vernal areas of the Uinta Basin, is divided into two distinctive sections: the lower of marine sandstone and the upper of brackish-water sandstones, sandy and carbonaceous shales, and coal.

The Tabby Mountain area exposes a representative section of the Mesaverde Group for the western part of the basin. The lower part is more than 850 feet thick and comprised of massive sandstone with fossils. The upper section is greater than 2,100 feet thick and consists of sandstone, sandy shales, coal, and fossils. In this region, the Mesaverde Group is unconformably overlain, suggesting a period of uplift and erosion.

In the Vernal region the lower section includes a near-shore marine sandstone which thins to the east. The sandstone actually is two sandstone members: Asphalt Ridge and Rim Rock Sandstones separated by a shale parting.

The Asphalt Ridge Sandstone, the basal member of the Mesaverde Group, is exposed along Asphalt Ridge. This yellow-to-white, soft sandstone bed contains no bituminous material. The sandstone is approximately 100 feet thick with a transitional upper boundary.

The Rim Rock Sandstone outcrops from Vernal, Utah to the Colorado border. The type locality for this gray, medium- to fine-grained sandstone is the Rim Rock Hogback located in the northeast section of the basin. The sandstone is cross-bedded, and contains bituminous material, plus black chert grains. This member thins eastward and ranges from 100 to 600 feet in thickness.

The upper section of the Mesaverde Group includes brackish water sandstone interbedded with brightly colored shales and thin coalbeds. This section is referred to as the Williams Fork Formation, and is poorly exposed throughout the region. The pink and purple shale colors resulted from burning coalbeds cooking the formation. The Williams Fork Formation in the Vernal Region is unconformably overlain by the Duchesne, Green River, and Wasatch Formations. Bituminous material occurs above and below the unconformity, suggesting the material is related to it.

The Mesaverde Group found in the Wasatch Plateau and Book Cliffs coal field to the east is comparable lithologically to the aforementioned Mesaverde Group of the Uinta Basin. The group in the plateau includes the basal Star Point Sandstone and the Blackhawk and Price River Formations (Figure 3-11).

The Star Point Sandstone intertongues with the underlying Mancos Shale. The unit ranges in thickness from 200 to 450 feet, and consists of three prominent ridge-forming sandstone beds, separated by shale or thin sandstone partings (Spieker, 1931). The sandstone thins to the east over the plateau and adjacent Book Cliffs area, illustrating the retreating phase of the Mancos sea (Spieker and Reeside, 1925).

A sharp conformable boundary separates the underlying Star Point Sandstone from the overlying Blackhawk Formation. The type locality for the formation is the Blackhawk mine, located on the plateau's east side.

The member is a slope-forming unit, sandwiched between two prominent ridge formers. The formation ranges from 700 to 1,000 feet thick and consists of sandstone, shale, and coal (Spieker, 1931).

The sandstone beds in the Blackhawk Formation are generally fine- to medium-grained and tan in color, similar to the underlying Star Point Sandstone. Present in the plateau are a few white sandstone beds, which usually underlie some of the coalbeds, and can be traced eastward through the Book Cliffs area (Spieker, 1931).

The formation's shale beds are separated into three categories: abundant gray-green clay shale, massive-to-laminated carbonaceous shale, and gray shale which is associated with coal. All the shale is of continental origin (Spieker, 1931).

The Blackhawk Formation in the Wasatch Plateau and the Book Cliffs is the major coal-bearing unit of the Mesaverde Group. Thick coalbeds are found in the lower half of the formation with thin coalbeds present through the total unit. The Hiawatha coalbed is the formation's basal bed and clearly separates the Blackhawk Formation from the Star Point Sandstone (Spieker, 1931).

The overlying Price River Formation is distinctive from the Blackhawk Formation because it is generally coarser grained and contains conglomerates (Spieker, 1931). In addition to the conglomerate, the Price River Formation also consists of sandstone, conglomerate, and a small amount of shale. The basal member of the formation is a massive sandstone referred to as the Castlegate Sandstone. This coarse-grained sandstone contains Small lenses of quartz and chert pebbles and ranges from 150 to 400 feet thick. The upper member of the Price River Formation is a slope- forming sandstone which ranges from 600 to 800 feet thick. The upper boundary of the formation is relatively precise because of the overlying conglomerate bed (Spieker and Reeside, 1925).

Cretaceous

The Currant Creek Formation ranges from Late Cretaceous to Eocene in age. The formation correlates to the North Horn Formation, Colton Formation, and Flagstaff Limestone of the Wasatch Plateau, and to the Wasatch Formation of the Uinta Basin (Garvin, 1969). The formation is exposed in the southern foothills of the Uinta Mountains in the northwest corner of the Uinta Basin. The unit reaches its maximum thickness of 4,800 feet in the Currant Creek region of Utah and thins substantially to the east and west. The formation contains conglomerates, sandstones, and colored shales with its most distinctive bed being a 190-foot conglomerate located at the formation's base (Garvin, 1969).

The Cretaceous Age North Horn Formation consists of varicolored shales with interbeds of sandstone. The formation also contains light amounts of conglomerate, coal, and limestone. The type locality for this formation is the North Horn Mountain where the formation is 1,650 feet thick. To the east this formation thins to less than 400 feet thick (Williams, 1950). Refer to Figure 3-12 for an isopach map showing the interval from top of Dakota Sandstone to the top of the Mesaverde Group and North Horn Formation.

Tertiary

The Eocene Series of the Tertiary Period includes the Wasatch, Green River, and Uinta Formations. The Wasatch Formation's only exposure is in the extreme eastern part of the Uinta Basin where it forms Raven Ridge. The formation, composed of white, pink, and green shales with thinly bedded sandstone, is 850 feet thick at Raven Ridge and thickens to greater than 3,000 feet to the west. In many areas it is difficult to distinguish the Wasatch Formation from the underlying North Horn and Tuscher Formations, and this generally results in a composite isopach map of the Wasatch, North Horn, and Tuscher Formations (Figure 3-13).

In the south portion of the basin the Colton Formation which overlies the Flagstaff Limestone is considered to be the same age as the Wasatch Formation. In areas where the Colton Formation is found, the section is sometimes referred to as the Wasatch-Colton Formation (Murany, 1964). The Colton Formation is composed of reddish-pink sandstones and shales, and varies greatly in thickness.

The Wasatch Formation, as classified for the plateau, consists of three units. The lower member contains sandstone, shale, conglomerate, and limestone with a thickness of 1,200 to 2,000 feet. The middle unit is referred to as the Flagstaff Limestone Member, consists mainly of fresh water limestone, and attains a thickness of 1,000 feet in the southern end of the plateau. The limestone thins northward and eastward and is undefinable in the Book Cliffs area.

The upper Wasatch Formation member consists of shale with thin beds of limestone and a minimal amount of sandstone. The unit is approximately 1,000 feet thick but has been completely eroded over a majority of the area (Spieker and Reeside, 1925).

In the western part of the basin the Wasatch Formation is completely overlapped by the Green River Formation, while to the far southwest, the Wasatch Formation of the Wasatch Plateau is devoid of any definable overlying Green River Formation (Spieker and Reeside, 1925). Outcrops of the overlying Green River Formation occur in the southern part of the Uinta Basin. The formation includes gray-green to white clay shale, hard blocky sandstones a few feet thick, plus oil shales and bituminous sandstone in the middle of the section. The formation's thickness ranges from 1,800 feet at the Duchesne County line to greater than 5,000 feet near the town of Duchesne, Utah. In the south and middle portions of the basin, Green River strata is conformably overlain by the Uinta Formation whereas the north side of the basin is marked by an unconformity. In this area the Duchesne River Formation overlies the Green River Formation.

The Uinta Formation outcrops in the central area of the Uinta Basin. The formation is conformable with the overlying Duchesne River Formation to the north and the underlying Green River Formation to the south. The unit is composed of variegated shales and sandstone beds which vary from less than one foot to greater than 50 feet thick. The formation has been divided into two units. The lower unit has more shale and mudstone but less sandstone than the upper unit (Williams, 1950). The total formation thickness ranges from 700 to 5,400 feet, depending on the boundary placement above and below the unit.

Oligocene

It is questionable if the Duchesne River Formation was deposited within the Eocene or Oligocene depositional cycle. For purposes of this report the Duchesne River Formation will be discussed within the Oligocene

Epoch. Refer to Figure 3-14 for a generalized sketch, north to south, showing the relationships among formations of Paleocene to Oligocene Age.

Sediments for the Duchesne River Formation were derived from the ancestral Uinta Mountains to the north. The formation is composed of reddish-orange shales, buff sandstone with shale interbeds, and conglomerate. The formation ranges from 1,300 to 3,000 feet thick and is subdivided into four lithostratigraphic units. In ascending order they are: the Brennan Basin Member; Dry Gulch Creek Member; Lapoint Member; and Starr Flat Member (Anderson and Picard, 1972).

The Brennan Basin Member, the most widespread of the four formation members, is composed of lenses of sandstone with reddish brown fine-grained rocks. Conglomerate is evident in the member along Asphalt Ridge. The unit crops out from the Utah-Colorado state line west to Currant Creek in widths of up to 16 miles noted. The member's thickness reaches a maximum of 1,950 feet in Brennan Basin, and thins westward to 720 feet and pinches out to the east. The change in thickness is a result of different deposition rates and intertonguing with the underlying Uinta Formation (Anderson and Picard, 1972).

The Dry Gulch Creek Member consists of brown to gray fine-grained rocks with thick sandstone beds. The member conformably overlies the Brennan Basis Member with the unit's type locality being Dry Gulch Creek located west and northwest of Roosevelt, Utah. The thickness of the member is the most uniform of the four, and ranges from approximately 500 to 660 feet thick over the northern part of the basin (Anderson and Picard, 1972).

The Lapoint Member is composed of gray-green bentonitic claystone with minor conglomerate, sandstone, and other fine-grained rocks. The type locality for this member is Twelvemile Wash located east and northeast of Lapoint, Utah. The unit thickness ranges from 20 feet to a maximum of 1,045 feet north of Roosevelt, Utah (Anderson and Picard, 1972).

The Starr Flat Member contains reddish brown conglomeratic sandstone with limited amounts of fine-grained rocks. The unit is found near the south base of the Uinta Mountains, and probably is a remnant of a clastic wedge covering the south flank of the mountains. The unit reaches a maximum thickness of 770 feet, and thins to less than 120 feet northward onto the Uinta Mountains (Anderson and Picard, 1972).

Miocene

The Bishop Conglomerate is the main member of the Miocene Series. It lies with an angular unconformity on rocks varying in age from Precambrian to Oligocene. The conglomerate consists of boulders one to six feet in diameter intermixed with gravel and sand, and ranges up to a maximum of 500 feet thick.

Quarternary

Pleistocene glacial drift covers the north edge of the Uinta Basin where rivers valleys emerge from the mountains. Alluvium is evident along most of the larger stream channels.

Igneous Rocks

Volcanic agglomerate and andesitic extrusives of late Eocene or early Oligocene Age are found in the extreme northwestern portion of the Uinta Basin. Igneous dikes cut through sedimentary strata in the northern part of the Wasatch Plateau coal field (Spieker, 1931). The dikes trend east at right angles to the major faults.

3.6 BASIN HYDROLOGY

3.6.1 Surface Hydrology

The Green River, the principal river draining the basin, has its head waters in the Green River Basin in Wyoming, and flows southwestward across the eastern half of the Uinta Basin (See Figure 3-2). Average water discharge of the Green River at Jensen, Utah, in the northeast corner of the basin is measured to be 4,607 cubic feet per second (Table 3-2) (Iorns, Hembree, and Oakland, 1965). The western half of the basin is drained by the Strawberry River which flows east across the basin and joins the Duchesne River east of Duchesne, Utah. The Duchesne River flows from the northwest and joins the Green River south of Ouray, Utah. The average water discharges for the Strawberry and Duchesne Rivers at Duchesne, Utah are 157 and 323 cubic feet per second, respectively (Iorns, Hembree, and Oakland, 1965). The White River flows west out of Colorado to meet the

Green River at Ouray, Utah. The White River drains the southeast section of the Uinta Basin, and has an average discharge of 764 cubic feet per second as measured at Watson, Utah, five miles upriver from its confluence with the Green River (Iorns, Hembree, and Oakland, 1965).

The Price and San Rafael Rivers are the principal rivers draining the northern and central parts of the Wasatch Plateau, respectively. These rivers eventually merge with the Green River near the town of Green River on the southern boundary of the basin. All of the rivers eventually drain into the Colorado River to the southeast.

The rivers and streams in the basin follow a centripetal drainage pattern. Streams crossing the northern part of the basin trend sharply east and southeast before entering major streams or rivers such as the Duchesne and White Rivers. The centripetal drainage pattern is controlled in many areas by the underlying geologic structure.

It has been estimated that half of the volume of annual stream flow occurs in May and June. During that period, maximum runoff from snowmelt on the south slopes of the Uinta Mountains, and the north slopes of the White River Plateau, takes place.

Streams and rivers in the northern Uinta Basin are actively eroding their channels and dissecting the previously deposited flood plains. Many have eroded so deeply that they are in the process of draining the unconsolidated Pleistocene aquifer zone. Except for a limited number of locations, the streams and rivers have minimum contact with the consolidated rock aquifers (Hood, 1976).

3.6.2 Subsurface Hydrology

Southern and Central Uinta Basin

The most important aquifers in the central and southern parts of the Uinta Basin are the Pleistocene glacial outwash zone, Pleistocene and Holocene alluvium, Duchesne River Formation, Uinta Formation, Wasatch Formation, and the Weber Quartzite. The Duchesne River Formation consists of sandstone. Near fractured areas, wells have been known to yield greater than 100 gallons of water per minute. The Weber Quartzite aquifer zone is known to produce large amounts of water near outcrop areas (Feltis, 1968).

Less important aquifers are the Mesozoic Navajo Sandstone and Mississippian limestones. A majority of the older formations contain briny water although some exceptions to this are known in the southern Uinta Basin where the Uinta and Green River Formations contain fresh-to-slightly saline groundwater.

Wells within the Green River Formation yield from 17 to 7,200 barrels of water per day, as indicated by 17 oil and gas wells in the Uinta Basin (Feltis, 1968). Fresh and slightly saline water occur as springs around the exposed area of the formation in the central basin area and in a few locations on the north flank.

Northern Uinta Basin

Aquifers in the northern part of the Uinta Basin underlie an area of approximately 5,200 square miles. The area includes the northern part of the Strawberry, Duchesne, and White River drainage basins plus the Green River drainage area, north of the point where the White River converges with the Green River (Hood, 1976). Two hundred feet of the stratigraphic section consist of unconsolidated material in the northern part of the basin, and it contains the most permeable aquifer in the area. The rest of the section consists of consolidated rocks which contain important aquifers with low-to-moderate permeability. The permeability in the consolidated rocks is derived from intergranular porosity and fracturing caused by folding, faulting, and basin subsidence (Hood, 1976).

Hood (1976) classifies seven formations as the most important water-bearing units because of potential recharge to groundwater systems, and their potential well yields. The seven formations, from youngest to oldest, are: Pleistocene Age glacial outwash and alluvium, Duchesne River Formation, Uinta Formation, Currant Creek Formation, Glen Canyon Sandstone, Weber Quartzite, and Mississippian limestone. Table 3-3 contains additional aquifer information. There are eight additional formations of lesser importance as aquifers. The development of these eight formations has been restricted because of the thinness of the zones, poor quality of the water, or low permeability. Maximum yields occur in areas where these units are fractured; for this reason, these aquifers are locally important.

The remaining formations in the northern Uinta Basin have low permeabilities; some of the formations contain evaporites which degrade the chemical quality of the groundwater.

Groundwater recharge of the northern Uinta Basin area occurs mainly from precipitation, although recharge by snowmelt does take place in the winter and spring, and along stream valleys in summer. The average groundwater recharge in the northern Uinta Basin is 500,000 acre/feet (Hood, 1976).

The estimated minimum groundwater in storage is 28 million acre/feet (Hood, 1976). This estimate includes only fresh or slightly saline water classified as usable. Mineral content of the groundwater increases as the water moves downward.

Glacial Outwash and Alluvial Aquifer Zone

The glacial outwash and alluvial aquifer zone of Pleistocene Age is considered by Hood to be the most productive in the northern part of the Uinta Basin, and it contains the main aquifer in Ashley Valley near Vernal, Utah. In most areas, the aquifer consists of discontinuous terrace coverings with thin saturated sections. The outwash and alluvium form narrow continuous aquifers in many mountain canyon bottoms and stream valleys.

The zone's water is under unconfined conditions, and the permeability ranges from low to very high. Well yields from the aquifers range from less than 1 to 3 cubic feet per second (Hood, 1976).

Duchesne River Formation and Uinta Formation Aquifer Zone

The Duchesne River and Uinta Formations are considered one aquifer zone because of their common hydrologic and lithologic characteristics. The lower sandstone beds of the Duchesne River Formation combine with the upper sandy beds of the Uinta Formation to form one aquifer zone. The Duchesne River Formation is of Oligocene Age and the Uinta Formation is considered to be Eocene. This aquifer zone covers approximately 1,000 square miles in northern Uinta Basin and is the bedrock aquifer system most widely used for water supply in the basin. The majority of the water is used for stock, and domestic purposes.

The aquifer zone has a low to very high permeability. The highest permeability occurs near outcrops west of Roosevelt, Utah, in the basin's center, and the lowest permeability occurs to the north and east of northern Uinta Basin. Wells from this zone yield an average of 1 cubic foot per second (Hood, 1976).

Currant Creek Formation Aquifer Zone

The Currant Creek Formation is Upper Cretaceous Age, and is considered important because of its 2,000-foot thickness. The zone's permeability ranges from low to very high depending on the degree of deformation and leaching in fracture zones. In most areas water is unconfined within the formation (Hood, 1976).

Glen Canyon Sandstone Aquifer Zone

The Glen Canyon Sandstone ranges from 700 to 1,100 feet thick and includes the Nugget Sandstone in the western part of the northern Uinta Basin--the main component of the aquifer zone. The sandstone in this formation is fine-grained, which limits pore space. Highest yields of fresh water from wells and springs occur in the eastern part of the basin, north of Lapoint, Utah. In this area the sandstone has been deformed by folding and faulting which has increased the well yields. The average yield from this aquifer zone is one cubic foot per second and water has a tendency to be slightly saline (Hood, 1976).

Weber Quartzite (Sandstone) Aquifer Zone

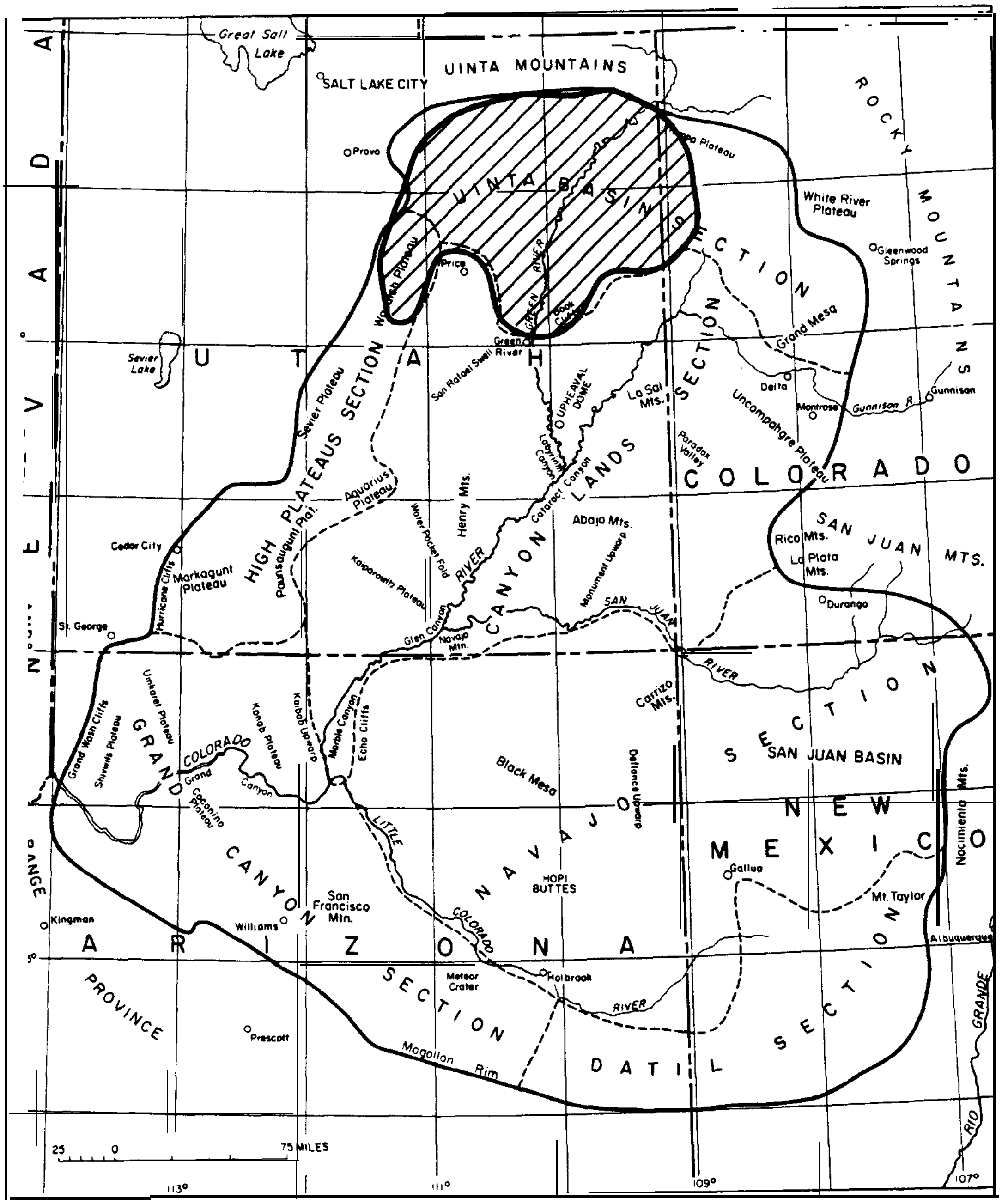
The lower Permian Weber Quartzite aquifer zone is important as an aquifer over the total northern Uinta Basin because it is highly fractured, allowing water to travel freely. Permeability within this zone ranges from very low to very high. Tests have determined that wells yield up to four cubic feet of water per second. Fresh water generally occurs from the shallow wells and springs while saline water is obtained at depths of 7,500 feet (Hood and Fields, 1977).

Mississippian Limestone Aquifer Zone

The Mississippian limestone is considered an important aquifer zone mainly because of its importance to the groundwater recharge system. Limestone caverns hold large amounts of water, and maximum development occurs in areas where maximum structural disturbance and fairly large outcrops coincide. Permeability ranges from low to very high, with low permeability occurring in the undisturbed areas (Hood, 1976).

3.7 ENERGY RESOURCES OTHER THAN COAL

In addition to coal resources, the Uinta Basin contains significant quantities of oil and gas in Mesozoic and Cenozoic rocks. Oil reserves have been extensively developed in the Jurassic Morrison Formation, and the Tertiary Wasatch, Green River, and Uinta Formations. As of 1970, the Uinta Basin contained seven of the top 20 oil-producing wells in the state, classifying the area as a top oil producer nationwide (Stowe, 1972). Natural gas is being produced from the Jurassic Morrison Formation, the Cretaceous Dakota and Ferron Sandstones, and the Tertiary Green River, Wasatch, and Uinta Formations (Stowe, 1972).



EXPLANATION

Uinta Basin Outline

Figure 3-l. Index Map of the Colorado Plateau Province with Sectional Boundaries, Showing the Location of the Uinta Basin Report Area (Thornbury, 1965; After Hunt, U.S.G.S. Professional Paper 279)

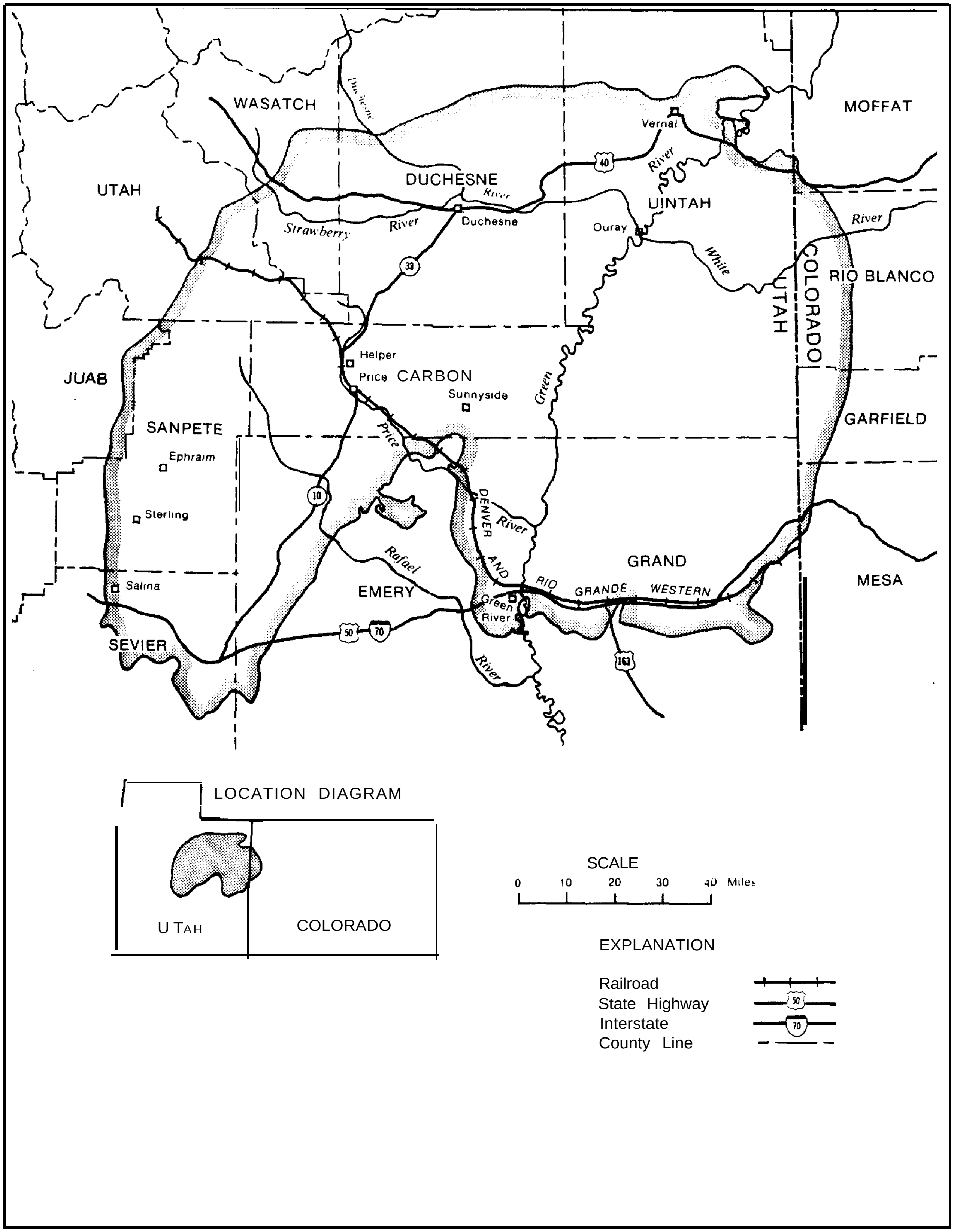


Figure 3-2. Index Map Showing Locations of Major Towns, Highways, Railroads, and Counties in the Uinta Basin

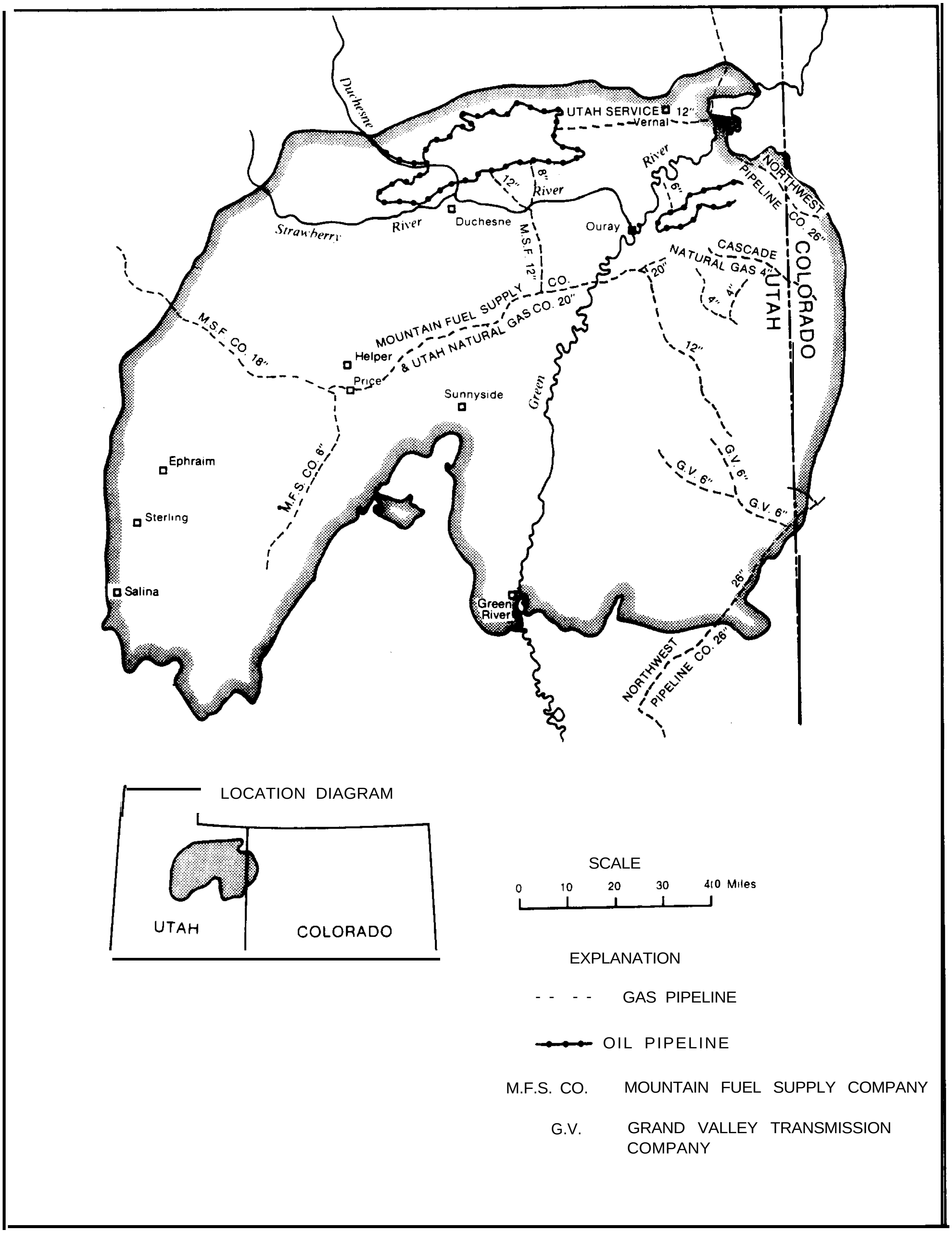


Figure 3-3. Major Oil and Gas Pipelines in the Uinta Basin (After Staff, Utah Geological and Mineral Survey, 1977)

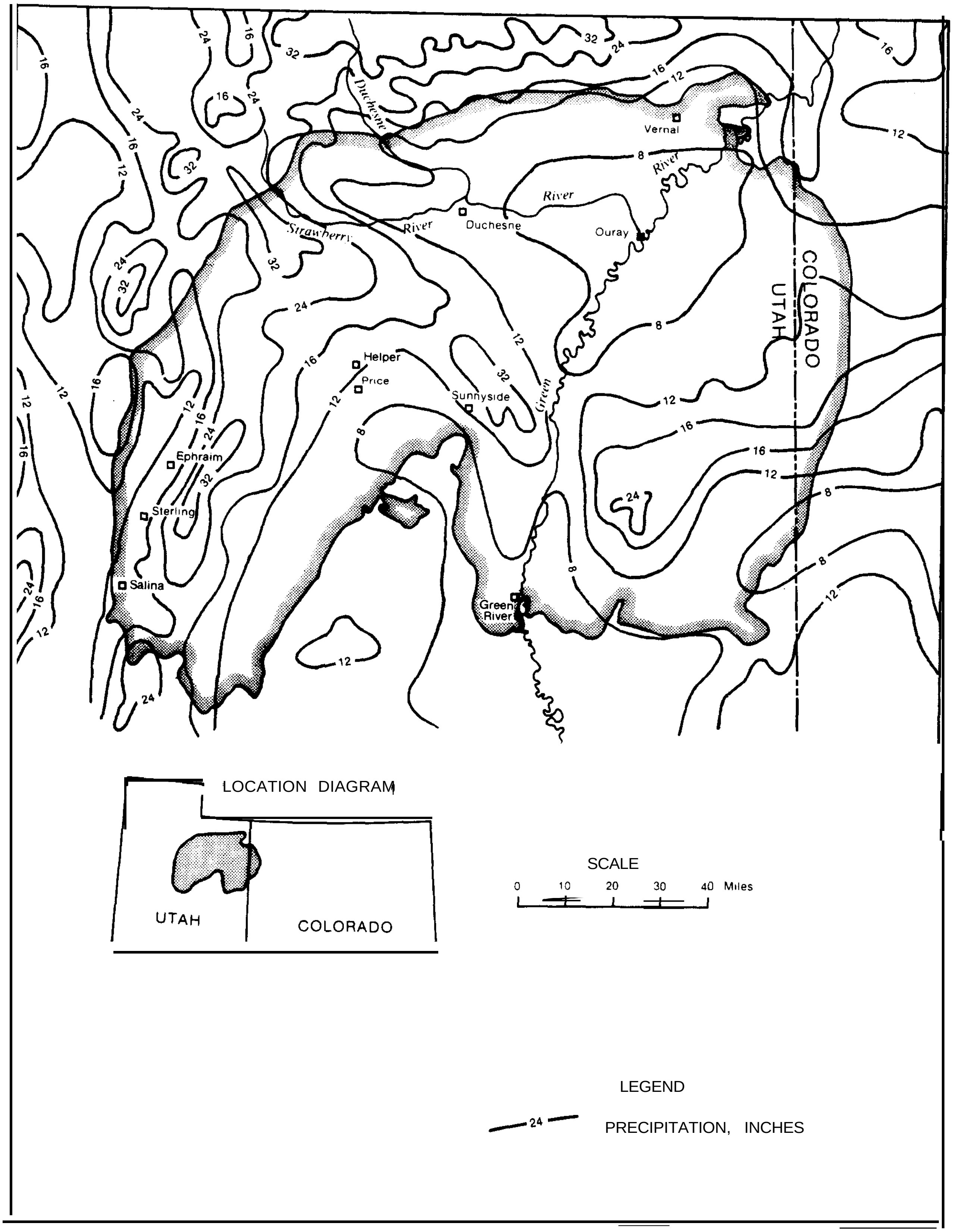


Figure 3-4. Isoline Map Showing the Mean Annual Precipitation of the Uinta Basin (After NOAA, 1974)

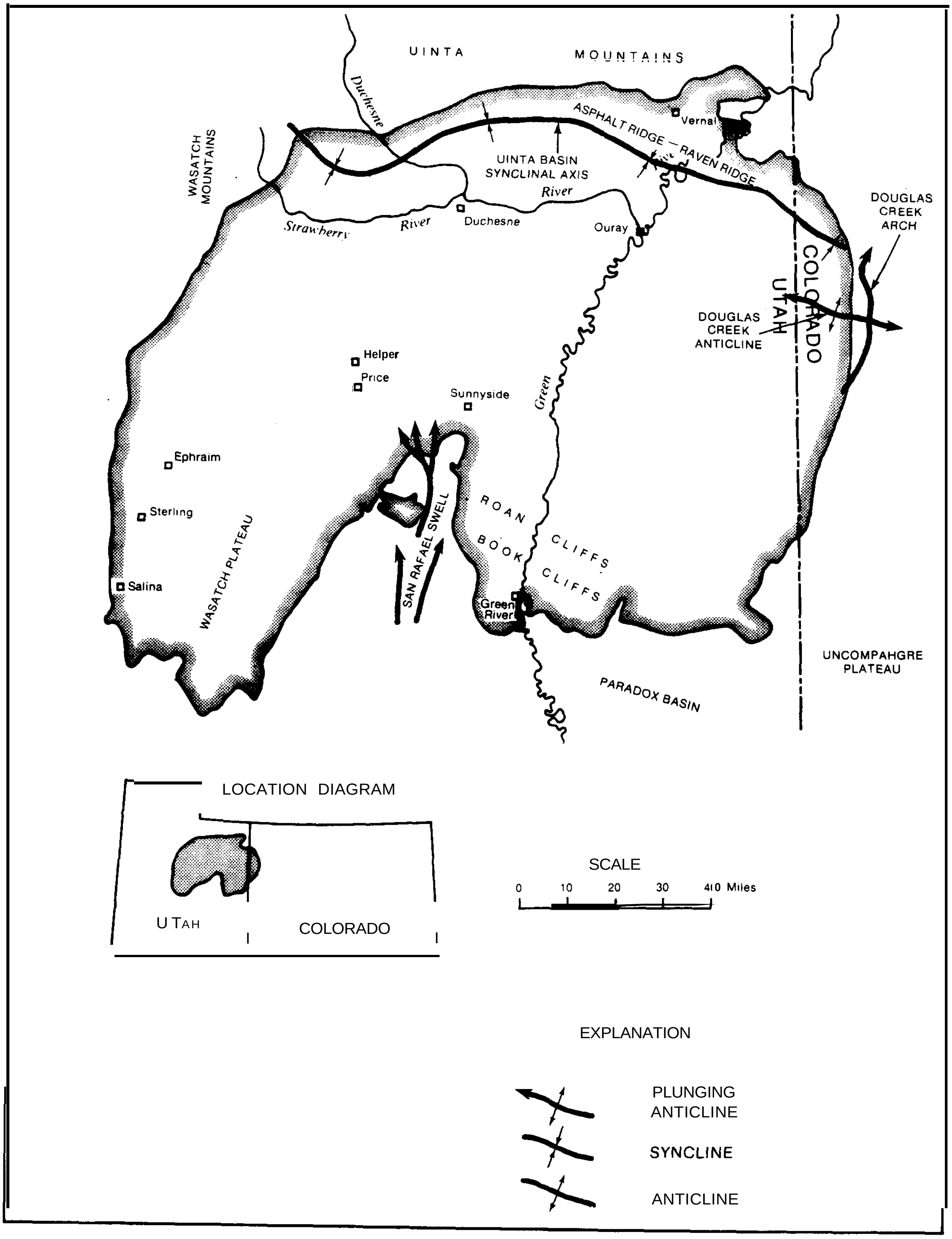


Figure 3-5. Prominent Structural Features Within and Surrounding the **Uinta Basin** (After Osmond, 1974)

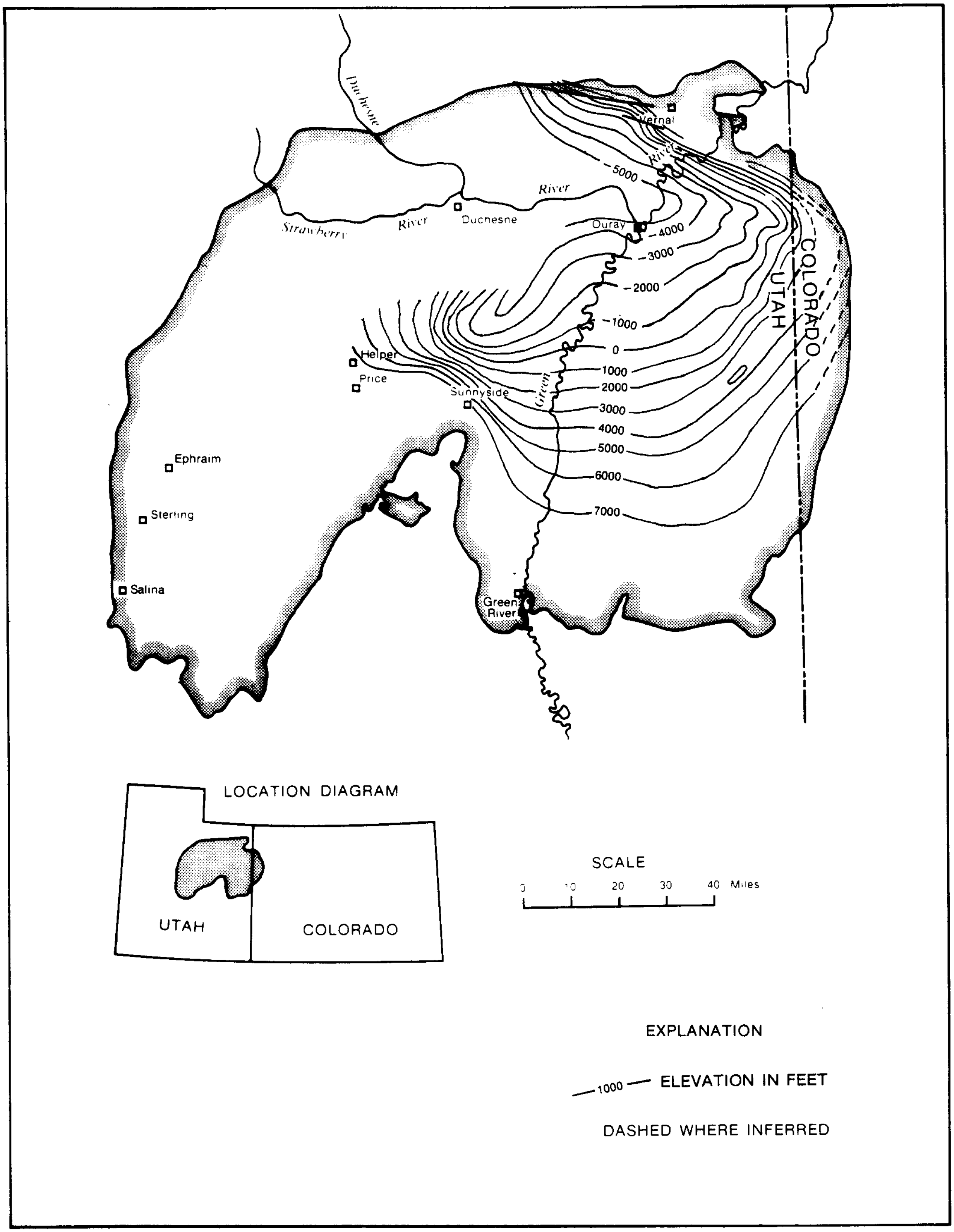
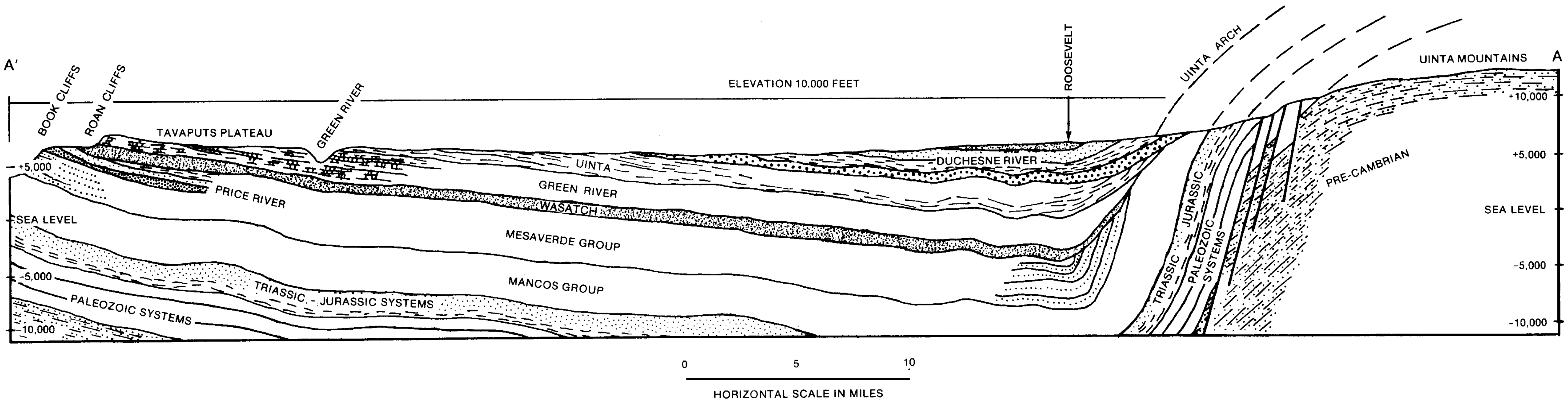


Figure 3-6. Structure Contour on Top of the Mesaverde Group, Uinta Basin (After Doelling, 1972)



LOCATION DIAGRAM

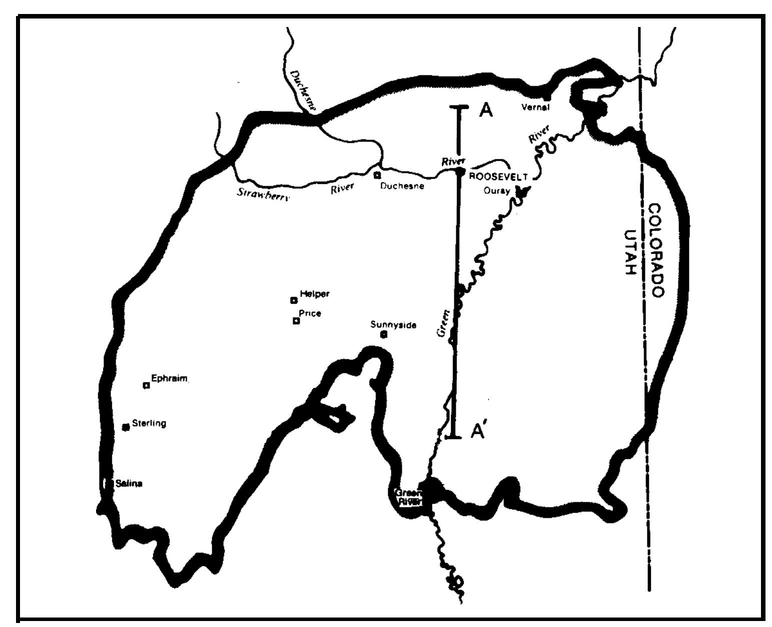


Figure 3-7. North to South Cross Section of the Uinta Basin (After Childs, 1950)

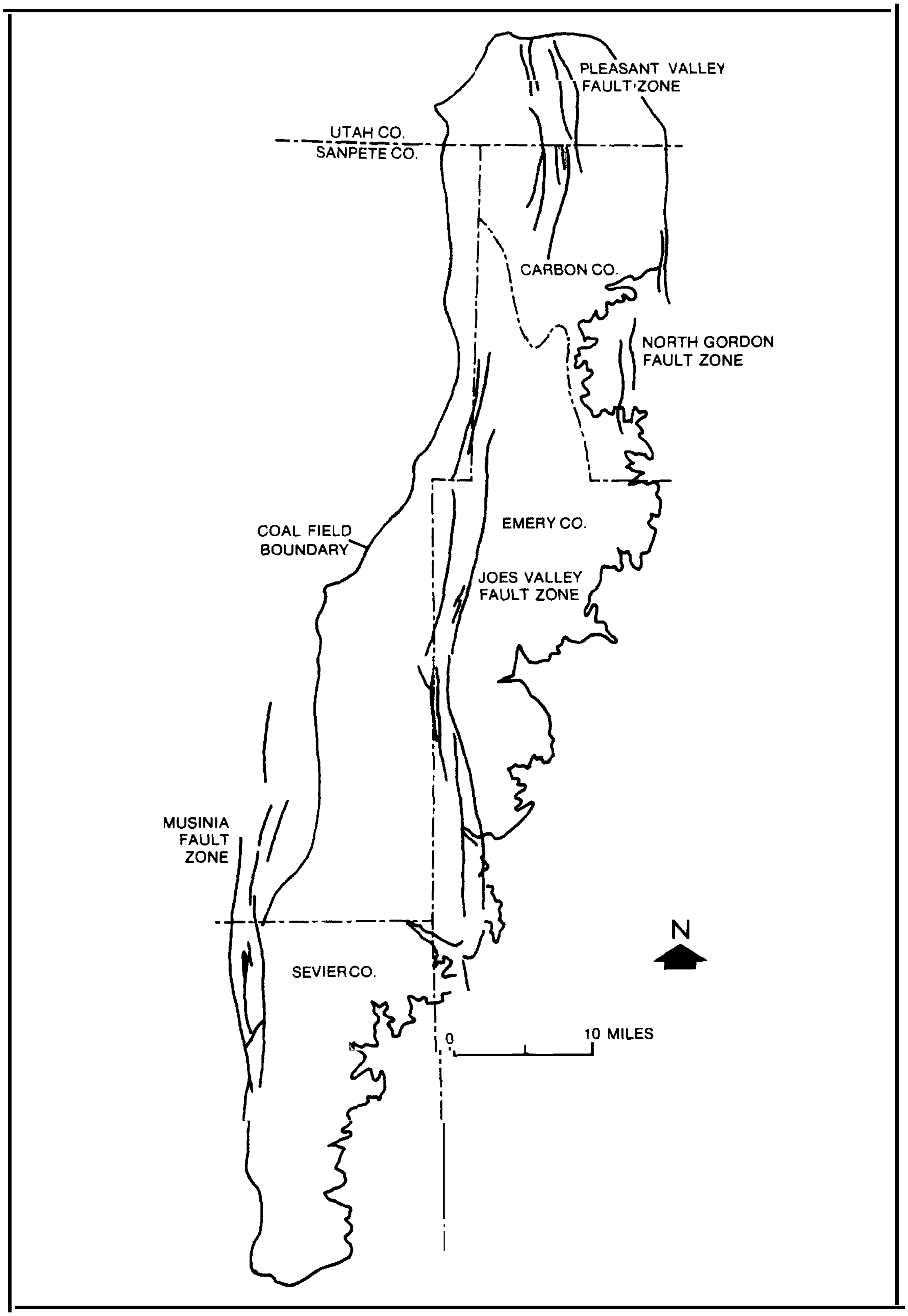


Figure 3-8. Map Showing the Wasatch Plateau Fault Zones in Relation to the Wasatch Plateau Coal Field (After Doelling, 1972). Refer to Figure 4-1 for Location of the Wasatch Plateau Coal Field

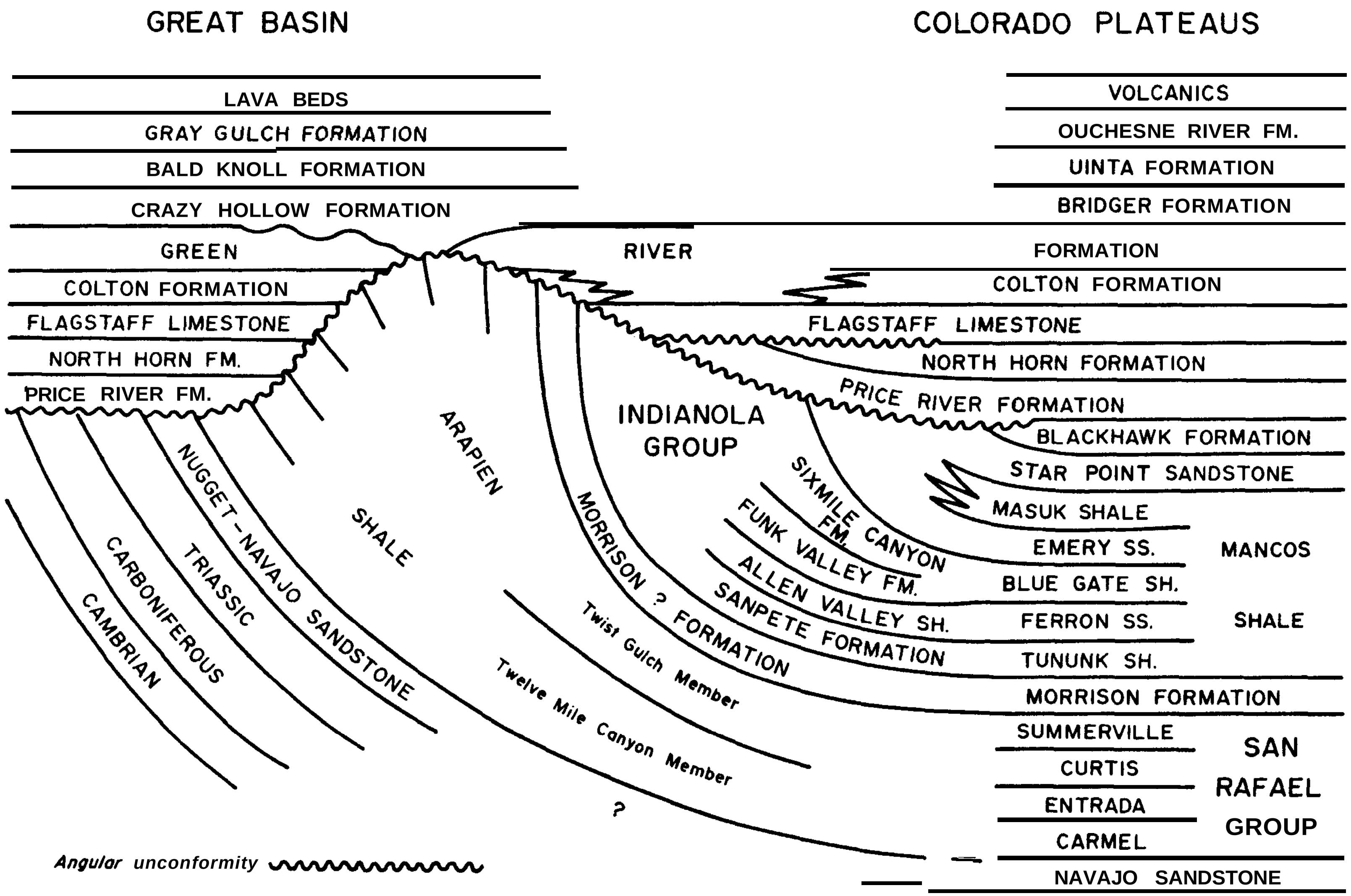


Figure 3-9. Stratigraphic Cross Section from Great Basin to Colorado Plateau Through Sanpete County, Showing Generalized Regional Correlations (Pratt and Callaghan, 1970; After Spieker, 1949)

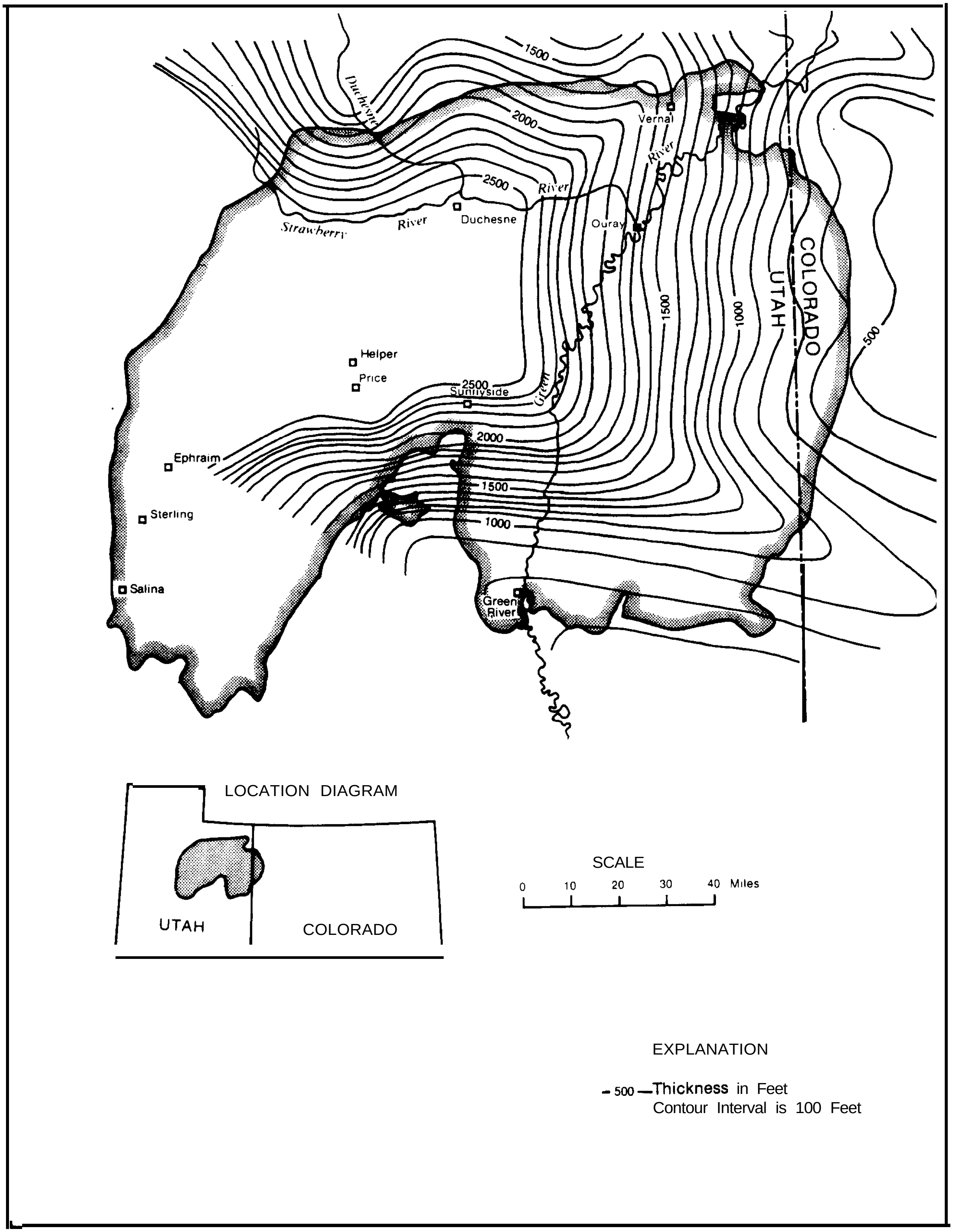


Figure 3-10. Isopach Map of the Pennsylvania System, Restored in Areas Affected by Post-Mississippian Erosion (After Osmond, 1964)

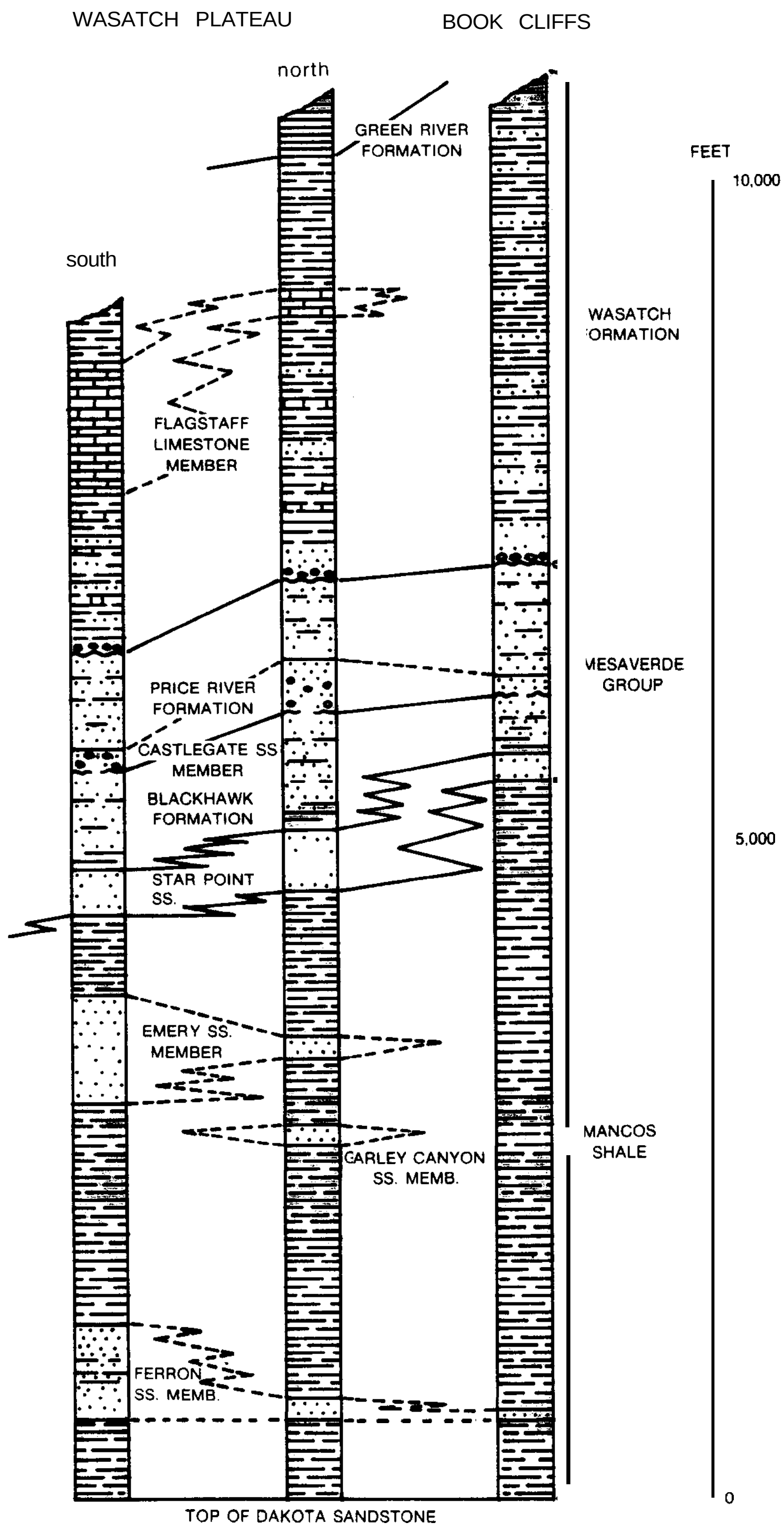


Figure 3-11. Columnar Sections of the Cretaceous and Tertiary Formations of the Wasatch Plateau and Book Cliffs (Spieker and Heeside, 1925)

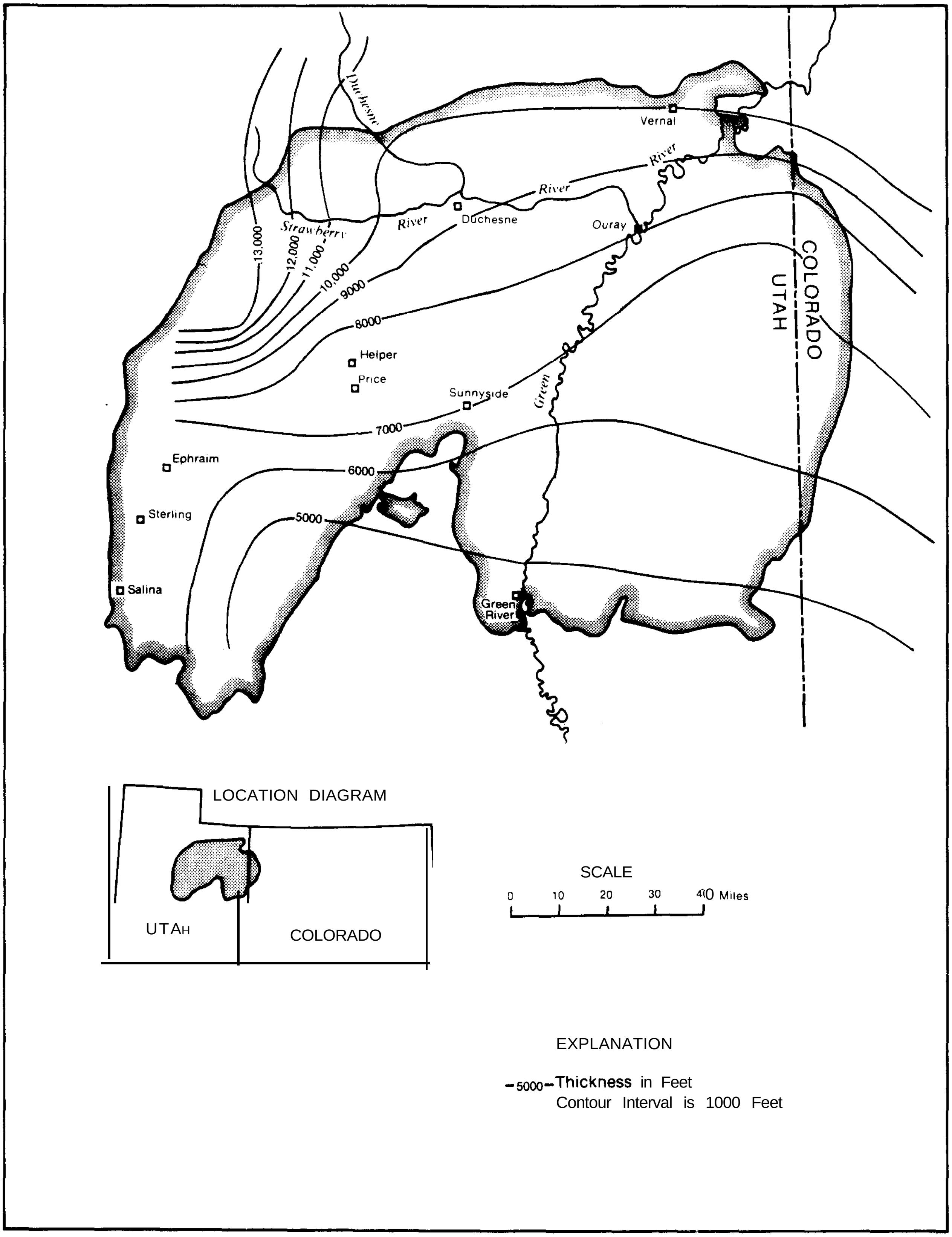


Figure 3-12. Isopach Map of Interval from Top of Dakota Sandstone to Top of Mesaverde Group and North Horn Formation (Osmond, 1964)

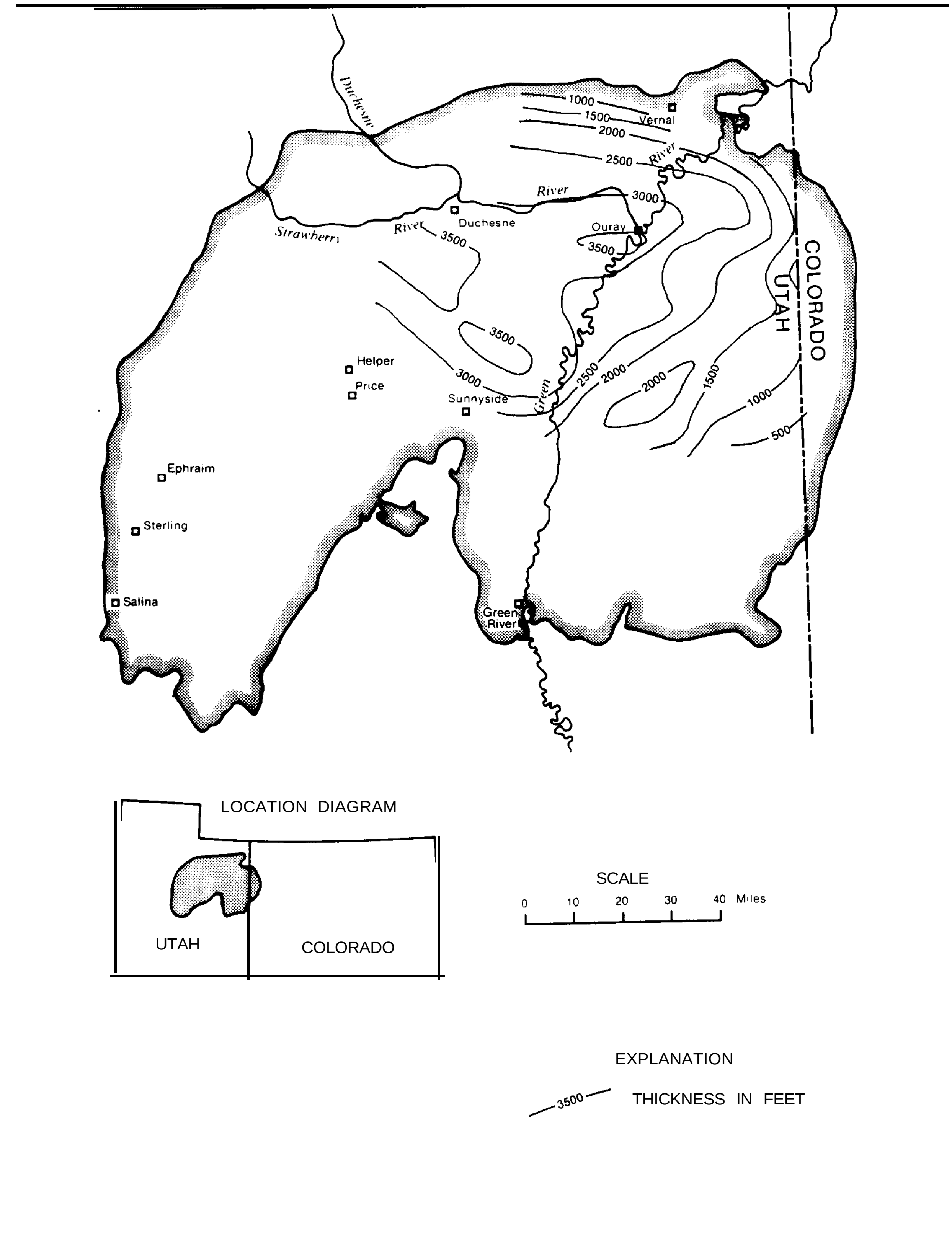


Figure 3-13. Isopach Map of the Wasatch-North Horn-Tuscher Formations (After Murany, 1963)

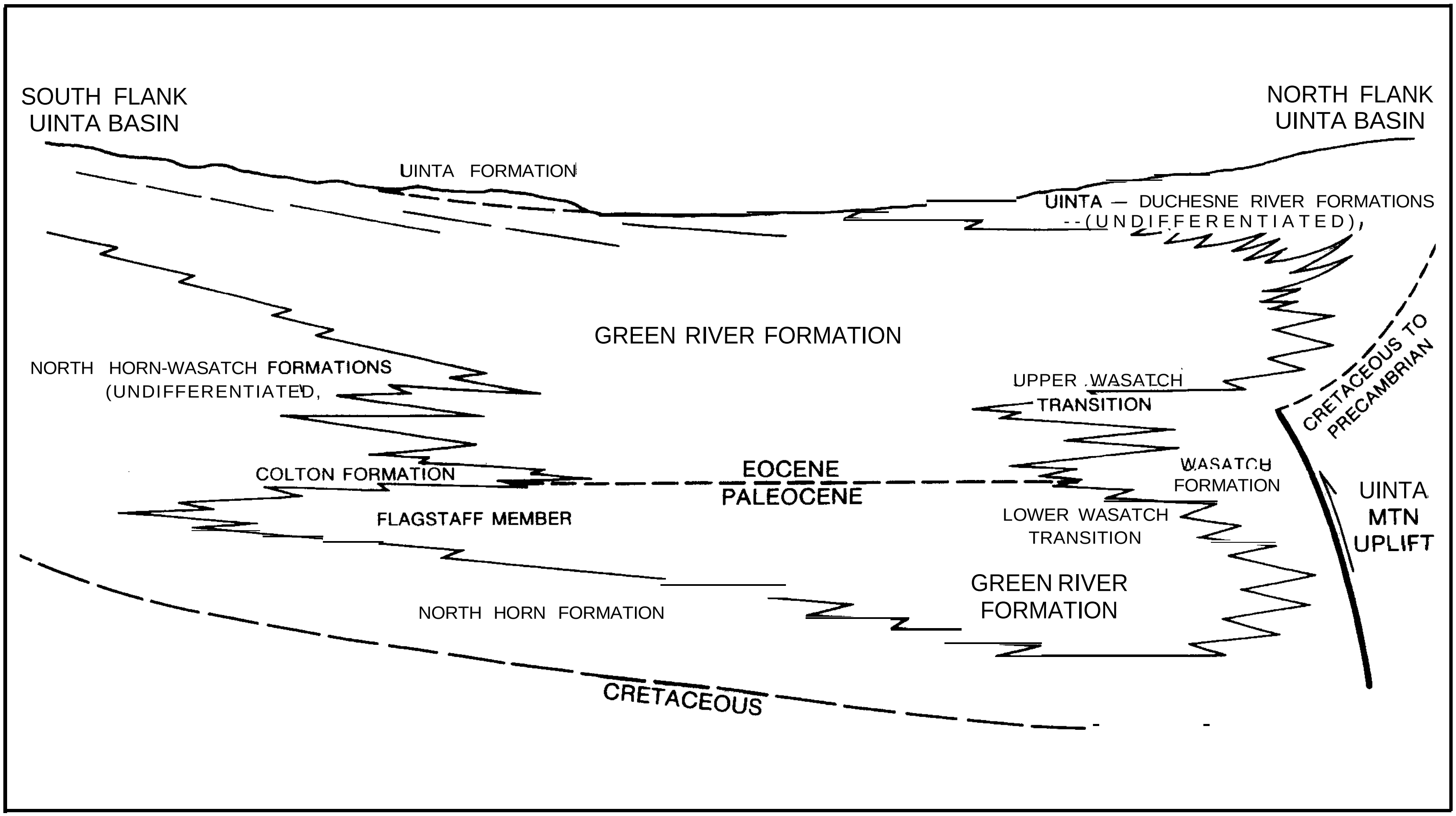


Figure 3-14. Diagrammatic Cross Section North to South Across the Western Part of the Uinta Basin Showing Relationships Among Formations of Paleocene to Oligocene Age (After Hood and Fields, 1977)

Table 3-1. General Stratigraphic Column of the Uinta Basin (After Hood, 1976; Osmond, 1965; Spieker, 1931; Stokes, 1950; and Walton, 1944)

GEOLOGIC TIME		GROUP AND FORMATION		CHARACTER OF BEDS	THICKNESS	
					EAST	WEST
Quarternary		Alluvium		Alluvium, Gravel Surfaces, Talus Deposits, and Other Windblown Deposits		
		Pleistocene Glacial Deposits		Glacial Drift, Alluvium, and Terrace Deposits	0–70	0–70
Tertiary	Miocene	Bishop Conglomerate		Conglomerate, Boulders 1 to 6 Feet in Diameter, Sand and Gravel	0–500	0–500
	Oligocene	Duchesne River Formation		Varicolored Shale, Sandstone, and Conglomerate	1370	1500
	Eocene	Uinta Formation		Shale with Sandstone Interbeds	700–1650	1800–5400
		Green River Formation		Green to White Shale, Sandstone, Oil Shale in Middle of Formation	1800–2400	0–5000
		Wasatch Formation		Varicolored Sandstone, Shale, Limestone	0–5000	–
Paleocene Deposits Absent Due to Unconformity						
Cretaceous		Currant Creek Formation		Conglomerate, Sandstone, and Varicolored Shales	–	0–4800
		North Horn Formation		Varicolored Shale with Sandstone Interbeds	0–400	0–2000
Upper Cretaceous		Mesaverde Group		Upper Section – Brackish-water Sandstone, Sandy Shale, Carbonaceous Shale, and Coal	0–3000	1000–2200
				Lower Section – Marine Sandstone, Buff to Gray	0–500	300–1000
		Mancos Shale (Including Frontier Sandstone Member)		Black Marine Shale, Thick Massive Sandstone, Shaly Sandstone	5000–6000	800–3500
		Dakota Sandstone		Cross-bedded Tan Sandstone	30–50	30–50
Jurassic		Morrison Formation		Varicolored Shale with Sandstone Interbeds	780–800	780–800
Triassic		Chinle Formation		Shale with Minor Sandstone and Conglomerate	230	300–380
		Moenkopi Formation		Shale, Sandstone, Siltstone and Limestone	2300	800
Permian		Park City Formation		Argillaceous, Sandy Limestone	80–500	80–500
Pennsylvanian		Weber Sandstone		Massive Sandstone	1000–1500	1000–1500
		Morgan Formation		Varicolored Shale and Limestone with Sandstone	300–800	300–800
Mississippian		Upper	Manning Canyon Shale Humbug Formation Great Blue Formation Molas Formation Doughnut Formation	Interbedded Shale, Limestone, and Sandstone	0–900	0–900
		Lower	Redwall Formation Leadville Formation Deseret Formation Madison Formation	Massive Dolomite and Limestone	0–1100	0–1100
Devonian		—		Sandstone, Shale, Carbonate	1000	2000
No Identifiable Silurian or Ordovician Deposits						
Cambrian		Tintic Quartzite or Lodore Formation		Sandstone, Shale, and Carbonate	O-2000	0-2000
Precambrian		Uinta Mountain Group		Quartzite with Shale and Conglomerate	12 ,ooo-20,000	
		Uncompahgre Suite		Schist, Gneiss and Granite		

Table 3-2. Water Discharge and Dissolved-Solids Discharge at Selected Stations in the Uinta Basin, 1914-57 (After lorns, Hembree and Oakland, 1965)

STATION	DRAINAGE AREA (SQ MI)	WATER DISCHARGE		DISSOLVED SOLIDS			
		AVERAGE (CFS)	AVERAGE ANNUAL (ACRE-FT)	WEIGHTED, AVERAGE CONCENTRATION (PPM)	AVERAGE DISCHARGE (TONS PER DAY)	AVERAGE ANNUAL YIELD PER SQUARE MILE (TONS)	AVERAGE ANNUAL DISCHARGE (TONS)
Green River at Jensen, Utah	26,160	4.607	3,338,000	316	3,930	55	1,435,000
Duchesne River at Duchesne, Utah	660	323	234,000	218	190	105	69,400
Strawberry River at Duchesne, Utah	1,040	157	113,700	396	168	59	61,360
Duchesne River Near Randlett, Utah	3,920	767	555,700	608	1,260	117	460,200
White River Near Meeker, Colorado	762	638	462,200	244	420	201	153,400
White River Near Watson, Utah	4,020	764	553,500	439	905	82	330,600
Green River Near Ouray, Utah	35,500	6,223	4,508,000	392	6,590	68	2.407.000
Price River at Woodside, Utah	1,500	116	84,040	2,110	662	161	241,600

Table 3-3. Geologic Units that Outcrop in the Northern Uinta Basin with Information on the Major Aquifer Zones (After Hood and Fields, 1977)

Era	Geologic Time	Geologic Unit: Western Part of Basin	Geologic Unit: Eastern Part of Basin	Average Aquifer Thickness (FT)*	Minimum Area of Aquifer Zone (Acres)*	Well Yields Average (CFS)*	Ground Water Storage (Million AC-FT)*	Aquifer Description*
CENOZOIC	Quaternary	Alluvium, Gravel Surfaces, Talus Deposits, Dune Sand and Other Windblown Deposits	Alluvium, Gravel Surfaces, Talus Deposits, Dune Sand and Other Windblown Deposits					
		a/ Glacial Deposits, Alluvium of Pleistocene Age, and Terrace Deposits	a/ Glacial Deposits, Alluvium of Pleistocene Age, and Terrace Deposits	50	400,000	1–3	2.0	
	Tertiary	b/ Browns Park Formation	b/ Browns Park Formation					
		Extrusive Igneous Rocks						
		a/ Duchesne River Formation	a/ Duchesne River Formation	1,000	640,000	1	6.4	
		a/ Uinta Formation	a/ Uinta Formation	200	760,000	1	1.5	Uppermost sandy section of formation combines with Duchesne River Formation to form one zone
		Green River Formation	Green River Formation					
		Wasatch Formation	Wasatch Formation					
MESOZOIC	Cretaceous	a/ Currant Creek Formation		2,000	230,000		2.3	Sandstone aquifer zone
			b/ Mesaverde Group					
		Mancos Shale (Including b/ Frontier Sandstone Member)	Mancos Shale (Including b/ Frontier Sandstone Member)					
		Dakota Sandstone and Cedar Mountain Formation, Undivided	Dakota Sandstone and Cedar Mountain Formation, Undivided					
	Jurassic	Morrison Formation	Morrison Formation					
		b/ Curtis Formation	b/ Curtis Formation					
		b/ Entrada Sandstone	b/ Entrada Sandstone					
		Twin Creek Limestone	Carmel Formation					
	Jurassic and Triassic	a/ Glen Canyon Sandstone, Nugget Sandstone	a/ Glen Canyon Sandstone, Nugget Sandstone	900	690,000	1	6.2	Nugget and Glen Canyon Sandstone – same
	Triassic	Chinle Formation (Including b/ Gartra Member)	Chinle Formation (Including b/ Gartra Member)					
		Mahogany Formation Thaynes Formation (or Group) Woodside Formation	Moenkopi Formation					
PALEOZOIC	Permian	Park City Formation (or Group)	Park City Formation (or Group)					
	Permian and Pennsylvanian	a/ Weber Quartzite	a/ Weber Quartzite	1,300	880,000	1–4	8.6	East of the Uinta River Canyon, also called the Weber Sandstone
	Pennsylvanian	b/ Morgan Formation	b/ Morgan Formation					Sandstone aquifer zone
	Pennsylvanian and Mississippian	Manning Canyon Formation	Manning Canyon Formation					
	a/ Mississippian	Upper Mississippian Rocks, Undivided Lower Mississippian Rocks, Undivided	Mississippian Rocks, Undivided	950				Cavernous limestone in rocks principal aquifer
	Cambrian	Tintic Quartzite	Lodore Formation					
	Precambrian	Red Pine Shale of Uinta Mountain Group						
		Unnamed Quartzite Unit of Uinta Mountain Group	Unnamed Quartzite Unit of Uinta Mountain Group					
		Lower Part of the Uinta Mountain Group, Undivided						

*Information available for major aquifer zones

Geologic Units: a, considered to be a major hydrologic unit because of large areal extent or thickness, large yields to wells or springs, or function as recharge media; b, considered to be an important hydrologic unit, but restricted in potential development because of limitations in thickness, distribution, or chemical quality of water.

4. COAL RESOURCES BY AREA

Coals of the Uinta Basin and Wasatch Plateau are contained within seven coal fields or regions (Figure 4-l). The coal areas are located on the basin's perimeter and cover the majority of the Wasatch Plateau. The Uinta Basin includes a small part of northwest Colorado, west of the Douglas Arch; however, because of that area's limited coal content, it will not be discussed in this report.

Counterclockwise from the northeast corner of the basin, the coal areas are the Vernal coal field, Tabby Mountain coal field, Sevier-Sanpete region, Wasatch Plateau coal field, Emery coal field, Book Cliffs coal field, and Sego coal field. These coal fields and regions cover approximately 3,016 square miles of the 11,550 square miles of the basin, and plateau. Important coals within this region are of Cretaceous age. Figure 4-2 shows the regional correlation of the Cretaceous age deposits and Table 4-l the relationship of the major Cretaceous coal among the seven coal fields.

The majority of the Utah coal information in this section was extracted from the Utah Geological and Mineralogical Survey's Monograph Series by Doelling and Graham (1972).

Environment of Deposition--Coal

During the Cretaceous Period marine water covered the Uinta Basin from its east edge to the western boundary of the Basin and Range Province. From Early to Late Cretaceous subsidence and deposition occurred in the Uinta Basin until the tectonic activity of the Larimide orogeny pushed the shoreline eastward. Transgression and regression of the seas and the associated deltaic environment created conditions favorable to the growth and accumulation of large quantities of vegetation which formed coalbeds up to 25 feet thick. Coals formed during the transgressive phase of the seas are the Ferron and Frontier coals located in the Tabby Mountain and Vernal coal fields. Coals formed during the regressive cycle of the seas are the Blackhawk Formation of the Wasatch Plateau coal field, the Book Cliffs coal field, and the Neslen Member coal of the Sego coal field (Doelling, 1972).

The majority of sediments deposited during the Cretaceous Period formed a yellow-gray, tan or brown, fine- to coarse-grained, sandstone. This sandstone is highly lenticular and is found in thin to massive beds. Shales and mudstones also were deposited with varying amounts of coal, and carbonaceous material.

4.1 VERNAL COAL FIELD

The Vernal coal field, located in northeast Utah, lies principally in Uintah County and covers the northeast corner of the basin. It is 40 miles long in the east-west direction, 24 miles wide north to south, and covers an area of approximately 960 square miles (Doelling and Graham, 1972). The major coalbeds are of Cretaceous age and are found in two formations, the Frontier Sandstone, and the Mesaverde Formation. Coalbeds within the two formations generally are thin, split and steeply dipping (Doelling and Graham, 1972).

In the coal field, the Frontier Sandstone ranges from 150 to 300 feet thick and is composed of clay shale, silty and sandy shale, carbonaceous shale, sandy siltstone, sandstone, and coal. Figure 4-3 correlates the Frontier Sandstone sections throughout the field and illustrates variation in coal thickness over the area. The sandstone is divided into lower and upper members. The lower member is 75 to 203 feet thick, and consists of clay shale, silty to sandy shale, and shaly sandstone. The unit is a slope former with a few thin beds of resistant sandstone (Doelling and Graham, 1972). The upper member, the major coal-bearing unit, is divided into three units: a lower thick massive sandstone; a 10 to 50 foot thick coal zone; and a resistant sandstone caprock. The coal generally is split, and is ranked as high-volatile B or C bituminous with a medium sulfur content (Doelling and Graham, 1972). Tables 4-2 and 4-3 show a comparison of ultimate and proximate analyses of coalbeds and zones within the seven coal fields of the Uinta Basin.

The Mesaverde Formation is divided into four units: the Asphalt Ridge Member; the Rim Rock Member; the third; and the forth units. Sections of the Mesaverde Formation in the Vernal coal field are shown in Figure 4-4. The coals within this formation generally are subbituminous C rank.

The Asphalt Ridge Sandstone is the basal unit of the formation and is approximately 110 feet thick along Asphalt Ridge. The member is composed of yellow to white, fine- to medium-grained, subangular sandstone and siltstone. The Rim Rock Sandstone's type locality is the Rim Rock Hogback, a topographical escarpment extending from the Green River eastward into Colorado. The unit is composed of fine- to coarse-grained sandstone interbedded with shale, coal, and carbonaceous shale, and ranges from 150 to 530 feet thick. The coal within this unit is found east of the Green River, and consists of a few lenticular, thin coalbeds (Doelling and Graham, 1972).

The'third and fourth units also are known as the Upper Mesaverde Williams Fork Formation. The third unit is a medium resistant interbedded sandstone and shale, while the fourth unit is composed of soft sandstone and shale. Within the third and fourth units are numerous lignitic coalbeds and a few bituminous coals. The quality of the coal improves to the east throughout the coal field and has a low-sulfur content.

Original resources in the field for the Frontier Sandstone and Mesaverde Formation have been estimated to be 164.3 million short tons and 12.9 million short tons, respectively. Before 1955, 254,000 short tons of coal were mined from the Frontier Sandstone, with less than 2,000 short tons removed from the Mesaverde Formation (Doelling and Graham, 1972). The amount of coal mined out after 1955 is considered insignificant.

The federal government owns and controls approximately half of the coal field, with the rest of the fields' ownership divided between the Ouray and Uintah Indian Reservations, the State of Utah, and the National Park Service (Doelling and Graham, 1972).

4.2 TABBY MOUNTAIN COAL FIELD

The Tabby Mountain coal field is located on the southwest flank of the Uinta Mountains. Extending 35 miles east to west and varies from 1 to 3 miles north to south, the field covers an estimated 70 square miles of Wasatch and Duchesne counties in Utah (Doelling and Graham, 1972).

Coals in this field are contained in two steeply dipping Upper Cretaceous formations: the Frontier Sandstone and the Mesaverde Formation. These two formations have multiple coal zones, and each contains thick coalbeds (Figure 4-5). The Frontier Sandstone is a gray to yellow, fine- to coarse-grained, thin to thickly bedded sandstone with coal. In one section of the sandstone, along Red Creek in sections 16 and 21, T.15S, R.9W., 27 feet of coal was measured by Lupton (1912) in four coalbeds. Coal within the sandstone is subbituminous C rank (Doelling and Graham, 1972). Tables 4-2 and 4-3 present additional coal rank and quality information. The upper section of the Mesaverde Formation contains the greatest number of coalbeds of the two formations. The formation ranges from 550 to 4,000 feet thick within this coal field and contains coal ranked as high-volatile C bituminous. In one section of the Mesaverde Formation, along Red Creek in sections 22, 23, and 26, T.15S., R.9W., over 29 feet of coal was measured by Lupton (1910) (Doelling and Graham 1972).

Total resources in the coal field are estimated to be 1.8 billion short tons, with approximately 231 million short tons found in coalbeds greater than four feet thick, and under less than 3,000 feet of cover. Of the 231 million tons, 168 million tons are located in the Mesaverde Formation, the Frontier Sandstone containing the remaining 63 million tons. Total past production in the field is estimated as only a few thousand tons (Doelling and Graham, 1972).

Private entities and the National Forest Service account for 45 and 36 percent of the field's land ownership, respectively. The Uinta and Ouray Indian Reservations own an estimated 17 percent, and the State of Utah and the Bureau of Land Management each own less than one percent of the land (Doelling and Graham, 1972).

4.3 SEVIER-SANPETE REGION

The Sevier-Sanpete region consists of four coal fields in Sevier and Sanpete Counties in central Utah, the Mount Pleasant, Sterling, Wales, and Salina Canyon (Figure 4-6).

The Mount Pleasant coal field is located in the northeast corner of the region and covers approximately 30 square miles. The field measures 10 miles north to south, and averages 3 miles wide. Major coalbeds occur in the Upper Cretaceous lower Blackhawk Formation with minor thin coalbeds in the North Horn, Price River, and upper Blackhawk Formations. The lower Blackhawk Formation contains six coalbeds referred to as A to F in descending order. Refer to Figure 4-7 for correlation of coalbeds through the four coalfields. These coalbeds possibly are continuous with the Wasatch Plateau coals. The thickest coalbed is the top A bed which averages 5.7 feet thick, and occurs approximately 955 feet from surface level. A 71-foot interval is between the A and B coalbeds (Doelling, 1972). The B coalbed averages 2 feet thick, and has the highest Btu/lb level within the coal field. A 63-foot interval separates the B bed from the 3.5-foot C bed. Between the C and D coalbeds a 47-foot interval is found. The D bed averages 5 feet thick with a 3-foot interval separating it from the E coalbed. The 3-foot thick E bed is separated from the 1.5-foot thick F bed by a 100-foot interval. The E and F beds have the highest ash content of the Mount Pleasant coal field. The six coalbeds are high-volatile C to A bituminous in rank (Tables 4-2 and 4-3) (Doelling, 1972). Coal resources in the Blackhawk Formation for this field are estimated to be 249 million tons, with the previously mined-out coal considered negligible (Doelling, 1972).

The Sterling coal field covers less than 2 square miles on the west edge of the Wasatch Plateau in the central part of the region. The Cretaceous Six Mile Canyon Formation is the major coal-bearing zone, and contains six coalbeds or zones which range from 1 to 4 feet thick (Figure 4-7). The coalbeds or zones are separated by sandstone intervals ranging from 3 to 75 feet thick. The coal primarily dips 15" to 30" southeast with a limited area in the north end of the field dipping 20" to 50" east (Doelling, 1972). The coalbeds generally are split, and lenticular with the coal being a lustrous black. Two principal joint patterns occur, one oriented north to south, and the other east to west. One analysis has been completed for the B coalbed ranking it as high-volatile C bituminous. (Doelling, 1972). Minor coalbeds are located in the Blackhawk Formation and Castlegate Sandstone in the Sterling coal field. Resource estimates for most coal within the field are lacking because of limited studies of the area. The one exception is the Blackhawk Formation where there are an estimated 2 million tons of resources. As of 1955 only 60,000 tons of reserves had been mined out of the field (Doelling, 1972).

The Wales coal field is located on the east flank of the Gunnison Plateau in the northern half of Sanpete County. The field covers 5.5 miles north to south and because of steeply dipping beds is only 1 mile wide. Major coalbeds are in the middle unit of the Cretaceous North Horn Formation with minor coals found in the Colton and South Flat Formations (Figure 4-7). Coalbeds within this field are lenticular and badly split by bone and shale. The coals are high in ash and sulfur content, and generally are bituminous in rank. The coalbeds dip 10" to 16" west and have been known to dip as steeply as 64° west (Doelling, 1972). The last mining operation within the Wales Coal Field occurred in 1955, the total amount of coal produced being 175,000 tons (Doelling, 1972). Resource estimates are not available for this field.

The Salina Canyon coal field covers a 40-square mile area in the southern half of the Sevier-Sanpete region. The field contains three important coal zones in the Cretaceous upper Blackhawk Formation (Figure 4-7). The two uppermost zones contain thin beds, whereas the lower zone contains thick coalbeds which range up to 6.5 feet thick which are located approximately 110 feet above the base of the Blackhawk Formation. Thin lenticular coalbeds are also found in the Castlegate Sandstone. As of 1955, 430,000 tons of coal had been mined out of the field, with a total resource estimate for the Blackhawk Formation being approximately 86.4 million tons (Doelling, 1972).

The Sevier-Sanpete region's land is owned and controlled by the National Forest Service, the Bureau of Land Management, the State of Utah, and private interests. The possibilities of mining being rejuvenated in the area are low for the following reasons: the coalbeds are thin and split; the beds are lenticular and limited in their area1 extent; the majority of coal has thick cover; and regional proximity to major transportation routes is lacking (Doelling, 1972).

4.4 WASATCH PLATEAU COAL FIELD

The Wasatch Plateau coal field includes parts of Emery, Carbon, Sevier, and Sanpete Counties. The northerly trending coal field is 90 miles in length, 7 to 20 miles wide, and covers approximately 1,100 square miles (Doelling, 1972). The coalbeds are found in the Upper Cretaceous

Blackhawk Formation. Beds of this formation dip gently in a west-northwesterly direction and are displaced by numerous fault zones. These fault zones cut through the coal field parallel to the north-south axis of the field. On the field's east boundary, coal crops out on cliff faces, while to the west the Wasatch monocline and faulting cause the coal to drop under 2,500 feet of cover (Doelling, et al, 1979). In the north part of the field the coal dips into the Uinta Basin. The northeast portion of the field is similar to the Book Cliffs coal field, but the two fields are separated by the North Gordon Fault Zone. Along the south boundary of the coal field, the coal is almost entirely under volcanics.

The Blackhawk Formation is 700 to 1,500 feet thick and consists of sandstone, shale, carbonaceous shale, and coal. The formation forms slopes and ledges between the overlying Castlegate Sandstone (basal unit of the Price River Formation) and the underlying Star Point Sandstone. The coalbeds are located in the lower 300 feet of the formation (Figure 4-8). Twenty-two coalbeds greater than 4 feet thick have been identified, with the most important being the Hiawatha, Castlegate "A", Blind Canyon, and Wattis coalbeds (Table 4-4). The beds generally are not continuous north to south through the field (Figures 4-9 and 4-10). The coal is generally thick in the northern half of the coal field, with thinner coalbeds found in central and far southern parts of the field (Doelling, 1972).

The coalbed's rank decreases towards the southern end of the field. To the north the coalbeds are ranked as high-volatile B bituminous (Tables 4-2 and 4-3). Coalbeds in the southern end of the local field are high-volatile C bituminous, and there are local areas of high-volatile A bituminous coal. The coals contain between 6 to 8 percent resin (Doelling, 1972).

Resources of the Wasatch Plateau coal field are 6,230 million tons with potential reserves, comprised of coalbeds greater than 4 feet thick and under less than 3,000 feet of cover, estimated to be 3,888 million tons. An estimated 100 million tons of coal was mined from the field as of 1972. Private property and National Forest Service lands overlie the majority of coal-bearing strata (Doelling, 1972).

4.5 EMERY COAL FIELD

The Emery coal field also known as the Castle Valley coal field, lies along the Emery-Sevier county line directly east of the lower third of the Wasatch Plateau coal field. The field is 35 miles long, 6 miles wide, and covers approximately 210 square miles (Doelling, 1972).

The important coalbeds are found in the upper portion of the Ferron Sandstone Member of the Mancos Shale (Figure 4-11). The coal crops out in the southeast margin of the field below the sandstone cliffs where the beds dip gently 3" to 5" westward. The coal thins to the north and disappears in outcrops, while to the west and northwest, coal is buried under overlying formations, and to the south, beneath volcanics. Thirteen coalbeds have been defined in four zones, with total coal zone thickness ranging from 400 to 500 feet. The coalbeds are labeled A through M, in ascending order. The most important coalbeds are the A and C beds in the lower coal zone and the I bed in the upper coal zone (Figure 4-12). Coalbeds within the Ferron Sandstone Member contain high-volatile C bituminous coals and are generally lenticular and discontinuous (Tables 4-2 and 4-3) (Doelling, 1972). Coalbeds in the lower zone are lower in sulfur content and higher in ash than coal found in the upper zone. The 13 coalbeds have an average thickness of 13 feet with six coalbeds greater than 4 feet thick. In some instances two coalbeds will coalesce to form a thicker coal body up to 25 feet thick (Doelling, Smith, and Davis, 1979).

Coalbeds A to E occur in the basal 75-foot interval of the sandstone. Coals F and G are found in the middle 75- to 150-foot interval, and coalbeds H to L are found in an upper zone ranging from 75 to 125 feet thick. The M bed is located near the top of the unit.

In the Emery coal field, original coal resources were estimated to be greater than 1.4 billion tons in beds greater than 4 feet thick and under less than 3,000 feet of cover. Seventy-five percent of the resources is estimated to be under less than 1,000 feet of cover. As of 1972, approximately 1.6 million tons of coal had been mined from the field, the majority from two mines (Doelling, 1972).

Half of the Emery coal field is owned and controlled by the Bureau of Land Management, with the remaining half divided between the private sector, the National Forest Service, and the State of Utah (Doelling, 1972).

4.6 BOOK CLIFFS COAL FIELD

The Book Cliffs coal field extends from the North Gordon fault zone, 70 miles southeast along the Book Cliffs to the Green River. The coal field averages 4 miles wide and covers an estimated 280 square miles. The field is a northward dipping monocline with coal exposed along cliffs at the south boundary of the Uinta Basin. The cliff-front is irregular, and deeply cut by perpendicular drainages (Doelling, 1972).

Within the field major coal deposits are found in the Upper Cretaceous Blackhawk Formation which ranges in thickness from 400 to 1,300 feet (Figure 4-13). The formation was deposited by the sea's eastward regression during the Cretaceous Period, causing coalbeds to the west to be slightly older than those in the east. The beds dip gently to moderately an average of 3" to 7" northeast. Individual coalbeds reach a maximum of 25 feet thick with average coalbed thickness ranging from 6 to 13 feet (Figures 4-14 and 4-15). The coal has a low sulfur content, and a high-volatile B bituminous rank (Table 4-2 and 4-3).

Along the western margin of the coal field, partings of carbonaceous mudstone and/or bone shale divide some of the coalbeds into splits. To the east, a few coalbeds contain partings of carbonaceous mudstone or sandstone tongues. Volcanic ash parting have been discovered in Upper Cretaceous coals which are older than the Upper Cretaceous Blackhawk Formation.

Coal within the Book Cliffs coal field has well developed cleat, and contains cone-shaped masses of slickensided rock referred to as "bells," "pots," "camel-backs" or "tortoises" (Young, 1976). Clastic dikes cut through the coal at high angles causing nearby coal composition to be altered.

The coal field is subdivided into four areas: Castlegate, Soldier Canyon, Sunnyside, and Woodside (Figure 4-16). Important coalbeds and zones within the Book Cliffs coal field are: the Spring Canyon, Castlegate, and Kenilworth in the Castlegate area; the Gilson and Rock

Canyon in the Soldier Canyon area; the Lower Sunnyside in the Sunnyside area; and the Beckwith zone in the Woodside area (Figure 4-17).

The western half of the Book Cliffs coal field has seven widely traceable coalbeds in the Blackhawk and Price River Formations. Each of the seven beds is greater than 14 feet thick, and all occur in the lower 500 feet of the Blackhawk Formation. The coalbeds are, in ascending order: the Aberdeen (Castlegate "A"), Kenilworth (Castlegate "D"), Gilson, Fish Creek, Rock Canyon, Lower Sunnyside, and Upper Sunnyside. In general, the coals are highly attrital with a few vitrain bands with the majority of the coal showing closely spaced cleats (Young, 1976).

The Castlegate "A" coalbed, also referred to as the Aberdeen bed, is exposed near Castlegate, Utah and can be traced for 18 miles from Spring Canyon to Coal Creek Canyon. The maximum known thickness for this bed is 19.8 feet at the Kenilworth mine. There is an interval of approximately 200 feet between the Castlegate "A" bed and the Castlegate "D" bed (Young, 1976).

The Castlegate "D" or Kenilworth coalbed is a widespread lenticular coal with a maximum recorded thickness of 18.8 feet at Kenilworth, Utah, although the bed averages 6.7 feet. At the coalbed's thickest point, it is assumed that the Castlegate "D" bed has coalesced with the Gilson and Fish Creek coalbeds. The interval between the Castlegate "D" and Gilson coalbeds ranges up to 47 feet where mapped (Young, 1976).

The Gilson coalbed reaches a maximum thickness of 11 feet in areas where it has not coalesced with the Castlegate "D" bed. The Gilson bed is usually one bench, but local shale partings split the coalbed into two or three benches. Between the Gilson and Fish Creek coalbeds there is an interval of sandstone, and shale ranging up to 60 feet thick.

The Fish Creek coalbed is not well recorded. Where the coalbed separates from the Castlegate "D" coalbed it is known to have a maximum thickness of 5 feet. The Fish Creek and Rock Canyon coalbeds are separated by a 10- to 35-foot interval of sandstone, shale, and sandy shale. The Rock Canyon coalbed has a maximum recorded thickness of 7.8 feet near

Soldier Creek with the bed thinning to the east. The Rock Canyon and Lower Sunnyside coalbeds are separated by 60 to 160 feet of sandstone and shale (Young, 1976).

The Sunnyside coalbed is the most widespread and uniformably thick coal in the western Book Cliffs coal field. The coal can be traced southeast from Kenilworth to Woodside, Utah. North of Whitmore Canyon the coal splits into three beds referred to as the lower, middle and upper beds. The lower bed thins rapidly and pinches out, but where it does exist in quantity it is an excellent coking coal. The middle bed, also referred to as the lower Sunnyside bed, is found directly on a prominent beach sandstone bed. The upper coalbed or upper Sunnyside, is lenticular, and has reached a maximum thickness of 22 feet. The coal in this bed is also an excellent coking coal (Young, 1976).

The resource estimate for the Book Cliffs field is approximately 3,700 million short tons, which includes coalbeds greater than 4 feet thick and under less than 3,000 feet of cover. As of 1972, approximately 209 million short tons of coal had been removed from the coal field. The Bureau of Land Management controls more than half the coal field with private property, and the State of Utah owns the remainder (Doelling, 1972).

4.7 SEGO COAL FIELD

The Sego coal field is located in east central Utah along the Book Cliffs between the Green River and Colorado state line. The coal field is 65 miles wide, and encompasses approximately 390 square miles (Doelling and Graham, 1972).

The Upper Cretaceous Neslen Member of the Price River Formation contains four major coal zones in the field (Figure 4-18). The Neslen Member consists of quartzose sandstone, subgraywackes, siltstone, shale, and coal. The thin to massive sandstone beds within this member contain fine- to medium-size subangular grains. The coal is found in beds ranging from 1 to 7 feet thick. The coal is high-volatile C bituminous, and is impure along the majority of the outcrop area (Tables 4-2 and 4-3) (Doelling and Graham, 1972). The coalbeds dip gently to moderately northward into the Uinta Basin. The cliff-front is irregular and is deeply cut by perpendicular drainages. The beds are developed between Nash Canyon and Thompson's Canyon in the west central area of the field.

The four coal zones, in ascending order, are the Palisade, Ballard, Chesterfield, and Carbonera (Figure 4-16). The Palisade coal zone is 40 to 50 feet thick, and the Ballard coal zone is approximately 10 feet thick. The Ballard and Chesterfield coal zones are separated by a thick, cliff-forming sandstone. The Chesterfield zone is 50 feet thick, and is the only coal zone to produce significant quantities of coal in the Thompson and Sego Canyon areas. The Carbonera coal zone ranges from 100 to 150 feet thick, and outside of the developed area the coal thickens locally (Doelling and Graham, 1972).

Estimated original coal resources in the Sego Coal Field are 294 million tons of coal in beds greater than 4 feet thick. The Carbonera coal zone contains 9 million tons of resources; the Chesterfield coal zone 116 million tons; Ballard coal zone, 93 million tons; and the Palisade coal zone, 76 million tons. An estimated 2.65 million tons of coal has been mined from the Sego field; the majority removed from the Thompson and Sego Canyon areas (Doelling and Brakan, 1972). The Bureau of Land Management owns and controls over 85 percent of the coal field, with the State of Utah and private ownership accounting for the remaining area (Doelling and Graham, 1972).

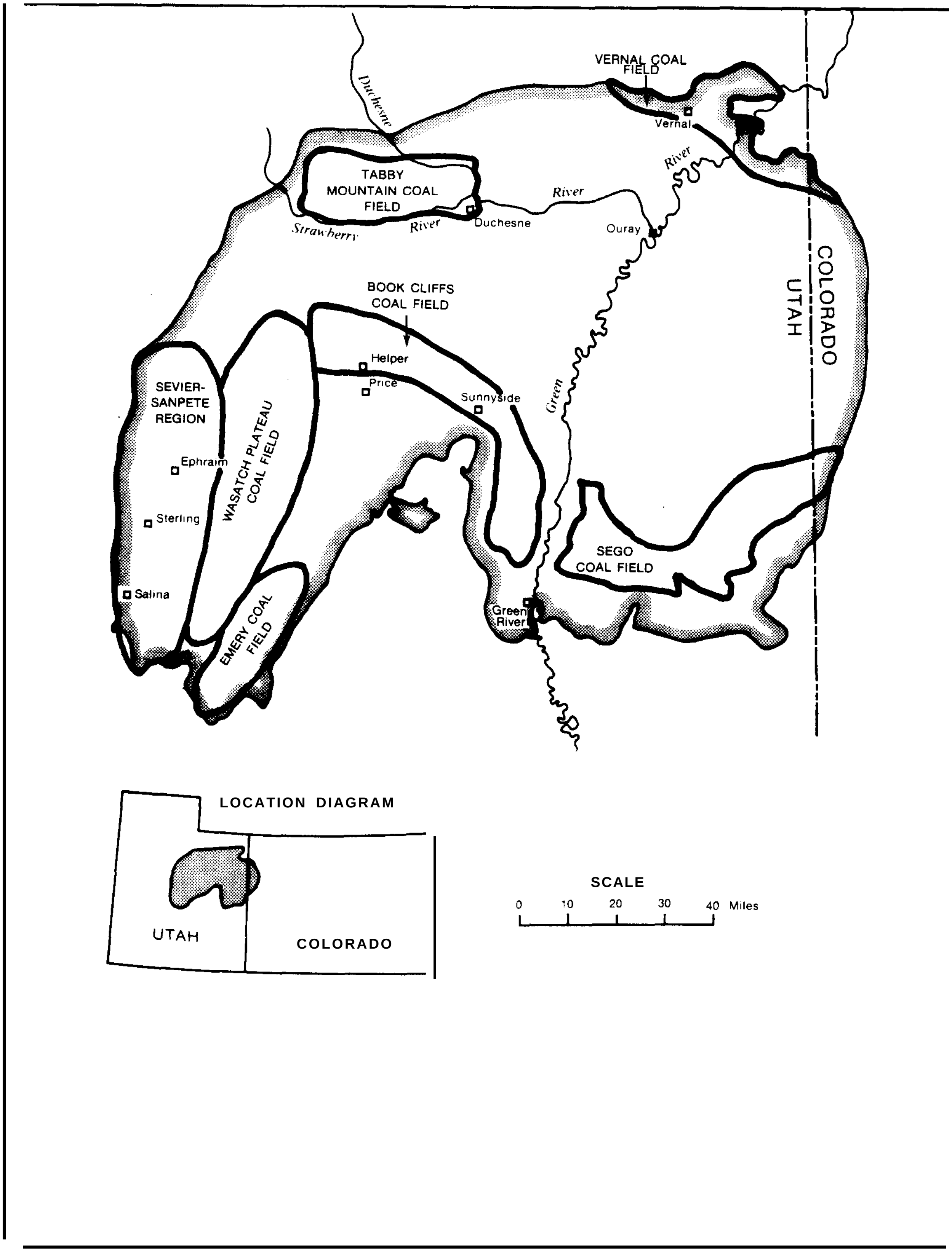


Figure 4-1. Map Showing the Location of the Uinta Basin Coal Fields and Region

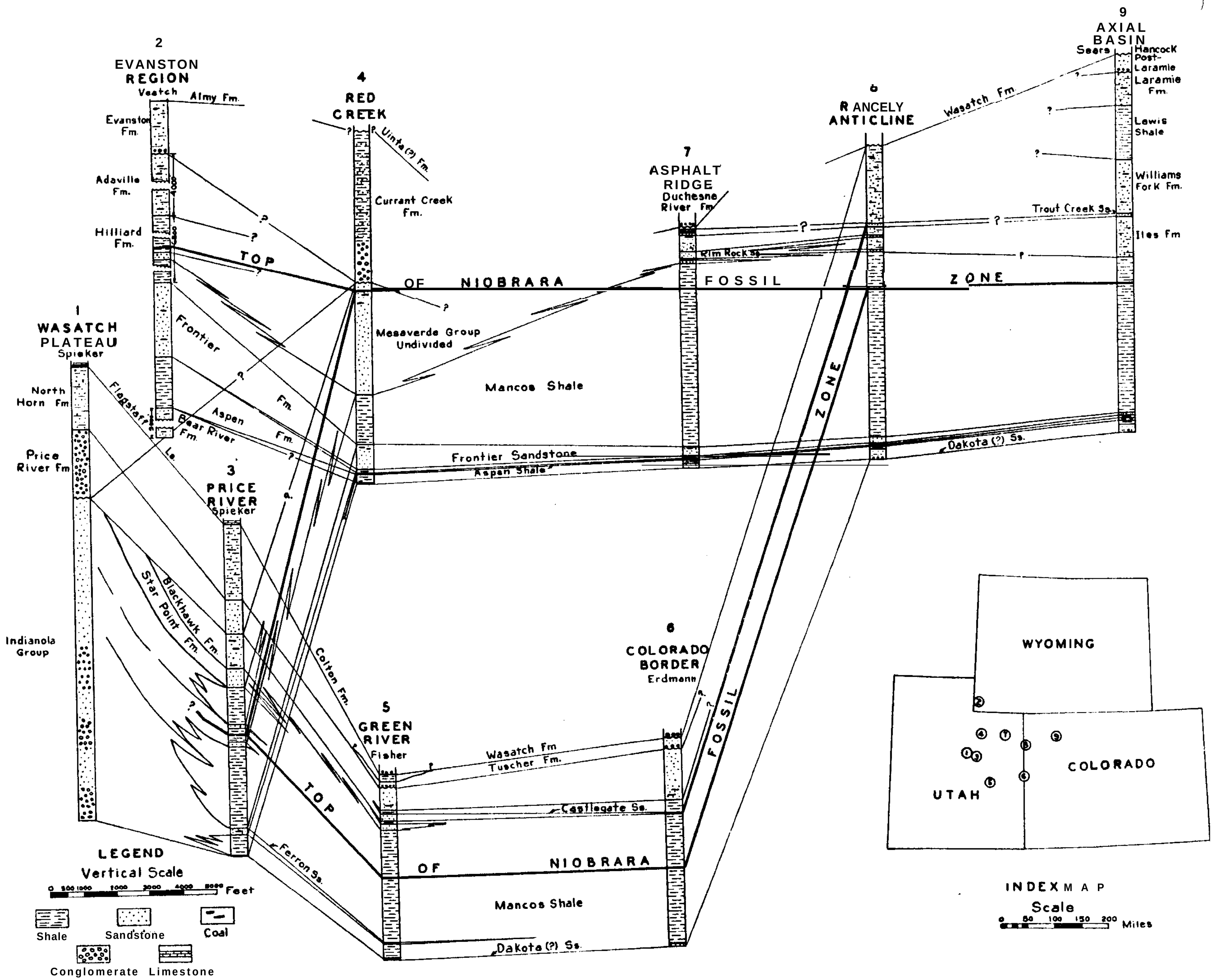


Figure 4-2. Regional **Cretaceous** Correlation Diagram (Walton, 1944)

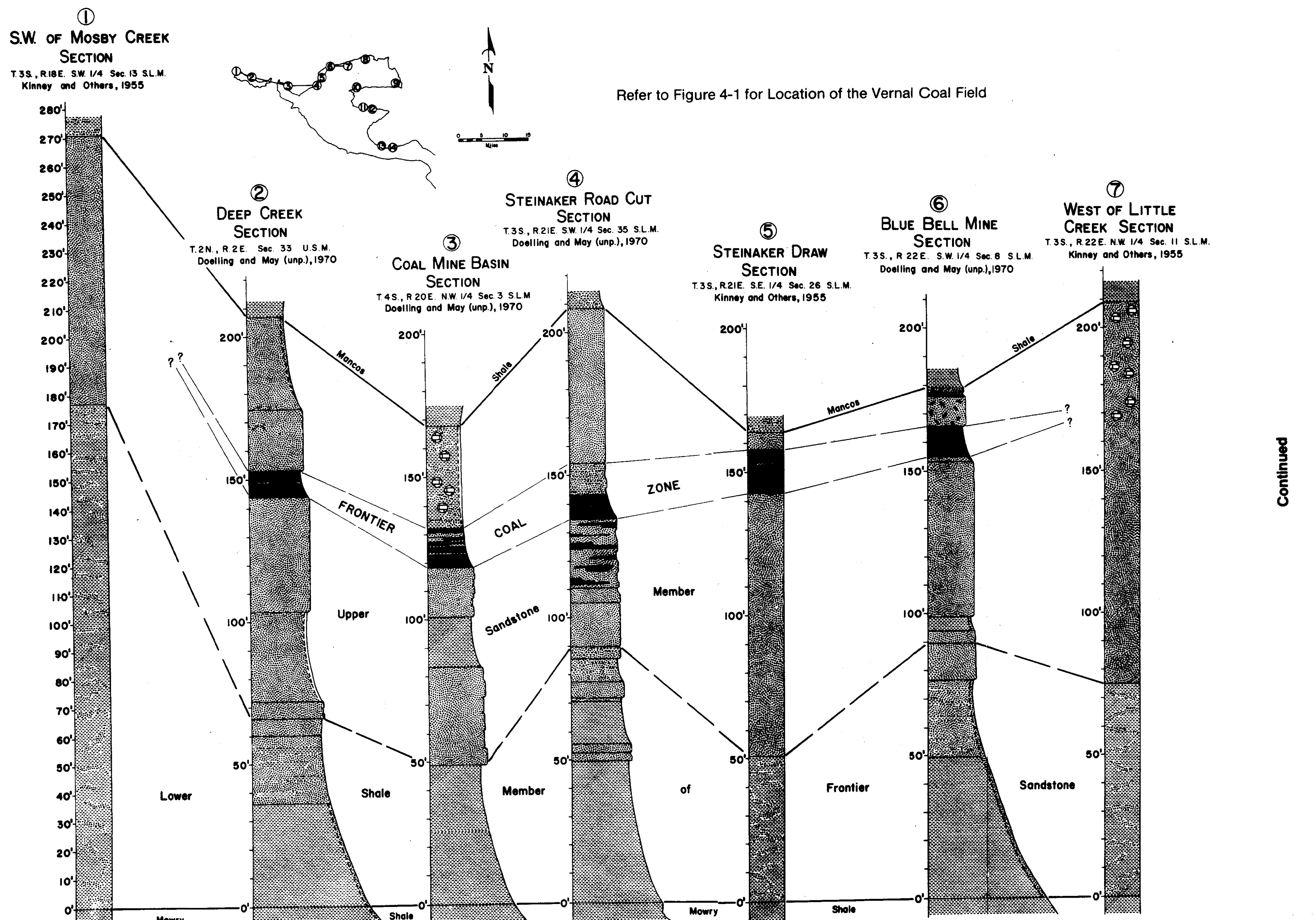


Figure 4-3. Sections of the Frontier Sandstone, Vernal Coal Field (Doelling and Graham, 1972)

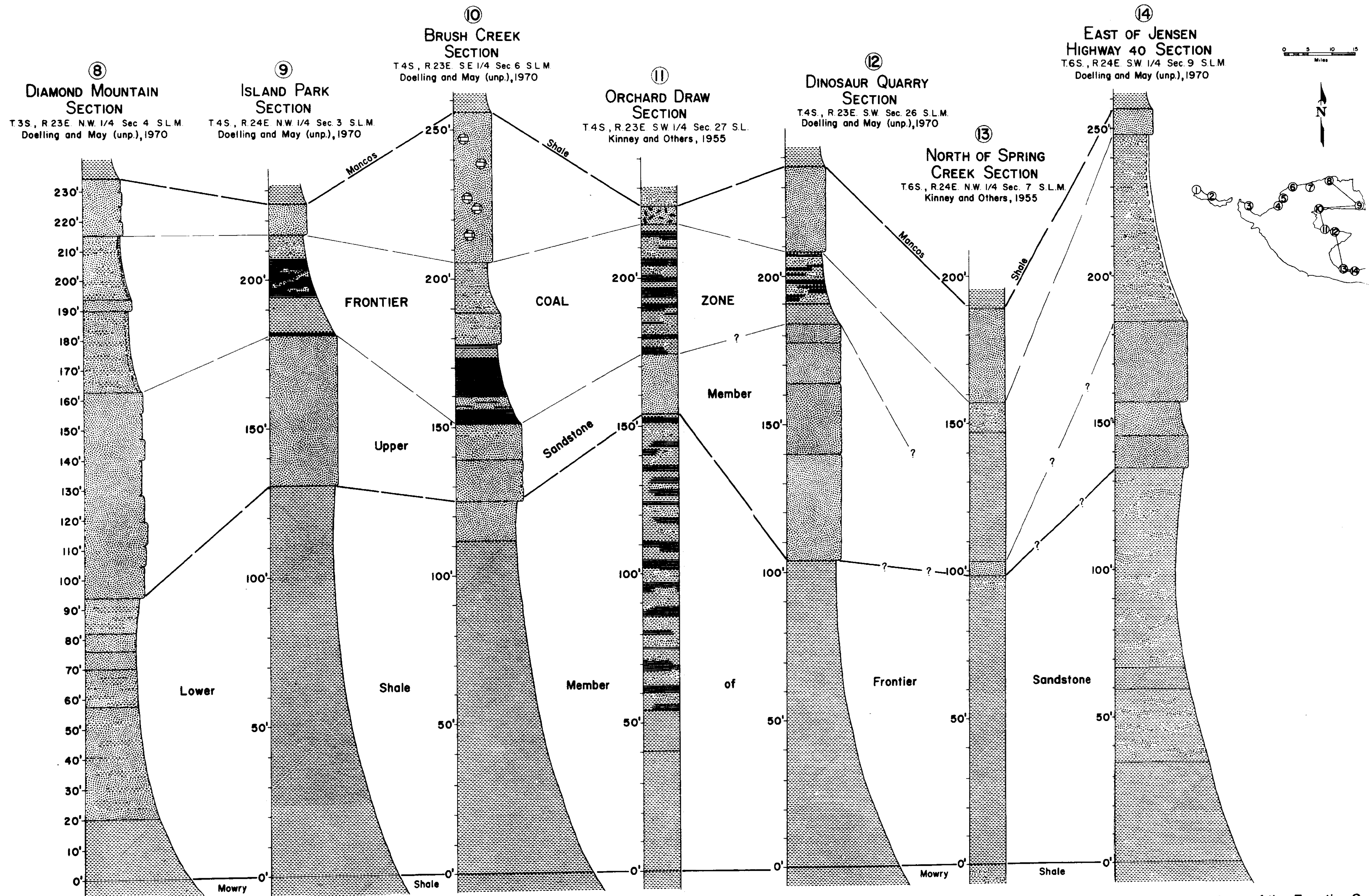


Figure 4-3. Sections of the Frontier Sandstone, Vernal Coal Field (Doelling and Graham, 1972) (Continued)

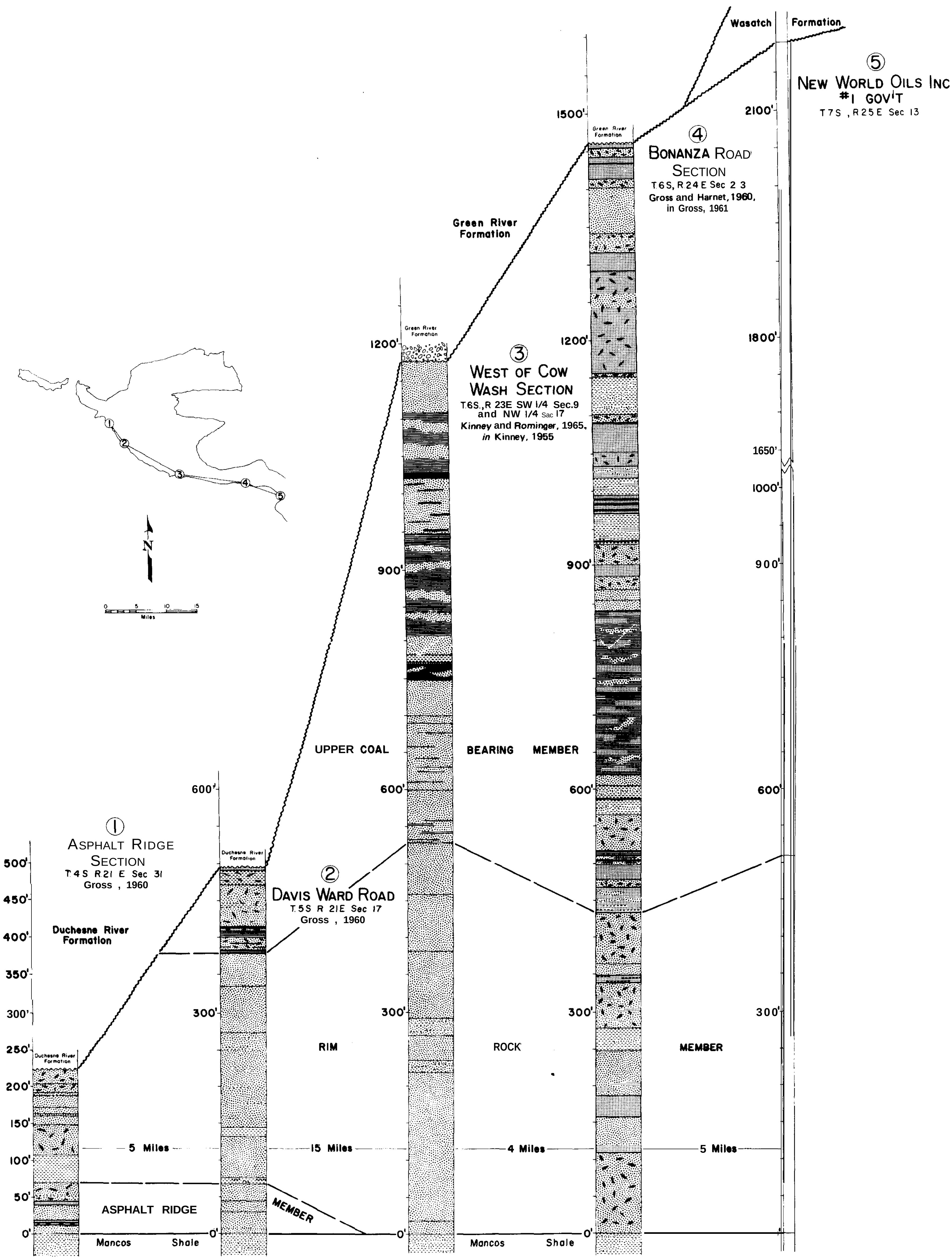


Figure 4-4. Sections of the Mesaverde Formation, Vernal Coal Field (Doelling and Graham, 1972). Refer to Figure 4-1 for Location of the Vernal Coal Field

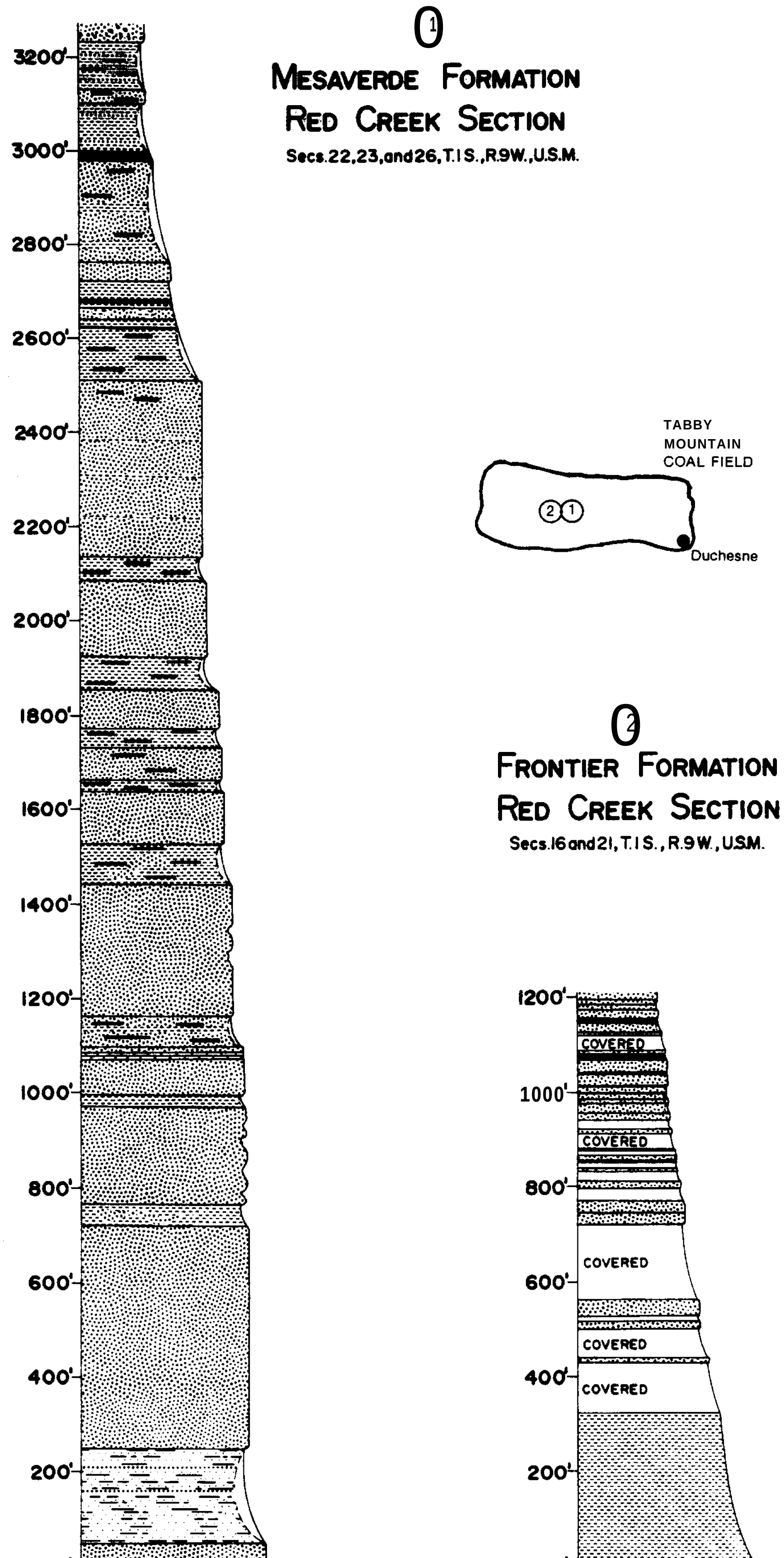


Figure 4-5. Sections of the Mesaverde and Frontier Formations, Tabby Mountain Coal Field (Doelling and Graham, 1972). Refer to Figure 4-l for Location of the Tabby Mountain Coal Field

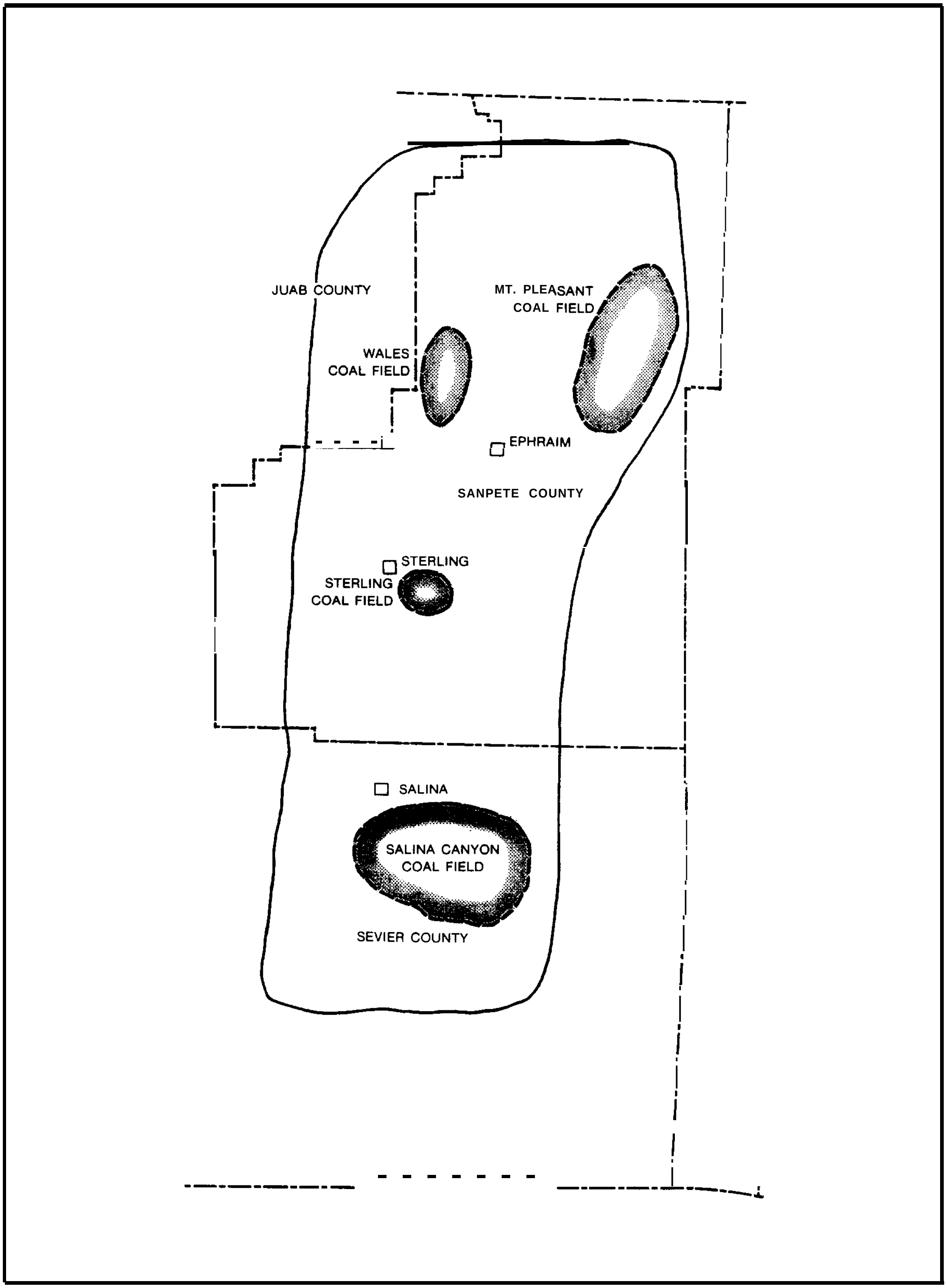
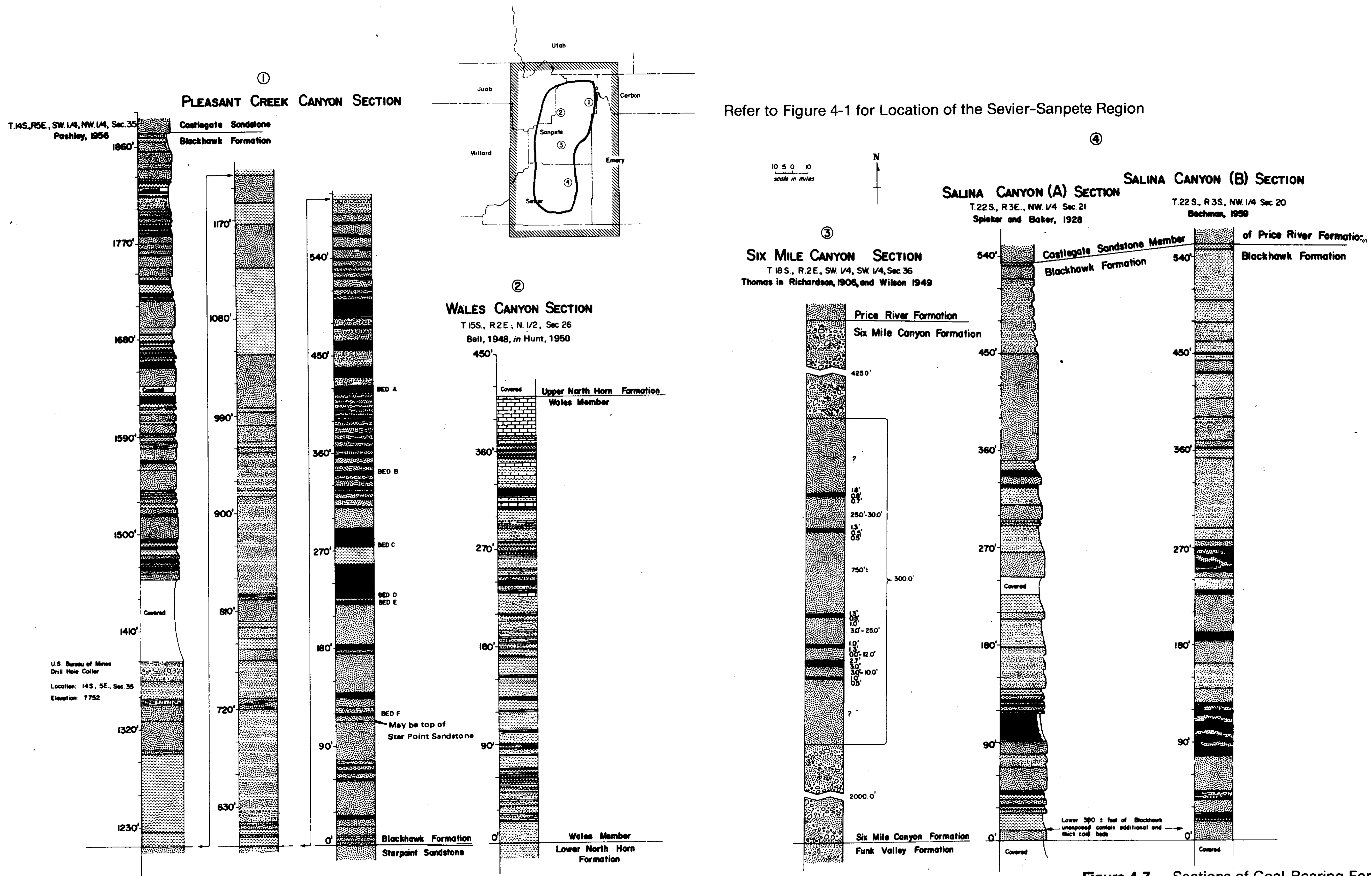
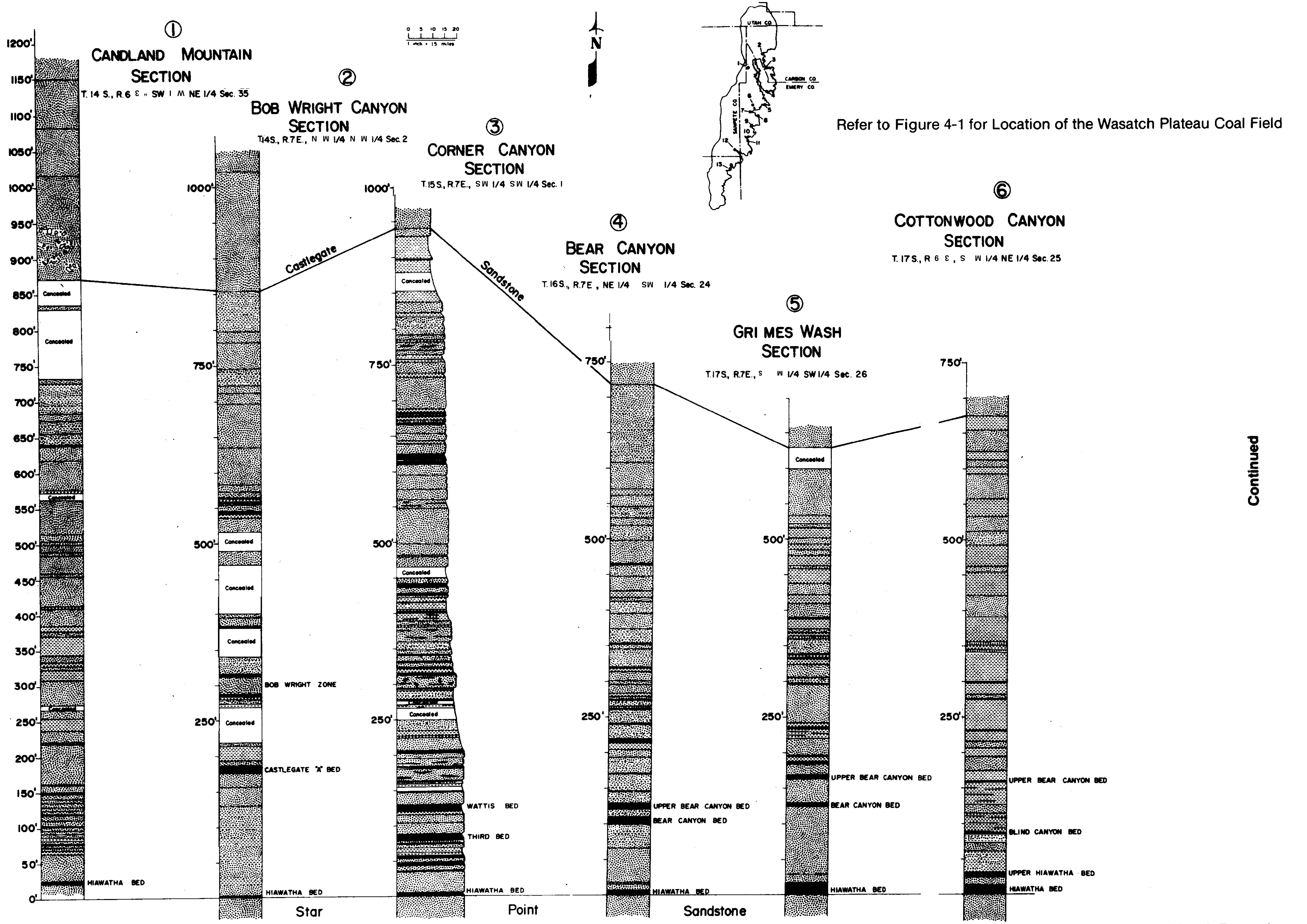


Figure 4-6. Map Showing the Location of Coal Fields Within the Sevier-Sanpete Region (After Doelling, 1972). Refer to Figure 4-l for Location of the Sevier-Sanpete Region



Refer to Figure 4-1 for Location of the Sevier-Sanpete Region

Figure 4-7. Sections of Coal-Bearing Formations in the Sevier-Sanpete Region (Doelling, 1972)



Refer to Figure 4-1 for Location of the Wasatch Plateau Coal Field

Figure 4-8. Sections of Blackhawk Formation, Wasatch Plateau Coal Field (Doelling, 1972)

Continued

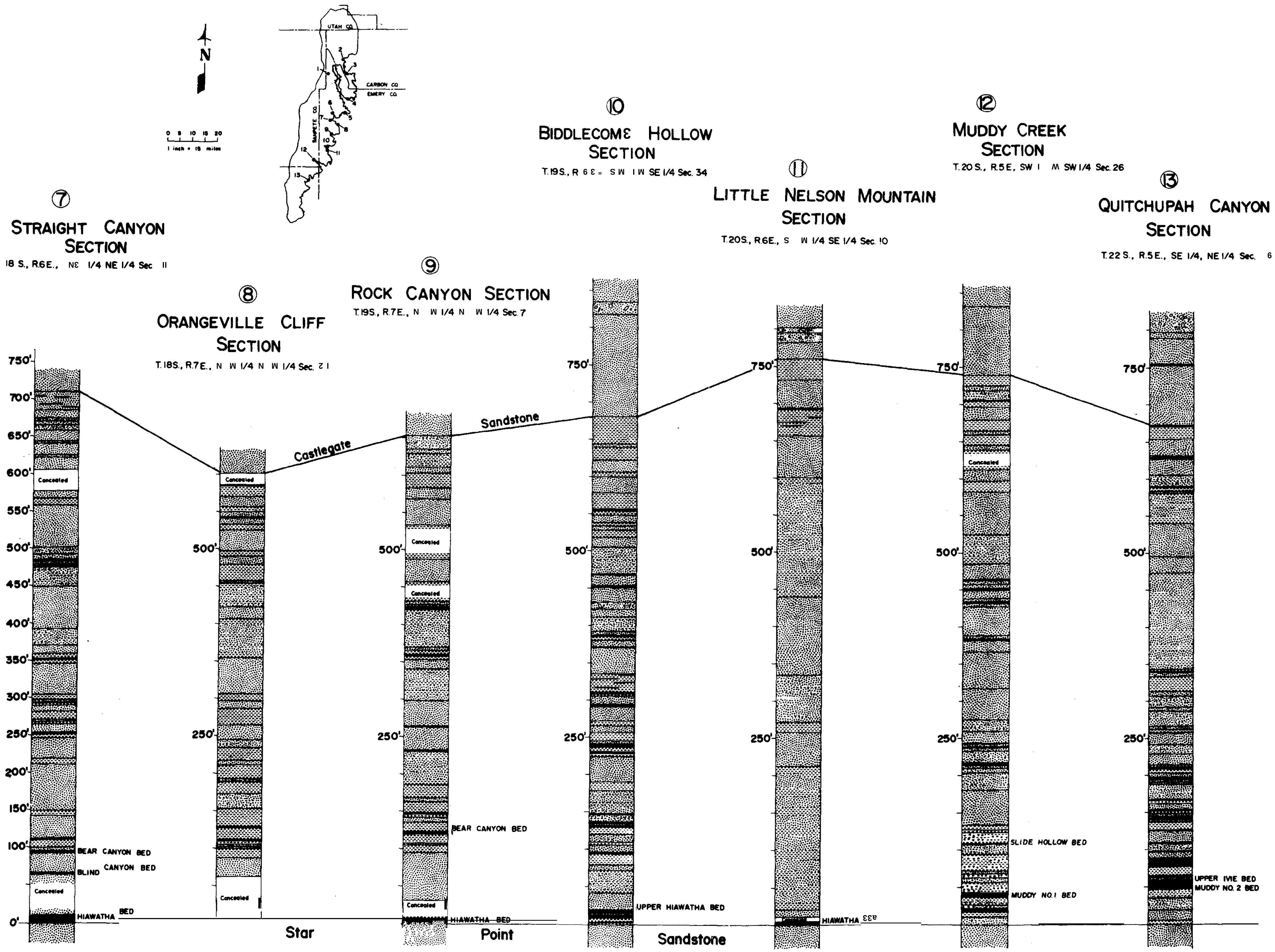


Figure 4-8. Sections of Blackhawk Formation, Wasatch Plateau Coal Field (Doelling, 1972) (Continued)

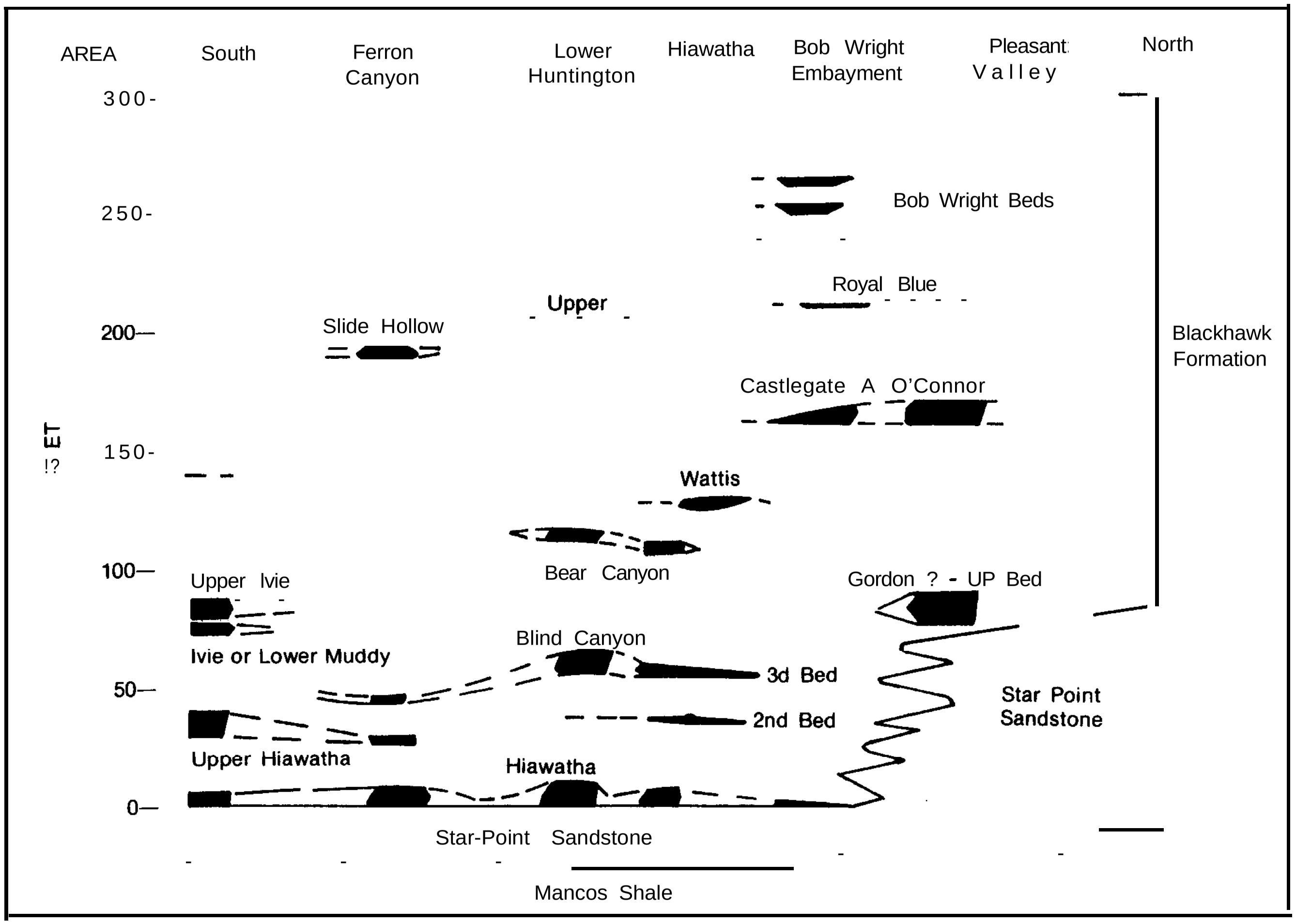


Figure 4-9. Correlations Between Coalbeds of the Wasatch Plateau Coal Field (Doelling, Smith, and Davis, 1979)

Coalbed	Area of Importance
Bear Canyon bed	Cottonwood-Huntington Canyon
Upper Bear Canyon bed	Huntington Canyon
Blind Canyon bed	Huntington and Cottonwood Canyon
Bob Wright coal zone	Gordon Creek and Pleasant Valley
Candland bed	Huntington Canyon
Castlegate "A" bed	Pleasant Valley, Gordon Creek, and Huntmgton Canyon
Cottonwood bed	Cottonwood Canyon
Fourth bed	Huntmgton Canyon
Gordon bed	Gordon Creek
Haley bed	Pleasant Valley
Hiawatha bed	All Areas Except Pleasant Valley
Ivie bed	South
Upper Ivie bed	South
Muddy No 1 bed	Flagstaff Peak
Muddy No. 2 bed	South
Second bed	Hiawatha
Slide Hollow bed	Flagstaff Peak
Tank bed	Hiawatha
Third bed	Huntmgton Canyon
Union Pacific bed	Pleasant Valley
Upper bed of Grimes Wash	Cottonwood Canyon
Upper Hiawatha bed	Cottonwood Canyon, Flagstaff Peak, South
Wattis	Hiawatha

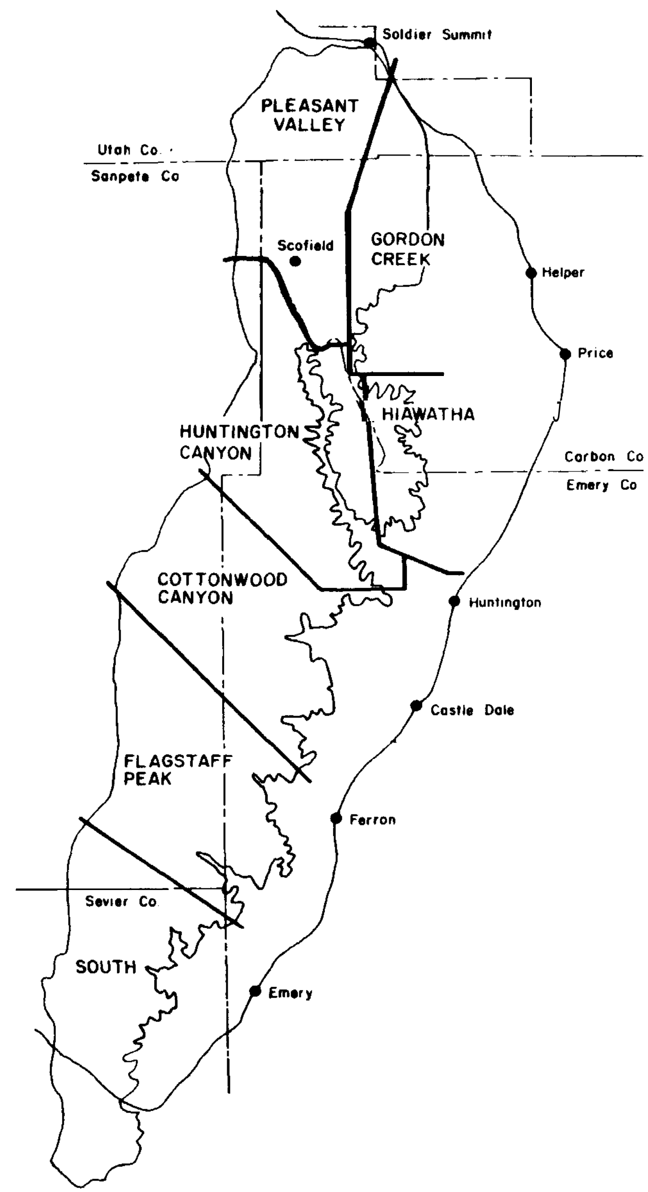


Figure 4-10. Map Showing Major Areas Within the Wasatch Plateau Coal Field with Corresponding Important Coalbeds (Doelling, 1972)

Refer to Figure 4-1 for Location of the Emery Coal Field

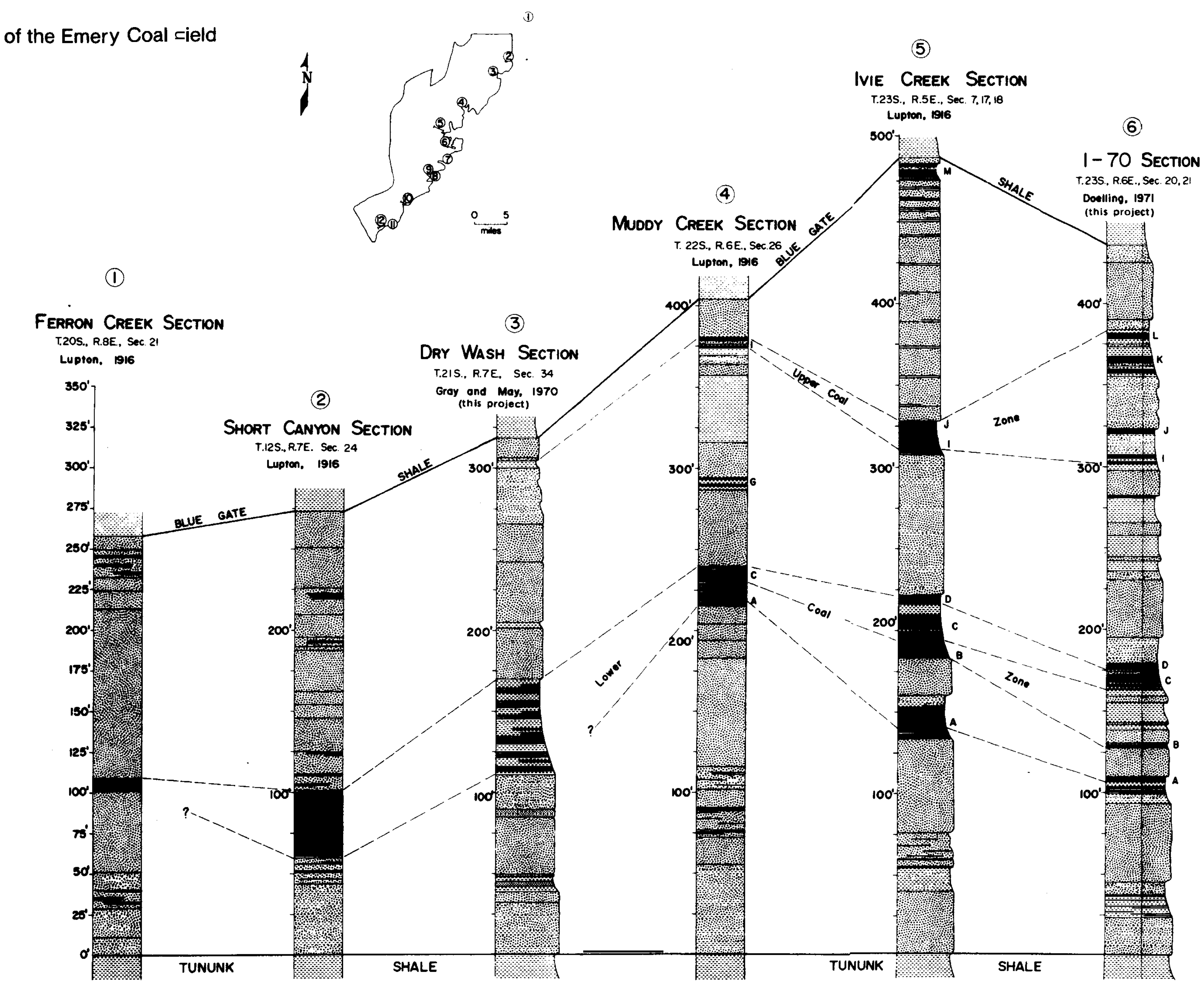


Figure 4-11. Sections of the Ferron Sandstone Member of the Mancos Shale, Emery Coal Field (Doelling, 1972)

Continued

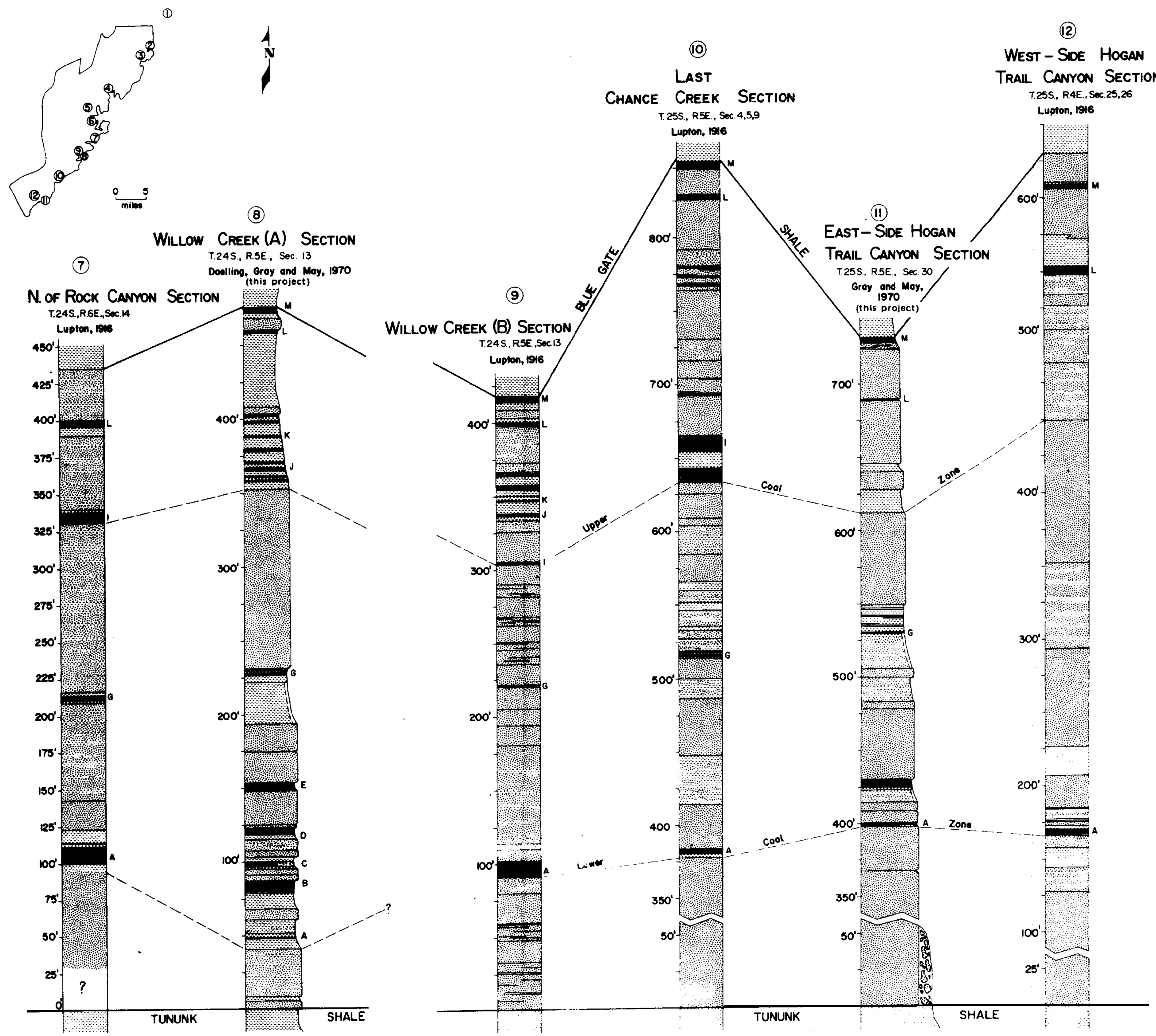


Figure 4-11. Sections of the Ferron Sandstone Member of the Mancos Shale, Emery Coal Field (Doelling, 1972) (Continued)

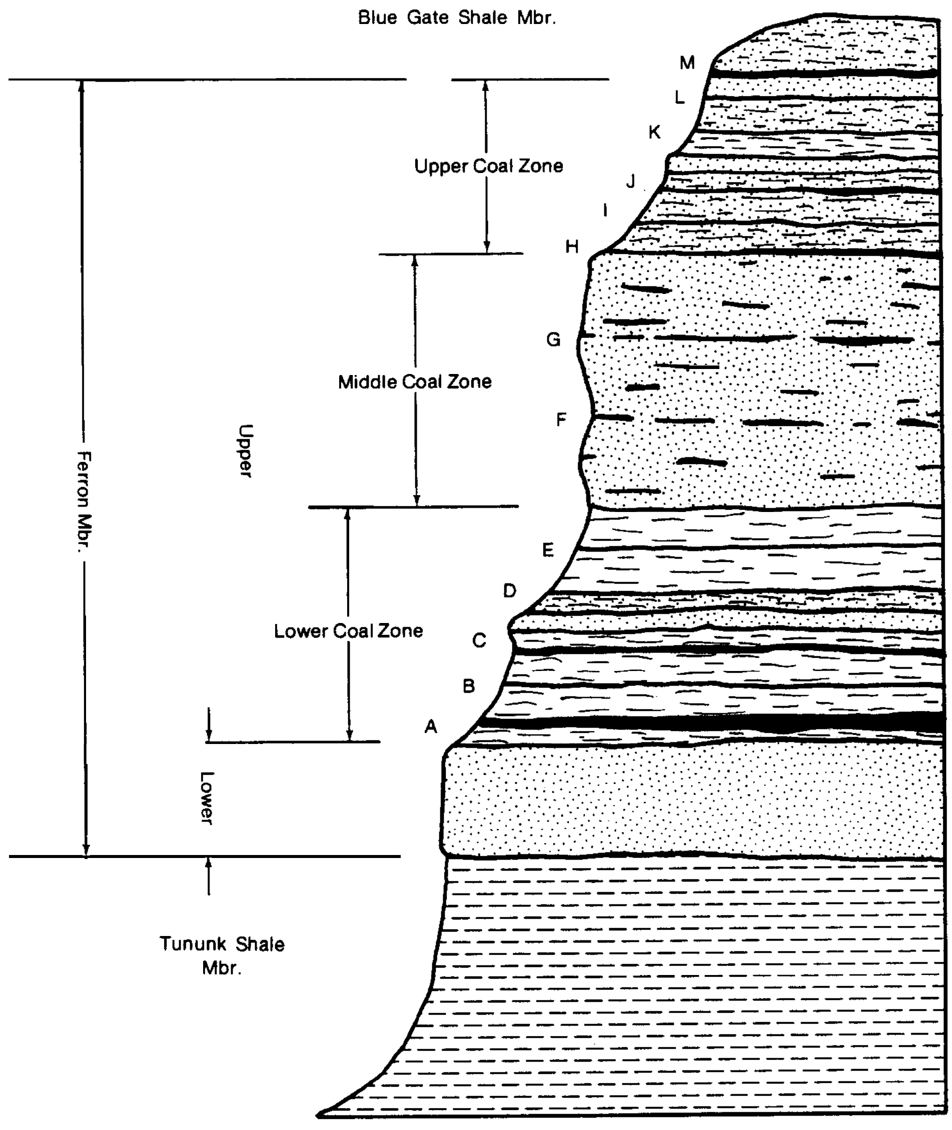


Figure 4-12. Stratigraphic Column of the Ferron Member Coal Zones and Coalbeds, Emery Coal Field (Doelling, Smith, and Davis, 1979)

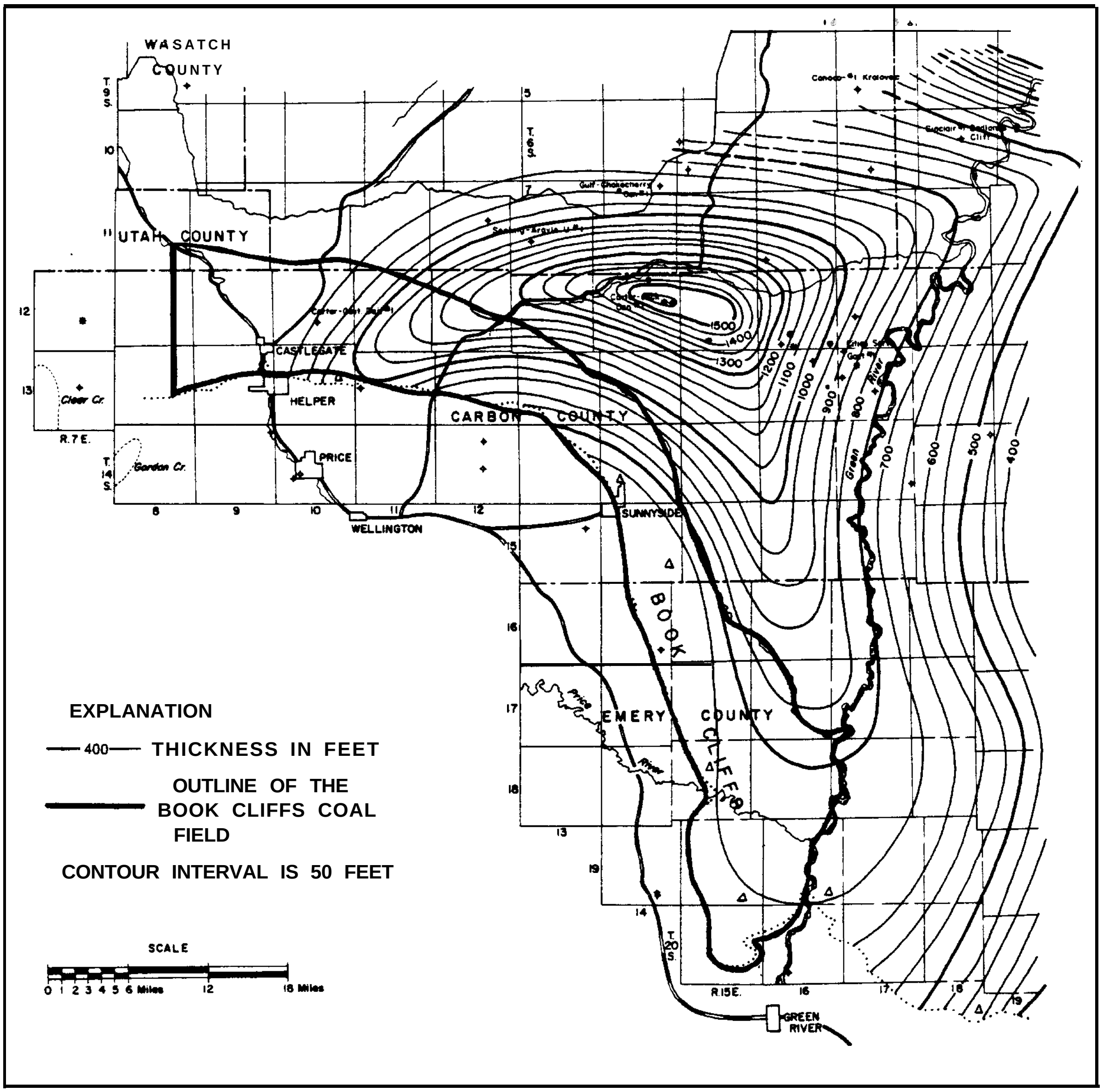
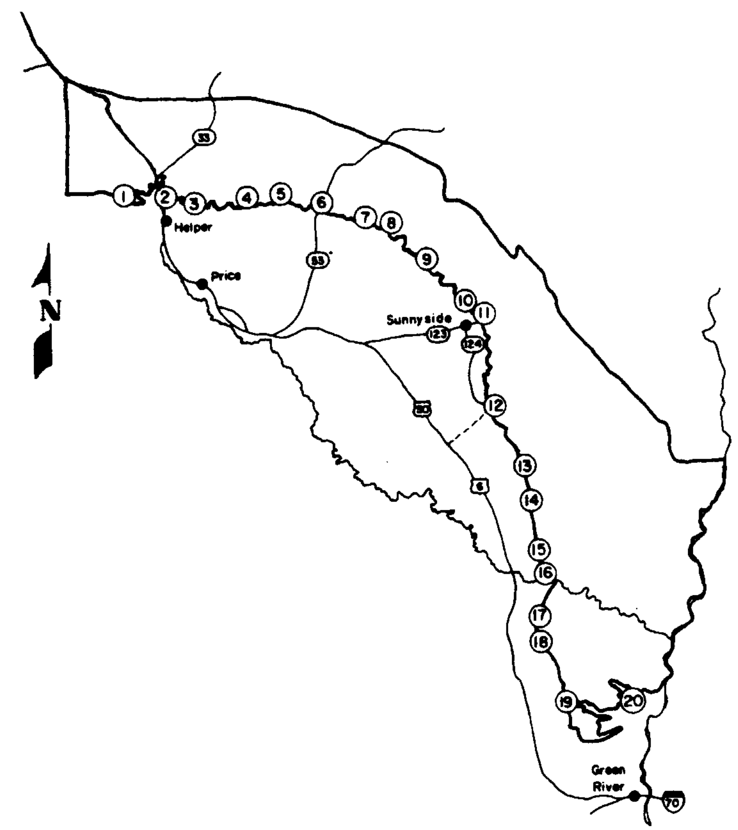
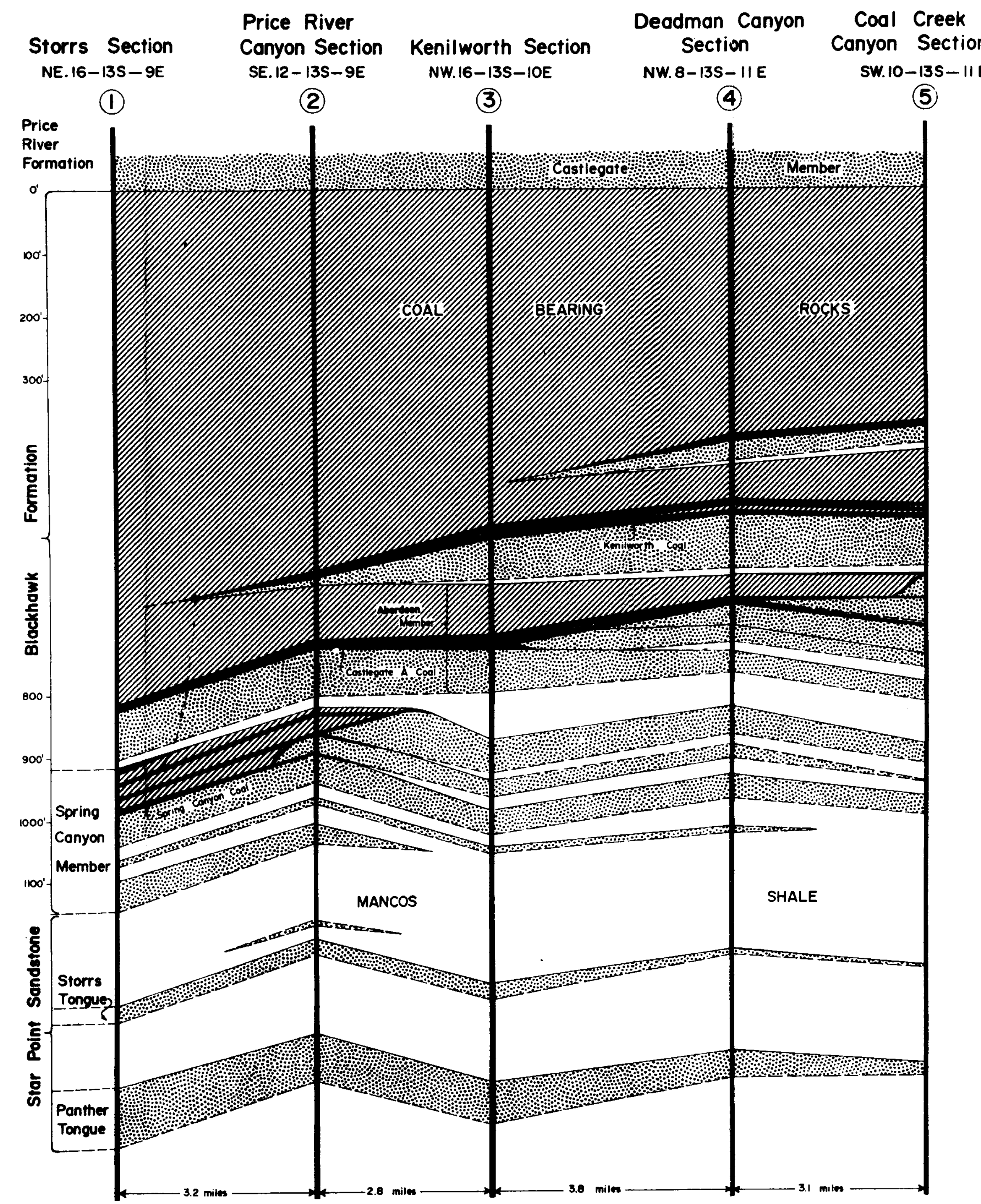


Figure 4-13. Isopach Map of Blackhawk Formation, Book Cliffs Coal Field (After Doel ling, 1972)

Refer to Figure 4-1 for Location of the Book Cliffs Coal Field





Continued

Figure 4-14. Stratigraphic Cross Section Showing Coalbed Relationships within the Book Cliffs Coal Field (Doelling, 1972)

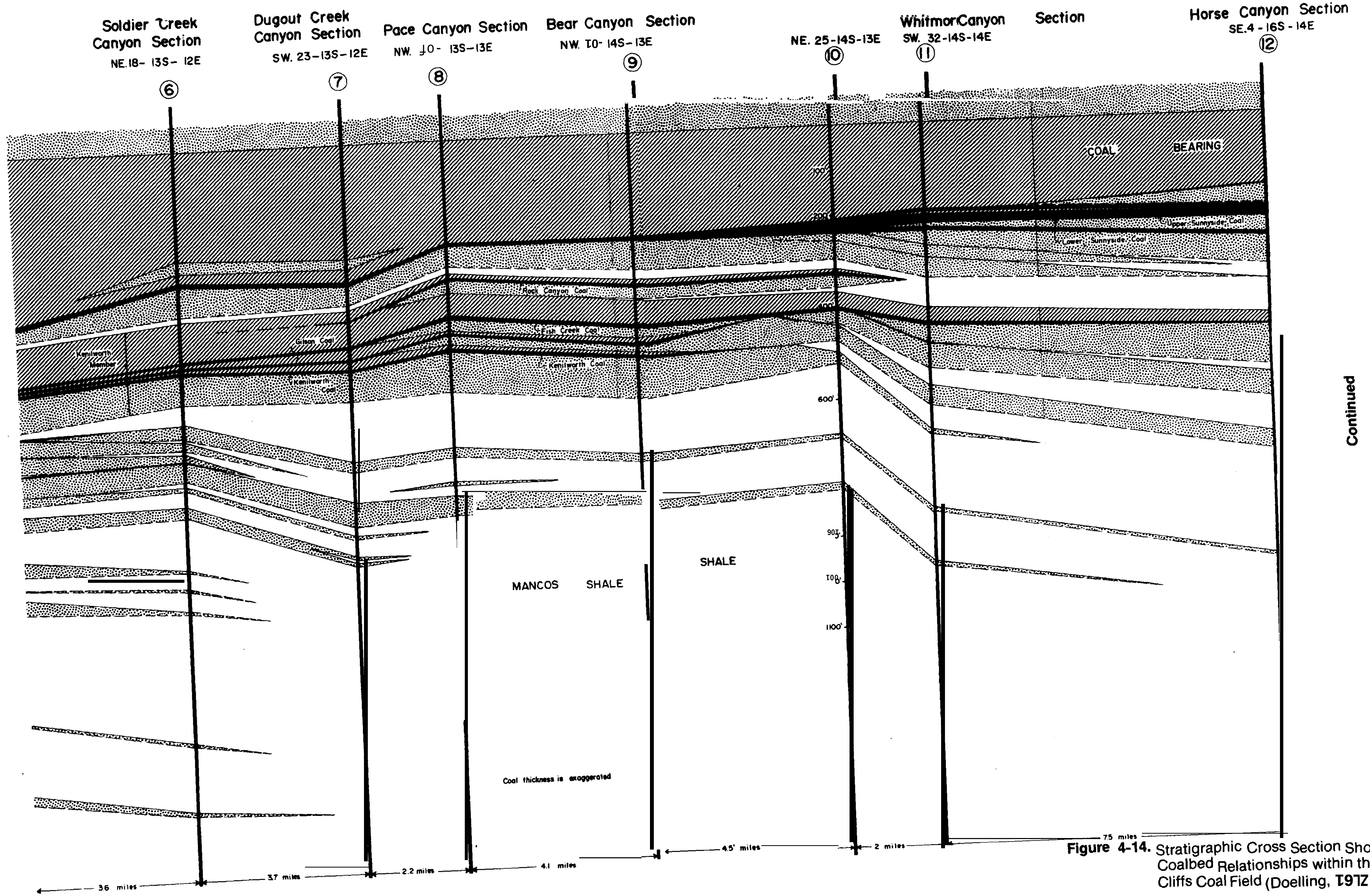


Figure 4-14. Stratigraphic Cross Section Showing Coalbed Relationships within the Book Cliffs Coal Field (Doelling, 1972) (Continued)

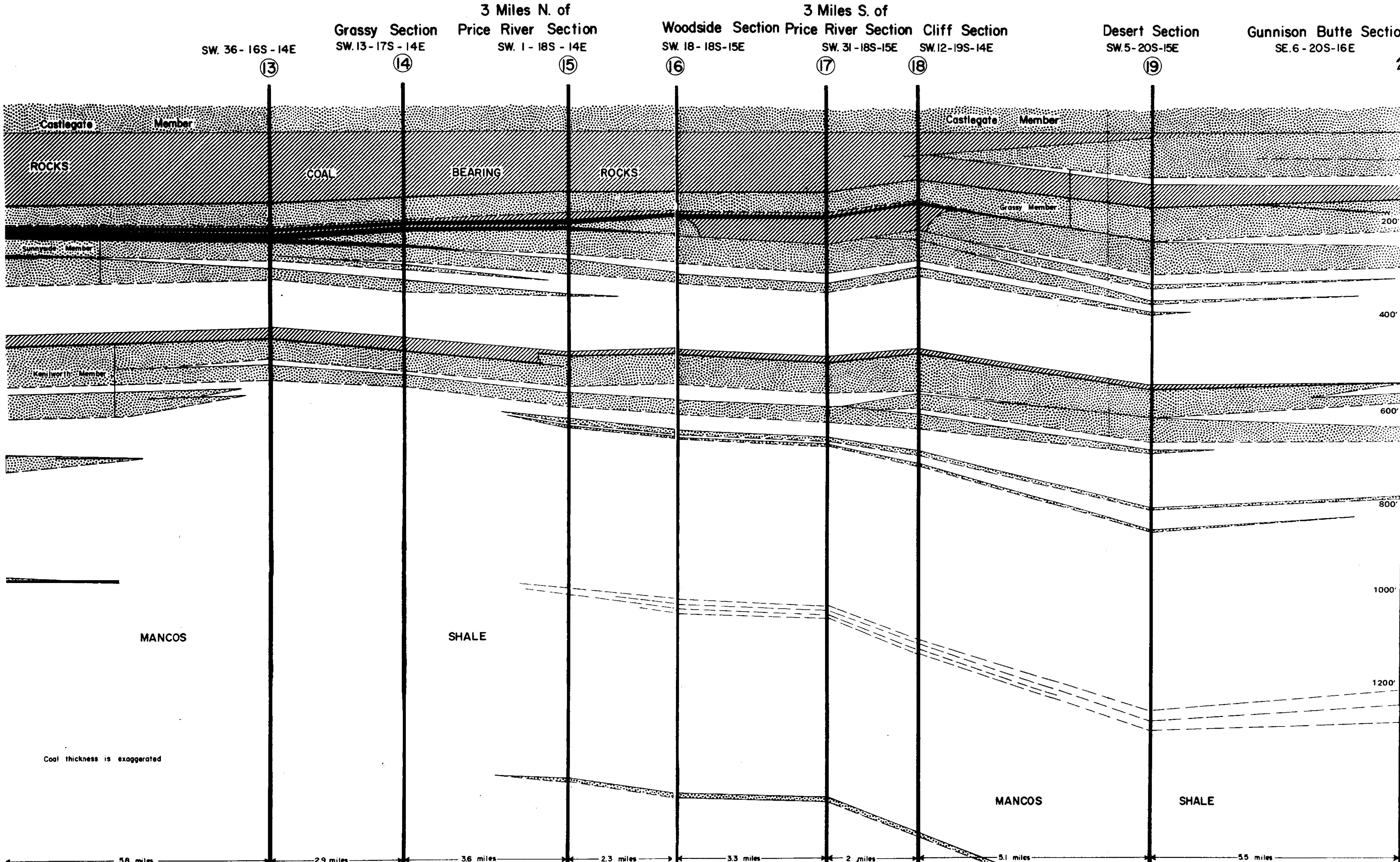


Figure 4-14. Stratigraphic Cross Section Showing Coalbed Relationships within the Book Cliffs Coal Field (Doelling, 1972) (Continued)

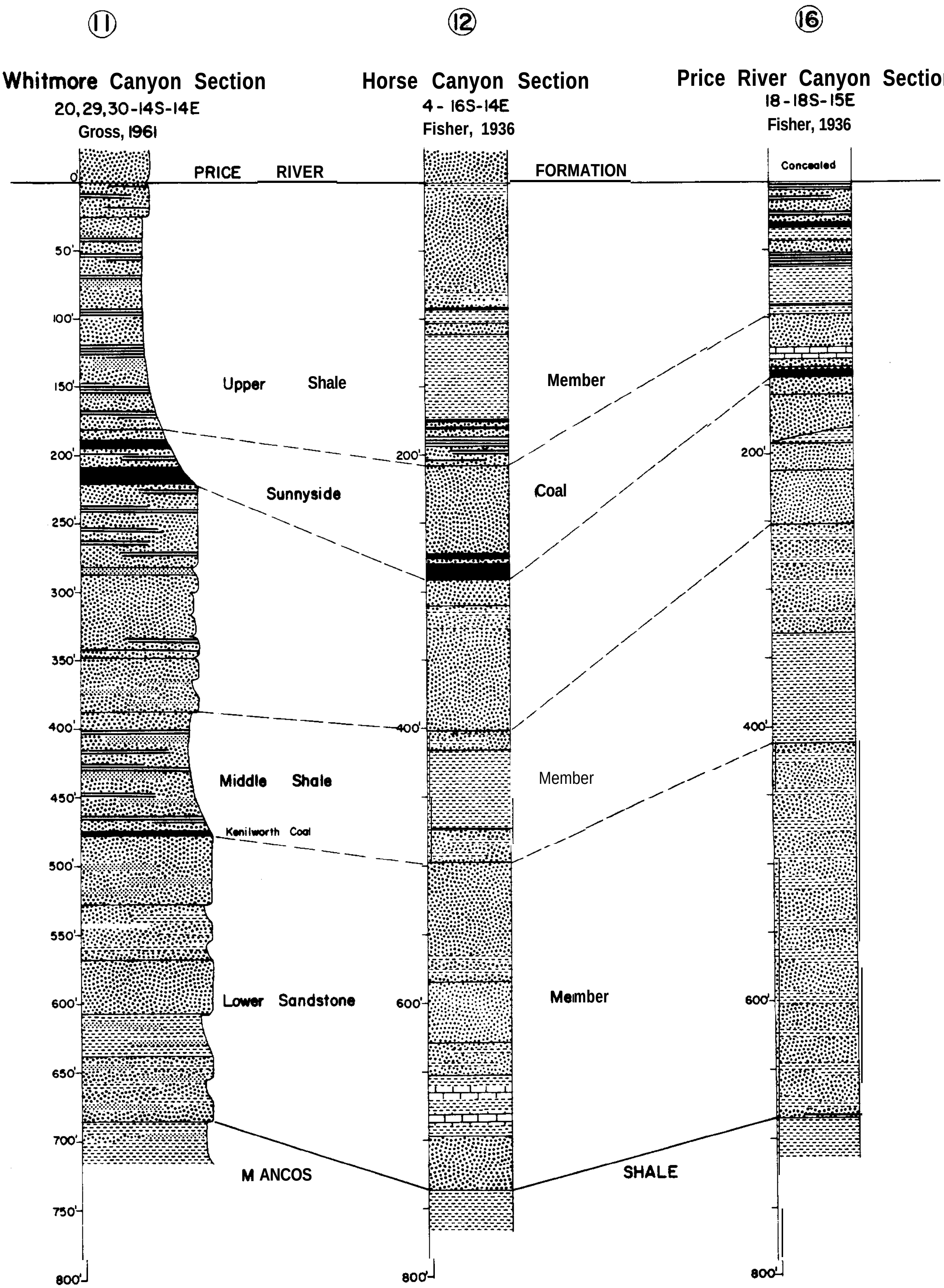


Figure **4-15.** Selected Sections of the Book Cliffs Coal **Field** (Doelling, 1972). Section Locations Correspond to Figure 4-14 **Location** Map. Refer to **Figure** 4-l for Location of the Book Cliffs Coal Field

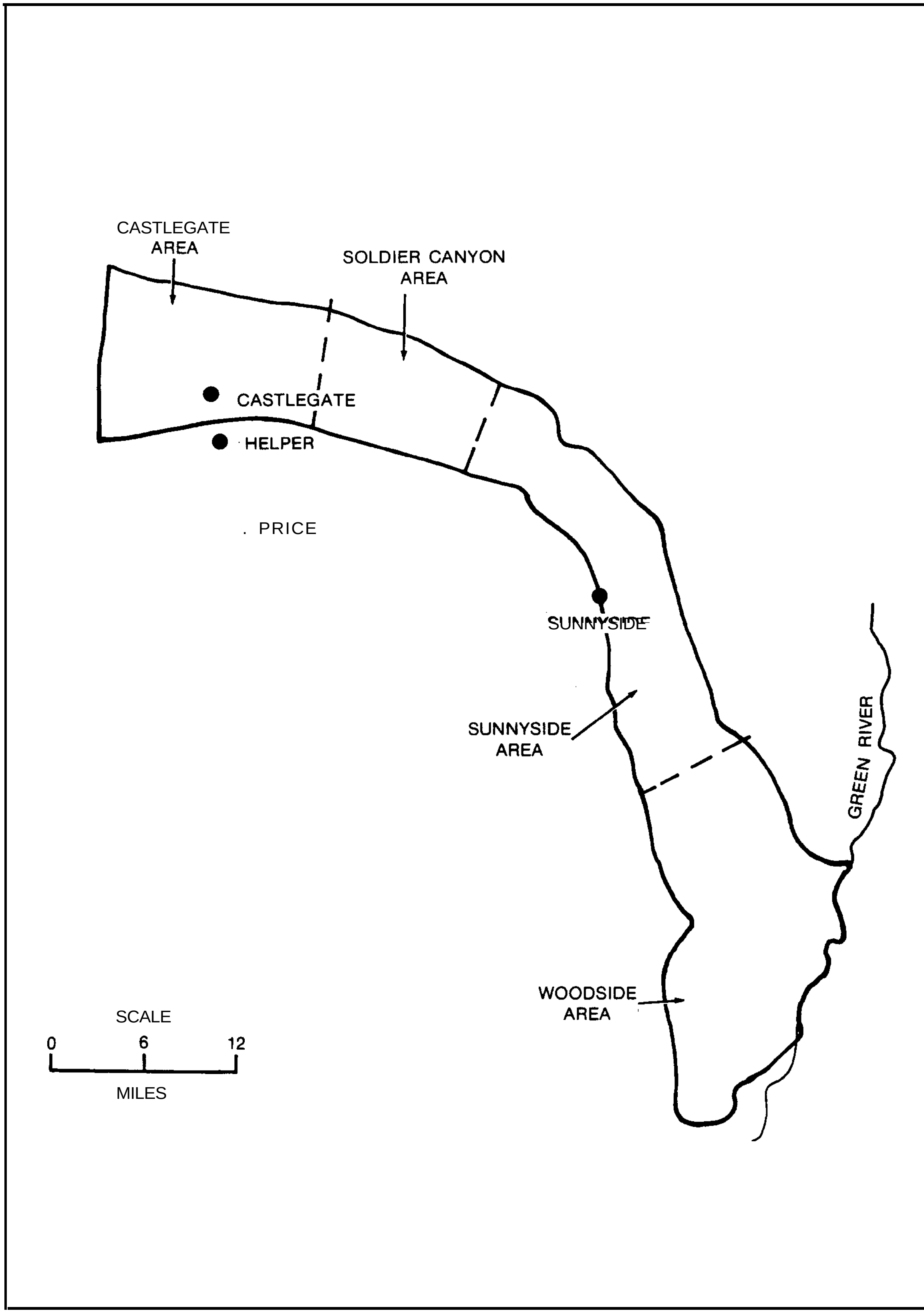


Figure 4-16. Map Showing the Four Major Areas of the Book Cliffs Coal Field (After Doelling, 1972). Refer to Figure 4-1 for Location of the Book Cliffs Coal Field

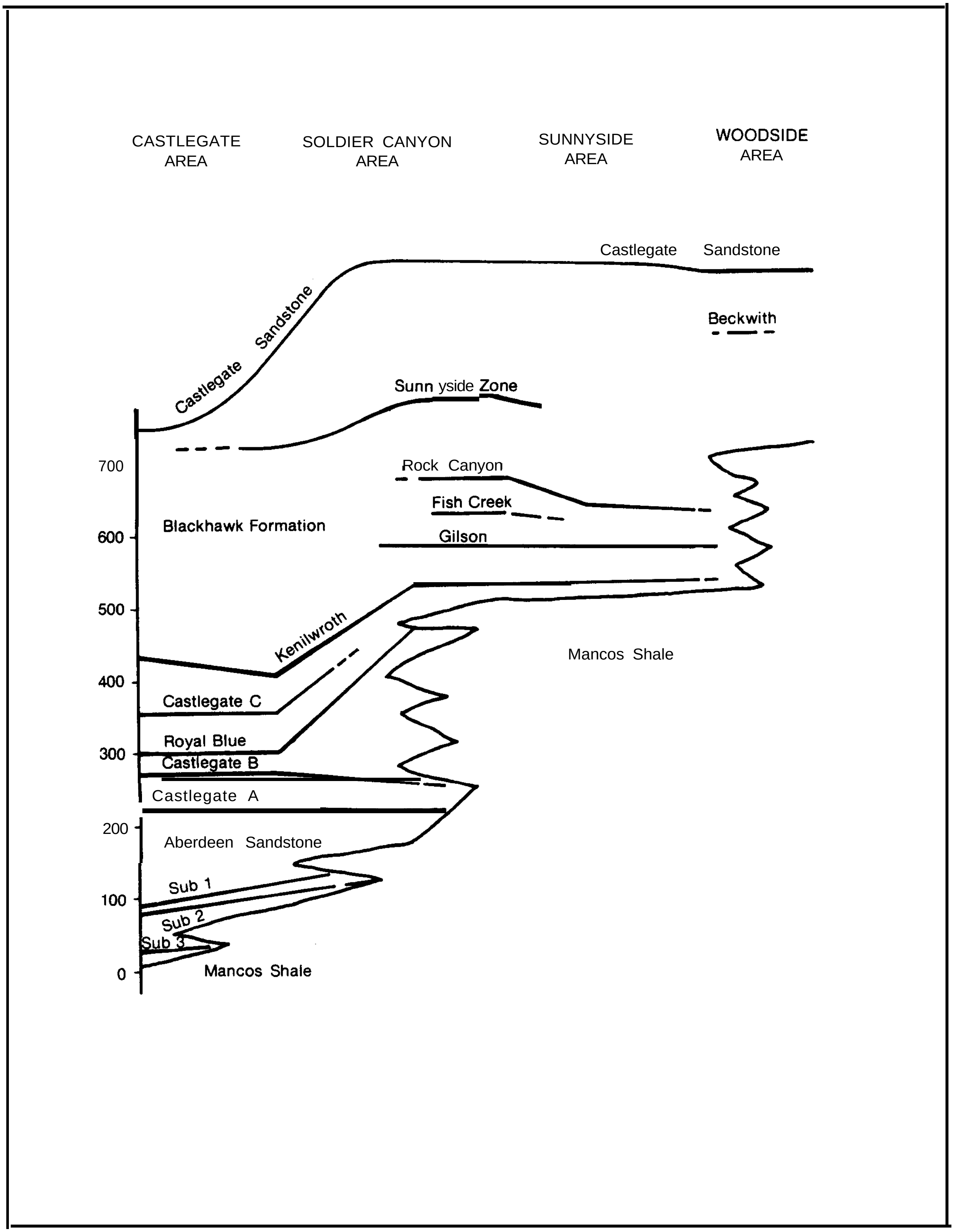


Figure 4-17. Correlation of Coalbeds of the Book Cliffs Coal Field (Doelling, Smith, and Davis, 1979)

Refer to Figure 4-1 for Location of the Sego Coal Field

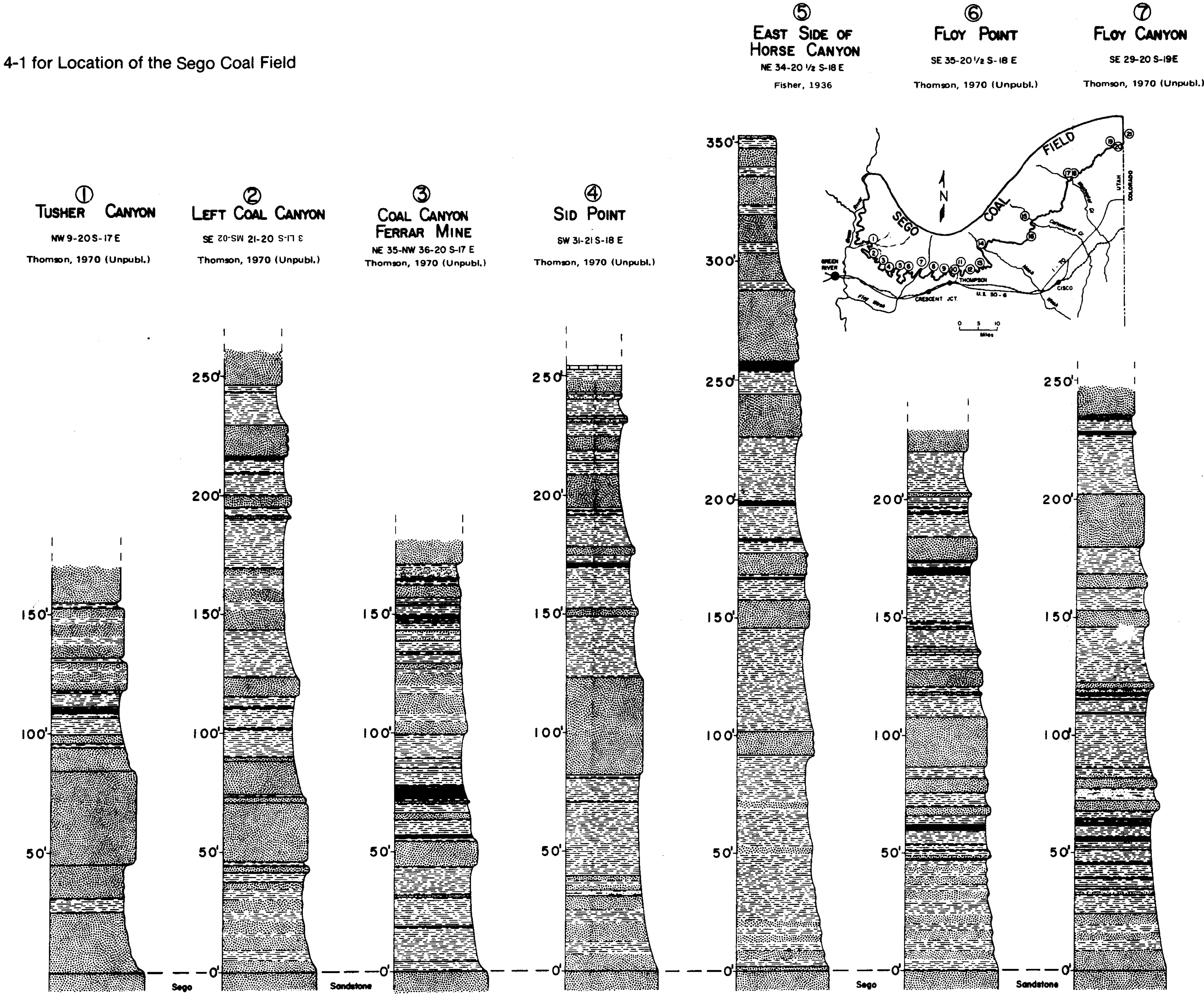


Figure 4-18. Sections of the Neslen Member, Price River Formation, Sego Coal Field (Doelling and Graham, 1972)

Continued

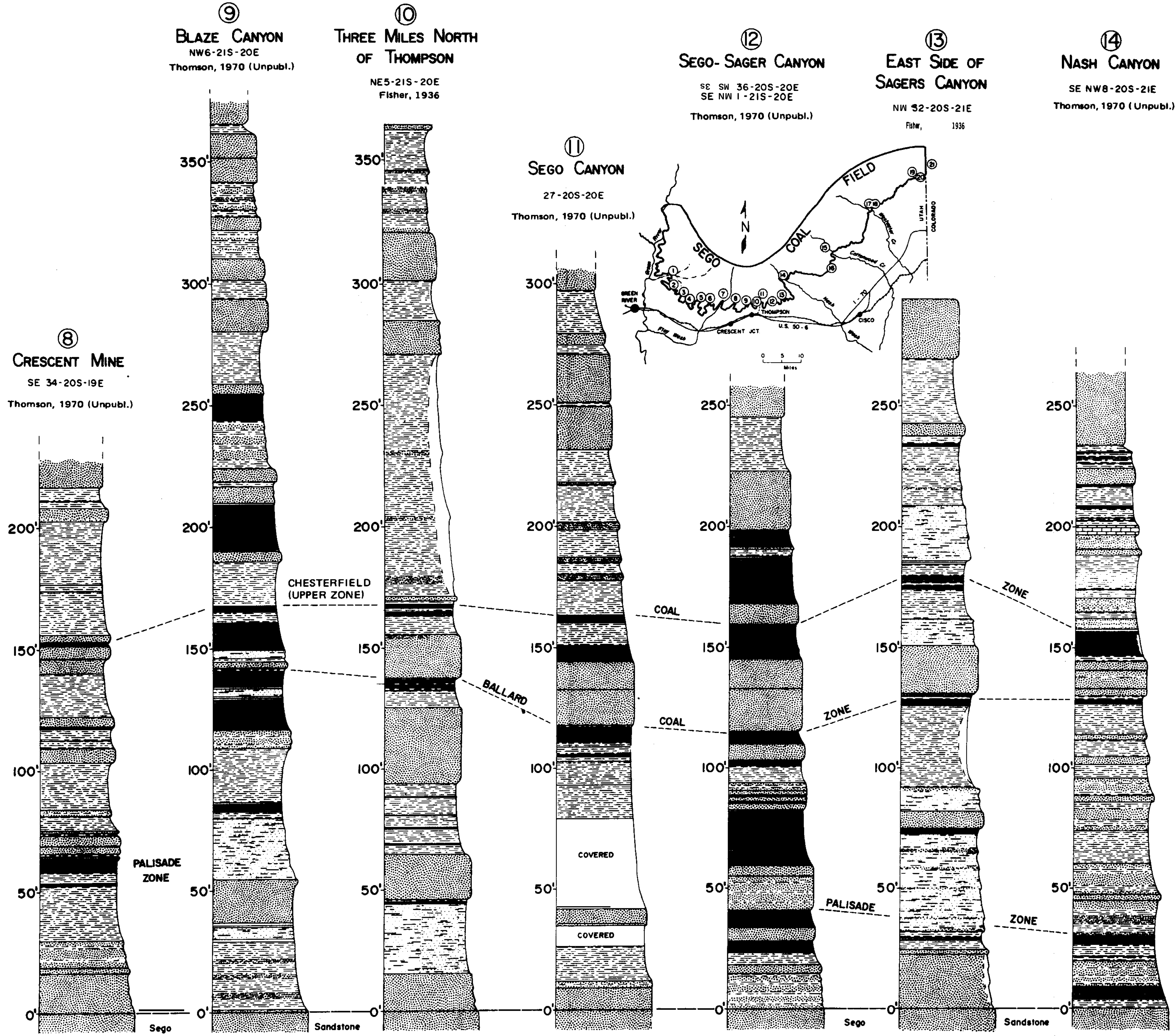


Figure 4-18. Sections of the Neslen Member, Price River ! ormation, Sego Coal Field (Doelling and Graham, 1972) (Continued)

Continued

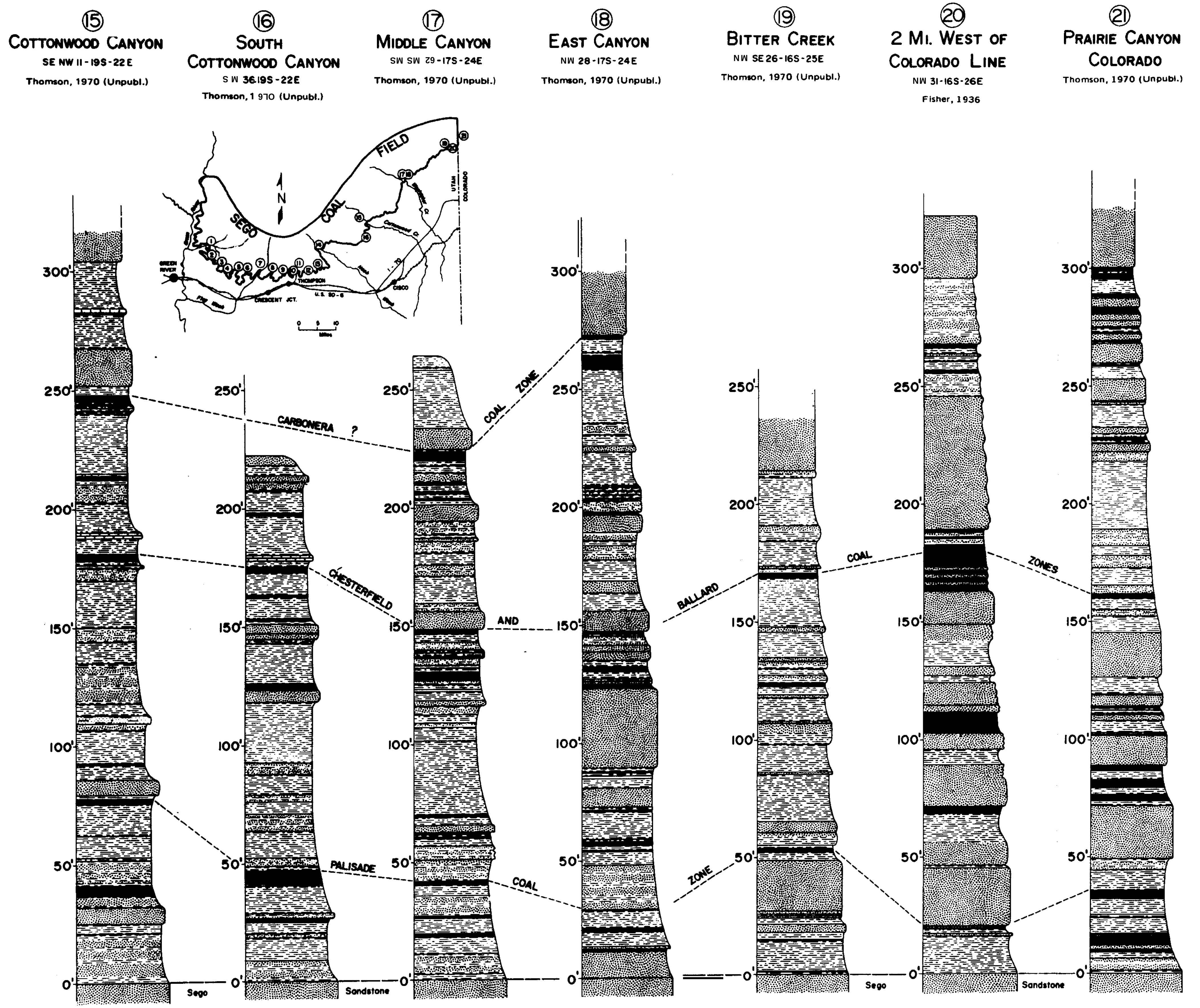


Figure 4-18. Sections of the Neslen Member, Price River Formation, Sego Coal Field (Doelling and Graham, 1972) (Continued)

Table 4-1. Divisions of the Major Cretaceous Coal-Bearing Units Within the Uinta Basin Coal Fields and Region

PERIOD	GEOLOGIC UNIT	VERNAL COAL FIELD	TABBY MOUNTAIN COAL FIELD	SEVIER-SANPETE REGION	WASATCH PLATEAU COAL FIELD	EMERY COAL FIELD	BOOK CLIFFS COAL FIELD	SEGO COAL FIELD
Tertiary		Wasatch Formation		Flagstaff Limestone				
Cretaceous			Currant Creek Formation	North Horn Formation* (Wales Coal Field)	North Horn Formation	North Horn Formation	North Horn Formation	Tuscher Formation
	Mesaverde Group	Williams Fork Formation* Rim Rock Sandstone* Asphalt Ridge Formation	Upper Mesaverde Group* Lower Mesaverde Group	Price River Formation Blackhawk Formation* (Mount Pleasant and Salina Canyon Coal Fields) South Flat Formation Six Mile Canyon Formation* (Sterling Coal Field) Funk Valley Formation Allen Valley Shale Sanpete Formation	Price River Formation Blackhawk Formation* Star Point Sandstone	Price River Formation Blackhawk Formation Star Point Sandstone	Price River Formation Blackhawk Formation* Star Point Sandstone	Price River Formation* (Neslen Member)
	Mancos Shale	Frontier Sandstone* (Upper Member)	Upper Shale Member Frontier Sandstone* Mowry Shale	Mancos Shale	Mancos Shale	Masuk Shale Emery Sandstone Blue Gate Member Ferron Sandstone* Tununk Shale Member	Mancos Shale	Mancos Shale

* Major Coal Formation

Table 4-2. Average Ultimate Analyses (As-Received) of Coalbeds and Zones Within the Uinta Basin Coal Fields (After Doelling, 1972; and Doelling and Graham, 1972)

SOURCE*	COAL FIELD	COALBED/ ZONE	SULFUR WT. %	HYDROGEN WT. %	CARBON WT. %	NITROGEN WT. %	OXYGEN WT. %	NUMBER OF TESTS
1	VERNAL							
	West	Frontier Zone	1.7	5.5	63.7	1.1	18.6	6
2	WASATCH PLATEAU	Hiawatha Bed	0.6	6.0	71.6	1.4	13.8	5
	Central	Bear Canyon Bed	0.5	6.3	74.2	1.4	13.3	5
2	EMERY							
	North	Upper Coal Zone No. 1 Bed	1.0	5.1	70.7	1.3	11.8	3
2	BOOK CLIFFS							
	West	Castlegate A Bed	0.5	5.7	71.8	1.4	14.5	1
		Castlegate B Bed	0.7	5.6	69.6	1.4	13.8	2
		Royal Blue Bed	0.7	5.6	72.3	1.3	15.1	1
		Castlegate C Bed	0.5	5.8	73.1	1.4	14.5	1
		Castelgate D Bed	0.4	5.7	74.0	1.4	11.2	1
		Kenilworth Bed	0.6	5.9	71.9	1.4	13.1	1
	East	Lower Sunnyside Bed	1.0	5.8	73.8	1.5	13.1	2
		Sunnyside Bed	1.1	5.7	73.4	1.6	12.6	2
1	SEGO							
	West	Palisade Bed	0.7	5.2	63.9	1.5	16.3	2
		Chesterfield Bed	0.8	5.3	67.2	1.5	4.9	3
		Ballard Zone	0.7	5.3	62.6	1.4	15.5	2

*Source:

1. Doelling, H. H. & R. L. Graham, Monograph Series No. 2, 1972
2. Doelling, H. H. Monograph Series No. 3, 1972

Table 4-3. Selected Proximate Analyses (As-Received) of Coal Within the Uinta Basin Coal Fields and Region (After Doelling, 1972; and Doelling and Graham, 1972)

SOURCE*	COAL FIELD OR REGION	COAL	NO. OF SAMPLES	MOISTURE (%)	VOLATILE MATTER (%)	FIXED CARBON (%)	ASH (%)	SULFUR (%)	BTU/LB
1, 4	Vernal	Frontier Formation Average	–	9.1	39.4	48.5	12.5	1.6	11,509
		Mesaverde Formation Average	–	12.8	42.7	39.9	17.5	0.8	8,950
4	Tabby Mountain	Frontier Sandstone Average	–	15.4	34.3	36.3	13.0	0.8	8,450
		Winchester Bed	3	19.4	33.5	36.9	10.2	0.7	8,110
1		Mesaverde Lower Zone	1	19.2	37.0	37.6	6.2	0.7	8,723
		Mesaverde Formation Average	–	13.6	38.8	41.5	6.7	1.1	10,285
		Fraughton Bed	2	15.4	39.2	39.4	7.1	0.9	10,321
2	Wasatch Plateau	Field Average	–	6.1	43.4	47.4	6.7	0.6	12,589
	South	Ferron	1	11.9	36.4	42.7	9.0	0.5	–
		Hiawatha Bed	2	6.6	41.0	47.0	5.7	0.7	12,345
		Upper Hiawatha Bed	1	12.9	–	–	5.5	0.5	–
		Muddy No. 1 Bed	1	8.4	39.1	45.2	7.3	0.5	11,922
		Ivie Bed	2	13.4	36.2	43.8	6.7	0.6	10,570
	Central	Hiawatha Bed	4	5.1	45.0	45.2	4.9	0.6	13,243
		Blind Canyon Bed	5	4.8	41.1	45.6	9.1	0.6	12,650
		Bear Canyon Bed	6	6.0	43.8	45.5	4.6	0.5	13,410
2	North	Hiawatha Bed	2	7.3	37.5	49.1	4.9	0.7	11,696
		Hiawatha Lower Split	2	9.6	38.1	45.3	3.9	0.5	10,550
		Wattis Bed	1	7.3	41.0	47.7	4.0	0.9	12,530
		Castlegate "A" Bed	5	7.6	40.6	45.7	5.0	0.5	12,500
		Bob Wright Bed	1	2.8	46.0	46.9	4.3	0.5	13,070

Continued

* Source:
1. Doelling, H. H. and R. L. Graham, Monograph Series No. 2, 1972
2. Doelling, H. H. Monograph Series No. 3, 1972
3. Doelling, H. H., A. D. Smith, and F. D. Davis, Methane Content of Utah Coals, 1979
4. Keystone Coal Industry Manual, 1979

Table 4-3. Selected Proximate Analyses (As-Received) of Coal Within the Uinta Basin Coal Fields and Region (After Doelling, 1972; and Doelling and Graham, 1972) (Continued)

OURCE*	COAL FIELD OR REGION	COAL	NO. OF SAMPLES	MOISTURE (%)	VOLATILE MATTER (%)	FIXED CARBON (%)	ASH (%)	SULFUR (%)	BTU/LB
2.4	Sevier-Sanpete Region	Mount Pleasant Field	7	3.4	42.9	45.6	8.1	0.8	12,890
		Salina Canyon Field	12	7.6	42.2	42.2	9.8	0.5	11,367
		Sterling Field	1	8.2	42.6	43.2	6.1	0.9	11,767
		Wales Field	9	5.0	34.2	46.4	14.8	4.3	10,119
2	Emery	Field Average	(#)	(47) 7.4	(46) 37.7	(46) 448	(47) 8.5	(46) 1.0	(44) 11,450
	North	Lower Coal Zone, "C" Bed	3	8.1	35.6	41.4	14.9	0.9	10,245
		Upper Coal Zone, "I" Bed	4	4.8	40.6	46.9	7.8	1.9	12,498
	South	Ferron Bed	1	23.6	32.6	33.3	10.6	2.9	7,823
		Lower Coal Zone, "A" Bed	3	13.0	33.4	41.4	12.2	0.4	8,801
		"M" Bed	1	10.2	36.2	37.6	16.0	0.9	9,526
		Upper Zone	2	12.4	36.5	41.5	9.6	1.7	10,232
		Ivie Bed	3	12.9	36.3	43.4	7.4	0.6	10,570
3	Book Cliffs	Field Average		4.8	–	49.1	6.7	0.9	12,760
		Castlegate Area Average	–	4.3	42.6	46.4	6.6	0.5	12,825
		Soldier Canyon Area Average	–	4.8	38.6	49.3	7.0	0.5	12,531
		Sunnyside Area Average	–	5.0	38.2	50.5	6.4	1.1	12,648
		Woodside Area Average	–	5.5	37.5	50.1	6.7	0.7	12,664
2	East	Lower Sunnyside Bed	4	5.9	36.2	51.7	6.4	0.8	12,420
		Sunnyside Bed	2	4.7	38.6	51.3	5.5	1.1	13,384

Continued

* Source:
1. Doelling, H. H. and R. L. Graham, Monograph Series No. 2, 1972
2. Doelling, H. H. Monograph Series No. 3, 1972
3. Doelling, H. H., A. D. Smith, and F. D. Davis, Methane Content of Utah Coals, 1979
4. Keystone Coal Industry Manual, 1979

Table 4-3. Selected Proximate Analyses (As-Received) of Coal Within the Uinta Basin Coal Fields and Region (After Doelling, 1972; and Doelling and Graham, 1972) (Continued)

SOURCE*	COAL FIELD OR REGION	COAL	NO. OF SAMPLES	MOISTURE (%)	VOLATILE MATTER (%)	FIXED CARBON (%)	ASH (%)	SULFUR (%)	BTU/LB
2	Book Cliffs West	Castlegate "A" Bed	6	5.4	41.1	48.0	5.5	0.5	12,827
		Castlegate "B" Bed	4	4.8	41.9	45.6	7.9	0.5	12,650
		Castlegate "C" Bed	3	3.9	41.7	49.4	4.8	0.5	13,118
		Castlegate "D" Bed	2	4.6	45.2	43.1	7.5	0.4	12,730
		Gilson Bed	2	6.0	39.7	50.0	4.4	0.5	13,085
		Sunnyside Bed	2	4.7	—		4.5	0.5	
		Beckwith Zone	1	4.8	33.6	50.2	11.4	1.2	
		Rock Canyon Bed	4	5.2	39.1	49.4	6.5	1.1	12,600
		Kenilworth Bed	4	4.5	41.5	45.9	8.2	0.4	12,553
		Liberty Bed	2	5.2	43.1	45.0	6.6	0.9	12,703
		Aberdeen Bed	2	4.5	40.9	48.1	6.8	0.5	12,642
		Royal Blue Bed	2	4.2	42.6	48.5	4.7	0.7	12,940
		Royal No. 2 Bed	2	3.0	43.0	47.8	6.3	0.5	13,136
1.3	SEGO	Field	(#)	(27)	(23)	(23)	(27)	(27)	(18)
		Average		9.1	34.7	468	11.1	0.6	10,940
1	East	Carbonera Zone	1	10.0	42.2	41.2	6.6	0.6	10,270
1	West	Palisade	(#)	(6)	(5)	(5)	(6)	(6)	(4)
		Zone		7.7	35.9	44.6	10.9	0.6	11,610
		Ballard Zone	4	10.9	32.2	42.7	14.2	0.6	10,230
		Chester-	(W)	(15)	(12)	(12)	(15)	(15)	(8)
		Field Zone		8.4	34.7	46.5	10.9	0.6	11,247

* Source:
1. Doelling, H. H. and R. L. Graham, Monograph Series No. 2, 1972
2. Doelling, H. H. Monograph Series No. 3, 1972
3. Doelling, H. H., A. D. Smith, and F. D. Davis, Methane Content of Utah Coals, 1979
4. Keystone Coal Industry Manual, 1979

Table 4-4. Coalbed Thicknesses Within the Wasatch Plateau Coal Field (Keystone Coal Industry Manual, 1979)

COALBEDS	LOCATION	AVERAGE DEVELOPED THICKNESS (FT)	MAXIMUM EXPOSED THICKNESS (FT)
NORTHERN WASATCH PLATEAU			
Bob Wright	North	4-7 (Several Beds)	15
Candland	Local Only	4-12	16
Royal Blue	Northeast	Thin	16
Castlegate "A"	North	5-15	19
Bear Canyon	South	5-10	16
Gordon Wattis	North	3-9 (Several Local Beds)	30
Blind Canyon	South	4-8	15
Hiawatha	Continuous	6-l 7	25
SOUTHERN WASATCH PLATEAU			
Upper Ivie	Continuous	6-14	14
Ivie	South	5-8	10
Muddy 2	Local	4-6	6
Muddy 1	Local	3-5	9
Upper Hiawatha	North	5-10	17
Hiawatha	North	5-7	9

5. POTENTIAL METHANE RESOURCE

5.1 METHANE DATA IN EXISTING LITERATURE

The Utah Geological and Mineral Survey (UGMS) has been working under a grant from the U.S. Bureau of Mines (USBM), and later, the Department of Energy (DOE) (Grant No. ET-76-G-01-9004) to collect data on the methane content of the various coals in Utah. As a part of these studies, the UGMS, from 1975 to 1979, collected 164 core samples from seven of the more than 20 coal fields listed for Utah. The core samples collected were mainly from coals, although nine samples were taken from rocks adjacent to the coalbeds. Sampling was confined to those areas being actively mined, and for which significant data are available.

The coal samples collected by UGMS were placed in sealed canisters and the gas content of the samples desorbed. The gas released was measured using standard USBM desorption techniques and data collected on the lost and desorbed gas. Upon completion of desorption, the samples were sent to USBM where they were crushed, and the residual gas content determined. From information gained on the lost, desorbed, and residual gas, it was possible to determine the total gas content of the sample in cubic centimeters of gas per gram of coal.

Data collected by UGMS during the 1975-1979 project period were tabulated and reported as a part of its Special Study Series in August 1979. Work on this project continues, and additional samples have been collected for gas measurement. As of this date, these data have not been published by UGMS.

Since its establishment in 1910, USBM has been concerned with the methane in coal mines where its presence in a mine's atmosphere constitutes a hazard that can lead to explosive conditions. Deeper mining and the higher methane content generally associated with deeper coalbeds prompted the Bureau to begin collecting data on the measured methane emission rates of U.S. coal mines with an emission of at least 100,000 cu ft/day, and from mines in coalbeds with total mine emissions in excess of one million cu ft/day. Data from this source relevant to the Uinta

Basin are shown in Table 5-l. While it cannot be utilized directly to determine the in-place gas content of the coals, this information is useful to delineate those areas having higher gas contents, and which may contain quanitites sufficient for commercialization.

USBM also is conducting research to determine the effectiveness of long holes in degasifying an area. After a section of Kaiser Steel Company's Sunnyside No. 1 mine in the Book Cliffs coal field was closed to mining because of excessive methane emissions, the Bureau drilled two horizontal holes from outside entries to degasify the virgin coal in advance of mining operations (Perry, et al, 1978). Gas flow from the holes was monitored for a g-month period following completion of the holes. This procedure decreased face emissions by about 40 percent in that section of the mine.

In 1978, Mountain Fuel Resources, Inc. submitted a proposal to DOE (DOE Contract No. DE-AC2179MC10734) to conduct a demonstration project for methane recovery from unminable coalbeds. As part of this study, Mountain Fuels proposed to drill three holes into coalbeds in the Book Cliffs coal field to demonstrate drilling, fracturing, and techniques for methane recovery from coal. By mid-1980, two holes were drilled, samples were collected and desorbed by Mountain Fuel, and dewatering and stimulation design were in progress. Preliminary indications are that the recovery of gas in sufficient quantities for commercialization may be feasible.

5.2 METHANE DATA FOR UINTA BASIN COAL FIELDS

As noted, UGMS has collected coal samples and determined their methane content by desorption. These samples were collected from seven coal fields, four of which are part of this study. Fields for which data are available are the Wasatch, Emery, Book Cliffs, and Sego coal fields.

Wasatch Plateau Coal Field

The Wasatch Plateau coal field contains several coalbeds eight of which are presently being mined in 14 active coal mines (Figure 5-l) (Keystone, 1979). USBM's report (Irani, et al, 1977) on mine emissions lists no mines in this field as having emission rates in excess of 100,000 cu ft/day for 1971, 1973 or 1975.

UGMS has collected 18 coal samples from eight coalbeds in this field (Figure 5-2) (Doelling, et al, 1979). Desorption analysis for 16 samples was completed and that data appears in Table 5-2. Results of this analysis indicate that coals of the Wasatch field have a relatively low methane gas content. The desorbed gas values ranged from zero in the Upper O'Connor to a high value of 1.65 cubic centimeters per gram (cm^3/gm) (52.8 cu ft/ton) in the Hiawatha bed. The high value on the Hiawatha bed was obtained from a sample taken from in-mine drilling. On the average, the Hiawatha bed had the highest desorbed methane content at 0.63 cm^3/gm (20.2 cu ft/ton); and the lowest average gas content was in the Upper O'Connor which desorbed 0.015 cm^3/gm (0.48 cu ft/ton). Average gas content for all samples taken in the field was 0.34 cm^3/gm (10.9 cu f-t/ton).

Emery Coal Field

The Emery coal field, in the southeastern part of the Wasatch Plateau, has several mines presently in operation (Figure 5-2). As of 1972, the principal beds being mined, were the Ferron and Ivie coalbeds (Doelling, 1972). The USBM methane emission report (Irani, et al, 1977) lists no mines as having excessive emissions for the years 1971 or 1973. However, Consolidation Coal Company's Emery Mine in Emery County is listed as having an average emission rate in 1975 of 0.1 MMcfd (Table 5-1).

Samples were collected by UGMS from several sites in the Upper Ferron, Ferron, Lower Ferron, and Ferron "A" beds. Origin locations of the samples are shown in Figure 5-2. The samples were desorbed by the Survey and the results are presented in Table 5-3. Values of the total desorbed gas range from zero to a high of 0.55 cm^3/gm (17.6 cu ft/ton). The average methane content for all the samples is 0.15 cm^3/gm (4.8 cu ft/ton).

Book Cliffs Coal Field

Of all coal-bearing areas within the Uinta Basin, none has been explored or mined more than the Book Cliffs coal field, with 25 mining operations reported in eight coalbeds (Doelling, 1972). Some of these mining operations also have been shown as having the basin's highest methane emission rate as measured by USBM. During the period from 1971 to 1975, six mines were listed by the Bureau as having emissions in excess of 0.1 MMcfd. The highest emission rate for this period was found in Kaiser

Steel Corporation's Sunnyside No. 1 mine in Carbon County, which had emission rates of 1.2 MMcfd, 1.9 MMcfd, and 1.4 MMcfd for 1971, 1973 and 1975, respectively. The Sunnyside No. 1 (see Figure 5.1 for location) is currently mining the Sunnyside coalbed, and four other coal mining operations in the same coalbed in Carbon County also have had emission rates in excess of 0.1 MMcfd. The high gas content found in one section of the Sunnyside No. 1 mine forced its closing.

USBM used the closed section in the Sunnyside No. 1 for a research project to determine the effectiveness of long holes in degasifying in advance of mining operations (Perry, et al, 1978). Two holes, measuring 430 feet'and 450 feet respectively, were drilled horizontally into the coalbed. The initial gas flow from these holes was 160,000 and 127,000 cfd, respectively. Total gas production 16 days after completion declined to slightly over 144,000 cfd. At the end of a g-month period, the two holes had produced over 35 MMcf of commercial-quality gas (Perry, et al, 1978). Samples of the coal were collected by UGMS, and the desorption information for those samples (Numbers 12 through 17) is shown in Table 5-4.

UGMS also collected 76 other coal samples from 12 coalbeds or zones in the Book Cliffs field. Origin locations of the samples are shown in Figure 5-3, and the results of the desorption tests are in Table 5-4. Coals of the Book Cliffs field, as expected from the emission rates, show a higher total gas content as compared to other coal-bearing regions of the Uinta Basin. UGMS data show the gas concentrations as ranging from a low of 0.10 cm^3/gm (3.2 cu ft/ton) in the Castlegate A to a high of 11.02 cm^3/gm (352.6 cu ft/ton) in the Castlegate D coalbed. The lowest average coalbed methane content was found in the Gilson, with a total gas value of 1.13 cm^3/gm (36.2 cu ft/ton), and the highest average total gas value occurred in Subseam 1, below the Aberdeen Sandstone, with a value of 8.52 cm^3/gm (272.5 cu ft/ton). Average value for all samples taken from the Book Cliffs field is 3.11 cm^3/gm (99.5 cu ft/ton) (Doelling et al, 1979).

An interesting fact noted by UGMS was that coalbeds north of the Carbon-Emery county line are moderately gassy (1 to 5 cm^3/gm) to gassy (greater than 5 cm^3/gm), whereas the coals south of the county line contain much less gas, although there is no difference in coal quality (Doelling, et al, 1979). No explanation for this phenomenon is apparent, but Doelling, et al, (1979) note the coincidence of high magnetic readings in areas of gassy coal, and suggest that materials in the basement may have been responsible for increasing heat or pressure, which would favor gas formation or the formation of coking coal.

Gas content of coalbeds in the Books Cliffs field prompted Mountain Fuels Resource, Inc. (1978) to undertake a project to investigate the potential for the commercial recovery of methane from coalbeds. Working in cooperation with DOE, Mountain Fuel, selected sites in the Whitmore Park area (Figure 5-4) to drill three vertical wells. By late 1980, two of the three had been drilled and coal samples collected and desorbed to determine their gas content. Results of the desorption analysis are shown in Table 5-5. The data shown indicate that coals in that area have a very high gas content, with several samples exceeding 12 cm^3/gm (384 cu ft/ton). Coalbeds with gas contents of 7 cm^3/gm (220 cu ft/ton) are considered as potential reservoirs for connnercial exploitation. As of late 1980, problems with pumps and tubing caused delays, so that no production data from these wells are presently available. The drilling of the third well has been delayed by permitting problems.

Sego Coal Field

The eastern extension of the Books Cliffs area is known as the Sego coal field. Like the Book Cliffs field, it is also a narrow, elongated field with outcrops along the southern boundary of the basin. The Green River is the boundary separating the Book Cliffs from the Sego field. Doelling (1972) noted that mining activity was being carried out in the Palisade, Chesterfield, and Ballard coal zones. Gas emissions from the mining operations are not very high as USBM lists no mines with emissions in excess of 0.1 MMcfd.

UGMS collected 26 samples (Figure 5-5) and desorbed them to determine their gas content. Data from the UGMS samples are shown in Table 5-6. In general, all the coal zones showed a low gas content. Average values of total gas for the four major coal zones are: Carbonera, 0.57 cm^3/gm (18.2 cu ft/ton); Chesterfield, 0.67 cm^3/gm (21.4 cu ft/ton); Ballard, 0.25 cm^3/gm (8.1 cu ft/ton); and Palisade, 0.21 cm^3/gm (6.8 cu ft/ton).

Vernal Coal Field

Coal for local use was produced from the Vernal coal field in the late 1800s. By the turn of the century 20 mines where active in the field, production peaking from 1903 to 1905. Coal production declined following the use of imported coal from Carbon County, Utah, and Colorado, and owing to the use of other fuel sources. The last mine closed in 1957, and total field production was approximately 250,000 tons. The amount of coal produced from 1955 to 1972 is considered insignificant (Doelling and Graham, 1972).

Testing for methane gas has not been attempted in this coal field, due possibly to the availability of better coalbeds in zones within other fields of the basin.

Tabby Mountain Coal Field

The Tabby Mountain coal field outcrops were discovered between 1885 and 1910. During this period only three mines produced significant quantities of coal. From 1910 to 1948 only one mine remained open, and after 1948 no coal was mined. Total production from this field has been considered insignificant (Doelling and Graham, 1972).

Testing for methane gas in the coal field has not been attempted, probably because of the lack of available gas transportation routes or pipelines. Moreover, the field contains a poor quality coal when compared to other fields in the basin.

Sevier-Sanpete Region

Prior to 1900 the Sterling field was the only coal field within the Sevier-Sanpete region with a significant annual coal production. The Wales coal field never produced over 10,000 tons annually, and the Salina Canyon coal field produced less than 1,000 tons annually before 1925. Besides the known fact that is was locally mined (Doelling, 1972), there is a lack of information on the Mt. Pleasant coal field.

The higher quality coal in Carbon County and the 1930s depression caused the shutdown of mines within the Sevier-Sanpete region. As of 1972, no fields were operating in the region, and the total coal produced from the four fields is estimated to have been 665,000 tons (Doelling, 1972).

Testing for the availability of methane gas has not been attempted because of the coalbeds' poor quality, and the availability of better coalbeds within the basin.

5.3 ESTIMATED RESOURCE VOLUME

Presently available information is inadequate to estimate accurately the methane content of Uinta Basin coals. The exact prediction of total in-place methane resource for the basin would require more desorption analyses and data on coal quality and quantity from areas where exploration has not been extensive. Moreover, the extent of the coals into the central part of the basin has not yet been ascertained and, if present, coals would represent a substantial resource (UGMS, 1980, personal communication). UGMS is continuing an expanded program of methane desorption which will help delineate the resource more accurately in the future. However, based on the information presented in the preceding sections, it is possible to estimate the methane resource in those areas for which data are available.

Several methods can be used to determine an area's total methane content. If desorption data and the area's total coal reserves are known, the computations are quite simple. Data available for the Uinta Basin are fairly complete, but do not allow a complete assessment of each field on a bed-by-bed basis. To derive a sense of uniformity in calculations, it was decided to take the low values for each bed having desorption data, and from this determine the average low methane content for each field for which data were available. The same procedure was applied to determine the average high methane content for each field. To determine the average methane content of a field, all the desorption data were used. These figures then were multiplied by known or estimated resources for the field to determine the potential methane resource.

The Wasatch Plateau coal field is estimated to contain 6,230 million tons of coal in beds greater than 4 feet thick and under less than 3,000 feet of overburden. The average low methane content for the Wasatch area is 0.15 cm^3/gm (4.8 cu ft/ton), and the average high value 0.37 cm^3/gm (11.9 cu ft/ton). Using these values gives an estimated low methane resource of 29.9 billion cubic feet and a high resource value of 74.1 billion cubic feet of gas. The average gas content is 0.34 cm^3/gm (11.0 cu ft/ton) for an estimated field total of 68.5 billion cubic feet.

The Emery coal field is not as extensive and the gas content is somewhat lower. The average low methane content is 0.05 cm^3/gm (1.9 cu ft/ton) and the high value is 0.31 cm^3/gm (9.9 cu ft/ton). Coal resources for this field are estimated to be 1.4 billion tons which would make the estimated low methane resource 2.7 billion cubic feet of gas; and the high value 13.9 billion cubic feet. The average methane content is 0.15 cm^3/gm (4.8 cu ft/ton) which makes an average reserve of 6.72 billion cubic feet.

The high gas content of the Book Cliff coal field makes it the largest and best potential methane reservoir. The average low and high methane values by desorption are 1.63 cm^3/gm (52.2 cu ft/ton) and 5.99 cm^3/gm (191.6 cu ft/ton), respectfvely. Estimated coal resources for the Book Cliffs have been placed at 3.7 billion tons which would produce an average low and high methane content of 193.1 billion cubic feet and 708.9 billion cubic feet, respectively. The overall average methane content is 3.11 cm^3/gm (99.5 cu ft/ton) or 368.2 billion cubic feet of gas. The data that were gathered in the Whitmore Park area had substantially higher gas values. The average of their samples was 10.2 cm^3/gm (327.5 cu ft/ton). If that is taken as an average field value, the overall average total gas content for the area is 1,211.8 billion cubic feet of gas.

The Sego field does not have the gas content of the Book Cliff area but the average low desorbed gas content, 0.08 cm^3 (2.5 cu ft/ton) and the average high desorbed content, 1.36 cm^3/gm (43.5 cu ft/ton) are better than those of the Emery and Wasatch coal fields. The total resources for the Sego field are 294 million tons which would provide low and high methane resources of 735 million and 12.79 billion cubic feet of gas, respectively. The average value of desorbed gas is 0.34 cm^3/gm (10.9 cu ft/ton) which makes the field average 3.2 billion cubic feet.

Detailed gas contents or data regarding average gas in the Vernal, Tabby Mountains, and Sevier-Sanpete coal fields are not available. The total coal resources of these three areas are estimated to be 2,314.6 million tons of coal. It appears that the coals in these areas contain some quantity of gas. The lack of information seems to indicate the content is probably low, so that any estimate for those areas should be low. The lowest gas values for any field were found in the Emery coal field. If the values of desorbed gas for that field are applied to the areas for which no gas data are available, it is possible to make at least a general statement about gases in those regions: using this rationale, the low gas content is 4.4 billion cubic feet and the high gas content is 22.6 billion cubic feet. The average value would be 11.3 billion cubic feet of gas.

Using the resource figures generated by this method, the total estimated gas resource for the seven coal areas of the Uinta Basin can be calculated. UGMS data would estimate the low value to be 230.8 billion cubic feet and the high value to be 832.3 billion cubic feet of gas. An average value would be 457.9 billion cubic feet. If the higher average value of 10.2 cc/gm (327.5 cu ft/ton) from the Mountain Fuel project is used for the seven coal areas having an estimated 13.9 billion tons of reserves, the total average gas content would be 4,552 billion cubic feet of gas.

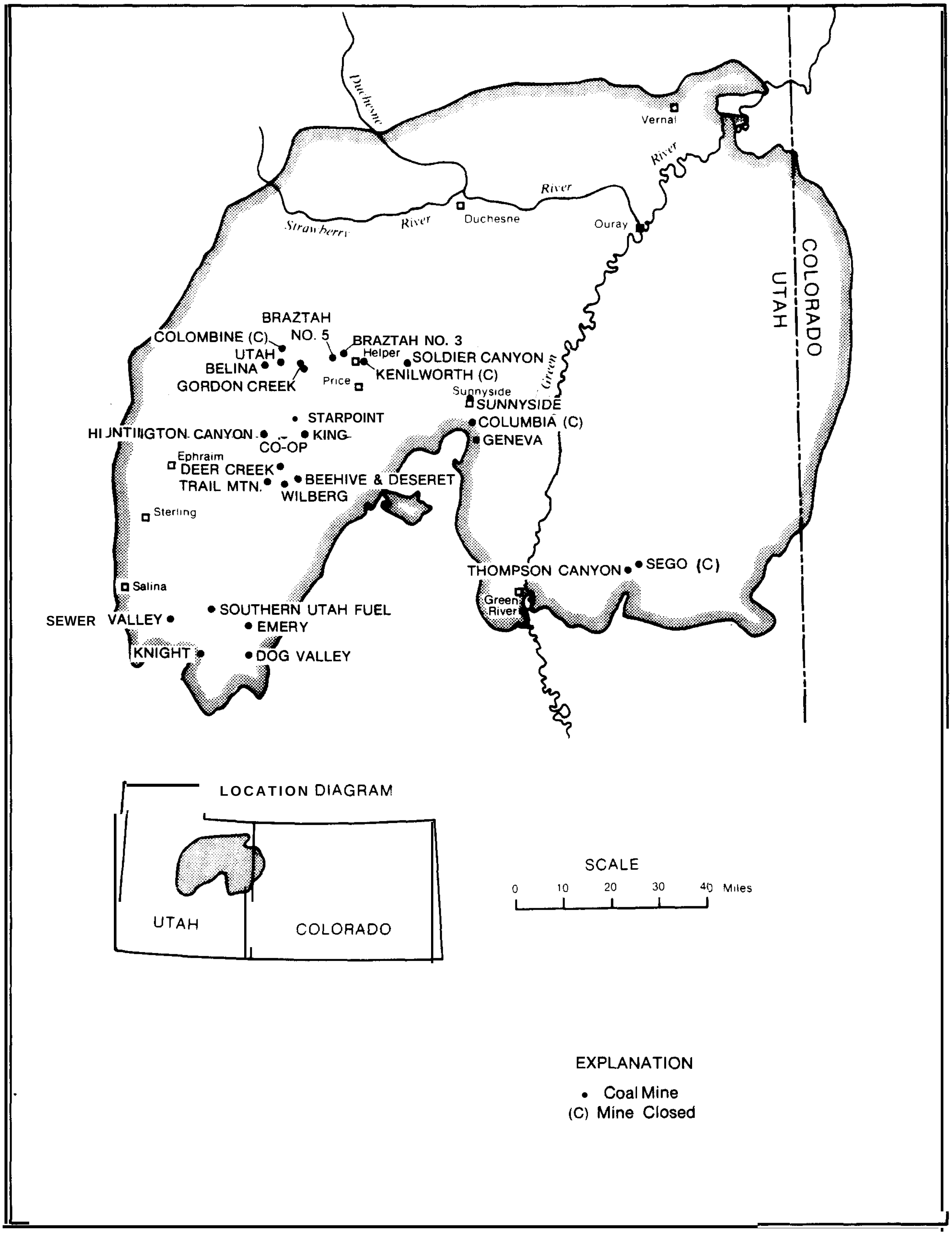


Figure 5-1. Map Showing Active and Closed Mines Located in the Uinta Basin (After Staff, Utah Geological and Mineral Survey, 1977)

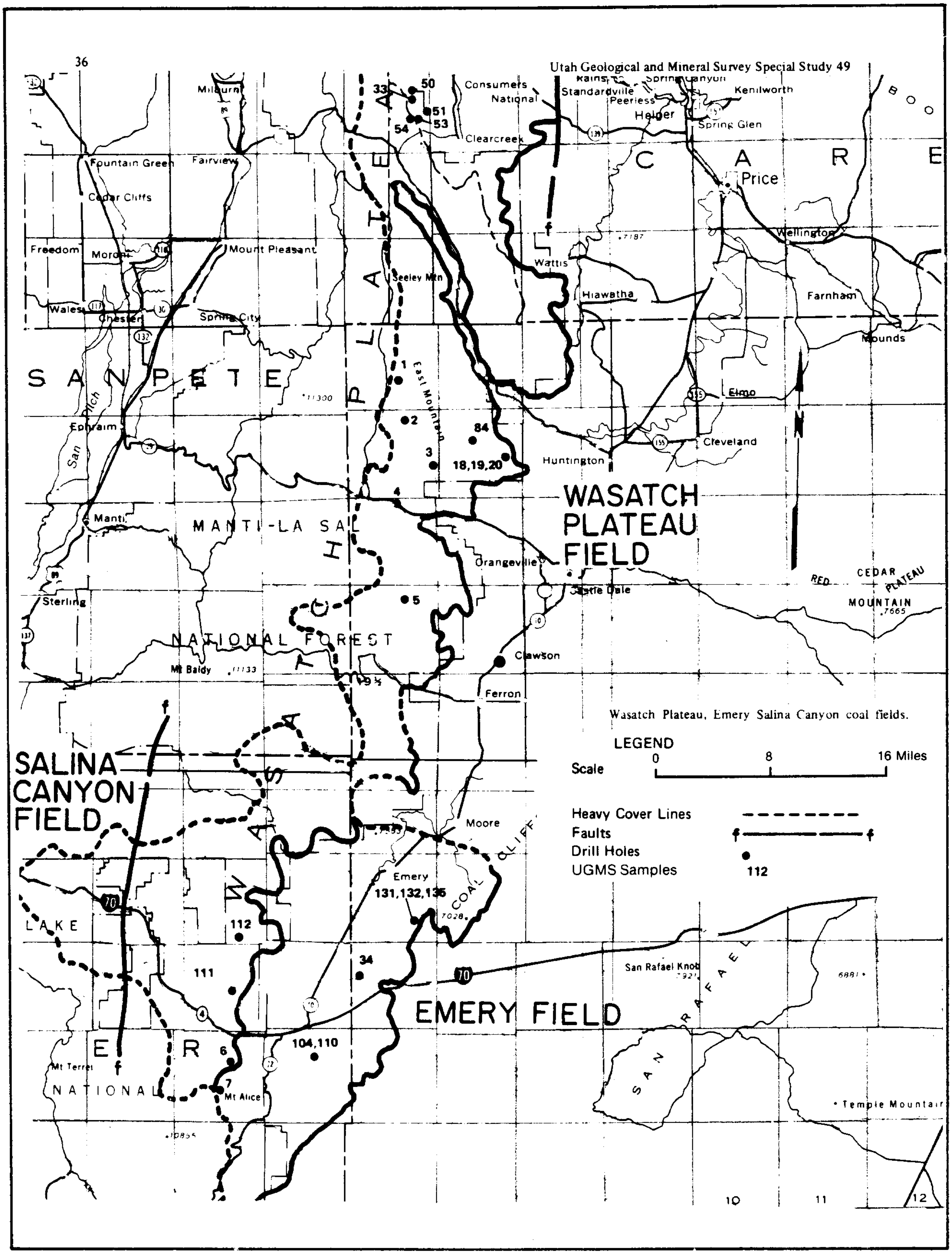


Figure 5-2. Map Showing Location of U.G.M.S. Well Sites in the Wasatch Plateau and Emery Coal Fields (After Doelling, Smith, and Davis, 1979)

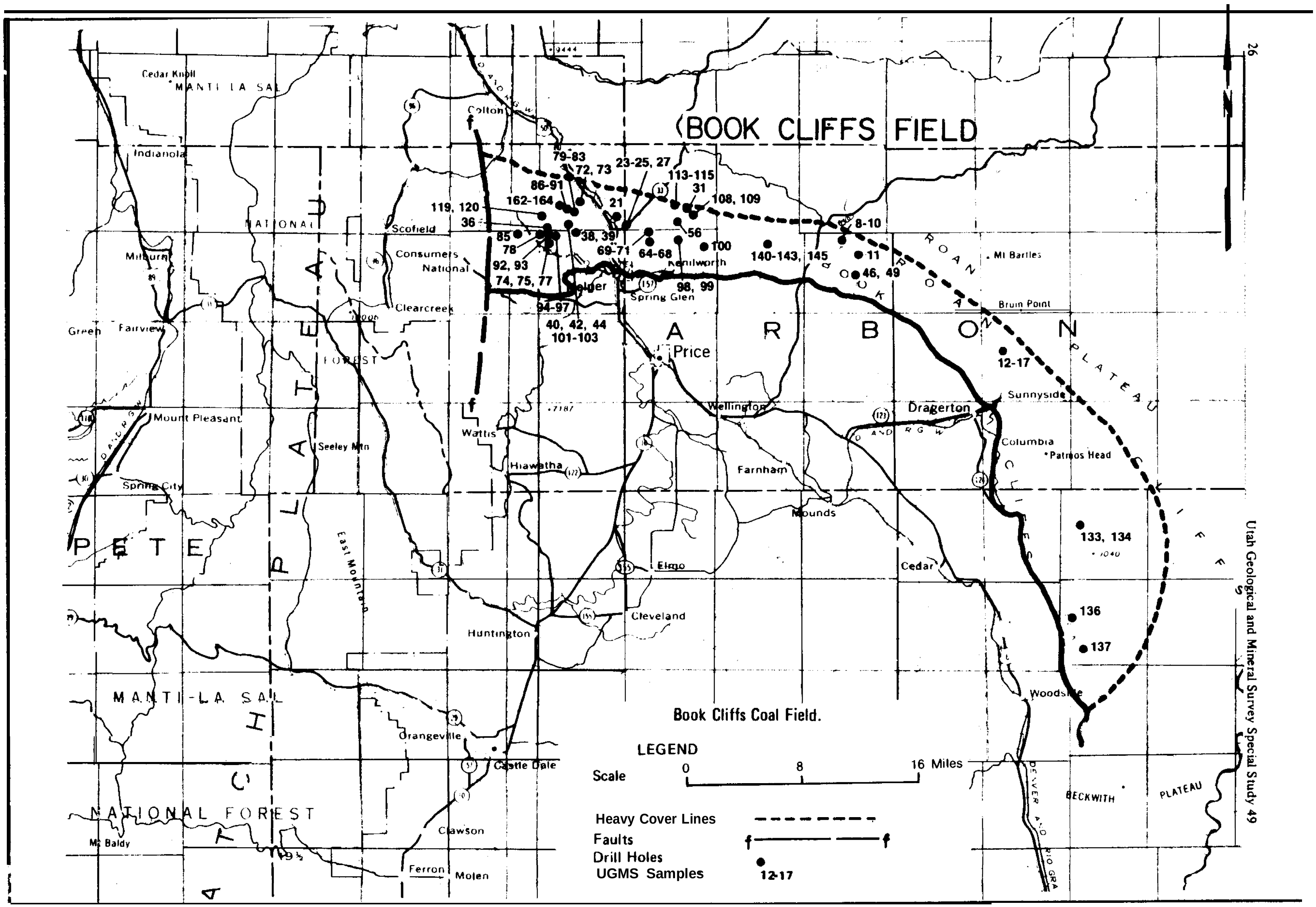


Figure 5-3. Map Showing Location of U.G.M.S. Well Sites in the Book Cliffs Coal Field (After Doelling, Smith, and Davis, 1979)

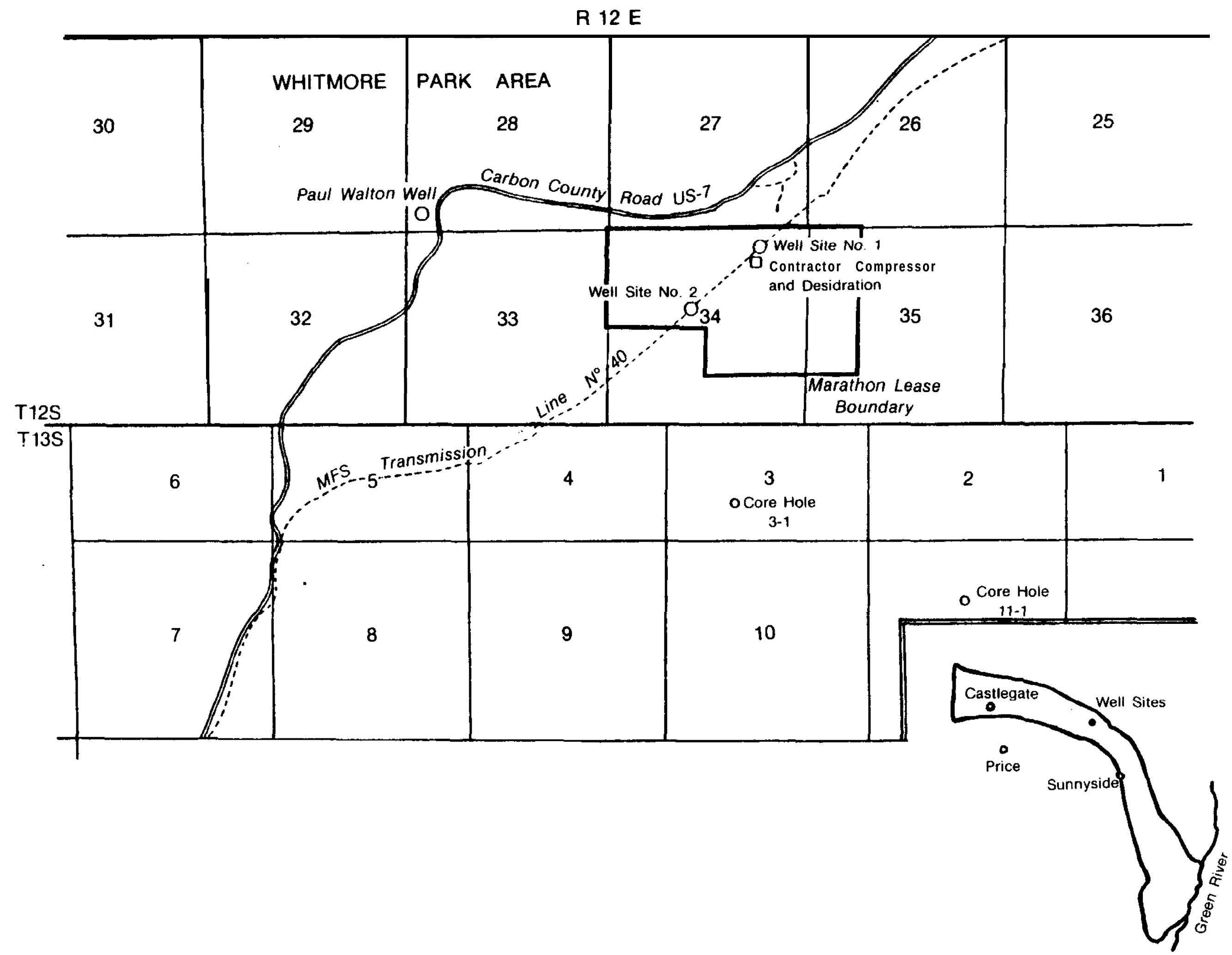


Figure 5-4. Map Showing Location of the Mountain Fuel Resources Whitmore Park No. 1 and No. 2 Well Sites in the Book Cliffs Coal Field (Mountain Fuel Resources, Inc., 1978)

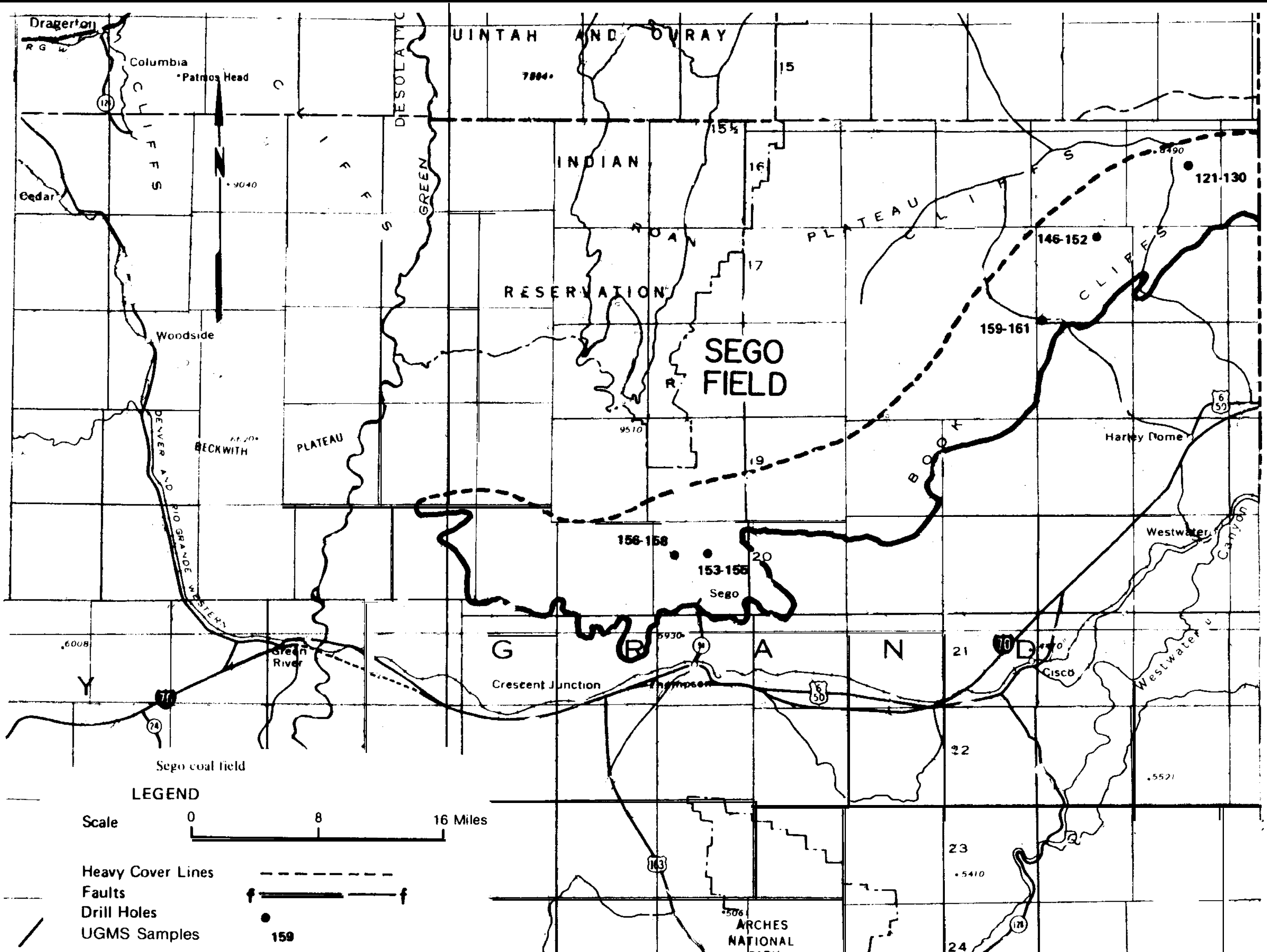


Figure 5-5. Map Showing Location of U.G.M.S. Well Sites in the Sego Coal Field (After Doelling, Smith, and Davis, 1979)

Table 5-1. Average Daily Methane Emission from Mines with Emission Rates of 100,000 cfd or Greater (After Irani, Jansky, Jeran, and Hassett, 1977)

Coal Field	Mine	Location	Coalbed	1971 MMcfd	1973 MMcfd	1975 MMcfd
Book Cliffs	Sunnyside No. 1 Kaiser Steel Corp.	Carbon County, Utah	Upper Sunnyside Lower Sunnyside	1.2	1.9	1.4
	Kennilworth North American Coal Corp.	Carbon County, Utah	Upper Sunnyside Lower Sunnyside	0.9	0.7	—
	Sunnyside No. 3 Kaiser Steel	Carbon County, Utah	Upper Sunnyside Lower Sunnyside	0.3	0.3	0.4
	Soldier Canyon Premium Coal Co.	Carbon County, Utah	Upper Sunnyside Lower Sunnyside	0.2	0.2	0.2
	Carbon No. 2 Carbon Fuel Co.	Carbon County, Utah	Upper Sunnyside Lower Sunnyside	0.2	0.1	—
	Braztah No. 3 Braztah Corp.	Carbon County, Utah	Castlegate B	—	—	0.2
Emery	Emery Consolidation Coal Co.	Emery County, Utah	Ferron J	—	—	0.1

Table 5-2. Selected Desorption Data from the U.G.M.S. for the Wasatch Plateau Coal Field (After Doelling, Smith, and Davis, 1979)

UGMS Sample No.	Location	Coalbed or Zone	Thickness of bed (ft)	Depth interval (feet)	Lost and desorbed gas cc/gm	Residual gas cc/gm	Total gas cc/gm
53	NW24-13S-6E	Up. O'Connor	15.9	699.3-700.3	0.02	0.01	0.03
54	SE23-13S-6E	Up. O'Connor	10.1	1015.0-1016.0	0.00	0.00	0.00
50	SE11-13S-6E	Lwr. O'Connor	7.5	1457.2-1458.2	0.01	0.004	0.01
51	NW24-13S-6E	Lwr. O'Connor	10.2	627.2-628.2	0.02	0.01	0.03
5	SE3-19S-6E	Bear Canyon	3.5	970.3-971.3	0.04	0.02	0.06
6	NE15-24S-4E	Upper Ivie	4.3	80.8-81.8	0.08	0.05	0.13
7	SE21-24S-4E	Upper Ivie	4.0	275.6-276.6	0.06	0.05	0.11
111	NW22-23S-4E	Ivie	4.5	755.2-756.8	0.00	Tests Incomplete	
112	NE34-22S-4E	Ivie	4.5	812.0-813.2	0.00	Tests incomplete	
33	NE14-13S-6E	Flat Canyon	3.0	1367.2-1368.2	0.16	0.11	0.27
20	NE23-17S-7E	Blind Canyon	7.0	149.5-152.0[1]	0.27	0.18	0.45
1	SW22-16S-6E	Hiawatha Bed	4.6	871.8-872.8	0.07	0.11	0.18
2	SE3-17S-6E	Hiawatha Bed	9.4	616.0-617.0	0.90	0.43	1.33
3	SE24-17S-6E	Hiawatha Bed	8.9	356.1-357.1	0.05	0.08	0.13
4	NW3-18S-6E	Hiawatha Bed	7.5	447.8-448.8	0.61	0.04	0.65
18	NE23-17S-7E	Hiawatha Bed	10.5	112.0-113.9[1]	0.99	0.66	1.65
19	NE23-17S-7E	Hiawatha Bed	10.5	114.0-116.8[1]	0.14	0.12	0.26
84	16-17S-7E	Hiawatha Bed	7.9	87.7-89.0	0.00	0.21	0.21

[1]In-mine drilling

Table 5-3. Selected Desorption Data from the U.G.M.S. for the Emery Coal Field (After Doelling, Smith, and Davis, 1979)

UGMS Sample No.	Location	Coalbed or Zone	Thickness of bed (ft)	Depth Interval (feet)	Lost and desorbed gas cc/gm	Residual gas cc/gm	Total gas cc/gm
104	NE10-24S-5E	Upper Ferron	3.3	343.4-344.4	0.00	Test Incomplete	
131	NW26-22S-6E	Ferron	24.4	83.8-85.0	0.34[1]	0.16	0.50
132	NW26-22S-6E	Ferron	24.4	98.1-99.0	0.00	0.00	0.00
135	NW26-22S-6E	Ferron	2.8	239.0-240.0	0.00	0.00	0.00
110	NE10-24S-5E	Lower Ferron	1.9	584.2-585.3	0.00	Test Incomplete	
34	NE18-23S-6E	"A"	3.0	388.3-389.5	0.07	0.04	0.11

[1]Lost gas not recor.

Table 5-4. Available Desorption Data from the U.G.M.S. for the Book Cliffs Coal Field (After Doelling, Smith, and Davis, 1979)

UGMS Sample No.	Location	Coalbed or Zone	Thickness of bed (ft)	Depth Interval (feet)	Lost and desorbed gas cc/gm	Residual gas cc/gm	Total gas cc/gm
133	NW17-16S-15E	Beckwith	1.7	1073.0-1074.7	0.09	0.00	0.09
12	SW17-14S-14E	Sunnyside	7.0	19.0-21.0[1]	1.11	0.78	1.89
13	SW17-14S-14E	Sunnyside	7.0	41.5-43.0[1]	1.00	0.69	1.69
14	SW17-14S-14E	Sunnyside	7.0	61.5-64.0[1]	2.24	1.45	3.69
15	SW17-14S-14E	Sunnyside	7.0	68.0-70.2[1]	2.46	1.58	4.04
16	SW17-14S-14E	Sunnyside	7.0	41.5-44.5[1]	1.97	1.39	3.36
17	SW17-14S-14E	Sunnyside	7.0	44.5-47.0[1]	0.58	0.29	0.87
8	4-13S-12E	Sunnyside	11.8	1797.8-1798.8	2.79	1.97	4.76 X
136	NE19-17S-15E	Sunnyside	3.1	924.5-926.0	0.39	0.00	0.39
137	29-17S-15E	Sunnyside	2.9	915.9-917.2	0.00	0.31	0.31
140	SW3-13S-11E	Sunnyside	1.2	373.2-374.4	3.62	0.90	4.52
134	NW17-16S-15E	Sunnyside	4.1	1202.8-1204.2	0.26	0.00	0.26 X
9	4-13S-12E	Rock Canyon (L)	4.6	2352.1-2353.1	3.31	2.08	5.39 X
10	4-13S-12E	Rock Canyon (U)	3.9	2339.2-2340.2	1.69	1.08	2.77
46	SW15-13S-12E	Rock Canyon	7.9	1705.4-1706.4	2.47	0.40	2.87
141	SW3-13S-11E	Rock Canyon	4.3	434.5-435.7	0.39	0.91	1.30
49	SW15-13S-12E	Fish Creek	4.8	1726.7-1727.7	4.13	3.02	7.15 X
11	10-13S-12E	Gilson	3.0	2038.6-2039.6	0.77	0.53	1.30
142	SW3-13S-11E	Gilson	8.0	475.0-476.0	0.00	1.58	1.58
143	SW3-13S-11E	Gilson	8.0	481.6-482.6	0.00	0.51	0.51
23	SW31-12S-10E	Castlegate D	7.5	159.9-160.7	0.67	0.45	1.12
24	SW31-12S-10E	Castlegate D	7.5	169.3-170.1	0.76	0.50	1.26
31	SW26-12S-10E	Kenilworth	7.4	2448.3-2449.5	6.69	4.25	10.94 X
25	SW31-12S-10E	Kenilworth	26.0	245.0-246.0	0.76	0.59	1.35
38	NE4-13S-9E	Castlegate D	6.4	1429.8-1431.4	0.99	0.59	1.58
74	SE6-13S-9E	Castlegate D	4.0	147.5-149.0	0.22	0.50	0.72
79	SE28-12S-9E	Castlegate D	3.6	1134.0-1135.8	4.77	0.80	5.57 X
86	SW28-12S-9E	Castlegate D	6.3	1099.1-1101.2	0.00	1.50	1.50
X 101	SE32-12S-9E	Castlegate D	9.2	1306.4-1307.6	0.15	2.80	2.95
108	NE35-12S-10E	Kenilworth	9.4	2819.5-2820.6	0.00	2.20	2.20
109	NE35-12S-10E	Kenilworth	9.4	2825.9-2827.2	0.94	1.70	2.64
113	NW27-12S-10E	Kenilworth	10.8	3175.9-3176.9	10.61	0.41	11.02 X
75	SE6-13S-9E	Castlegate C	4.1	196.9-198.0	0.17	0.50	0.67
21	NE36-12S-9E	Castlegate C	13.0	1247.7-1249.0	0.42	0.28	0.70
27	SW31-12S-10E	Castlegate C	111.5	299.5-300.5	1.26	0.87	2.13
64	SE5-13S-10E	Castlegate C	10.7	555.3-556.5	0.61	0.70	1.31
65	SE5-13S-10E	Castlegate C	10.7	561.7-563.0	0.70	0.70	1.40
69	NE5-13S-10E	Castlegate C	5.0	897.2-898.4	1.16	0.50	1.66
114	NW27-12S-10E	Castlegate C	8.5	3291.3-3292.4	10.21	0.41	10.63
85	NE2-13S-8E	Castlegate B	4.7	439.3-440.6	0.05	1.19	1.24
87	SW28-12S-9E	Castlegate B (Rider)	1.5	1232.9-1234.1	6.40	0.80	7.20
92	NE6-13S-9E	Castlegate B (U)	4.1	501.7-503.4	0.65	1.10	1.75
93	NE6-13S-9E	Castlegate B (L)	3.4	510.1-511.4	0.63	0.40	1.03

[1]Hoizontal drill hole in Sunnyside No. 1 mine.

Continued

Table 5-4. Available Desorption Data from the U.G.M.S. for the Book Cliffs Coal Field (After Doelling, Smith, and Davis, 1979) (Continued)

UGMS Sample No.	Location	Coalbed or Zone	Thickness of bed (ft)	Depth Interval (feet)	Lost and desorbed gas cc/gm	Residual gas cc/gm	Total gas ccfgm
94	NW5-13S-9E	Castlegate B	4.9	736.1-737.3	1.20	1.80	3.00
77	SE6-13S-9E	Castlegate B	4.2	315.3-316.3	0.38	0.66	1.02
70	NW6-13S-9E	Castlegate B	5.6	351.5-352.5	0.14	0.79	0.93
70	NE5-13S-10E	Castlegate B	4.8	971.6-972.8	0.50	0.60	1.10
98	SE3-13S-10E	Castlegate B	4.8	971.6-972.8	0.50	0.60	1.10
36	SE31-12S-9E	Castlegate A	5.4	2170.0-2172.9	5.68	3.69	9.37
40	SE32-12S-9E	Castlegate A	10.0	1952.1-1953.0	0.30	0.21	0.51
72	NE28-12S-9E	Castlegate A	24.0	2641.3-2642.7	8.03	0.90	8.93
7 3	NE28-12S-9E	Castlegate A	24.0	2654.8-2658.3	9.17	0.22	9.39
80	SE281 2S-9E	Castlegate A	6.1	1194.6-1196.6	0.00	3.90	3.90
81	SE28-12S-9E	Castlegate A	3.6	1215.5-1217.0	6.85	0.30	7.15
88	SW28-12S-9E	Castlegate A	7.5	1333.4-1335.2	6.68	0.40	7.08
119	SW30-12S-9E	Castlegate A	11.4	3014.5-3015.6	0.65	1.21	1.86
120	SW30-12S-9E	Castlagate A	11.4	3023.7-3025.0	3.45	1.20	4.65,
162	NE29-12S-9E	Castlegate A	6.1	1937.5-1938.7	0.38	2.30	2.68
39	NE4-13S-9E	Castlegate A	10.0	1644.6-1646.0	0.09	0.06	0.15
56	SE34-12S-10E	Castlegate A	16.9	2558.0-2559.2	5.11	0.80	5.91
115	NW27-12S-1OE	Castlegate A	9.0	3353.43354.9	1.67	0.90	2.57
66	SE5-13S-10E	Castlegate A	3.6	590.8-591.8	1.09	1.50	2.59
67	SE5-13S-10E	Castlagate A	3.6	591.8-592.8	1.03	1.20	2.23
68	SE5-13S-10E	Castlegate A	8.5	192.0-193.5	0.10	0.00	0.10
71	NE5-13S-10E	Castlagate A	9.6	1002.6-1004.0	0.83	1.30	2.13
99	SE3-13S-10E	Castlegate A	11.7	824.3-825.7	0.16	1.10	1.26
100	NE12-13S-10E	Castlegate A	9.9	568.4-569.7	2.44	0.30	2.74
95	NW5-13S-9E	Castlegate A	8.8	777.0-778.9	0.00	0.30	0.30[2]
145	SW3-13S-11E	Castlegate A	4.0	757.0-758.4	0.52	0.51	1.03
82	SE28-12S-9E	Subseam 1	4.9	1394.0-1395.3	7.45	0.80	8.25
89	SW28-12S-9E	Subseam 1	4.1	1502.0-1503.9	6.72	0.68	7.40
163	NE29-12S-9E	Subseam 1	6.2	2082.8-2083.8	8.70	1.20	9.90
42	SE32-12S-9E	Subseam 2	10.0	2186.1-2187.1	1.50	1.11	2.61
83	SE28-12S-9E	Subseam 2	7.0	1435.1-1436.6	6.43	2.00	8.43
90	SW28-12S-9E	Subseam 2	3.4	1512.5-1514.4	0.86	1.49	2.35
97	NW5-13S-9E	Subseam 2	4.8	935.0-936.9	0.11	1.80	1.91
102	SE32-12S-9E	Subseam 2	5.1	1740.7-1742.0	0.00	1.50	1.50
164	NE29-12S-9E	Subseam 2	3.3	2109.0-2110.0	0.97	1.10	2.07
44	SE32-12S-9E	Subseam 3	2.5	2221.3-2222.3	0.24	0.16	0.40
91	SW28-12S-9E	Subseam 3	7.6	1550.6-1552.4	0.01	0.50	0.51
96	NW5-13S-9E	Subseam 3	8.0	961.6-962.9	1.24	0.80	1.84
103	SE32-12S-9E	Subseam 3	9.7	1760.7-I 762.1	0.00	2.30	2.30

[2]Close to old workings

Table 5-5. Desorption Data from Mountain Fuel Resources Whitmore Park (W.P.) Well Sites No. 1 and No. 2 in the Book Cliffs Coal Field (Mountain Fuel Resources, Inc., 1978)

Sample	Description	Depth, ft	Weight, g	Volume* Desorbed, cc	Lost Gas, cc	Residual Gas, cc	Total Gas, cc	CH_4 Content, cc/g	CH_4 Content, ft³/ton
1 (W.P. No. 1)	Sandstone	2736	—	799	—	—	799	—	—
2 (W.P. No. 1)	Gilson Coal	3099	849.6	9,593	1500	678	11,771	13.9	443
3 (W.P. No. 1)	Sandstone	3092	—	129	—	—	129	—	—
4 (W.P. No. 1)	Shale with Coal	3109	—	126	—	—	126	—	—
5 (W.P. No. 1)	Shale	2718	—	723	—	—	723	—	—
6 (W.P. No. 2)	Sandstone	2560	—	475	—	—	475	—	—
7 (W.P. No. 2)	Shale with Coal	2628	—	588	—	—	588	—	—
8 (W.P. No. 2)	Coal Stringer	2664	495.7	4,621	1390	586	6,597	13.3	426
9 (W.P. No. 2)	Coal Stringer	2688	1408.0	10,168	1080	2737	13,985	9.9	318
10 (W.P. No. 2)	Lower Sunnyside	2714-20	848.8	5,972	990	770	7,732	9.1	292
11 (W.P. No. 2)	Sunnyside Stringer	2703	930.6	9,174	3540	1182	13,896	14.9	478
12 (W.P. No. 2)	Rock Canyon	2864-67.5	600.4	4,262	740	318	5,320	8.9	284
13 (W.P. No. 2)	Stringer	2876-77.5	657.1	6,141	1340	754	8,235	12.5	401
14 (W.P. No. 2)	Upper Rock Canyon Stringer	2862.5-63	432.0	4,117	1175	281	5,573	12.9	413
15 (W.P. No. 2)	Fish Creek (Carb.)	2883	641.3	2,958	795	0	3,753	5.9	187
16 (W.P. No. 2)	Upper Gilson	2934-37	716.5	6,986	800	889	8,675	12.1	387
17 (W.P. No. 2)	Lower Gilson	2934-37	528.0	5,272	740	657	6,669	12.6	404
18 (W.P. No. 2)	Soldier Creek Mine	Rock Canyon Outcrop	—	—	—	—	—	—	—

*Includes altitude correction.

Table 5-6. Selected Desorption Data from the U.G.M.S. for the Sego Coal Field (After Doelling, Smith, and Davis, 1979)

UGMS Sample No.	Location	Coalbed or Zone	Thickness of bed (ft)	Depth Interval (feet)	Lost and desorbed gas cc/gm	Residual gas cc/gm	Total gas cc/gm
146	SE3-17S-24E	Carbonera	1.0	107.8-108.7	0.00	0.02	0.02
147	SE3-17S-24E	Carbonera	2.2	117.8-118.4	0.02	0.00	0.02
159	SW31-17S-24E	Carbonera	1.0	193.2-193.7	0.60	0.20	0.80
160	SW31-17S-24E	Carbonera	4.7	238.1-238.9	1.03	0.40	1.43
153	NW15-20S-20E	Chesterfield	3.5	735.6-736.4	0.00	0.31	0.31
154	NW15-20S-20E	Chesterfield	1.8	742.3-743.1	0.00	0.29	0.29
161	SW31-17S-24E	Chesterfield	2.2	277.8-278.5	1.10	0.30	1.40
121	NE15-16S-25E	Ballard	0.7	296.6-297.2	0.00	0.00	0.00
122	NE15-16S-25E	Ballard	1.8	335.2-336.4	0.00	0.00	0.00
123	NE15-16S-25E	Ballard	3.3	392.1-394.0	0.00	0.00	0.00
124	NE1616.S25E	Ballard	7.5	408.8-409.6	0.09	0.00	0.09
125	NE15-16S-25E	Ballard	2.3	415.0-415.7	0.00	0.00	0.00
126	NE15-16S-25E	Ballard	4.4	421x-422.8	0.00	0.00	0.00
148	SE3-17S-24E	Ballard	5.0	190.8-191.7	0.00	0.02	0.02
149	SE3-17S-24E	Ballard	4.7	196.8-197.5	0.00	0.00	0.00
150	SE3 17S-24E	Ballard	1.0	253.3-254.0	0.15	0.16	0.31
151	SE3-17S-24E	Ballard	0.8	370.3-370.9	0.00	0.16	0.16
155	NW15-20S-20E	Ballard?	3.4	860.0-861.1	0.00	0.45	0.45
156	SE17-20S-20E	Ballard (U)	4.2	504.1-505.3	0.47	0.30	0.77
157	SE17-20S-20E	Ballard (1)	3.2	528.8-530.0	1.30	0.20	1.50
127	NE15-16S-25E	Palisade	1.9	491.3493.1	0.05	0.00	0.05
128	NE15-16S-25E	Palisade	1.4	622.3623.8	0.11	0.00	0.11
129	NE15-16S-25E	Palisade	1.3	625.6-626.8	0.00	0.00	0.00
130	NE15-16S-25E	Palisade	2.0	652.3654.3	0.00	0.00	0.00
152	SE3-17S-24E	Palisade	3.8	408.0-408.7	0.00	0.00	0.00
158	SE17-20S-20E	Palisade	2.4	616.8-617.8	0.81	0.30	1.11

6. CONCLUSIONS AND RECOMMENDATIONS

6.1 CONCLUSIONS

The Uinta Basin of Utah and Colorado contains a significant amount of methane gas in the Upper Cretaceous coal-bearing units. Information regarding the potential methane resource is available for the Wasatch Plateau, Emery, Book Cliffs, and Sego coal fields, all of which are located in the southern half of the basin. Specific gas content information is lacking for the Vernal, Tabby Mountain, and Sevier-Sanpete coal areas and for the deeper parts of the basin. Gas contents for such areas are speculative.

The primary methane target area shown in Figure 6-1 covers approximately 620 square miles including the Book Cliffs coal field, and additional areas in parts of Carbon, Grand and Emery Counties in Utah. The primary area was selected because:

- Of the four coal fields where coal samples were tested for their gas content by the Utah Geological and Mineral Survey (UGMS), the data show highest gas yields from the Book Cliffs coal field, north of the Carbon-Emery County line.

- Two wells drilled by the Mountain Fuel Resources, Inc., in the Book Cliffs field, showed high gas contents ranging from 5.9 cc/gm (187 cu ft/ton) to 13.9 cc/gm (443 cu ft/ton) per coalbed.

- Numerous mines within the target area provide emission data reflecting large amounts of methane gas being released from the Sunnyside coalbeds.

Information for the Wasatch Plateau, Emery, and Sego coal fields provide only limited gas content data. Data from UGMS show significantly lower gas content than samples taken in the target area. Additional testing of the methane gas content should be undertaken in these areas, helping to further delineate these areas with respect to development of their methane resource potential.

Because of the absence of methane gas data for the Vernal, Tabby Mountain, and Sevier-Sanpete coal areas, and the deeper portions of the basin, a testing program should be developed to explore their methane potential.

6.2 RECOMMENDATIONS

The following program is recommended for investigating the methane recovery potential of the Uinta Basin.

- Obtain geophysical logs and gas information from oil and gas wells penetrating coal-bearing zones in the basin.
- Cooperate with the U.S. and Utah geological surveys and other private organizations to collect coal core, coal chip, and gas samples to perform methane desorption tests, and analyses.
- Collect other pertinent information, through logs, personal contacts, reports, and mine data, and from personnel working within the basin area.
- Construct a lineation map of the basin concentrating in the primary target area shown on Figure 6-1 to better define areas for further testing.
- Participate in a detailed study of the target area to help pinpoint test sites for methane exploration.
- Perform drilling, logging, sampling, and flow testing of test sites chosen by the detailed study.

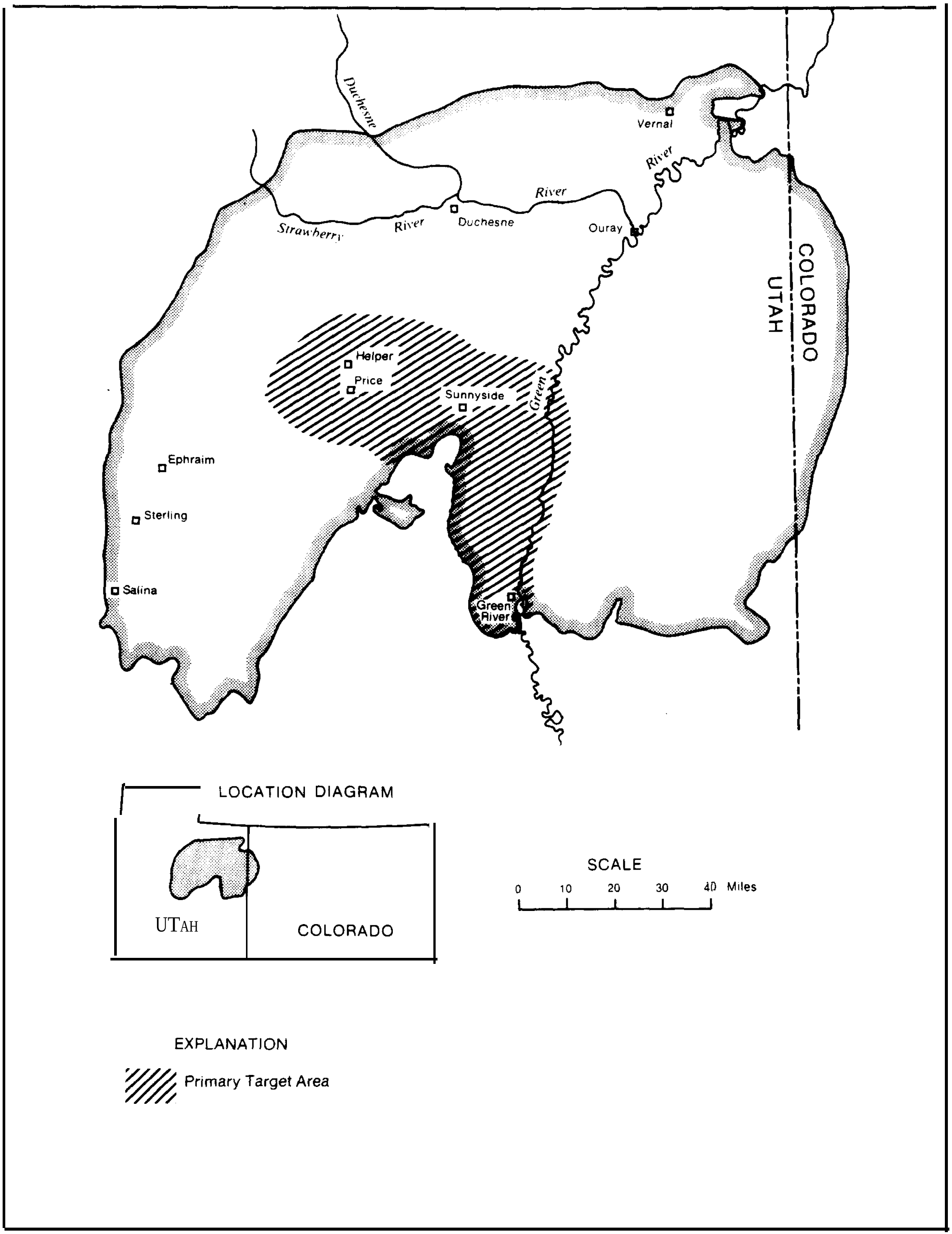


Figure 6-1. Primary Methane Target Area of the Uinta Basin

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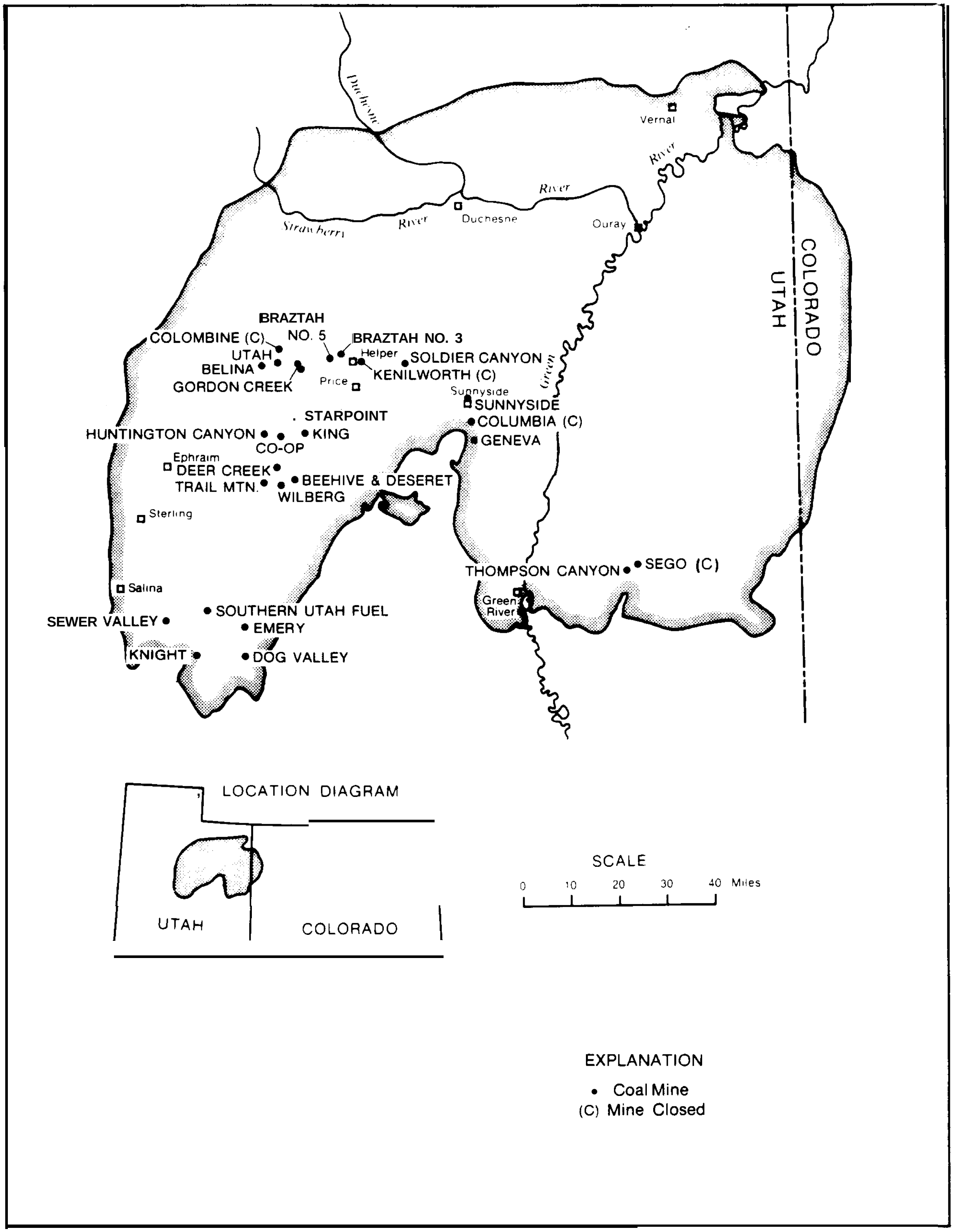


Figure 5-1. Map Showing Active and Closed Mines Located in the Uinta Basin (After Staff, Utah Geological and Mineral Survey, 1977)

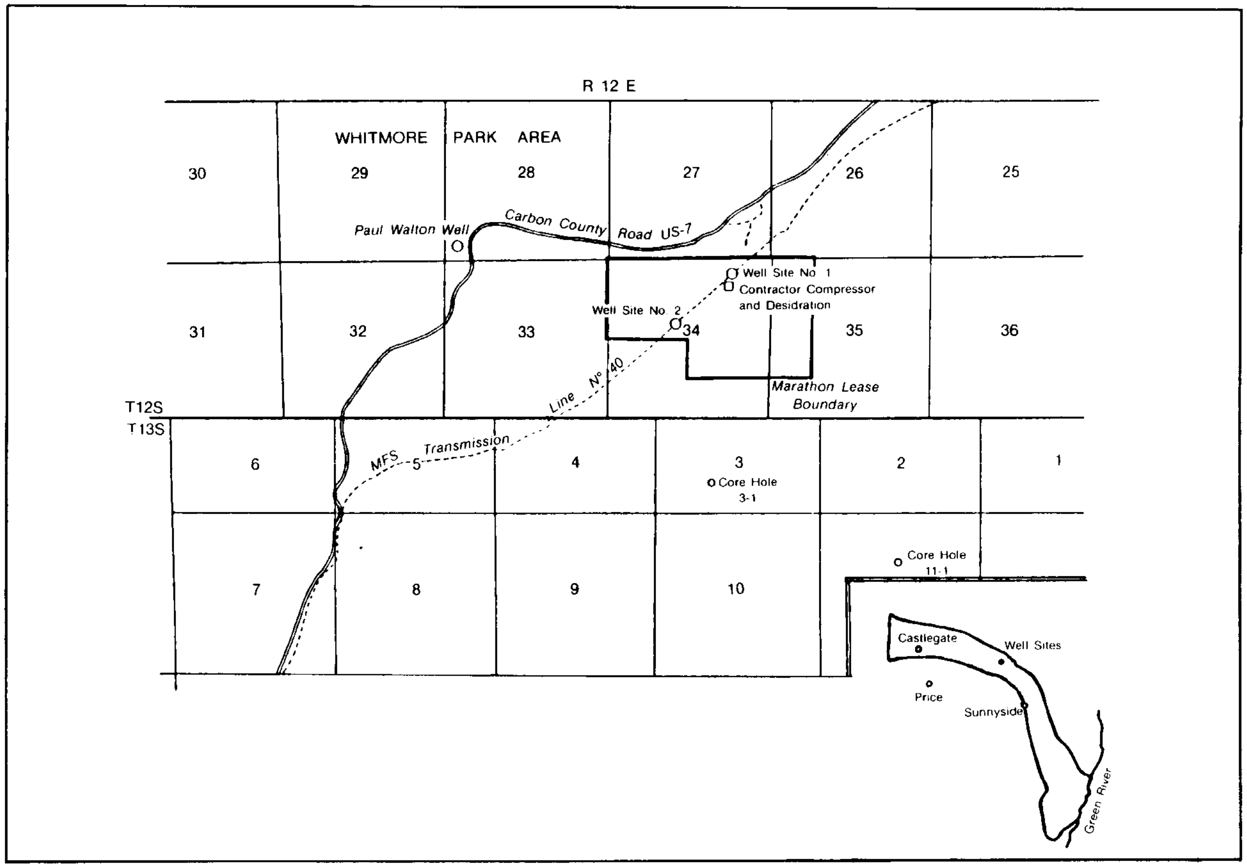
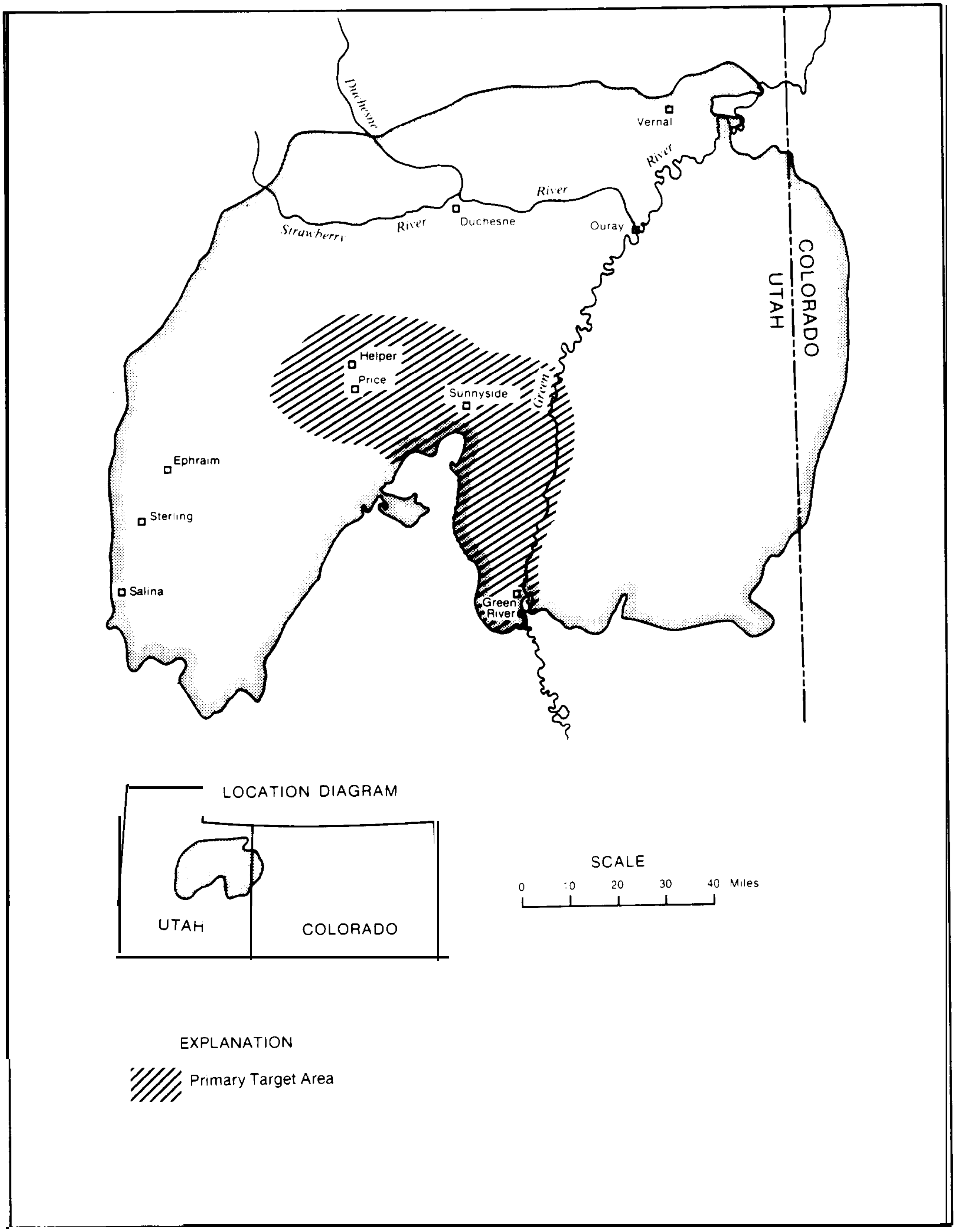


Figure 5-4. Map Showing Location of the Mountain Fuel Resources Whitmore Park No. 1 and No. 2 Well Sites in the Book Cliffs Coal Field (Mountain Fuel Resources, Inc., 1978)

U10-1



Vernal
Duchesne
River
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Ephraim
Sterling
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Green
River
LOCATION DIAGRAM
UTAH
COLORADO
SCALE
0 10 20 30 40 Miles
EXPLANATION
Primary Target Area

APPENDIX A

TOPOGRAPHIC MAPS COVERING THE UINTA BASIN

A-l. USGS Topographic Map Index - Scale 1:250,000

A-2. USGS Topographic Map Index to Utah (7 1/2')

A-3. USGS Topographic Map Index to Colorado (7 1/2')

A-4. Index to Topographic Maps of the United States at a Scale of 1:1,000,000

A-5. Great Salt Lake, United States - Scale: 1:1,000,000

A-6. Grand Canyon, United States - Scale: 1:1,000,000

APPENDIX B

GEOLOGIC MAPS COVERING THE UINTA BASIN

B-1. Geologic Map Index of Utah, 1979

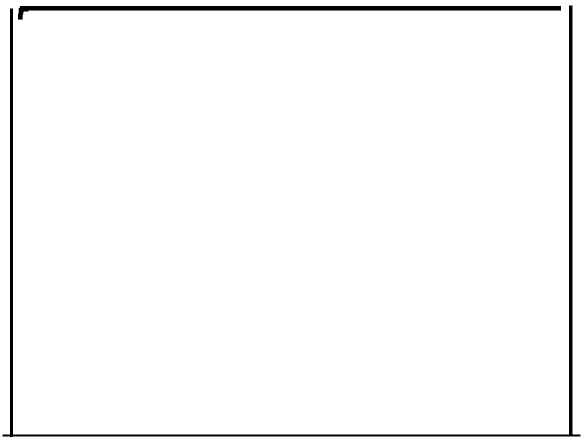
B-2. Geologic Map Index of Colorado, 1977

APPENDIX C

WATER-RESOURCES INVESTIGATIONS IN THE UINTA BASIN

List of Geological Survey
Geologic and Water-Supply Reports and Yaps for

COLORADO



Decexnber 1977

U.S. DEPARTMENT OF THE INTERIOR

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

GEOLOGIC AND WATER-SUPPLY REPORTS AND MAPS

COLORADO

December 1977

This list contains reports and maps published by the Geological Survey relating to the geology and mineral and water resources of Colorado. A separate list of bibliographies and publications of general interest is available on request, as are a general catalog of Geological Survey publications (not including topographic maps), and State indexes to topographic mapping.

Bulletins, professional papers, water-supply papers, and other book reports for which a price is stated, including some that have gone out of print at the Government Printing Office, as indicated by an asterisk (*), are for sale by the BRANCH OF DISTRIBUTION, US. GEOLOGICAL SURVEY, 1200 SOUTH EADS STREET, ARLINGTON, VA 22202, and from the U.S. Geological Survey, Public Inquiries Offices: Federal Building, Room 1012, 1961 Stout Street, Denver, CO 80294; and Federal Building, Room 8102, 125 South State Street, Salt Lake City, UT 84138 (authorized agents of Superintendent of Documents). Prepayment is required and should be made by check or money order payable to the U.S. Geological Survey. Numerous libraries and educational institutions throughout the country are depositories for this material and a list of Colorado depositories is included.

Maps, folios, hydrologic atlases. and charts are sold by the Geological **Survey.** They may be purchased over the counter or ordered from the BRANCH OF DISTRIBUTION, U.S. GEOLOGICAL SURVEY, BLDG. 41, FEDERAL CENTER, DENVER, CO 80225. Remittances should be made by check or money order payable to U.S. Geological Survey. A discount of 30 percent is allowed on an order of $300 or more, based on the retail price. No other discount is applicable. Maps may also be purchased *over* the counter at the U.S. Geological Survey offices where books are sold, and at the Survey's Public Inquiries Offices: Geological Survey, National Center, Room 1C402, 12201 Sunrise Valley Drive, Reston, Va.; and General Services Building, Room 1028. 19th and F Streets, NW., Washington, D.C.

References to geologic information on Colorado may be obtained from the following Geological Survey publications: Geologic Man Index of Colorado., described herein, and from Bibliographies of North American Geology - Bulletins *746 (1785-1918), *747 (1785-1918), "823 (1919-28), *937 (1929-39), "985 (1950), *1025 (1951), *1035 (1952-53), *1049 (1940-49), *1054 (1954), *1065 (1955), *1075 (1956), *1095 (19571, *1115 (1958), *1145 (1959), * 1195 (1950-59) set of 4 volumes, *1196 (1960), "1197 (1961), *1232 (1962), *1233 (19631, *1234 (1964), '1235 (1965), 1266 (1966), $8.25, "1267 (19671, "1268 (1968), 1269 (1969) $11.35, and 1370 (1970) $8.70. Bibliographies and indexes of publications relating to ground water are Water-Supply Papers *992 (1879-1945), *1492 (1946-55), *1863 (1963), and * 1864 (1964). A water resources investigations folder, available free upon request to the Geological Survey, 420 National Center, 12201 Sunrise Valley Drive, Reston, VA 22092, shows the location of stream-gaging stations, observation wells, quality-of-water sample collection sites, area1 hydrologic studies, average annual runoff, average discharge of principal streams, and availahility of ground water. A brief text lists the hydrologic network, the area1 and Statewide projects, and selected references, Additional information is obtainable from Assistant Director, Central Region, U.S. Geological Survey, Denver Federal Center, Denver, CC 80225, and Director and State Geologist, Colorado Geological Survey, 254 Columbine Bldg., Denver. CO 80203.

Information on altitudes in the United States is contained in Bulletins *5, *76, *160, "274, "689, *817, and *1212; information on boundaries and areas of the United States, with historical outlines of boundary changes, is contained in Bulletins "13, "171, *226, *302, *689, *817, "1212. and Professional Paper 909:, information on results of primary triangulation and primary traverse from 1894 to 1918 is contained in Bulletins * 122, * 181, * 201, "216, *245, "276, *310, *440, "'496, *551, "644, "709, and Parts 1 of the *18th, *19th, *20th, and * 21st Annual Reports. Further information on more recent triangulation, transit traverse, and spirit leveling in Colorado is obtainable upon specific request.

Current *Publications* are announced by means of monthly notices. "New Publications of the Geological Survey." Free on application to the Geological Survey, 329 National Center, 12201 Sunrise Valley Drive, Reston, VA 22092.

ANNUAL REPORTS

*Second. 1880-80. 1882. Contains: Abstract of report on geology and mining industry of Leadville, Lake County, Colo., by S. F. Emmons. p. 201-290.

"Sixth, 1884-84. 1885. Contains: Mount Taylor and the Zuni Plateau, by C. E. Dutton. p. 105198.

*Eighth, 1886-87. 1889. Part 1 contains: The fossil butterflies of Florissant, Colo., by S. H. Scudder. p. 433-474.

*Ninth, 1887-88. 1889. Contains: On the geology and physiography of a portion of northwestern Colorado and adjacent parts of Utah and Wyoming. by C. A. White. p. 667-712.

"Thirteenth. 1891-92. 1892. Part 3 (18931 contains: Report upon the construction of topographic maps and the selection and survey of reservoir sites in the hydrographic basin of Arkansas River, Colo., by A. H. Thompson. p. 429-444.

"Fourteenth, 1892-93. 1893. Part 2 (1894) contains: The laccolithic mountain groups of Colorado, Utah, and Arizona, by Whitman Cross. p. 157-241.

"Sixteenth, 1894-95. 1896. Part 2 (1895) contains: Geology and mining industries of the Cripple Creek district, Colorado, by Whitman Cross and R. A. F. Penrose, Jr. p. 1-209; Water resources of a portion of the Great Plains, by Robert Hay. p. 535-588.

*Seventeenth. 1895-96. 1896. Part 2 contains: Geology of Silver Cliff and the Rosita Hills. Colo., by Whitman Cross. p. 263.403; The mines of Custer County, Colo., by S. F. Emmons. p. 405-472; The underground water of the Arkansas Valley in eastern Colorado, by G. K. Gilbert. p. 551-601.

*Eighteenth, 1896-97. 1897. Part 3 11898) contains: Preliminary report on the mining industries of the Telluride quadrangle, Colorado, by C. W. Purington. p. 745-850.

*Twentieth, 1898-99. 1899. Part 2 ı 1900) contains: Devonian fossils from southwestern Colorado: The fauna of the Ouray limestone, by G. H. Girty. p. 25-81. Part 5 (1900) contains: The forests of the United States, by Henry Gannett. p. l-37; Pikes Peak, Plum Creek. and South Platte reserves. by J. G. Jack. p. 39-115: White River Plateau Timber Land Reserve, by G. B. Sudworth. p. 1171179; and Battlement Mesa Forest Reserve, by G. B. Sudworth. p. 181-243.

*Twenty-first, 1899-1900. 1900. Part 2 contains: Geology of the Rico Mountains, Colo., by Whitman Cross and A. C. Spencer. p. 7-165. Part 4 (1901) contains: The High Plains and their utilization, by W. D. Johnson. p. 601-741. (See Twenty-second Annual Report.)

*Twenty-second, 1900-1901. 1901. Part 1 contains: The asphalt and bituminous rock deposits of the United States, by G. H. Eldridge. p. 209-452. Part 2 contains: The ore deposits of the Rico Mountains, Colo., by F. L. Ransome. p. 229-398. Part 3 (1902) contains: The Rocky Mountain coal fields, by L. S. Storrs. p. 415-471. Part 4 (1902) contains: The High Plains and their utilization (conclusion), by W. D. Johnson. p. 631.669.

(Beginning with the twenty-third (1901-2), the annual reports of the Geological Survey contain no technical papers but were published separately until 1933. Since 1933 a condensed form has been included in the annual report of the Secretary of the Interior. For the fiscal years 1936 to 1963, a limited number of copies of the report as it appeared in the annual report of the Secretary were reprinted separately for official use; copies of these may be had free by persons directly interested. insofar as they are in stock.1

MINERAL RESOURCES OF THE UNITED STATES

The annual volumes of Mineral Resources of the United States contain statistics of production by calendar years and matters relating to technology and resources. Some of the chapters deal with a particular mineral or group of minerals, but much of the information is statistical. These volumes are not listed. The volumes of Mineral Resources were issued by the Geological Survey for the years 1882 to 1923. Reports for 1924 and subsequent years are published by the Bureau of Mines, Washington, DC 20244. as Minerals Yearbooks.

MONOGRAPHS

*10. Dinocerata-A monograph of an extinct order of gigantic mammals, by 0. C. Marsh. 1866. 243 p.
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*21. Tertiary rhynchophorous Coleoptera of the United States, by S. H. Scudder. 1893.206 p.
“27. Geology of the Denver Basin in Colorado, by S. F. Emmons, Whitman Cross, and G. E. Eldridge. 1896.
*31. Geology of the Aspen mining district, Colorado, with atlas, by J. E. Spurr. 1898. 260 p., and atlas of 30 sheets folio.
*35. The later extinct floras of North America, by J. S. Newberry. 1898. 295 p.
“40. Adephagous and clavicorn Coleoptera from the Tertiary deposits at Florissant, Colo., by S. H. Studder. 1900. 148 p.
*44. Pseudoceratites of the Cretaceous, by Alpheus Hyatt. 1903. 351 p.
*49. The Ceratopsia, by J. B. Hatcher. 1907.300 p.
“51. Cambrian Brachiopoda, by C. D. Walcott. 1912. In two parts. Part 1, 872 p.; part 2, 363 p.
*54. The Mesozoic and Cenozoic Echinodermata of the United States, by W. B. Clark and M. W. Twitchell. 1915. 341 p.

GEOLOGIC FOLIOS

*7. Pikes Peak, Colo., by Whitman Cross. 1894. 8 p., 5 maps.
*9. Anthracite-Crested Butte, Colo., by S. F. Emmons, Whitman Cross, and G. H. Eldridge. 1894. 11 p., 8 maps.
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*48. Tenmile district special, Colorado, by S. F. Emmons. 1898. 6 p., 4 maps.
*57. Telluride, Colo., by Whitman Cross and C. W. Purington. 1899. 19 p., 4 maps
“‘58. Elmoro. Colo.. bv R. C. Hills. 1899. 6 p., 5 mans.
“60. La Plata, Colo., by Whitman Cross, A. C. Spencer, and C. W. Purington. 1899 (1901). 14 p., 4 maps.
“68. Walsenburg, Colo., by R. C. Hills, 1900. 6 p., 6 maps,
*71. Spanish Peaks, Colo., bv R. C. Hills. 1901. 7 p., 6 maps.
*120. Silverton, Colo.. by Whitman Cross, Ernest Howe, and F. L. Ransome. 1905. 34 p., 4 maps.
“131. Needle Mountains, Colo., by Whitman Cross, Ernest Howe, J. D. Irving, and W. H. Emmons. 1905. 14 p.. 4 maps.
‘135. Nepesta. Colo., by C. A. Fisher. 1906. 6 p., 3 maps.
-153. Ouray. Colo., by Whitman Cross, Ernest Howe, and J. D. Irving. 1907.20 p., 3 maps.
*171. Engineer Mountain, Colo., by Whitman Cross, and A. D. Hole. 1910. 14 p., 3 maps.
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*203. Colorado Springs, Colo., by G. I. Finlay. 1916. 16 p., 5 maps.
*214. Raton-Brilliant-Koehler, N. Mex.-Colo., by W. T. Lee. 1922. 17 p.. 10 maps.

PROFESSIONAL PAPERS

*16. The Carboniferous formations and faunas of Colorado, by G. H. Girty. 1903. 546 p.
32. Preliminary report on the geology and underground water resources of the central Great Plains, by N. H. Darton. 1905. 433 p.

"52. Geology and underground waters of the Arkansas Valley in eastern Colorado, by N. H. Darton. 1906. 90 p.

"54. Geology and gold deposits of the Cripple Creek district, Colorado, by Waldeman Lindgren and F. L. Ransome. 1906. 516 p.

*63. Economic geology of the Georgetown quadrangle (together with the Empire district). Colorado, by J. E. Spurr and G. H. Garrey, with general geology, by S. H. Ball. 1908. 422 p.

"67. Landslides in the San Juan Mountains, Colo., including a consideration of their causes and their classification, by Ernest Howe. 1909. 58 p.

*75. Geology and ore deposits of the Breckenridge district, Colorado, by F. L. Ransome. 1911.187 p.

*90. Shorter contributions to general geology, 1914. 1915. Contains: Geology of the pitchblende ores of Colorado, by E. S. Bastin. p. 1-5; Dike rocks of the Apishapa quadrangle, Colorado, by Whitman Cross. p. 17-31; Contributions to the stratigraphy of southwestern Colorado, by Whitman Cross and E. S. Larsen. p. 39-50; The history of a portion of Yampa River, Colo., and its possible bearing on that of Green River, by E. T. Hancock. p. 183-189.

*94. Economic geology of Gilpin County and adjacent parts of Clear Creek and Boulder Counties, Colo., by E. S. Bastin and J. M. Hill. 1917. 379 p.

*95. Shorter contributions to general geology, 1915. 1916. Contains: Eocene glacial deposits in southwestern Colorado. bv W. W. Atwood. p. 13-26; Relation of the Cretaceous formations to the Rocky Mountains in Coloradoand New Mexico, by W. T. Lee. p. 27-58.

*98. Shorter contributions to general geology. 1916. 1917. Contains: The flora of the Fox Hills sandstone, by F. H. Knowlton. p. 85-93.

* 100. The coal fields of the United States. 1929. Contains: General introduction, by M. R. Campbell. p. 1-33. (Published in June 1917.)

* 101. Geology and paleontology of the Raton Mesa and other regions in Colorado and New Mexico, by W. T. Lee and F. H. Knowlton. 1917 (1918). 450 p.

*120. Shorter contributions to general geology, 1918. 1919. Contains: Some American Cretaceous fish scales, with notes on the classification and distribution of Cretaceous fishes, by T. D. A. Cockerell. p. 165-206.

*130. The Laramie flora of the Denver Basin. with a review of the Laramie problem, by F. H. Knowlton. 1922. 175 p.

*131. Shorter contributions to general geology, 1922. 1923. Contains: Revision of the flora of the Green River formation. with descriptions of new species. by F. H. Knowlton. p. 133-182; Fossil plants from the Tertiary lake beds of south-central Colorado, by F. H. Knowlton. p. 183-197; The fauna of the so-called Dakota Formation of northern central Colorado and its equivalent in southeastern Wyoming, by J. B. Reeside, Jr. p. 199-212.

*132. Shorter contributions to general geology. 1923-24. 1925. Contains: Relations of the Wasatch and Green River Formations in northwestern Colorado and southern Wyoming, with notes on oil shale in the Green River Formation, by J. D. Sears and W. H. Bradley. p. 93-107.

*134. Upper Cretaceous and Tertiary formations of the western part of San Juan Basin, Colo., and N. Mex.. by J. B. Reeside. Jr.. and Flora of the Animas Formations, by F. H. Knowlton. 1924. 117 p.

*135. The composition of the river and lake waters of the United States, by F. W. Clarke. 1924. 199 p.

*138. Mining in Colorado-A history of discovery, development, and production, by C. W. Henderson. 1926. 263 p.

*148. Geology and ore deposits of the Leadville mining district, Colorado, by F. S. Emmons, J. D. Irving, and G. F. Loughlin. 1927. 368 p.

* 149. Correlation of geologic formations between east-central Colorado, central Wyoming, and southern Montana, by W. T. Lee. 1927. 80 p.

*151. The cephalopods of the Eagle sandstone and related formations in the Western Interior of the United States, by J. B. Reeside, Jr. 1927. 87 p.

*154. Shorter contributions to general geology, 1928. 1929. Contains: Algae reefs and oolites of the Green River Formation, by W. H. Bradley. p. 203-223; Additions to the flora of the Green River Formation, by R. W. Brown. p. 279-299.

*155. The flora of the Denver and associated Formations of Colorado, by F. H. Knowlton. 1930. 142 p.

*158. Shorter contributions to general geology, 1929. 1930. Contains: The occurrence and origin of analcite and meerschaum beds in the Green River Formation of Utah, Colorado, and Wyoming, by W. H. Bradley. p. 1-7; The contact of the Fox Hills and Lance Formations, by C. E. Dobbin and J. B. Reeside, Jr. p. 9-25; The varves and climate of the Green River epoch, by W. H. Bradley. p. 87-110.

*166. Physiography and Quaternary geology of the San Juan Mountains, Colo., by W. W. Atwood and K. F. Mather. 1932. 176 p.

*168. Origin and microfossils of the oil shale of the Green River Formation of Colorado and Utah, by W. H. Bradley. 1931. 58 p.

*169. Geology and ore deposits of the Bonanza mining district, Colorado, by W. S. Burbank, with a section on history and production, by C. W. Henderson. 1932. 166 p.

*176. Geology and ore deposits of the Breckenridge mining district, Colorado, by T. S. Lovering. 1934. 64 p.

*178. Geology and ore deposits of the Montezuma quadrangle, Colorado, by T. S. Lovering. 1935. 119 p.

*183. Correlation of the Jurassic formation of parts of Utah, Arizona, New Mexico, and Colorado, by A. A. Baker, C. H. Dane, and J. B. Reeside, Jr. 1936. 66 p.

*185-B. Paleozoic formations of the Mosquito Range, Colo., by J. H. Johnson. 1934 (1935). p. 15-34.

*185-C. The recognizable species of the Green River flora, by R. W. Brown. 1934 (1935). p. 45-77.

*185-D. A flora of Pottsville age from the Mosquito Range, Colo., by C. B. Read. 1934. p. 79-96.

*185-I. Geomorphology of the north flank of the Uinta Mountains, by W. H. Bradley. 1936. p. 136-204.

*186-J. Additions to some fossil floras of the Western United States, by R. W. Brown. 1937. p. 163-206.

*186-K. The stratigraphy of the Upper Cretaceous rocks north of the Arkansas River in eastern Colorado, by C. H. Dane, W. G. Pierce, and J. B. Reeside, Jr. 1937. p. 207-232.

*189-I. Fossil plants from the Colgate member of the Fox Hills sandstone and adjacent strata, by R. W. Brown. 1939. p. 239-275.

*197-A. Alkalic rocks of Iron Hill, Gunnison County, Colo., by E. S. Larsen. 1942. p. A1-A64.

*219. Geology and ore deposits of the La Plata district, Colorado, by E. B. Eckel, with sections bv J. S. Williams. F. W. Galbraith. and others. 1949 (1950). 179 p.

*221-D. Cretaceous plants from southwestern Colorado, by R. W. Brown. 1950. p. 45-66.

*221-G. Pre-Wisconsin soil in the Rocky Mountain region-A progress report, by C. B. Hunt and V. P. Sokoloff. 1950. p. 109-123.

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*227. Pegmatite investigations in Colorado, Wyoming, and Utah, 1942-44, by J. B. Hanley, E. W. Heinrich, and L. R. Page. 1950. 125 p.

'233-B. Molluscan fauna of the Morrison Formation, by Teng-Chien Yen, with a summary of the stratigraphy, by J. B. Reeside, Jr. 1952. p. 21-51.

*235. Geology and ore deposits of the west slope of the Mosquito Range, Colo., by C. H. Behre, Jr. 1953. 176 p.

*239. Scaphitoid cephalopods of the Colorado group, by W. A. Cobban. 1951 (1952). 42 p.

*245. Geology and ore deposits of the Boulder County tungsten district, Colorado, by T. S. Lovering and Ogden Tweto. 1953 (1954). 199 p.

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*254-B. Nonmarine mollusks of Late Cretaceous age from Wyoming, Utah, and Colorado, by Teng-Chien Yen. 1954. p. 45-66.

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"'274-B. Dakota group in northern Front Range foothills, Colorado, by K. M. Waagé. 1955. p. 15-51.
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*279. Cenozoic geology of the Colorado Plateau, by C. B. Hunt. 1956. 99 p.
*289. Geology and ore deposits of the Garfield quadrangle, Colorado, by M. G. Dings and C.S. Robinson. 1957. 110 p.
"291. Stratigraphy of the uppermost Triassic and the Jurassic rocks of the Navajo Country. by J. W. Harshbarger. C. A. Repenning, and J. H. Irwin. 1957. 74 p.
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"319. Geology and ore deposits of the Chicago Creek area, Clear Creek County, Colo., by J. E. Harrison and J. D. Wells, 1959. 92 p.
*320. Geochemistry and mineralogy of the Colorado plateau uranium ores, compiled by R. M. Garrels and E. S. Larsen 3d. 1959. 236 p.
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"352-B. The shape of alluvial channels in relation to sediment type, by S. A. Schumm. 1960. p.17-30.
"352-C. Effect of sediment characteristics on erosion and deposition in ephemeral-stream channels, by S. A. Schumm. 1961. p. 31-70.
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"355. Studies of the Mowry shale (Cretaceous) and contemporary formations in the United States and Canada, by J. B. Reeside, Jr., and W. A. Cobban. 1960. 126 p.
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"356-D. Geology of uranium in coaly carbonaceous rocks, by J. D. Vine. 1962. p. 113-170.
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"366. Ash-flow tuffs: Their origin. geologic relations, and identification, by C. S. Ross and R. L. Smith. 1961. 81 p.
*371. Geology of uranium and associated ore deposits, central part of the Front Range mineral belt, Colorado, by P. K. Sims and others. 1963. 119 p.
*372-A. The meteorologic phenomenon of drought in the Southwest, by H. E. Thomas. 1962. p. Al-A43.
*372-B. General effects of drought on water resources of the Southwest, by J. S. Gatewood, Alfonso Wilson, H. E. Thomas, and L. R. Kister. 1964. p. B1-B55.
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*374-B. Joints in Precambrian rocks, Central City-Idaho Springs area, Colorado, by J. E. Harrison and R. H. Moench. 1961. p. Bl-B14.

*374-I. Yampa Canyon in the Uinta Mountains, Colo., by J. D. Sears. 1962. p. I1-I33.

*375. Paleocene flora of the Rocky Mountains and Great Plains, by R. W. Brown. 1962. 119 p.

*378-A. Geology and ore deposits of the South Silverton mining area, San Juan County, Colo., by D. J. Varnes. 1963. p. Al-A56.

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Title page and contents for volume available free on application to the Geological Survey.

*400-A. Geological Survey Research 1960, Synopsis of geologic results. 1960. p. Al-A136.

*400-B. Short papers in the geological sciences, Articles l-232. 1960. p. Bl-B515. Contains the following articles, which are not available separately.

2. Varieties of superbene zinc deposits in the United States, by A. V. Heyl, Jr., and C. N. Bozion. p. B2.

4. Relation of the Colorado mineral belt to Precambrian structure, by Ogden Tweto and P. K. Sims. p. B8.

5. Pre-ore age of faults at Leadville, Colo., by Ogden Tweto. p. B10.

6. Pre-ore propylitization, Silverton caldera, Colorado, by W. S. Burbank. p. B12.

7. Ring-fractured bodies in the Silvarton caldera, Colorado, by R. G. Luedke and W. S. Burbank. p. B13.

8. Relation of mineralization to caldera subsidence in the Creede district, San Juan Mountains, Colo., by T. A. Steven and J. C. Ratté. p. B14.

22. Distribution and lithologic characteristics of sandstone beds that contain deposits of copper, vanadium, and uranium, by R. P. Fischer and J. H. Stewart. p. B42.

34. Pre-mineralization faulting in the Lake George area, Park County, Colo., by C. C. Hawlev. W. N. Sharp, and W. R. Griffitts. p. B71.

35. Bertrandite-bearing griesen—A new beryllium ore, in the Lake George district, Colorado, by W. N. Sharp and C. C. Hawley. p. B73.

44. Geochemical prospecting for beryllium, by W. R. Griffitts and Uteana Oda. p. B90.

45. Variations in base-metal contents of monzonitic intrusives, by W. R. Griffitts and H. M. Nakagawa. p. B93.

50. Thermoluminescence and porosity of host rocks at the Eagle mine, Gilman, Colo., by C. H. Roach. p. B107.

111. Pliocene sediments near Salida, Chaffee County, Colo., by R. E. Van Alstine, and G. E. Lewis. p. B245.

112. Some Late Cretaceous strand lines in northwestern Colorado and northeastern Utah, by A. D. Zapp and W. A. Cobban. p. B246.

113. Stratigraphy and structure of the Precambrian metamorphic rocks in the Tenmile Range, Colo., by A. H. Koschmann and M. H. Bergendahl. p. B249.

114. Salt anticlines and deep-seated structures in the Paradox basin, Colorado and Utah, by H. R. Joesting and J. E. Case. p. B252.

115. Distribution and physiographic significance of the Browns Park Formation, Flaming Gorge and Red Canyon areas, Utah-Colorado, by W. R. Hansen, D. M. Kinney, and J. M. Good. p. B257.

116. Probable late Miocene age of the North Park Formation in the North Park area, Colorado, by W. J. Hail, Jr., and G. E. Lewis. p. B259.

117. Paleocene and Eocene age of the Coalmont Formation, North Park, Colo., by W. J. Hail, Jr., and E. B. Leopold. p. B260.

118. Pre-Cutler unconformities and early growth of the Paradox Valley and Gypsum Valley salt anticlines, Colorado, by D. P. Elston and E. R. Landis. p. B261.

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54. Origin of cross-strata in fluvial sandstone layers in the Chinle Formation (Upper Triassic) on the Colorado Plateau, by J. H. Stewart. p. B127.
55. Fossil woods associated with uranium on the Colorado Plateau, by R. A. Scott. p. B130.
56. Late Cenozoic events of the Leadville district and upper Arkansas Valley, Colo. by Ogden Tweto. p. B133.
57. Movement of the Slumgullion earthflow near Lake City. Colo.. bv D. R. Crandell and D. J. Varnes. p. B136.
58. Relations of metals in lithosols to alteration and shearing at Red Mountain, Clear Creek County, Colo., by P. K. Theobald, Jr., and C. E. Thompson. p. B139.
59. Hydrology of small grazed and ungrazed drainage basins, Badger Wash area, western Colorado, by G. C. Lusby. p. B141.
60. Abandonment of Unaweep Canyon, Mesa County, Colo., by capture of the Colorado and Gunnison Rivers, by S. W. Lohman. p. B144.
61. Tripartition of the Wasatch Formation near De Beque in northwestern Colorado, by J. R. Donnell. p. B147.
80. Stratigraphy of desert varnish, by C. B. Hunt. p. B194.
96. Age of the Ohio Creek conglomerate, Gunnison County, Colo., by D. L. Gaskill. p. B230.
99. Corals from Permian rocks of the northern Rocky Mountain region, by Helen Duncan. p. B235.
121. Four environments of thorium-, niobium-, and rare-earth-bearing minerals in the Powderhorn district of southwestern Colorado, by D. C. Hedlund and J. C. Olson. p. B283.
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125. Grantsite-A new hydrated sodium calcium vanadyl vandate from New Mexico and Colorado-A nreliminarv description. bv A. D. Weeks. M. L. Lindberg, and Robert Meyrowitz. p. B293.
131. Relation of supports to geology in the Harold D. Roberts Tunnel, Colo., by E. E. Wahlstrom, L. A. Warner, and C. S. Robinson. p. B303.

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153. Spheroidal coal in the Trinidad coal field, south-central Colorado, by R. B. Johnson. p. C20.
154. Potential oil-shale reserves of the Green River Formation in the southeastern Uinta Basin, Utah and Colorado, by W. B. Cashion. p. C22.

195. Proposed classification of ground-water provinces, hydrologic units, and chemical types of ground water in the Upper Colorado River Basin, by D. A. Phoenix. p. C125.
196. Metamorphism and structural history of the Coal Creek area, Front Range, Colo., by J. D. Wells, D. M. Sheridan, and A. L. Albee. p. C127.
197. Early and late growth of the Gypsum Valley salt anticline, San Miguel County, Colo., by E. R. Landis, E. M. Landis, E. M. Shoemaker, and D. P. Elston. p. C131.
198. Emplacement of the Wilson Peak stock and associated intrusive rocks, San Miguel Mountains, Colo., by C. S. Bromfield. p. C137.
199. Stream directions in Triassic rocks of the Colorado Plateau, by F. G. Poole. p. c139.
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44. Use of inflatable packers in multiple-zone testing of water wells, by F. C. Koopman, J. H. Irwin, and E. D. Jenkins. p. B108.

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90. *Clioscaphites saxitonianus* (McLearn)—A discrete ammonite zone in the Niobrara Formation at Pueblo, Colo., by G. R. Scott and W. A. Cobban. p. C85.

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C. Host rocks and their alterations as related to uranium-bearing veins in the conterminous United States, by G. W. Walker. p. 37-53.

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Information on water levels and artesian pressure in observation wells											
1935	* 777		1946	* 1075		1952	*1225		1966-70	*1980	$2.35
1936	* 817		1947	*1100		1953	*1269				
1942	* 948		1948	*1130		1954	*1326				
1943	* 990		1949	*1160		1955	*1408				
1944	* 1020		1950	*1169		1956.60	*1760				
1945	* 1027		1951	*119.5		1961-65	*184R				

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Information on the quality of the suface water
("a" indicates data on quality of water for irrigation)

Year	WSP	Price	Year	WSP	Price	Year	WSP	Price	Year	WSP	Price
1941	'942			'1353		1959	'1645		1964(a)	* 1960	
1942	-950		(a)	* 1430		(a)	* 1699		1965	* 1963	
1943	*970		1955	*1401		1960	'1743			'1964	
1944	* 1022			• 1402			* 1744			* 1965	
1945	* 1030			* 1403			* 1745		(a)	* 1967	
1946	* 1050		(a)	* 1465		(a)	*1746		1966	* 1993	
1947	'1102		1956	'1451		1961	*1883			*1994	
1948	'1133			*1452			*1884			*1995	
1949	*1163			* 1453			*1885		1967	'2013	
1950	*1189		(a)	* 1485		(a)	* 1886			2014	
1951	* 1200		1957	-1521		1962	* 1943			*2015	
(a)	*1264			* 1522			* 1944		1968	*2095	
1952	* 1251			'1523			* 1945			'2096	
	* 1252		(a)	'1524			* 1946			2097	$3.45
	'1253		1958	*1572		1963	* 1949			* 2098	
	'1362			* 1573			* 1950		1969	2145	3.25
1953	'1291			'1574			'1951			2146	3.85
	'1292		(a)	* 1575		(a)	* 1952			2147	4.00
(a)	* 1293		1959	* 1643		1964	* 1956			*2148	
	* 1380			*1644			* 1957		1970	2150	3.50
1954	'1351						* 1958			*2155	
	* 1352									2157	4.50
										215.3	3.40

Stream measurements in the years mentioned

Year	WSP	Price	Year	WSP	Price	Year	WSP	Price	Year	WSP	Price
1897	'15			*357		192x	'666			-927	
	*16			*358			*667			*928	
1898	*28			'359			'669			'929	
1899	*37		1914	'386		1929	*686		1942		
	*38			'387			*689			*957	
1900	'49					1930	*701			'958	
	'50		1915	'406			'702			'959	
1901	*66			*407			*704		1943	'976	
	*75					1931	'716			*977	
1902	*84		1916	*436			*719			*978	
	*85			*437		1932	*731			*979	
1903	[illegible]			-439			*733		1944	*1006	
	[illegible]		1917	'456			'734			'1007	
1904	'131			'457		1933	*746			*1008	
	'133			*459			*749			* 1009	
1905	*172		1918	* 476		1934	*761		1945	* 1036	
	* 173			'477			*762			*1037	
	*174			*479			*763			* 1038	
	*175		1919.20	'506			'764			* 1039	
1906	'208			-507		1935	*786		1946	* 1056	
	'209			*509			* 787			*1057	
	*210		1921	*526			*788			* 1058	
	-211			*527			*789			"1059	
1907-e	*246			'529		1936	'806		1947	*1086	
	*247		1922	* 546			*807			*1087	
	*248			'547			* 808			*1088	
	*249			"549			*809			*1089	
1909	'266		1923	-566		1937	*826		1948	*1116	
	*267			* 567			*827			*1117	
	*268			'569			*828			'1118	
	'269		1924	*586			'829			'1119	
1910	'286			'587		1938	*856		1949	-1146	
	*287			'589			*857			*1147	
	* 288		1925	* 606			*858			-1148	
	*289			'607			*859			*1149	
1911	*306			*608		1939	*876		1950	*1176	
	*307			* 609			*877			*1177	
	* 308		1926	*626			*878			*1178	
	-309			'627			*879			*1179	
1912	"326			*628		1940	*896		1951	'1210	
	*327			*629			*897			'1211	
	*328		1927	*646			*898			*1212	
	*329			*647			'899			'1213	
1913	'356			* 643		1941	'926		1952	*1240	

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Year	WSP	Price	Year	WSP	Price	Year	WSP	Price	Year	WSP	Price
Stream measurements in the years mentioned-Continued											
	*1241		1955	*1391			* 1561			*1919	
	'1242			* 1392			*1562			*1921	
	* 1243			* 1393			*1563			*1923	
1963	* 1280		1956	* 1440		1959	* 1630		1961-65	* 1924	
	* 1281			*1441			*1631			* 1925	
	*1282			* 1442			'1632		1966.70	2118	$5.65
	*1283			*1443		1959	* 1633			*2119	
1954	* 1340		1957	'1510		1960	*1710			'2121	6 15
	*1341			'1511			*1711			'2123	5.70
	'1342		1957	*1512			*1712			*2124	
	*1343			*1513			*1713			2125	4 40
1955	*1390		1958	* 1560		1961-65	*1918				

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***GEOLOGIC MAP INDEX OF COLORADO,** by Leona Boardman. 1954. Shows by colored outlines areas in Colorado for which geologic maps have been published and locates many mine maps that show local geology. A text printed on margin of sheet gives the scale. data, author, and sources of publication of each geologic map. Scale 1:750,000.

GEOLOGIC MAP INDEX OF COLORADO, PART B, 1953-69, compiled by W. L. McIntosh and M. F. Eister. 1972. Lat 37' to 41°. long 102" to 109". Scale 1:1,000,000 (1 inch about 16 miles.) 50¢.

GEOTHERMAL GRADIENT MAP OF NORTH AMERICA, by the Geothermal Survey of North America Subcommittee of the American Association of Petroleum Geologists' Research Committee. 1976. Scale 1:5,000,000. Two sheets. $4 per set.

SUBSURFACE TEMPERATURE MAP OF NORTH AMERICA, by the Geothermal Survey of North America Subcommittee of the Association of Petroleum Geologists' Research Committee. 1976. Scale 1:5,000,000. Two sheets. $4 per set.

***VEINS, FAULTS AND MINES OF THE FRONT RANGE MINERAL BELT, COLORADO,** by T.S. Lovering and E.N. Goddard. 1950 (1951). Scale 1:62,500. (Issued as plate 3 of Professional Paper 223.)

GEOLOGIC QUADRANGLE MAPS: Scale 1:24,000, except as indicated; $1.75 each, except as indicated.(The corresponding maps bearing the prefix MF in the Minerals Investigations series are preliminary maps printed in black and white.)

GQ-33. Bull Canyon, Colo. Geology, by F. W. Cater, Jr. 1954. Lat 38" 07'39" to 38" 15', long 108" 45' to 108" 52'30".

GQ-55. Gateway, Colo. Geology, by F. W. Cater, Jr. 1975. Lat 38" 37'30" to 38" 45', long 108" 52'30" to 109".

GQ-57. Atkinson Creek, Colo. Geology, by E. F. McKay. 1955. Lat 38" 22'30" to 38" 30', long 108" 37'30" to 108" 45'. (See Map MF-18.)

GQ-58. Red Canyon, Colo. Geology, by E. J. McKay 1955. Lat 38" 22'30" to 38" 30', long 108" 45' to 108" 52'30". (See Map MF-17.)

GQ-59. Gypsum Gap. Colo. Geology, by F. W. Cater, Jr. 1955. Lat 38" to 38" 07'30", long 108" 37'30" to 108" 45'. (See Map MF-19.)

GQ-60. Pine Mountain, Colo. Geology, by F. W. Cater, Jr. 1955. Lat 38" 37'30" to 38" 45', long 108" 45' to 108" 52'30". (See Map MF-20.)

GQ-61. Calamity Mesa, Colo. Geology, by F. W. Cater, Jr. 1955. Lat 38" 30' to 38° 37'30", long 108" 45' to 108" 52'30". (See Map MF-32.)

GQ-64. Horse Range Mesa, Colo. Geology, by F. W. Cater, Jr. 1955. Lat 38" to 38" 07'30", long 108" 52'30" to 109". (See Map MF-29.)

GEOLOGIC QUADRANGLE MAPS-Continued

GQ-65. Naturita NW, Colo. Geology, by F. W. Cater, Jr. 1955. Lat 38” 07’30” to 38” 15′, long 108” 37’30” to 108” 45’. (See Map MF-30.)

GQ-66. Joe Davis Hill, Colo. Geology, by F. W. Cater, Jr, 1955. Lat 37” 52’30” to 38°, long 108” 45’ to 108” 52’30”. (See Map MF-27.)

GQ-68. Egnar, Colo. Geology, by F. W. Cater, Jr. 1955. Lat 37” 52’30” to 38°, long 108” 52’30” to 109”. (See Map MF-26.)

GQ-69. Hamm Canyon, Colo. Geology, by F. W. Cater, Jr. 1955. Lat 38” to 38” 07′30″, long 108” 45’ to 108” 52’30”. (See Map MF-21.)

GQ-71. Davis Mesa, Colo. Geology, by F. W. Cater, Jr. 1955. Lat 38” 15’ to 38” 22′30″, long 108° 45’ to 108” 52’30”. (See Map MF-31.)

GQ-72. Paradox, Colo. Geology. by C. F. Withington. 1955. Lat 38” 15’ to 38” 22′30″, long 108” 52’30” to 109”. (See Map MF-22.)

GQ-77. Anderson Mesa, Colo. Geology, by F. W. Cater, Jr. 1955. (1956). Lat 38” 07’30” to 38” 15′, long 108” 52’30” to 109”. (See Map MF-25.)

GQ-78. Uravan, Colo. Geology, by F. W. Cater, Jr., A. P. Butler, Jr., and E. J. McKay. 1955. Lat 38” 15’ to 38” 22′30″, long 108” 37’30” to 108” 45′, (See Map MF-24.)

GQ-81. Juanita Arch, Colo. Geology, by E. M. Shoemaker. 1955. Lat 38” 30’ to 38” 37′30″, long 108” 52’30” to 109”. (See Map MF-28.)

GQ-83. Rock Creek, Colo. Geology, by E. M. Shoemaker. 1956. Lat 38” 22’30” to 38” 30′, long 108° 52’30” to 109” (See Map MF-23.)

GQ-103. Golden, Colo. Bedrock geology, by Richard Van Horn. 1957. Lat 39” 45’ to 39 52′30″, long 105” 07’30” to 105” 15’.

GQ-151. Louisville, Colo. Bedrock geology, by F. D. Spencer. 1961. Lat 39” 52’30” to 40°, long 105” 07’30” to 105” 15’.

GQ-152. Ouray, Colo. Geology, by R. G. Luedke and W. S. Burbank. 1962. Lat 38” to 38” 07′30″, long 107” 37’30” to 107” 45’.

GQ-267. Geology of the Central City quadrangle, Colorado, by P. K. Sims. 1964. Lat 39” 45’ to 39” 52′30″, long 105” 30’ to 105” 37’30”.

GQ-291. Geology of the Ironton quadrangle, Colorado, by W. S. Burbank and R. G. Luedke. 1964. Lat 37” 52’30” to 38”. long 107” 37’30” to 107” 45’.

GQ-397. Geologic map of the Fort Lupton quadrangle, Weld and Adams Counties, Colo., by P. E. Soister. 1952. Lat 40” to 40” 07′30″, long 104” 45’ to 104” 52’30”.

GQ-398. Geologic map of the Hudson quadrangle, Weld and Adams Counties, Colo., by P. E. Soister. 1965. Lat 40° to 40° 07′30″, long 104° 37’30” to 104” 45’.

GQ-399. Geologic map of the Platteville quadrangle, Weld County, Colo., by P. E. Soister. 1965. Lat 40” 07’30” to 40° 15’. long 104° 45’ to 104” 52’30”.

GQ-486. Geologic map of the Cerro Summit quadrangle, Montrose County, Colo., by R. G. Dickinson. 1965 (1966). Lat 38” 22’30” to 38” 30′, long 107” 37’30” to 107” 45’.

GQ-504. Geologic map of the Telluride quadrangle, southwestern Colorado, by W. S. Burbank and R. G. Luedke. 1966. Lat 37” 52’30” to 38”. long 107” 45’ to 107” 52’30”.

GQ-511. Geologic map of the Marcellina Mountain quadrangle, Gunnison County, Colo., by D. L. Gaskill and L. H. Godwin. 1966. Lat 38” 52’30” to 39°, long 107” 07’30” to 107” 15’.

GQ-512. Geologic map of the Marble quadrangle, Gunnison and Pitkin Counties, Colo., by D. L. Gaskill and L. H. Godwin. 1966. Lat 39” to 39” 07′30″, long 107” 07’30” to 107” 15’.

GQ-536. Geologic map of the Dolores Peak quadrangle, Dolores and San Miguel Counties, Colo., by A. L. Bush and C. S. Bromfield. 1966, Lat 37” 45’ to 37” 52′30″, long 108” to 108” 07’30”.

GQ-578. Geologic map of the Oh-be-joyful quadrangle, Gunnison County, Colo., by D. L. Gaskill, L. H. Godwin, and F. E. Mutschler. 1967. Lat 38” 52’30” to 39°, long 107” to 107” 07’30”.

GQ-596. Geologic map of the Mount Tyndall quadrangle, Custer County, Colo., by M. R. Brock and Q. D. Singewald. 1968. Lat 38” 07’30” to 38” 15′, long 105” 15’ to 105” 22’30”. 2 sheets. Accompanied by 5-page text.

GQ-631. Geologic map of the Bristol Head quadrangle, Mineral and Hinsdale Counties, Colo., by T. A. Steven. 1967. Lat 37” 45’ to 38°, long 107” to 107” 15’. Scale 1:62,500.

GQ-702. Geologic map of the Elk Springs quadrangle, Moffat County, Colo., by J. R. Dyni. 1968. Lat 40° 15’ to 40° 30′, long 108” 15’ to 108” 30’. Scale 1:62,500.

GEOLOGIC QUADRANGLE MAPS-Continued

GQ-703. Geologic map of the Banty Point quadrangle, Rio Blanco County, Colo., by H. L. Cullins. 1968. Lat 40” to 40” 07′30″, long 108” 52’30” to 109”.

GQ-704. Geologic map of the Chair Mountain quadrangle, Gunnison and Pitkin Counties, Colo., by L. H. Godwin. 1968. Lat 39” to 39” 07′30″, long 107” 15’ to 107” 22’30”.

GQ-725. Geologic map of the Hanover NW quadrangle, El Paso County, Colo., by P. E. Soister. 1968. Lat 38” 37’30” to 38” 45′, long 104” 22’30” to 104” 30’.

GQ-747. Geologic map of the Black Ridge quadrangle, Delta and Montrose Counties, Colo., by W. R. Hansen. 1968. Lat 38” 37’30” to 38” 45′, long 107” 45’ to 107” 52’30”.

GQ-783. Geologic map of the Corral Bluffs quadrangle, El Paso County, Colo., by P. E. Soister. 1968. Lat 38” 45’ to 38” 52’30”. long 104” 30’ to 104” 37’30”.

GQ-788. Geologic map of the Maroon Bells quadrangle, Pitkin and Gunnison Counties, Colo., by Bruce Bryant. 1969. Lat 39” to 39” 07′30″, long 106” 52’30” to 107”.

GQ-797. Geologic map of the Rico quadrangle, Dolores and Montezuma Counties, Colo., by W. P. Pratt, E. T. McKnight, and R. A. DeHon. 1969. Lat 37” 37’30” to 37” 45′, long 108” to 108” 07’30”.

GQ-812. Geologic map of the Black Cabin Gulch quadrangle, Rio Blanco County, Colo., by W. B. Cashion. 1969. Lat 39° 45’ to 39° 52′30″, long 108” 30’ to 108” 37’30”.

GQ-823. Geologic map of the Casa Grande quadrangle, Colfax County, N. Mex., and Las Animas County, Colo., by C. L. Pillmore. 1969 (1970). Lat 36” 45’ to 37°, long 104” 45’ to 105”. Scale 1:62,500.

GQ-829. Geologic map of the Drake quadrangle, Larimer County, Colo., by W. A. Braddock, Prinya Nutalaya, S. J. Gawarecki, and G. C. Curtin. 1970. Lat 40° 22’30” to 40” 30′, long 105” 15’ to 105” 22’30”.

GQ-832. Geologic map of the Masonville quadrangle, Larimer County, Colo., by W. A. Braddock, R. H. Calvert, S. J. Gawarecki, and Prinya Nutalaya. 1970. Lat 40” 22’30” to 40” 30′, long 105” 07’30” to 105” 15’.

GQ-833. Geologic map of the Nederland quadrangle, Boulder and Gilpin Counties, Colo., by D. J. Gable. 1969 (1970). Lat 39° 52’30” to 40°, long 105” 30’ to 105” 37’30”.

GQ-835. Geologic map of the Mellen Hill quadrangle, Rio Blanco and Moffat Counties, Colo., by H. L. Cullins. 1969 (1970). Lat 40” 07’30” to 49” 15′, long 108” 52’30” to 109”.

GQ-853. Geologic map of the Snowmass Mountain quadrangle, Pitkin and Gunnison Counties, Colo., by F. E. Mutschler. 1970. Lat 39” to 39” 07’30”. long 107” to 107” 07’30”.

GQ-863. Geologic map of the Hayden Peak quadrangle, Pitkin and Gunnison Counties, Colo., by Bruce Bryant. 1970. Lat 39° to 39” 07′30″, long 106” 45’ to 106” 52’30”.

GQ-875. Geologic map of the Peoria quadrangle, Arapahoe and Adams Counties, Colo., by P. E. Soister. 1972. Lat 39” 37’30” to 39” 45′, long 104” to 104” 07’30”.

GQ-903. Geologic map of the Rangely quadrangle, Rio Blanco County, Colo., by H. L. Cullins. 1971. Lat 40” to 40” 07′30″, long 108” 45’ to 108” 52′30″.

GQ-932. Geologic map of the Highland Peak quadrangle, Pitkin County, Colo., by Bruce Bryant. 1972. Lat 39” 07’30” to 39” 15′, long 106” 52’30” to 107”.

GQ-933. Geologic map of the Aspen quadrangle, Pitkin County, Colo., by Bruce Bryant. 1971. Lat 39° 07’30” to 39” 15′, long 106” 45’ to 106” 52’30”.

GQ-952. Geologic map of the Mount Harvard quadrangle, Chaffee and Gunnison Counties, Colo., by M. R. Brock and Fred Barker. 1972. Lat 38” 45’ to 39°, long 106” 15’ to 106” 30’. Scale 1:62,500.

GQ-967. Geologic map of the Woody Creek quadrangle, Pitkin and Eagle Counties, Colo.. by V. L. Freeman. 1972. Lat 39° 15’ to 39” 22′30″, long 106” 52’50” to 107”.

GQ-978. Geologic map of the Tungsten quadrangle, Boulder, Gilpin, and Jefferson Counties, Colo., by D. J. Gable. 1972. Lat 39° 52’30” to 40°, long 105” 22’30” to 105” 30’.

GQ-1001. Geologic map of the Red Creek Ranch quadrangle, Wyoming, Utah, and Colorado, by H. W. Roehler. 1972. Lat 41” to 41” 07′30″, long 109” to 109” 07’30”.

GQ-1002. Geologic map of the Four J Rim quadrangle, Sweetwater County, Wyo., and Moffat County, Colo., by H. W. Roehler. 1972. Lat 41” to 41” 07′30″, long 108” 52’30” to 109”.

GQ-1004. Geologic map of the Ruedi quadrangle, Pitkin and Eagle Counties, Colo., by V. L. Freeman. 1972. Lat 39” 15’ to 39” 22′30″, long 106” 45’ to 106” 52’30”.

GQ-1011. Geologic map of the Wetterhorn Peak quadrangle, Colorado, by R. G. Luedke. 1972. Lat 38” to 38” 07′30″, long 107” 30’ to 107° 37’30”.

GQ-1018. Geologic map of the Brushy Point quadrangle, Rio Blanco and Garfield Counties, Colo., by H.W. Roehler. 1972. Lat 39” 37’30” to 39” 45′, long 108” 37’30” to 108” 45’.

GQ-1019. Geologic map of the Razorback Ridge quadrangle, Rio Blanco and Garfield Counties, Colo., by H. W. Roehler. 1972. Lat 39” 37’30” to 39” 45′, long 108” 30’ to 108” 37’30”.

GQ-1052. Geologic map of the Spar City quadrangle, Mineral County, Colo., by T. A. Steven and P. W. Lipman. 1973. Lat 37” 30’ to 37” 45′, long 106° 45’ to 107”. Scale 1:62,500.

GQ-1053. Geologic map of the Creede quadrangle, Mineral and Saguache Counties, Colo., by T. A. Steven and J. C. Ratte. 1973. Lat 37” 45’ to 38°, long 106” 45’ to 107”. Scale 1:62,500.

GQ-1070. Geologic map of the Carpenter Ridge quadrangle, Gunnison County, Colo., by D. C. Hedlund and J. C. Olson. 1973 (1974). Lat 38” 22’30” to 38” 30′, long 107” 07’30” to 107” 15’.

GQ-1071. Geologic map of the Gateview quadrangle, Gunnison County, Colo., by J. C. Olson and D. C. Hedlund. 1973 (1974). Lat 38” 15’ to 38” 22′30″, long 107” 07’30” to 107” 15’.

GQ-1073. Geologic map of the Indian Hills quadrangle, Jefferson County, Colo., by Bruce Bryant, R. D. Miller, and G. R. Scott. 1973 (1974). Lat 39° 30’ to 39° 37′30″, long 105” 07’30” to 105” 15’.

GQ-1086. Geologic map of the Calf Canyon quadrangle, Garfield County, Colo., by H. W. Roehler. 1973 (1974). Lat 39” 30’ to 39” 37′30″, long 108” 37’30” to 108” 45’.

GQ-1113. Geologic map of the Henderson Ridge quadrangle, Garfield County, Colo., by H. W. Roehler. 1973 (1974). Lat 39” 30’ to 39” 37′30″, long 108” 30’ to 108” 37’30”.

GQ-1115. Geologic map of the Kremmling quadrangle, Grand County, Colo., by G. A. Izett and C. S. V. Barclay. 1973 (1975). Lat 40° to 40° 15’. lonn 106° 15’ to 106” 30’. Scale 1:62,500.

GQ-1131. Geologic map of the Smizer Gulch quadrangle, Rio Blanco and Moffat Counties, Colo., by W. J. Hail, Jr. 1973 (1974). Lat 40° 07’30” to 40° 15′, long 108” 15’ to 108” 22’30”.

GQ-1134. Geologic map of the Iris NW quadrangle, Gunnison and Saguache Counties, Colo., by D. C. Hedlund and J. C. Olson. 1974. Lat 38” 22’30” to 38” 30′, long 106” 52’30” to 107”.

GQ-1144. Geologic map of the Lone Mountain quadrangle, Moffat County, Colo., by E. J. McKay. 1974. Lat 40° 30’ to 40” 45′, long 108” 15’ to 108” 30’. Scale 1:62,500.

GQ-1145. Geologic map of the Maybell quadrangle, Moffat County, Colo., by E. J. McKay and M. J. Bergin. 1974. Lat 40” 30’ to 40° 45′, long 108” to 108” 15’. Scale 1:62,500.

GQ-1153. Geologic map of the Big Mesa quadrangle, Gunnison County, Colo., by D. C. Hedlund. 1974 (1975). Lat 38” 22’30” to 38” 30’. lone 107” to 107” 07’30”.

GQ-1156. Geologic map of the Trail Mountain quadrangle,-Grand County, Colo., by G. A. Izett. 1974. Lat 40° 07’30” to 40° 15’. long 105” 52’30” to 106”.

GQ-1166. Geologic map of the Scrivner Butte quadrangle, Sweetwater County, Wyo., and Moffat County, Colo., by H. W. Roehler. 1974. Lat 41” to 41” 07′30″, long 108” 45’ to 108” 52’30”.

GQ-1177. Geologic map of the Rudolph Hill quadrangle, Gunnison, Hinsdale, and Saguache Counties, Colo., by J. C. Olson. 1974. (1975). Lat 38” 07’30” to 38” 15′, long 107” to 107” 07’30”. Scale 1:24,000. Paleotopographic-contour interval 100 feet.

GQ-1178. Geologic map of the Powderhorn quadrangle, Gunnison and Saguache Counties, Colo., by D. C. Hedlund and J. C. Olson. 1975. Lat 38” 15’ to 38” 22′30″, long 107” to 107” 07’30”. Scale 1:24,000. Paleotopographic-contour interval 100 feet.

GQ-1195. Geologic map of the Rough Gulch quadrangle, Rio Blanco and Moffat Counties, Colo., by W. J. Hail, Jr. 1974 (1975). Lat 40” 07’30” to 40” 15′, long 108” 22’30” to 108” 30’. Scale 1:24,000. Structure-contour intervals 100 and 500 feet.

GQ-1224. Geologic map of the Bottle Pass quadrangle, Grand County, Colo., by R. B. Taylor. 1975. Lat 39° 52’30” to 40°, long 105” 52’30” to 106”. Scale 1:24,000.

GQ-1229. Geologic map of the Niwot quadrangle, Boulder County, Colo., by D. E. Trimble. 1975. Lat 40” to 40” 07′30″, long 105” 07’30” to 105” 15’. Scale 1:24,000. (Supersedes OF 74-10).

GEOLOGIC QUADRANGLE MAPS-Continued

GQ-1248. Geologic map of the Black Hawk quadrangle, Gilpin, Jefferson, and Clear Creek Counties, Colorado, by R. B. Taylor. 1976. Lat 39” 45’ to 39” 52′30″, long 105” 22’30” to 105” 30’. Scale 1:24,000 (1 inch = 2,000 feet) Sheet 32 by 40 inches.

GQ-1277. Geologic map of the Ward quadrangle, Boulder County, Colo., by D. J. Gable and R. F. Madole. 1976. Lat 40” to 40° 07′30″, long 105” 30’ to 105” 37’30”. Scale 1:24,000.

GQ-1286. Geologic map of the Iris quadrangle, Gunnison and Saguache Counties, Colo., by J. C. Olson. 1976. Lat 38” 22’30” to 38” 30′, long 106” 45’ to 106” 52’ 30”. Scale 1:24,000. (Supersedes Open-File 75-63.)

GQ-1287. Geologic map of the Houston Gulch quadrangle, Gunnison and Saguache Counties, Colorado, by J. C. Olson. 1976, Lat 38” 22’30” to 38” 30′, long 106” 37’30” to 106” 45’. Scale 1:24,000. (Supersedes Open-tile 75-62.)

GQ-1323. Geologic map of the Big Narrows quadrangle, Larimer County, Colorado, by J. T. Abbott. 1976. Lat 40” 37’30” to 40° 45′, long 105” 22’30” to 105” 30’. Scale 1:24,000 (1 inch = 2,000 feet) Sheet 3” by 34 inches.

GQ-1337. Geologic map of the Squaw Pass quadrangle, Clear Creek, Jefferson, and Gilpin Counties. Colorado, by D. M. Sheridan and S. P. Marsh. 1976 (1977). Lat 39” 37’30” to 39” 45’. long 105” 22’30” to 105” 30’. Scale 1:24,000 (1 inch = 2,000 feet). Sheet 29 by 42 inches.

GQ-1343. Geologic map of the Milligan Lakes quadrangle, Park County, Colorado, by D. G. Wyant and Fred Barker. 1976 (1977). Lat 39” 15’ to 39” 22′30″, long 105” 45’ to 105” 52’30”. Scale 1:24,000 (1 inch = 2,000 feet). Sheet 31 by 33 inches.

GQ-1345. Geologic map of the Jefferson quadrangle, Park and Summit Counties, Colorado, by Fred Barker and D. G. Wyant. 1976. (1977). Lat 39” 22’30” to 39” 30′, long 105” 45′ to 105” 52’30”. Scale 1:24,000 (1 inch = 2,000 feet). Sheet 30 by 31 inches.

GQ-1403. Geologic map of the Canyon of Lodore south quadrangle, Moffat County, Colorado, by W. R. Hansen, 1977. Lat 40” 30’ to 40° 37′30″, long 108” 52’30” to 109”. Scale 1:24,000 (1 inch = 2,000 feet). Sheet 29 by 42 inches.

GEOPHYSICAL INVESTIGATIONS MAPS

GP-125. Airborne radioactivity survey of part of Moffat County, Cola., north of 40” 45′, by R. W. Johnson. 1955. Scale 1:62,500. $1.25.

GP-126. Airborne radioactivity survey of part of Moffat County, Cola., south of 40” 45′, by R. W. Johnson. 1955. Scale 1:62,500. $1.25.

GP-505. Natural gamma aeroradioactivity map of the Denver area, Colorado, by Peter Popenoe. 1965. Lat 39” 07’30” to 40” 35′, long 104° to about 105” 15’. Scale 1:250,000. $1.25.

GP-557. Aeromagnetic map of the Denver area, Colorado, by A. J. Petty, J. L. Vargo, and F. C. Smith. 1966. Vicinity of lat 40°, long 104” 30’. Scale 1:250,000. $1.25.

GP-597. Aeromagnetic and gravity profiles of the United States along the 37th parallel—A contribution to the upper mantle project, by Isidore Zietz and J. R. Kirby. 1967. Lat 35” to 39°, long 70” to 125”. Scale 1:2,500,000. $1.25.

GP-638. Gravity map of the Trinidad quadrangle, Cola., by D. L. Peterson, Peter Popenoe, J. R. Gaca, and D. E. Karig. 1968. Lat 37” to 38°, long 104” to 106”. Scale 1:250,000. $1.25.

GP-836. Aeromagnetic map of Colorado, by Isidore Zietz and J. R. Kirby, Jr. 1972. Lat 37” to 41°, long 102” to 109”. Scale 1:500,000. $1.25.

GP-840. Aeromagnetic map of the Ridgway-Pagosa Springs area, southwestern Colorado. 1972 (1973). Lat 37” 15” to 38” 15″, long 106°30′ to 108°15′. Scale. 1:500,000. $1.25.

GP-880. Aeromagnetic map of Colorado, by Isidore Zietz and J. R. Kirby, Jr. 1972. Lat 37” to 41°, long 102” to 109”. Scale 1:000,000. $1.50.

GP-895. Bouguer gravity map of Colorado, compiled by J. C. Behrendt and L. Y. Bajwa. 1974. Lat 37” to 41”. long 102” to 109”. Scale 1:500,000. $1.25.

GP-896. Bouguer gravity and generalized elevated maps of Colorado, by J. C. Behrendt and L. Y. Bajwa. 1974 (1975). Lat 37’ to 41”. long 102” to 109”. Scale 1:1,000,000. 2 sheets. $2.75.

HYDROLOGIC INVESTIGATIONS ATLASES

HA-2. Areas of principal ground-water investigations in the Arkansas, White, and Red River basins, by S. W. Lohman and V. M. Burtis. 1953 (1954). Lat 31” to 39°, long 91’ to 106’. Scale 1:2,300,000. $1.

HYDROLOGIC INVESTIGATIONS ATLASES-Continued

HA-3. General availability of ground water and depth to water level in the Arkansas, White and Red River basins, by S. W. Lohman, V. M. Burtis, and others. 1953 (1954). Lat 31” to 39°, long 91” to 106”. Scale 1:2,500,000. (1975) $1.

HA-9. Ground-water resources of parts of Weld, Logan, and Morgan Counties, Colo., by L. J. Bjorklund, with a section on The Chemical quality of the ground water, by F. H. Rainwater. 1957 (1958). $1.50.

HA-41. Floods at Boulder, Colo. 1961 (1962). Scale 1:6,000. $1.75.

HA-61. Stream composition of the conterminous United States. bv E. H. Rainwater. 1962. 3 sheets. $6 per set.

HA-189. Calcium, sodium, sulfate, and chloride in stream water of the western conterminous United States to 1957, by J. H. Feth. 1965. 4 sheets. Scale 1:2,500,000. $5 per set.

HA-194. Generalized map showing annual runoff and productive aquifers in the conterminous United States, by C. L. McGuinness. 1964. Scale 1:5,000,000. $2.

HA-199. Preliminary map of the conterminous United States showing depth to and quality of shallowest ground water containing more than 1,000 parts per million dissolved solids, by J. H. Feth and others. 1965. Scale 1:3,168,000. 2 sheets. Accompanied by 31-page text. $1.75 per set.

HA-200. Chemical quality of public water supplies of the United States and Puerto Rico, 1962, shown as Statewide averages, mainly in graphic and tabular form, by C. N. Durfor and Edith Becker. 1964. $1.25.

HA-212. Annual runoff in the conterminous United States. bv M. W. Bushbv. 1966. Scale 1:7,500,000. $1.25.

HA-217. General availability of ground water and depth to water level in the Missouri River basin, by G. A. La Rocque, Jr. 1966. Lat 36” to 49°, long 90° to 114”. Scale 1:2,500,000. $1.75.

HA-235. Temperature of surface waters in the conterminous United States, by J. F. Blakey. 1966. Scale 1:5,000,000. 3 sheets. Accompanied by 8-page text. $1.75 per set.

HA-236. Ground water in Black Squirrel Creek valley, El Paso County, Colo., by H. E. McGovern and E. D. Jenkins. 1966. Vicinity of lat 38” 50′, long 104” 25’. $1.25.

HA-370. Geohydrology of the Piceance Creek structural basin between the White and Colorado Rivers. northwestern Colorado. bv D. L. Coffm. F. A. Welder, and R. K. Glanzman. 1971. Lat about 39” 15’ to 40” 15′, long about 108° to 108” 45’. 2 sheets. $2.50 per set.

HA-381. Hydrology of the San Luis Valley, south-central, Colorado, by P. A. Emery, A. J. Boettcher, R. J. Snipes, and H. J. McIntyre, Jr. 1971. Lat 37” to 38” 15′, long 105” 30’ to 106” 30’. 2 sheets. $2.50 per set.

HA-461. Hydrogeologic characteristics of the valley-fill aquifer in the Arkansas River valley, Bent County, Colo., by R. T. Hurr and J. E. Moore. 1972 (1973). Lat 38” to 38 10′, long 102” 45’ to 103” 22’30”. Scale 1:62,500. 2 sheets. $2.50 per set.

HA-477. Selected hydrologic data in the upper Colorado River basin, by Don Price and K. M. Waddell. 1973 (1974). Lat 36” to 43°, long 106” to 112”. Scale 1:2,500,000. 2 sheets. $3 per set.

HA-510. Reconnaissance investigation of ground water in the Rio Grande drainage basin—with special emphasis on saline ground-water resources, by T. E. Kelly. 1974. Lat 26” to 38” , long 98” to 108”. Scale 1:2,500,000. 4 sheets. $5.50 per set.

STATE HYDROLOGIC MAP

COLORADO. 1974. An overprint of the 1:500,000-scale State base map. Shows counties, location and names of all cities and towns and most of the smaller settlements, railroads, and township and range lines in black; water features in blue; hydrologic boundaries and codes in red; county codes in green. No contours. Sheet 41 by 58 inches. $1.25.

***INTERPRETING GEOLOGIC MAPS FOR ENGINEERING PURPOSES.** 1953 (1954). Six maps of the Hollidaysburg, Pa. quadrangle. Scale 1:62,500.

*LAND CLASSIFICATION MAPS OF THE CENTRAL GREAT PLAINS:

*Sheet 4, Northeastern Colorado, by Depue Falck, E. R. Greenslet, and R. E. Morgan.
*Sheet 5, Southeastern Colorado, by Depue Falck, E. R. Greenslet, and R. E. Morgan.

LAND CLASSIFICATION MAPS OF THE CENTRAL GREAT PLAINS-Continued

*Western Colorado, by L. R. Brooks, J. F. Deeds, Depue Falck, E. R. Greenslet, G. M. Kerr, and J. Q. Peterson. 2 sheets.

MISCELLANEOUS FIELD STUDIES MAPS

MF-12. Geologic map of the Pando area, Eagle and Summit Counties, Colo., by Ogden Tweto. 1953 (1954). Lat 39” 25’ to 39” 30′, long 106” 12’30” to 106” 22’30”. Scale 1:14,400. $1.75.

*MF-13. Geology of the Northgate fluorspar district, Colorado, by T. A. Steven. 1954. Scale 1:24,000. 2 sheets. (See Bulletin 1082-F and Professional Paper 274-M.)

MF-16. Preliminary geologic map showing the distribution of uranium deposits and principal ore-bearing formations of the Colorado Plateau region, compiled by W. I. Finch. 1955. Scale 1:500,000. $1.25.

*MF-17. Preliminary geologic map of the Red Canyon quadrangle, Colorado, by D. J. McKay. 1954. Lat 38” 22’30”. to 38” 30′, long 108° 45’ to 108” 52’30”. Scale 1:24,000. See Map GQ-58.)

*MF-18. Preliminary geologic map of the Atkinson Creek quadrangle, Colorado, by E. J. McKay and D. A. Jobin. 1954. Lat 38” 22’30” to 38” 30′, long 108” 37’30” to 108” 45’. Scale 1:24,000. (See Map GQ-57.)

*MF-19. Preliminary geologic map of the Gypsum Gap quadrangle, Colorado, by F. W. Cater, Jr. 1954 (1955). Lat 38” to 38” 07’30”., long 108” 37’30” to 108” 45’. Scale 1:24,000. (See Map GQ-59.)

*MF-20. Preliminary geologic map of the Pine Mountain quadrangle, Colorado, by F. W. Cater, Jr. 1954. Lat 38” 37’30” to 38” 45′, long 108” 45’ to 108” 52’30”. Scale 1:24,000. (See Map GQ-60.)

*MF-21. Preliminary geologic map of the Hamm Canyon quadrangle, Colorado, by F. W. Cater, Jr. 1955. Lat 38” to 38” 07′30″, long 108” 52’30”. Scale 1:24,000. (See Map GQ-69.)

*MF-22. Preliminary geologic map of the Paradox quadrangle, Colorado, by C. F. Withington. 1955. Lat 38” 15’ to 38” 22′30″, long 108” 52’30” to 109”. Scale 1:24,000. (See Map GQ-72.)

*MF-23. Preliminary geologic map of the Roc Creek quadrangle, Colorado, by E. M. Shoemaker. 1955. Lat 38” 22’30” to 38” 30′, long 108” 52’30” to 109”. Scale 1:24,000. (See Map GQ-83.)

*MF-24. Preliminary geologic map of the Uravan quadrangle, Colorado, by F. W. Cater, Jr., and E. J. McKay. 1955. Lat 38” 15’ to 38” 22’30”. lone 108° 37’30” to 108” 45’. Scale 1:24,000. (See Map GQ-78.)

*MF-25. Preliminary geologic map of the Anderson Mesa quadrangle, Colorado, by F. W. Cater, Jr. 1955. Lat 38” 07’30” to 38” 15′, long 108” 52’30” to 109”. Scale 1:24,000. (See Map GQ-77.)

*MF-26. Preliminary geologic map of the Egnar quadrangle, Colorado, by F. W. Cater, Jr. 1955. Lat 37” 52’30” to 38°, long 108” 52’30” to 109”. Scale 1:24,000. (See Map GQ-68.)

*MF-27. Preliminary geologic map of the Joe Davis Hill quadrangle, Colorado, by F. W. Cater, Jr. 1955. Lat 37” 52’30” to 38°, long 108” 45’ to 108” 52’30”. Scale 1:24,000. (See Map GQ-66.)

*MF-28. Preliminary geologic map of the Juanita Arch quadrangle, Colorado, by E. M. Shoemaker. 1955. Lat 38” 30’ to 38” 37’30”. long 108” 52’30” to 109”. Scale 1:24.000. (See Map GQ-81.)

*MF-29. Preliminary geologic map of the Horse Range Mesa quadrangle, Colorado, by F. W. Cater, Jr. 1954 (1955). Lat 38” to 38” 07’30”, long 108” 52’30” to 109”. Scale 1:24,000. (See Map GQ-64.)

*MF-30. Preliminary geologic map of the Naturita NW quadrangle, Colorado, by F. W. Cater, Jr. 1955. Lat 38” 07’30” to 38” 15’. lone 108” 37’30” to 108” 45’. Scale 1:24,000. (See Map GQ-65.)

*MF-31. Preliminary geologic map of the Davis Mesa quadrangle, Colorado, by F. W. Cater, Jr., and E. J. McKay, 1955. Lat 38” 15’ to 38” 22′30″, long 108” 45’ to 108” 52’30”. Scale 1:24,000. (See Map GQ-71.)

*MF-32. Preliminary geologic map of the Calamity Mesa quadrangle, Colorado, by F. W. Cater, Jr. 1955. Lat 38” 30’ to 38” 37’30”. long 108” 45’ to 108” 52’ 30”. Scale 1:24,000. (See Map GQ-61.)

MISCELLANEOUS FIELD STUDIES MAPS-Continued

MF-34. Geologic map of the Tennessee Pass area, Eagle and Lake Counties, Colo., by Ogden Tweto. 1956. Scale 1:14,400. 75¢.

*MF-37. Geologic and radiometric maps of the McKinley Mountain area, Wet Mountains, Colo.. by Q. D. Singewald and others, 1955. Scale 1:7,200. 4 sheets, (See Bulletin 1072-H and Map GQ-596.)

MF-54. Uranium and vanadium deposits of the Colorado Plateau that produced more than I.000 tons of ore through June 30, 1955. by R. T. Chew 3d. 1956. Scale 1:750,000. 75”.

*MF-96. Preliminary geologic map of Placerville quadrangle, Colorado, by A. L. Bush, C. S. Bromfield, and C. T. Pierson. 1956. Lat 38” to 38” 07'30”. long 108' to 108 07'30”. Scale 1:24,000. (See Bulletin 1072-E.)

MF-120. Uranium deposits and principal ore-bearing formations of the central Cordilleran foreland region, by T. L. Finnell and I. S. Parrish. 1958. Scale 1:750,000. 2 sheets. $1.50 per set. (See Bulletin 1087-I.)

MF-122. Preliminary geologic map of sections of the western part of the Gateway district, Mesa County, Colo., and Grand County, Utah, by L. J. Eicher, D. C. Hedlund, and G. A. Miller. 1957. Lat 38” 36'15” to 38” 45'. long 109” to 109° 10'. Scale 1:24,000. 75'.

“MF-123. Preliminary geologic map of the Mount Peale 1 SE quadrangle, Montrose County. Colo., and San Juan County, Utah, by W. D. Carter and J. L. Gualtieri. 1957. Lat 38” 15' to 38' 22'30”. long 109° to 109° 07'30”. Scale 1:24,000. (See Professional Paper 508.)

*MF-130. Preliminary tectonic map of northern Colorado and northeastern Utah, showing the distribution of uranium deposits, compiled by F. W. Osterwald and B. G. Dean. 1958. Scale 1:500,000. 2 sheets. (See Bulletin 1087-I.)

*MF-132. Preliminary geologic map of the Sentinel Peak NW quadrangle, Montezuma County, Colo., by E. B. Ekren and F. N. Houser. 1957. Lat 37” 07'30” to 37” 15', long 108” 52'30” to 109°. Scale 1:24,000. (See Professional Paper 481.)

*MF-139. Preliminary geologic map of the Mount Peale 1 NE quadrangle, San Juan County, Utah, and Montrose County, Colo., by W. D. Carter, J. L. Gualtieri, and E. M. Shoemaker. 1958. Lat 38' 22'30” to 38” 30', long 109” to 109” 07'30”. Scale 1:24,000. (See Professional Paper 508.)

MF-149. Preliminary geologic map of the Mount Peale 4 SE quadrangle, San Juan County, Utah, and San Miguel County, Colo., by G. W. Weir and W. P. Puffett. 1960 (1961). Lat 38” to 38” 07'30”. long 109” to 109° 07'30”. Scale 1:24,000. 75¢.

MF-150. Preliminary geologic map and section of the Mount Peale 4 NE quadrangle, San Juan County. Utah, and Montrose and San Miguel Counties, Colo., by G. W. Weir. W. D. Carter. W. P. Puffett, and J. 0. Gualtieri. 1960. (1961). Lat 38” 07'30” to 38' 15'. long 109' to 109° 07'30”. Scale 1:24,000. 75¢.

MF-169. Exploration for uranium-vanadium deposits by the U.S. Geological Survey in the Club Mesa area, Uravan district, Montrose County, Colo., by R. L. Boardman, L. R. Litsey, and H. E. Bowers. 1958. Scale 1:7,200. $1.50.

MF-176. Preliminary geologic map of the Gray Head quadrangle, San Miguel County, Colo., by A. L. Bush, C. S. Bromfield, 0. T. Marsh, and R. B. Taylor. 1961. Lat 37” 52'30” to 38”. long 107” 52'30” to 108”. Scale 1:24,000. $1.50.

*MF-179. Preliminary map of bedrock geology of the Ralston Buttes quadrangle, Jefferson County, Colo., by D. M. Sheridan. C. H. Maxwell, A. L. Albee, and Richard Van Horn. 1958. Lat 39” 45' to 39” 52'30”. long 105” 15' to 105” 22'30”. Scale 1:24,000. (See Professional Paper 520.)

*MF-203. Preliminary geologic map of the Slick Rock district, San Miguel and Dolores Counties, Colo., by D. R. Shawe, G. C. Simmons, and W. B. Rogers. 1961. Lat 37” 45' to 38”. lone 108” 37'30” to 109°. Scale 1:48,000. (See Bulletin 1107-B and Professional Pap& 576-A.)

*MF-216. Preliminary geologic map of the Moqui SW quadrangle. Montezuma County. Colo.. by F. N. Houser and E. B. Ekren. 1959. Lat 37” 15' to 37” 22'30", long 108” 52'30” to 109°. Scale 1:24,000. (See Professional Paper 481.)

*MF-217. Preliminary geologic map of the Cortez SW quadrangle, Montezuma County, Colo., by E. B. Ekren and F. N. Houser. 1959. Lat 37” 15' to 37” 22'30", long 108” 37'30” to 108” 45'. Scale 1:24,000. (See Professional Paper 481.)

*MF-221. Preliminary geologic map of the Moqui SE quadrangle, Montezuma County, Colo., by E. B. Ekren and F. N. Houser. 1959. Lat 37” 15’ to 37” 22′30″, long 108” 45’ to 108” 52’30”. Scale 1:24,000. (See Professional Paper 481.)

‘MF-223. Preliminary geologic map of the Little Cone quadrangle, San Miguel County. Colo., by A. L. Bush, 0. T. Marsh, and R. B. Taylor. 1959. Lat 37” 52’30” to 38°, long 108” to 108” 07’30”. Scale 1:24,000. (See Bulletin 1082-G.)

“MF-224. Preliminary geologic map of the Sentinel Peak NE quadrangle, Montezuma County, Colo., by E. B. Ekren and F. N. Houser. 1959. Lat 37” 07’30” to 37” 15′, long 108” 45’ to 108” 52’30”. Scale 1:24,000. (See Professional Paper 481.)

*MF-241. Exploration for uranium-vanadium deposits by U.S. Geological Survey 1948-56 in western Disappointment Valley area, Slick Rock district, San Miguel County, Colo. (West half) (East half?, by W. B. Rogers and D. R. Shaw. 2 Scale 1:12,000. 3 sheets. (See Professional Paper 576-A.)

MF-271. Preliminary geologic map of the Hot Sulphur Springs SE quadrangle, Grand County, Colo., by G. A. Izett and D. L. Hoover. 1963. Lat 40” to 40° 07′30″, long 106” to 106” 07’30”. Scale 1:24,000. 75¢.

“MF-273. Preliminary geologic map of the Mount Wilson quadrangle, San Miguel and Dolores Counties, Colo., by C. S. Bromtield and A. R. Conroy. 1963 (1964). Lat 37” 45’ to 37” 52′30″, long 107” 52’30” to 108”. Scale 1:24,000. (See Bulletin 1227.)

MF-291. Preliminary geologic map of the Hot Sulphur Springs SW quadrangle, Grand County, Colo., by G. A. Izett and C. S. V. Barclay. 1964. Lat 40” to 40” 07′30″, long 106” 07’30” to 106” 15’. Scale 1:24,000. 75¢.

MF-308. Preliminary engineering geologic map of the Golden quadrangle, Jefferson County, Colo., by M. E. Gardner and S. S. Hart. 1971 (1972.) Lat 39” 45’ to 39” 52′30″, long 105” 07’30” to 105” 15’. 6 sheets. Scale 1:24,000. Accompanied by 21-page text, $4.50 per set.

MF-309. Structure contours and overburden on the top of the Mahogany zone, Green River Formation, in the northern part of the Piceance Creek basin, Rio Blanco County, Colo., by A. C. Austin. 1971 (1972). Lat 39” 45’ to about 40” 10′, long 108” to about 108” 35’. Scale 1:62.500. 75¢.

MF-346. Historic trail map of the La Junta 2” quadrangle, Colorado, compiled by G. R. Scott. 1972. Lat 37” to 38°, long 102” to 104”. Scale 1:250,000. 759.

MF-347. Preliminary geologic map of the Barcus Creek SE quadrangle, Rio Blanco County, Colo., by R. J. Hail, Jr. 1972. Lat 40” to 40” 07′30″, long 108” 15’ to 108” 22’30”. Scale 1:24,000. 2 sheets. $1.50 per set.

MF-348. Geologic map of the Arvada quadrangle, Adams, Denver, and Jefferson Counties, Colo., by R. M. Lindvall. 1972. Lat 39” 45’ to 39” 52′30″, long 105” to 105° 07’30”. Scale 1:24,000. 2 sheets. $1.50 per set.

MF-352. Reconnaissance geologic map of the Beulah NE quadrangle, Pueblo County, Colo., by G. R. Scott. 1972. Lat 38” 07’30” to 38” 15′, long 104” 45’ to 104” 52’30”. Scale 1:24,000. 75¢.

MF-353. Reconnaissance geologic map of the Hobson quadrangle, Pueblo and Fremont Counties, Colo., by G. R. Scott. 1972. Lat 38” 15’ to 38” 22′30″, long 104” 52’30” to 105”. Scale 1:24,000. 75¢.

MF-354. Reconnaissance geologic map of the Swallows quadrangle, Pueblo County, Colo., by G. R. Scott. 1972. Lat 38” 15’ to 38” 22′30″, long 104” 45’ to 104” 52’30”. Scale 1:24,000. 75¢.

MF-482. Reconnaissance geologic map of Colorado Springs and vicinity, Colorado, by G. R. Scott and R. A. Wobus. 1973. Lat 38” 37’30” to 39°, long 104” 37’30” to 105”. Scale 1:62,500. 2 sheets. $1.50 per set.

MF-513. Map showing mined areas of the Boulder-Weld coal field, Colorado, by R. B. Colton and R. L. Lowrie. 1973. Lat 39” 55’ to 40” 07′30″, long 104” 52’30” to 105° 15’. Scale 1:24,000. 75¢.

MF-547. Reconnaissance geologic map of the Owl Canyon quadrangle, Pueblo County, Colo., by G. R. Scott. 1973 (1974). Lat 38” 07’30” to 38” 15′, long 104” 52’30” to 105”. Scale 1:24,000. 75¢.

MF-548. Reconnaissance geologic map of the Wetmore quadrangle, Custer and Pueblo Counties, Colo., by R. B. Taylor and G. R. Scott. 1973 (1974). Lat 38” 07’30” to 38” 15′, long 105” to 105° 07’30”. Scale 1:24,000. 75¢.

MF-551. Reconnaissance geologic map of the Beulah quadrangle, Pueblo County, Colo., by G. R. Scott and R. B. Taylor. 1973 (1974). Lat 38" to 38" 07'30", long 104" 52'30" to 105". Scale 1:24,000. 75¢.

MF-555. Reconnaissance geologic map of the Fair-play West, Mount Sherman, South Peak, and Jones Hill 7%minute quadrangles, Park, Lake, and Chaffee Counties, Colo., by Ogden Tweto. 1974. Lat 39" to 39" 15', long 106" to 106° 15'. Scale 1:62,500. 75¢.

MF-556. Geologic map of the Mount Lincoln 15-minute quadrangle, Eagle, Lake, Park, and Summit Counties. Colo.. by Ogden Tweto. 1974. Lat 39" 15' to 39" 30', long 106" to 106" 15'. Scale 1:62,500. 75¢.

MF-562. Reconnaissance geologic map of the Rockvale quadrangle, Custer and Fremont Counties, Colo.. by G. R. Scott and R. B. Taylor. 1974. Lat 38" 15' to 38" 22'30". lone 105" 07'30" to 105" 15'. Scale 1:24,000. 75¢.

MF-570. Preliminary geologic map of the Segar Mountain quadrangle, Rio Blanco County, Colo., by R. B. O'Sullivan. 1974. Lat 39" 52'30" to 40°, long 108" to 108" 07'30". Scale 1:24,000. 75¢.

MF-597. Reconnaissance geologic map of the Conifer quadrangle, Jefferson County, Colo., by Bruce Bryant. 1974. Lat 39" 30' to 39" 37'30", long 105" 15' to 105" 22'30". Scale 1:24,000. 75'.

MF-598. Reconnaissance geologic map of the Pine quadrangle, Jefferson County, Colo., by Bruce Bryant. 1974. Lat 39" 22'30" to 39" 30', long 105" 15' to 105" 22'30". Scale 1:24,000. 75¢.

MF-619. Preliminary geologic map and section of the Barcus Creek quadrangle, Rio Blanco County, Colo., by W. J. Hall, Jr. 1974. Lat 40° to 40° 07'30", long 108" 22'30" to 108" 30'. Scale 1:24,000. 75¢.

MF-628. Reconnaissance geologic map of the Electric Peak quadrangle, Custer and Saguache Counties, Colo., by G. R. Scott and R. B. Taylor. 1974. Lat 38" to 38" 15', long 105" 30' to 105" 45'. Scale 1:62,500. 75¢. (Reprinted 1977.)

MF-631. Geologic map and engineering data for the Highlands Ranch quadrangle, Arapahoe and Douglas Counties. Colo., by J. 0. Maberry and R. M. Lindvall. 1974 (1975). Lat 39" 30' to 39° 37'30", long 104° 52'30" to 105°. Scale 1:24,000. 3 sheets. $2.25 per set.

MF-651. Preliminary geologic map of the Buckskin Point quadrangle, Rio Blanco County, Colo., by G. N. Pipiringos and R. C. Johnson. 1975. Lat 40" to 40" 07'30", long 108 to 108" 07'30". Scale 1:24,000. Structure-contour interval 100 feet. 75¢.

MF-656. Geologic map of the Lafayette quadrangle, Adams. Boulder, and Jefferson Counties, Colo., by M. N. Machette. 1975. Lat 39° 52'30" to 40°, long 105" to 105" 07'30". Scale 1:24,000. 75¢.

MF-657. Reconnaissance geologic map of the Buena Vista quadrangle, Chaffee and Park Counties, Colo., by G. R. Scott. 1975. Lat 38" 45' to 39°, long 106" to 106" 15'. Scale 1:62,500. 75¢.

MF-658. Geologic map of the Poncha Springs quadrangle, Chaffee County, Colo., by G. R. Scott, R. E. Van Alstine, and W. N. Sharp. 1975. Lat 38" 30' to 38" 45', long 106" to 106" 15'. Scale 1:62,500. 75¢.

MF-666. Preliminary geologic map of the Craig 1" by 2" quadrangle, northwestern Colorado, compiled by Ogden Tweto. 1975. Lat 40" to 41°, long 106' to 108". Scale 1:250,000. 75¢.

MF-682. Reconnaissance geologic map of the Chama Peak quadrangle, Conejos and Archuleta Counties, Colo., by P. W. Lipman and W. J. Hail, Jr. 1975. Lat 37" to 37" 15', long 106" 45'. Scale 1:48,000. 75¢.

MF-688. Preliminary geologic map, oil shale yield histograms and stratigraphic sections, Long Point quadrangle, Garfield County, Colo., by R. C. Johnson. 1975. Lat 39 22'30" to 39" 30", long 108" 15' to 108" 22'30". Scale 1:24,000. 2 sheets. $1.50.

MF-689. Reconnaissance map showing relative amounts of soil and bedrock in the mountainous part of the Ralston Buttes quadrangle and adjoining areas to the east and west in Jefferson County, Colo., by K. L. Pierce and P. W. Schmidt. 1975. Lat 39 45' to 39" 52'30", long about 105" 14' to 105" 24'. Scale 1:24,000. 75¢.

MF-691. Preliminary geologic map of the Cutoff Gulch quadrangle, Rio Blanco and Garfield Counties, Colo., by W. J. Hail, Jr. 1975. Lat 39" 37'30" to 39" 45', long 108" 07'30" to 108° 15'. Scale 1:24,000. 2 sheets. $1.50.

MISCELLANEOUS FIELD STUDIES MAPS-Continued

MF-695. Reconnaissance map showing relative amounts of soil and bedrock in the mountainous part of the Eldorado Springs quadrangle, Boulder and Jefferson Counties, Colo., by K. L. Pierce and P. W. Schmidt. 1975. Lat 39” 52’30” to 40°, long 105” 15’ to about 105” 22’30”. Scale 1:24,000. 75¢.

MF-696. Preliminary map of landslide deposits, Vernal 1” by 2” quadrangle, Colorado and Utah, by P. E. Carrara, R. B. Colton, J. A. Holligan, and L. W. Anderson. 1975. Lat 40” to 41°, long 108” to 110”. Scale 1:250,000. 75¢.

MF-697. Preliminary map of landslide deposits, Grand Junction 1” by 2” quadrangle, Colorado and Utah, by R. B. Colton, J. A. Holligan, L. W. Anderson, and K. C. Shaver. 1975. Lat 37” to 38°, long 108” to 110”. Scale 1:250,000. 75¢.

MF-698. Preliminary map of landslide deposits, Moab 1” by 2” quadrangle, Colorado and Utah, by R. B. Colton, J. A. Holligan, L. W. Anderson, and K. C. Shaver. 1975. Lat 38” to 39°, long 108” to 110”. Scale 1:250,000. 75¢.

MF-699. Preliminary map of landslide deposits, Cortez 1” by 2” quadrangle, Colorado and Utah, by R. B. Colton L. W. Anderson, J. A. Holligan, P. E. Patterson, and K. C. Shaver. 1975. Lat 37” to 38°, long 108” to 110”. Scale 1:250,000. 75¢.

MF-700. Preliminary map of landslide deposits, Craig 1” by 2” quadrangle, Colorado, by R. B. Colton, J. A. Holligan, P. E. Patterson, and L. W. Anderson. 1975. Lat 40” to 41”. long 106° to 108”. Scale 1:250,000. 75¢.

MF-701. Preliminary map of landslide deposits, Leadville 1” by 2” quadrangle, Colorado, by R. B. Colton, J. A. Holligan, L. W. Anderson, and P. E. Patterson. 1975. Lat 39” to 40°, long 106” to 108°. Scale 1:250,000. 75¢.

MF-702. Preliminary map of landslide deposits, Montrose 1” by 2” quadrangle, Colorado, by R. B. Colton, P. E. Patterson, J. A. Holligan, and L. W. Anderson. 1975. Lat 38” to 39°, long 106” to 108”. Scale 1:250,000. 75¢.

MF-703. Preliminary map of landslide deposits, Durango 1° by 2” quadrangle, Colorado, by R. B. Colton, J. A. Holligan, and L. W. Anderson. 1975. Lat 37” to 38°, long 106” to 108”. Scale 1:250,000. 759.

MF-704. Preliminary map of landslide deposits, Greeley 1° by 2” quadrangle, Colorado, by R. B. Colton, J. A. Holligan, and L. W. Anderson. 1975. Lat 40” to 41°, long 104” to 106”. Scale 1:250,000. 75¢.

MF-705. Preliminary map of the landslide deposits, Denver 1” by 2” quadrangle, Colorado, by R. B. Colton, J. A. Holligan, and L. W. Anderson. 1975. Lat 39” to 40” long 104 to 106”. Scale 1:250,000. 75¢.

MF-706. Preliminary map of landslide deposits, Pueblo 1° by 2” quadrangle, Colorado, by R. B. Colton, G. R. Scott, J. A. Holligan, and L. W. Anderson. 1975. Lat 38” to 39°, long 104” to 106”. Scale 1:250,000. 75¢.

MF-707. Preliminary map of landslide deposits, Trinidad 1” by 2” quadrangle, Colorado, by R. B. Colton, J. A. Holligan, and L. W. Anderson. 1975. Lat 37” to 38°, long 104” to 106”. Scale 1:250,000. 75¢.

MF-708. Preliminary map of landslide deposits, La Junta 1” by 2” quadrangle, Colorado and Kansas, by R. B. Colton, L. W. Anderson, and J. A. Holligan. 1975. Lat 37” to 38°, long 102” to 104”. Scale 1:250,000. 75¢.

MF-713. Geologic map of the Spring Hill Creek quadrangle, Saguache County, Colo., by J. C. Olson, T. A. Steven, and D. C. Hedlund. 1975. Lat 38” 15’ to 38” 22′30″, long 106 52′30″ to 107”. Scale 1:24,000. 75¢.

MF-733. Geologic map of the Sawtooth Mountain quadrangle, Saguache County, Colo., by J. C. Olson and T. A. Steven. 1976. Lat 38” 15’ to 38” 22′30″, long 106” 45’ to 106” 52’30”. Scale 1:24,000. 75¢.

MF-736. Preliminary geologic map and correlation diagram of the White River City quadrangle, Rio Blanco County, Colo., by G. N. Pipiringos and R. C. Johnson. 1976. Lat 40” to 40° 07′30″, long 108” 07’36” to 108” 15’. Scale 124,000. $1.25.

MF-740. Reconnissance map showing relative amounts of soil and bedrock in the mountainous part of the Morrison-Evergreen quadrangles and adjoining areas to the west in Jefferson County, Colorado, by P. W. Schmidt. 1976. Lat 39” 37’30” to 39” 45′, long 105° 10′ to about 105” 22’30”. 75¢.

MF-741. Reconnaissance map showing relative amounts of soil and bedrock in the mountainous part of the Indian Hills auadranele. in Jefferson County. Colorado. by P. W. Schmidt. 1976. Lat 39" 30' to 39° 37'30", long 105° 07'30" to 105° 15'. Scale 1:24,000. $1.25.

MF-746. Structure contours and overburden on the top of the Mahogany zone, Green River Formation, in the southern part of Piceance Creek basin, Rio Blanco and Garfield Counties, Colo., by M. C. Mullens. 1976. Lat about 39" 20' to 39" 45', long about 108" to about 108" 40'. Scale 1:63,360. 75¢.

MF-748. Geologic map of the Razor Creek Dome quadrangle, Saguache County, Colo., by J. C. Olson and T. A. Steven. 1976. Lat 38" 15' to 38" 22'30", long 106" 37'30" to 106" 45'. Scale 1:24,000. 75¢.

MF-753. Preliminary geologic map of Wolf Ridge quadrangle, Rio Blanco County, Colo., by D. C. Duncan. 1976. Lat 39" 52'30" to 40°, long 108" 22'30" to 108" 30'. Scale 1:24,000. 75'.

MF-754. Preliminary geologic map of Square S Ranch quadrangle, Rio Blanco County, Colo., by D. C. Duncan. 1976. Lat 39" 52'30" to 40°, long 108" 15' to 108" 22'30". Scale 1:24,000. 75¢.

MF-755. Preliminary geologic map of Greasewood Gulch quadrangle, Rio Blanco County, Colo., by D. C. Duncan. 1976. Lat 39" 52'30" to 40°, long 108" 07'30" to 108" 15'. Scale 1:24,000. 75¢.

MF-756. Preliminary geologic map of Jessup Gulch quadrangle, Rio Blanco County, Colo., by D. C. Duncan. 1976. Lat 39" 45' to 39" 52'30", long 108" 07'30" to 108" 15'. Scale 1:24,000. 75¢.

MF-757. Preliminary geologic map of Rock School quadrangle, Rio Blanco County, Colo., by D. C. Duncan. Lat 39" 45' to 39" 52'30", long 108" 15' to 108" 22'30". Scale 1:24,000. 75¢.

MF-758. Preliminary geologic map of Yankee Gulch quadrangle, Rio Blanco County, Colo., by D. C. Duncan. 1976. Lat 39" 45' to 39" 52'30", long 108" 22'30" to 108" 30'. Scale 1:24,000. 75'.

MF-759. Reconnaissance geologic map of the Glentivar quadrangle, Park County, Colo., by R. A. Wobus. 1976. Lat 39" to 39" 07'30". lone 105" 30' to 105" 37'30". Scale 1:24,000. 75¢.

MF-760. Preliminary geologic map of the Leadville 1" x 2" quadrangle, northwestern Colorado, by Ogden Tweto, R. H. Moench, and J. C. Reed, Jr. 1976. Lat 39" to 40°, long 106" to 108". Scale 1:250,000. 75¢.

MF-761. Preliminary geologic map of the Montrose 1" x 20" quadrangle, southwestern Colorado, by Ogden Tweto, T. A. Steven, W. J. Hail, Jr., and R. H. Moench. 1976. Lat 38" to 39". lone 106" to 108". Scale 1:250,000. 75¢. (Reprinted 1977.)

MF-770. Reconnaissance map showing relative amounts of soil and bedrock in the Conifer quadrangle and adjoining areas to the west in Jefferson County, Colorado, by P. W. Schmidt, 1976. Lat 39" 30' to 39" 37'30", long 105" 15' to 105" 22'30". Scale 1:24,000. 75'

MF-771. Preliminary landslide overview map of the conterminous United States, by D. H. Radbruch-Hall, R. B. Colton, W. E. Davis, B. A. Skipp, Ivo Lucchitta, and D. J. Vamers. 1976. Lat 25" to 50°, long 65" to 125" Scale 1:7,500,000. 75¢.

MF-775. Geologic map of the Pueblo 1" by 2" quadrangle, south-central Colorado, by G. R. Scott, R. B. Taylor, R. C. Epis, and R. A. Wobus. 1976. Two sheets. Lat 38" to 39°, long 104" to 106". Scale 1:187,500 (1 inch = about 2.9 miles). Sheet 1, 30 by 40 inches; sheet 2, 30 by 36 inches $1.50. (Reprinted 1977.1

MF-778. Reconnaissance geologic map of the Picacho Mountains, Arizona, by Warren Yeend. 1976. Lat about 32" 40' to 33°, long 111" 15' to 11" 30'. Scale 1:62,500 (1 inch = about 1 mile). Sheet 25 by 31 inches. 75¢.

MF-786. Preliminary overview map of volcanic hazards in the 48 conterminous United States, by D. R. Mullineaux. 1976 (19771. Lat about 25" to about 50°, long about 65' to about 125". Scale 1:7,500,000 (1 inch = about 118 miles). Sheet 29 by 36 inches. 75¢. (Reprinted 1977.)

MF-788. Preliminary geologic map of Colorado, compiled by Ogden Tweto. 1976 (1977). Two sheets. Lat 37" to 41°, long 102" to 109". Scale 1:500,000 (1 inch = about 8 miles). Sheet 1, 42 by 52 inches; sheet 2, 42 by 34 inches. $1.50 per set.

MISCELLANEOUS FIELD STUDIES MAPS-Continued

MF-797. Isopach map and cross section of the Mahogany zone of the Green River Formation derived principally from geophysical well logs, eastern Uinta Basin, Utah and Colorado, by W. B. Cashion and G. H. Dixon. 1976. Lat about 39” 52’ 30” to about 40” 30′, long 108” to 110”. Scale 1:250,000 (1 inch = 4 miles). Sheet 26% by 31 inches. 75”.

MF-803. Reconnaissance map showing relative amounts of soil and bedrock in the Platte Canyon quadrangle, Jefferson County, Colorado, by P. W. Schmidt. 1976 (1977). Lat 39” 22’30” to 39” 30′, long 105” 07’30” to 105” 15’. Scale 1:24,000 (1 inch = 2,000 feet). Sheet 32 by 40 inches. 75¢.

MF-804. Reconnaissance map showing relative amounts of soil and bedrock in the Pine quadrangle and adjoining areas to the west in Jefferson County, COLORADO, by P. W. Schmidt. 1976 (1977). Lat 39” 22’30”. Scale 1:24,000 (1 inch = 2,000 feet). Sheet 29 by inches. 75¢.

MF-805. Reconnaissance geologic map of the Cripple Creek-Pikes Peak area, Teller, Fremont, and El Paso Counties, Colorado, by R. A. Wobus, R. C. Epis, and G. R. Scott. 1976. Lat 38” 37’30” to 38” 52′30″, long 105” to 105” 15’. Scale 1:48,000 (1 inch = 4,000 feet). Sheet 27 by 40 inches. 75¢. (Reprinted 1977.)

MF-810. Geologic map and details of the beryllium and molybdenum occurrences, Mount Antero, Chaffee County, Colorado, by W. N. Sharp. 1976 (1977). Lat about 38” 35’ to 42” 30′, long about 106” 10’ to 106” 17’30”. Scale 1:24,000 (1 inch = 2,000 feet). Two sheets: sheet 1, 32 by 42 inches; sheet 2, 24 by 44 inches. $1.50 per set.

MF-812. Seismicity map of the conterminous United States and adjacent areas, 1965-1974, by C. W. Stover. 1977. Lat about 25” to about 50°, long about 65” to about 125”. Scale 1:5,000,000 (1 inch = about 80 miles). Sheet 30 by 46 inches. 75¢.

MF-816. Reconnaissance geologic map of the Bailey quadrangle, Jefferson and Park Counties, Colorado, by Bruce Bryant. 1976 (1977). Lat 39” 22’30” to 39” 30′, long 105” 22’30” to 105” 30’. Scale 1:24,000 (1 inch = 2,000 feet). Sheet 29 by 36 inches. 75¢.

MF-819. Map showing potential snow avalanche areas in the Telluride quadrangle, San Miguel, Ouray, and San Juan Counties, Colorado, by R. G. Luedke. 1976. Lat 37” 52’30” to 38°, long 107” 45’ to 107” 52’30”. Scale 1:24,000 (1 inch = 2,000 feet). Sheet 29 by 30 inches. 75¢.

MF-824. Geologic map of the Weaver Ridge quadrangle, Uintah County, UTAH, and Rio Blanco County, COLORADO, by W. B. Cashion. 1977. Lat 39” 52’30” to 40°, long 109” to 109” 07’30”. Scale 1:24,000 (1 inch = 2,000 feet). Sheet 26 by 33 inches. 75¢.

MF-829. Preliminary geologic map and cross section of the Saddle quadrangle, Garfield County, COLORADO, by R. C. Johnson. 1977. Lat 39” 22’ 30” to 39” 30′, long 108” 22’30” to 108” 30’. Scale 1:24,000 (1 inch = 2,000 feet). Sheet 42 by 46 inches. 75¢.

MF-830. Preliminary geologic map of the Bull Fork quadrangle, Garfield and Rio Blanco Counties, COLORADO, by W. J. Hail, Jr. 1977. Lat 39” 37’30” to 39” 45′, long 108 15’ to 108” 22’30”. Scale 1:24,000 (1 inch = 2,000 feet). Sheet 30 by 44 inches. 75’.

MF-831. Preliminary geologic map of the Fort Logan quadrangle, Jefferson, Denver, and Arapahoe Counties, COLORADO, by R. M. Lindvall. 1976 (1977). Lat 39” 37’30” to 39” 45′, long 105” to 105” 07’30”. Scale 1:24,000 (1 inch = 2,000 feet). Sheet 31 by 44 inches. 75¢.

MF-836. Preliminary geologic map of the Indian Valley quadrangle, Rio Blanco and Moffat Counties, COLORADO, by G. N. Pipiringos and G. C. Rosenlund. 1977. Lat 40 07’30” to 40” 15′, long 108” 07’30” to 108” 15’. Scale 1:24,000 (1 inch = 2,000 feet). Sheet 29 by 36 inches. 75¢.

MF-837. Preliminary geologic map of the White Rock quadrangle, Rio Blanco and Moffat Counties, Colorado, by G. N. Pipiringos and G. C. Rosenlund. 1977. Lat 40° 07’30” to 40° 15′, long 108” to 108” 07′30″. Scale 1:24,000 (1 inch = 2,000 feet). Sheet 34 by 42 inches. 75¢.

MF-842. Reconnaissance geologic map of the Woodland Park quadrangle, Teller County, Colorado, by R. A. Wobus and G. R. Scott. 1977. Lat 38” 52’ 30″ to 39°, long 105” to 105” 07’30”. Scale 1:24,000 (1 inch = 2,000 feet). Sheet 29 by 31 inches. 75¢.

MF-861. Map and list of reported occurrences of platinum-group metals in the conterminous United States, by W. N. Blair, N. J Page and M. G. Johnson. 1977. 2 sheets. Scale 1:5,000,000 (1 inch = about 80 miles). Sheet 1, 35 by 41 inches; sheet 2, 29% by 31 inches. $1.50 per set.

MF-871. Photo interpretive map showing areas underlain by landslide deposits and areas susceptible to landsliding in the Louisville quadrangle, Boulder and Jefferson Counties, Colorado, by R. B. Colton and J. A. Holligan. 1977. Lat 39" 52'30" to 40°, long 105" 07'30" to 105" 15'. Scale 1:24,000 (1 inch = 2,000 feet). Sheet 29 by 30 inches. 75¢

MF-882: Preliminary geologic map of the Erie quadrangle, Boulder, Weld, and Adams Counties. Colorado, by R. B. Colton and L. W. Anderson. 1957. Lat 40" to 40" 07'30", long 105" to 105" 07'30". Scale 1:24,000 (1 inch = 2,000 feet). Sheet 28 by 35 inches. 75¢.

MF-892. Reconnaissance geologic map of the Canon City quadrangle, Fremont County, Colorado, by G. R. Scott, 1977. Lat 38" 22'30" to 38" long 105" 07'30" to 105" 15'. Scale 1:24,000 (1 inch = 2,000 feet). Sheet 30 by 37 inches. 75¢.

MINERAL INVESTIGATIONS RESOURCE MAPS

The following maps cover the resources indicated for the United States exclusive of Alaska and Hawaii. All are printed at a scale of 1:3,168,000 and are sold at $1.25 each, unless otherwise indicated.

MR-2. Uranium deposits, compiled by R. W. Schnable. 1955. Scale 1:5,000,000. $1.75.
MR-3. Potash occurrences, by M. F. Byrd. 1955. Scale 1:5,000,000. $1.75.
MR-13. Copper, by A. R. Kinkle, Jr., and N. P. Peterson. 1962.
MR-14. Borates, by W. C. Smith. 1962.
MR-15. Lead, by E. T. McKnight, W. L. Newman, and A. V. Heyl, Jr. 1962.
MR-16. Vanadium, by R. P. Fischer. 1962.
MR-17. Asbestos, by A. H. Chidester and A. F. Shride. 1962.
MR-18. Pyrophyllite, and kyanite and related minerals, by G. H. Espenshade. 1962.
MR-19. Zinc, by E. T. McKnight, W. L. Newman, and A. V. Heyl, Jr. 1962.
MR-20. Antimony, by D. E. White. 1962.
MR-21. Epigenetic uranium deposits, by A. P. Butler, Jr., W. I. Finch, and W. S. Twenhofel. 1962.
MR-22. Bismuth, by J. R. Cooper. 1962.
MR-23. Manganese, by M. D. Crittenden and Louis Pavlides. 1962.
*MR-24. Gold, by A. H. Koschmann and M. H. Bergendahl. 1962.
MR-25. Tungsten, by D. M. Lenunon and 0. L. Tweto. 1962.
MR-26. Chromite, by T. P. Thayer and M. H. Miller. 1962.
MR-27. Magnesite and brusite, by Benjamin Gildersleeve. 1962.
MR-28. Thorium and rare earths, by J. C. Olson and J. W. Adams. 1962.
MR-29. Titanium, by C. L. Rogers and M. C. Jaster. 1962.
MR-30. Mercury, by E. H. Bailey. 1962.
MR-31. Talc and soapstone, by A. H. Chidester and H. W. Worthington. 1962.
MR-33. Gypsum and anbydrite, by C. F. Withington. 1962.
*MR-34. Silver, by E. T. McKnight, W. L. Newman, Harry Klemic, and A. V. Heyl, Jr. 1962.
MR-35. Beryllium, by W. R. Griffitts, D. M. Larrabee, and J. J. Norton. 1962.
MR-36. Niobium and tantalum, by R. L. Parker, 1963.
MR-37. High-alumina kaolinitic clay, by Helen Mark. 1963.
MR-43. Barite, by D. A. Brobst. 1965.
MR-44. Tin, by P. L. Killeen and W. L. Newman. 1965.
MR-51. Iron, by M. S. Carr, P. W. Guild, and W. B. Wright. 1967. Accompanied by 20-page text.
MR-55. Molybdenum, by R. U. King. 1970. Accompanied by 21-page text.
MR-57. Reported occurrences of selected minerals in Colorado. 1971. Scale 1:500,000.
MR-58. Map showing localities and amounts of metallic mineral production in Colorado, by W. R. Marsh and R. W. Queen. 1974. Lat 37" to 41°, long 102" to 109". Scale 1:500,000.
MR-60. Fluorite, compiled by R. G. Worl, R. E. Van Alstine, and A. V. Heyl, 1974. Accompanied by 13-page text.
MR-70. Map showing fluorspar deposits in Colorado, compiled by B. T. Brady. 1975 (1976). Lat 37" to 41°, long 102" to 109". Scale 1500,000. Accompanied by 20-page text.

MINERAL INVESTIGATIONS (STRATEGIC) MAPS

*3-173. Geologic map of the Gateway area, Mesa County, Colo., and adjoining part of Grand County, Utah, by W. L. Stokes, R. T. Russell, R. P. Fischer, and A. P. Butler, Jr. 1945. Scale 1:63,360.

*3-212. Iron-ore deposits of the Western United States, by C. E. Dutton and M. S. Carr 1947 Scale 1:5,000,000. (See Bulletin 1082-C and Map MR-51.)

*3-226. Vanadium region of southwestern Colorado and southeastern Utah, by R. P. Fischer. 1947. Scale 1:187,500.(See Bulletin 936-P.)

MISCELLANEOUS INVESTIGATIONS SERIES

I-90. Photogeologic map of the Aneth-1 quadrangle, San Juan County, Utah, and Montezuma County, Colo., by R. J. Hackman. 1965. Lat 37" 22'30" to 37" 30', long 109° to 109" 07'30". Scale 1:24,000. $1.25.

I-97. Photogeologic map of the Aneth-8 quadrangle, San Juan County, Utah, and Montezuma Countv. Colo.. bv R. J. Hackman. 1955. Lat 37" 15' to 37" 22'30", long 109° to 109" 07'30". Scale 1~24,000. $1.25.

I-157. Photogeologic map of the Mount Peale-S quadrangle, San Juan County, Utah, and Montrose and San Miguel Counties, Colo., by R. J. Hackman. 1956. Lat 38" 07'30" to 38" 15', long 109° to 109" 07'30". Scale 1:24,000. $1.25.

I-165. Photogeologic map of the Mount Peale-l quadrangle, San Juan County, Utah, and Montrose County, Colo., by R. J. Hackman. 1956. Lat 38" 22'30" to 38" 30', long 109" to 109" 07'30". Scale 1:24,000. $1.25.

I-174. Photogeologic map of the Mount Peale-8 quadrangle, San Juan County, Utah, and Montrose County, Colo., by R. J. Hackman. 1956. Lat 38" 15' to 38" 22'30", long 109" to 109" 07'30". Scale 1:24,000. $1.25.

I-175. Paleotectonic maps of the Jurassic System, by E. D. McKee, S.S. Oriel, V. E. Swanson, J. E. MacLachlan, J. C. MacLachlan, K. B. Ketner, J. W. Goldsmith, R. Y. Bell, and D. J. Jameson, with a separate section on Paleogeography, by R. W. Imlay. 1956. Scales 1:2,500,000 and 1:5,000,000. $15.

I-176. Photogeologic map of the Mount Peale-16 quadrangle, San Juan County, Utah, and San Miguel County, Colo., by R. J. Hackman. 1956. Lat 38" to 38" 07'30", long 109 to 109" 07'30". Scale 1:24,000. $1.25.

I-274. Photogeologic map of the Escalante Forks quadrangle, Mesa, Montrose, and Delta Counties, Colo., by R. J. Hackman. 1958. Lat 38" 30' to 38" 45', long 108" 15' to 108" 30'. Scale 1:62,500. $1.25.

I-277. Photogeologic map of the Iris SE and Doyleville SW quadrangles, Saguache County, Colo., by Kathleen McQueen. 1958. Lat 38" 15' to 38" 22'30", long 106" 37'30" to 106" 52'30". Scale 1:31,680. $1.25.

I-278. Photogeologic map of the Coach Creek SE quadrangle, Grand County, Utah, and Mesa County, Colo., by R. J. Hackman. 1959. Lat 38" 45' to 38" 52'30", long 109" to 109" 07'30". Scale 1:24,000. $1.25.

I-279. Photogeologic map of the Coach Creek NE quadrangle, Grand County, Utah, and Mesa County, Colo., by R. J. Hackman. 1959. Lat 38" 52'30" to 39°, long 109" to 109" 07'30". Scale 1:24,000. $1.25.

I-281. Photogeologic map of the Yellow Jacket quadrangle, Montezuma and Dolores Counties, Colo., by R. J. Hackman. 1959. Lat 37" 30' to 37" 45', long 108" 30' to 108" 45'. Scale 1:62,500. $1.25.

I-282. Photogeologic map of the Delta quadrangle, Montrose and Delta Counties, Colo., by C. H. Marshall. 1959. Lat 38" 30' to 38" 45', long 108° to 108" 15'. Scale 1:62,500. $1.25.

I-283. Photogeologic map of the Norwood-l quadrangle, Montrose and Ouray Counties, Colo., by C. H. Marshall. 1959. Lat 38" 15' to 38" 30', long 108" to 108° 15'. Scale 1:62,500. $1.25.

I-299. Epigenetic uranium deposits in the United States, by W. I. Finch, I. S. Parrish, and G. W. Walker. 1959. Scale 1:5,000,000. 3 sheets. $4.25 per set.

I-300. Paleotectonic maps of the Triassic System, by E. D. McKee, S. S. Oriel, K. B. Ketner, M. E. MacLachlan, J. W. Goldsmith, J. C. MacLachlan, and M. R. Mudge. 1959. Scale 1:5,000,000. $15.

I-309. Geologic map of the igneous and metamorphic rocks of Colorado showing location of uranium deposits, compiled by E. A. Merewether. 1960. Lat 37" to 41°, long 102" to 109". Scale 1:500,000. $1.50.

I-322. Geologic map of the Willow Creek Butte quadrangle, Utah-Colorado, by W. R. Hansen. 1961. Lat 40° 52'30" to 41°, long 109° to 109° 07'30". Scale 1:24,000. $1.50.

I-332. Geologic map of a part of southwestern Wyoming and adjacent States, by W. H. Bradley. 1961. Scale 1:250,000. $1.25.

I-333. Preliminary geologic map of the Indian Hills quadrangle, Jefferson County, Colo., by G. R. Scott. 1961. Lat 39" 30' to 39° 37'30". long 105' 07'30" to 105°15'. Scale 1:24,000. $1.25.

I-360. Geology, structure. and uranium deposits of the Moab quadrangle, Colorado and Utah, compiled by P. L. Williams, 1964. Lat 38" to 39°, long 108" to 110°. Scale 1:250,000. 2 sheets. $3.25 per set. (Reprinted 1977.)

I-383. Preliminary geologic map of the Eldorado Springs quadrangle, Boulder and Jefferson Counties, Colo., by J. D. Wells. 1963. Lat 39" 52'30" to 40°, long 105" 15' to 105" 22'30". Scale 1:24,000. $1.25.

I-387. Fluoride content of ground water in the conterminous United States, by Michael Fleischer. 1962. Scale 1:5,000,000. $1.25.

I-404. Geologic map of the Grand Junction area, Colorado, by S. W. Lohman. 1975, Lat about 38" 48' to about 39" 12', long 108" 25' to 108" 47'. Scale 1:31,680. $1.75.

I-408. Geology of the Northwest and Northeast Pueblo quadrangles, Colorado, by G. R. Scott. 1964. Lat 38" 15' to 38" 22'30", long 104" 30' to 104" 45'. Scale 1:24,000. $1.25.

I-428. Geology of the sedimentary rocks of the Morrison quadrangle, Colorado, by J. H. Smith. 1964. Lat 39" 37'30" to 39" 45'. long 105" 07'30" to 105" 15'. Scale 1:24,000. Accompanied by 3-page text. $1.25.

I-439. Geologic and biostratigraphic map of the Pierre Shale between Jarre Creek and Loveland, Colo., by G. R. Scott and W. A. Cobban. 1965. Lat 39" 52'30" to 40" 22'30", long 104" 50' to 105' 17'30". Scale 1:48,000. Accompanied by I-page text. $1.75.

I-443. Preliminary geologic map of the Berthoud Pass quadrangle, Clear Creek and Grand Counties, Colo., by P. K. Theobald. 1965. Lat 30" 45' to 39° 52'30", long 105" 45' to 105" 52'30". Scale 1:24,000. $1.25.

I-448. Geologic and crustal cross section of the United States along the 37th parallel-A contribution to the upper mantle project, by Warren Hamilton and L. C. Pakiser. 1965. Scale 1:2,500,000. $1.50.

I-450 Paleotectonic maps of the Permian System, by E. D. McKee, S. S. Oriel, and others. 1967. $38.

I-496 Distribution of selected accessory minerals in the Caribou stock, Boulder County, Colo., by G. J. Neuerburg. 1967. Vicinity of lat 40°, long 105" 35'. Scale 1:12,000. $1.25.

I-558 Geologic map of the Trinidad quadrangle, south-central Colorado, by R. B. Johnson. 1969. Lat 37" to 38°, long 104" to 106". Scale 1:250,000. $1.50.

I-560 Geologic and structure contour map of the La Junta quadrangle, Colorado and Kansas, by G. R. Scott. 1968 (1969) Lat 37" to 38°, long 102" to 104". Scale 1:250,000. $1.75.

I-563 Geologic map and sections of the southwest quarter of the Dillon quadrangle, Eagle and Summit Counties, Colo., by M. H. Bergendahl. 1969. Lat 39" 30' to 39" 37'30", long 106" 07'30" to 106° 15'. Scale 1:24,000. $1.50.

I-584 Geologic Map of the Black Canyon of the Gunnison River and vicinity, western Colorado, by W. R. Hansen. 1971. Sheet 1, lat 38" 30' to 38" 37'30". long 107" 30' to 107" 52'30"; sheet 2, lat 38" 22'30" to 38" 30', long 107" 15' to 107" 37'30". Scale 1:31,680. 2 sheets. $3.50 per set.

I-597. Geologic map of the Southwest and Southeast Pueblo quadrangles, Colorado, by G. R. Scott. 1969 (1970). Lat 38" 07'30" to 38" 15'. long 104" 30' to 104" 45'. Scale 1:24,000. $1.75.

I-608. Maps showing distribution of selected accessory minerals in the Montezuma stock, Summit County, Colo., by G. J. Neuerburg. 1971. Lat about 39" 35' to 39" 37'30", long about 105" 50' to 105° 55'. Scale 1:31,680. $1.25.

I-629. Geology, structure, and uranium deposits of the Cortez quadrangle, Colorado and Utah, compiled by D. D. Haynes, J. D. Vogel, and D. G. Wyant. 1972. Lat 37" to 38°, long 108" to 110". Scale 1:250,000. 2 sheets. $3.25 per set. (Reprinted 1977.)

I-634. Maps showing soil analyses of interest for prospecting the Montezuma stock, Summit County, Colo., by G. J. Neuerburg. 1971. Lat about 39" 35' to 39" 37'30", long about 105" 50' to 105" 55'. Scale 1:31,680. $1.25.

I-687. Geologic map of the lower Cache La Poudre River basin, north-central Colorado, by L. A. Hershey and P. A. Schneider, Jr. 1972. Lat 40° 25' to 40° 50', long 104" 30' to 105" 10'. Scale 1:62,500. $1.50.

I-688. Generalized Tectonic map of North America, by P. B. King and G. J. Edmonston. 1972. Scale 1:15,000,000. $1.75.

I-697. Reconnaissance geologic map of the Cedaredge area, Delta County, Colo., by W. J. Hail, Jr. 1972. Lat 38" 45' to 39°, long 107" 45' to 108°. Scale 1:48,000. $1.75.

I-698. Reconnaissance geologic map of the Hotchkiss area, Delta and Montrose Counties, Colo., by W. J. Hail. Jr. 1972. Lat 38" 37'30" to 39°, long 107" 30' to 107" 45'. Scale 1:48,000. $1.75.

I-731. Generalized surficial geologic map of the Denver area, Colorado, by G. H. Chase and J. A. McConaghy. 1972 (1973). Lat 39" 22'30" to 40°, long 104" 37'30" to 105" 20'. Scale 1:62,500. $1.50.

I-736. Geologic and structure map of the Grand Junction quadrangle, Colorado and Utah, compiled by W. B. Cashion. 1973. Lat 39" to 40°, long 108" to 110°. Scale 1:250,000. $1.75.

I-750. Map showing geologic and structural control of ore deposits, Montezuma district, central Colorado, by G. J. Neuerburg and Theodore Botinelly. 1972 (1973). Lat 39" 30' to 39" 37'30", long 105" 47'30" to 105" 55'. Scale 1:31,680. $1.25.

I-761-A. Surticial and bedrock geologic map of the Golden quadrangle, Jefferson County, Colo., by Richard Van Horn. 1972. Lat 39" 45' to 39" 52'30". long 105" 07'30" to 105" 15'. Scale 1:24,000. $1.75. (Reprinted 1977.)

I-761-B. Map showing landslides in the Golden quadrangle, Jefferson County, Colo., by H. E. Simpson. 1973. Lat 39" 45' to 39" 52'30". long 105" 07'30" to 105" 15'. Scale 1:24,000. $1.50.

I-761-C. Map showing areas of potential rockfalls in the Golden quadrangle, Jefferson County, Colo., by H. E. Simpson. 1973. Lat 39" 45' to 39" 52'30". long 105" 07'30" to 105" 15'. Scale 1:24,000. $1.50.

I-761-D. Map showing earth materials that may compact and cause settlement in the Golden quadrangle, Jefferson County, Colo., by H. E. Simpson. 1973 (1974). Lat 39" 45' to 39" 45' to 39" 52'30", long 105" 07'30" to 105" 15'. Scale 1:24,000. $1.50.

I-761-E. Map showing man-modified land and man-made deposits in the Golden quadrangle, Jefferson County, Colo., by H. E. Simpson. 1973. Lat 39" 45' to 39" 52'30", long 105" 07'30" to 105" 15'. Scale 1:24,000. $1.25.

I-764. Geologic map of the Durango quadrangle, southwestern Colorado, compiled by T. A. Steven, P. W. Lipman, W. J. Hail, Jr., Fred Barker, and R. G. Luedke. 1974. Lat 37" to 38°, long 106" to 108". Scale 1:250,000. $1.75.

I-770-A. Geologic map of the Parker quadrangle, Arapahoe and Douglas Counties, Colo., by J. 0. Maberry and R. M. Lindvall. 1972. Lat 39" 30' to 39" 37'30", long 104" 45' to 104" 52'30". Scale 1:24,000. $1.75.

I-770-B. Map showing areas of past flooding in the Parker quadrangle, Arapahoe and Douglas Counties, Colo., by J. 0. Maberry. 1972. Lat 39" 30' to 39" 37'30", long 104" 45' to 104°52'30". Scale 1:24,000. $1.25.

1-770-C. Map showing transportation routes in the Parker quadrangle, Arapahoe and Douglas Counties, Colo.. bv J. 0. Maberrv. 1972. Lat 39" 30' to 39" 37'30", long 104 45' to 104" 52'30". Scale 1:24,000. $1.50."

I-770-D. Map showing relative swelling-pressure potential of geologic materials in the Parker quadrangle, Arapahoe and Douglas Counties, Colo., by J. 0. Maberry. 1972. Lat 39" 30' to 39" 37'30", long 104" 45' to 104" 52'30". Scale 1:24,000. $1.50.

I-770-E. Map showing landslide-deposits and areas of potential landsliding in the Parker quadrangle, Arapahoe and Douglas Counties, Colo., by J. 0. Maberry. 1972. Lat 39" 30' to 39" 37'30", long 104" 45' to 104" 52'30". Scale 1:24,000. $1.50.

I-770-F. Slope map of the Parker quadrangle, Arapahoe and Douglas Counties, Colo., by J. 0. Maberry. 1972. Lat 39" 30' to 39" 37'30". lone 104" 45' to 104" 52'30". Scale 1:24,000. $1.50.

I-770-G. Map showing relative erodibility of geologic materials in the Parker quadrangle, Arapahoe and Douglas Counties. Colo., by J. 0. Maberry. 1972. Lat 39" 30' to 39" 37'30", long 104" 45' to 104" 52'30". Scale 1:24,000. $1.50.

I-770-H. Map showing relative excavatability of geologic materials in the Parker quadrangle, Arapahoe and Douglas Counties, Colo., by J. 0. Maberry. 1972. Lat 39" 30' to 39" 37'30". long 104" 45' to 104" 52'30". Scale 1:24,000. $1.50.

1-770-I. Map showing inferred relative permeability of geologic materials in the Parker quadrangle, Arapahoe and Douglas Counties, Colo., by J. 0. Maberry. 1972. Lat 39” 30’ to 39” 37′30″, long 104” 45’ to 104” 52′30″, Scale 1:24,000. $1.50.

I-770-J. Map of deposits especially susceptible to compaction or subsidence, Parker quadrangle, Arapahoe and Douglas Counties, Colo., by J. 0. Maberry. 1972. Lat 39° 30’ to 39” 37′30″, long 104” 45’ to 104” 52’30”. Scale 1:24,000. $1.50.

I-770-K. Map showing approximate ground-water conditions in the Parker quadrangle, Arapahoe and Douglas Counties, Colo., by J. O. Maberry and E. R. Hampton. 1972. Lat 39” 30’ to 39” 37′30″, long 104° 45’ to 104” 52’30”. Scale 1:24,000. $1.50.

1-770-L. Map showing construction materials resources in the Parker quadrangle, Arapahoe and Douglas Counties, Colo., by J. 0. Maberry. 1973. Lat 39” 30’ to 39” 37′30″, long 104” 45’ to 104” 52’30”. Scale 1:24,000. $1.50.

I-770-M. Map of pioneer trails, stage stops, and areas with a view in the Parker quadrangle, Arapahoe and Douglas Counties, Colo., by J. 0. Maberry. 1973. Lat 39” 30’ to 39” 37′30″, long 104” 45’ to 104” 52’30”. Scale 1:24,000. $1.50.

I-770-N. Vegetation map of the Parker quadrangle, Arapahoe and Douglas Counties, Colo., by J. R. Keith and J. 0. Maberry. 1973. Lat 39” 30’ to 39” 37′30″, long 104” 45’ to 104” 52’30”. Scale 1:24,000. $1.50.

I-785-A. Map showing areas of selected potential geologic hazards in the Aspen quadrangle, Pitkin County, Colo., by Bruce Bryant. 1972. Lat 39” 07’30” to 39” 15′, long 106 45’ to 106” 52’30”. Scale 1:24,000. $1.50.

I-785-B. Map showing ground-water potential in the Aspen quadrangle, Pitkir County, Colo., by Bruce Bryant. 1972. Lat 39” 07’30” to 39” 15′, long 106” 45’ to 106” 52’30”. Scale 1:24,000. $1.50.

I-785-C. Map showing relative ease of excavation in the Aspen quadrangle, Pitkin County, Colo., by Bruce Bryant. 1972. Lat 39” 07’30” to 39” 15′, long 106” 45’ to 106” 52’30”. Scale 1:24,000. $1.50.

I-785-D. Map showing mines, prospects, and areas of significant silver, lead, and zinc production in the Aspen quadrangle, Pitkin County, Colo., by Bruce Bryant. 1972. Lat 39” 07’30” to 39” 15′, long 106” 45’ to 106° 52’30”. Scale 1:24,000. $1.25.

I-785-E. Slope map of the Aspen quadrangle, Pitkin County, Colo., by Bruce Bryant. 1972. Lat 39” 07’30” to 39” 15′, long 106” 45’ to 106° 52’30”. Scale 1:24,000. $1.50.

I-785-F. Map showing relative permeability of rocks and surficial deposits of the Aspen quadrangle, Pitkin County, Colo., by Bruce Bryant. 1972. Lat 39” 07’ 30” to 39” 15′, long 106” 45’ to 106” 52’30”. Scale 1:24,000. $1.25.

I-785-G. Map showing avalanche areas in the Aspen quadrangle, Pitkin County, Colo., by Bruce Bryant. 1972. Lat 39” 07’30” to 39” 15’, lone 106” 45’ to 106” 52’30”. Scale 1:24,000. $1.25.

I-785-H. Map showing typos of bedrock and surficial deposits in the Aspen quadrangle, Pitkin County, Colo., by Bruce Bryant. 1972. Lat 39” 07’30” to 39” 15′, long 106” 45’ to 106” 52’30”. Scale 1:24,000. $1.50.

I-786-A. Geologic map of the Evergreen quadrangle, Jefferson County, Colo., by D. M. Sheridan, J. C. Reed, Jr., and Bruce Bryant. 1972 (1973). Lat 39“ 37’30” to 39” 45′, long 105” 15’ to 105” 22’30”. Scale 1:24,000. $1.75.

I-786-B. Vegetation map of the Evergreen quadrangle, Jefferson County, Colo., by J. C. Reed, Jr., and J. R. Keith. 1972. Lat 39” 37’30” to 39” 45′, long 105” 15’ to 105” 22’30”. Scale 1:24,000. $1.50.

I-786-C. Slope map of the Evergreen quadrangle, Jefferson County, Colo., by P. W. Schmidt. 1972. Lat 39” 37’30” to 39” 45’, long 105” 15’ to 105” 22’30”. Scale 1:24.000. $1.50.

I-786-D. Map showing approximate density of houses in the Evergreen quadrangle, Jefferson County, Colo., by Bruce Bryant and J. C. Reed, Jr. 1972. Lat 39” 37’30” to 39 45′, long 105” 15’ to 105” 22’30”. Scale 1:24,000. $1.50.

I-786-E. Map showing approximate locations, depths, and estimated yields of water wells in the Evergreen quadrangle, Jefferson County, Colo., by P. W. Schmidt and J. C. Reed, Jr. 1972 (1973). Lat 39” 37’30” to 39” 45′, long 105” 15’ to 105” 22’30”. Scale 1:24,000. $1.25.

I-786-F. Map showing faults, joints, foliation, and surficial deposits in the Evergreen quadrangle, Jefferson County, Colo., by J. C. Reed, Jr., D. M. Sheridan, and Bruce Bryant. 1973. Lat 39” 37’30” to 39” 45′, long 105” 15’ to 105” 22’30”. Scale 1:24,000. $1.50.

I-786-G. Map showing thermal lineaments in the Evergreen quadrangle, Jefferson County, Colo., by T. W. Offield and H. A. Pohn. 1975. Lat 39” 37’30” to 39” 45′, long 105” 15’ to 105” 22’30”. Scale 1:24,000. $1.25.

I-790-A. Geologic map of the Morrison quadrangle, Jefferson County, Colo., by G. R. Scott. 1972. Lat 39° 37’30” to 39” 45′, long 105” 07’30” to 105” 15’. Scale 1:24,000. $1.75.

I-790-B. Map showing landslides and areas susceptible to landsliding in the Morrison quadrangle, Jefferson County, Colo., by G. R. Scott. 1972. Lat 39” 37’30” to 39” 45′, long 105” 07’30” to 105” 15’. Scale 1:24,000. $1.25.

1-790-C. Map showing areas containing swelling clay in the Morrison quadrangle, Jefferson County, Colo., by G. R. Scott. 1972. Lat 39” 37’30” to 39” 45′, long 105° 07′30″ to 105” 15’. Scale 1:24,000. $1.25.

I-790-D. Map showing potential source areas for non-metallic mineral resources. Morrison quadrangle, Jefferson County, Colo., by G. R. Scott. 1972. Lat 39” 37’30” to 39° 45′, long 105” 07’30” to 105” 15’. Scale 1:24,000. $1.50.

I-790-E. Map showing some points of geologic interest in the Morrison quadrangle, Jefferson County, Colo., by G. R. Scott. 1972. Lat 39” 37’30” to 39” 45′, long 105” 07’30” to 105” 15’. Scale 1:24,000. $1.50.

I-790-F. Map showing watercourses and areas inundated by historic floods in the Morrison quadrangle, Jefferson County, Colo., by G. R. Scott. 1972. Lat 39” 37’30” to 39” 45′, long 105” 07’30” to 105” 15’. Scale 1:24,000. $1.25.

I-790-G. Map showing inferred relative permeability of geologic materials in the Morrison quadrangle, Jefferson County, Colo., by G. R. Scott. 1972 (1973). Lat 39” 37’30” to 39” 45′, long 105” 07’30” to 105” 15’. Scale 1:24,000. $1.25.

I-791. Maps showing the approximate configuration and depth to the top of the Laramie-Fox Hills aquifer, Denver basin, Colorado, by J. C. Romero and E. R. Hampton. 1972. Lat about 38” 45’ to 40” 30′, long 104” to about 105”. Scale 1:500,000. $1.25.

I-792-A. Map showing rock fractures and veins in the Tungsten quadrangle, Boulder, Gilpin, and Jefferson Counties, Colo., by D. J. Gable. 1973. Lat 39” 52’30” to 40°, long 105” 22’30” to 105” 30’. Scale 1:24,000. $1.25.

I-792-B. Map showing density of dwelling units in the Tungsten quadrangle, Boulder, Gilpin, and Jefferson Counties, Colo., by H. R. Covington and D. J. Gable. 1973. Lat 39 52’30” to 40°, long 105” 22’30” to 105” 30’. Scale 1:24,000. $1.25.

I-792-C: Map showing water wells and springs in the Tungsten quadrangle, Boulder, Gilpin, and Jefferson Counties, Colo., by D. J. Gable. 1973. Lat 39” 52’30” to 40°, long 105” 22’30” to 105” 30’. Scale 1:24,000. $1.25.

I-828. Geologic map of the Platoro Caldera area, southeastern San Juan Mountains, southwestern Colorado, by P. W. Lipman. 1974 (1975). Lat 37” 15’ to 37” 30′, long 106 15’ to 106° 45’. Scale 1:48,000. $1.75.

I-830. Geologic map and sections of the Holy Cross quadrangle, Eagle, Lake Pitkin, and Summit Counties, Colo., by Ogden Tweto. 1974. Lat 39” 15’ to 39” 30′, long 106” 15’ to 106” 30’. Scale 1:24,000. 2 sheets. $3.50 per set.

I-833. Geologic map and cross sections of the La Veta Pass, La Veta, and Ritter Arroyo quadrangles, Huerfano and Costilla Counties, Colo., by J. D. Vine. 1974. Lat 37” 30’ to 37” 37′30″, long 104” 52’30” to 105” 15’. Scale 1:48,000. $1.50.

I-855-A. Lakes in the Boulder-Fort Collins-Greeley area, Front Range Urban Corridor, Colo., by J. F. Ficke and T. W. Danielson. 1973 (1974). Lat 40” to 40° 37′30″, long 104” 37’30” to 105” 22’30”. Scale 1:100,000. $1.75.

I-855-B. Land-use classification map of the Boulder-Fort CollinsGreeley area, Front Range Urban Corridor, Colorado, by L. B. Driscoll. 1974. Lat 40° to 40” 37′30″, long 104” 37’30” to 105” 22’30”. Scale 1:100,000. $1.75.

I-855-C. Map showing availability of hydrologic data, Boulder-Fort Collins-Greeley area, Front Range Urban Corridor, Colo., by E. R. Hampton G. A. Clark, and M. H. McNutt. 1974 (1975). Lat 40° to 40° 37′30″, long 104” 37’30” to 105” 22’30”. Scale 1:100,000. $1.25.

I-855-D. Map showing potential sources of gravel and crushed-rock aggregate, in the Boulder-Fort Collins-Greeley area, Front Range Urban Corridor, Colo., by R. B. Colton and H. R. Fitch. 1974. Lat 40” to 40° 37′30″, long 104° 37’30” to 105° 22′30″. Scale 1:100,000. $1.75.

I-855-E. Map showing flood-prone areas, Boulder-Fort Collins—Greeley area, Front Range Urban Corridor, Colo., by J. F. McCain and W. R. Hotchkiss. 1975. Scale 1:100,000. $1.25.

I-855-F. Map showing outstanding natural and historic landmarks in the Boulder-Fort Collins-Greeley area, Front Range Urban Corridor, Colorado, by B. N. Petrie. 1975. Lat 40” to 40° 37′30″, long 104” 37’30” to 105” 22’30”. Scale 1:100,000. $1.25.

I-856-A. Map showing potential sources of gravel and crushed-rock aggregate in the greater Denver area, Front Range Urban Corridor, Colo., by D. E. Trimble and H. R. Fitch. 1974. Lat 39° 22’30” to 40°, long 104” 37’30” to 105” 22’30”. Scale 1:100.000. $1.75.

I-856-B. Lakes in the Greater Denver area, Front Range Urban Corridor, Colo., by T. W. Danielson. 1975. Lat 39” 22’30” to 40”. lone 104” 37’30” to 105” 22’30”. Scale 1:100,000. $1.25.

I-856-C. Map showing availability of hydrologic data published by the U.S. Environmental Data Service, and by the U.S. Geological Survey and cooperating agencies, Greater Denver area, Front Range Urban Corridor, Colorado, by E. R. Hampton. 1975. Lat 39” 22’30” to 40°, long 104” 37’30” to 105” 22’30”. Scale 1:100,000. $1.25.

I-856-D. Map showing flood-prone areas, Greater Denver area, Front Range Urban Corridor. Colo.. by J. F. McCain and W. R. Hotchkiss. 1975. Lat 39” 22’30” to 40°, lona 104” 37’30” to 105” 22’30”. Scale 1:100,000. $1.25.

I-856-E. Land-use classification of the Greater Denver area, Front Range Urban Corridor, Colo., by L. B. Driscoll. 1975 (1976). Lat 39” 22’30” to 40°, long 104” 37’30” to 105” 22’30”. Scale 1:100,000. $1.75.

I-856-F. Map showing outstanding natural and historic landmarks in the greater Denver area, Front Range Urban Corridor. Colorado. by B. N. Petrie. 1976. Lat 39” 22’30” to 40°, long 104° 37′30″ to 105” 22’30”. Scale 1;100,000. $1.25.

I-856-G. Historic trail map of the Greater Denver area, Colorado, by G. R. Scott. 1976. Lat 39” 22’30” to 40°, long 104” 37’30” to 105” 22’30”. Scale 1:100,000 (1 inch = about 1.6 miles). Sheet 30 by 37 inches. $1.25.

I-857-A. Map showing potential sources of gravel and crushed-rock aggregate in the Colorado Springs-Castle Rock area, Front Range Urban Corridor, Colo., by D. E. Trimble and H. R. Fitch. 1974. Lat 38” 37’30” to 39” 22′30″, long 104” 37’30” to 105”. Scale 1:100,000. $1.75.

I-857-B. Land-use classification map of the Colorado Springs-Castle Rock area, Front Range Urban Corridor, Colorado, by L. B. Driscoll. Lat 38” 37’30” to 39” 22’30”. long 104” 37’30” to 105” 07’30”. Scale 1:100,000. $1.75.

I-857-C. Map showing flood-prone areas, Colorado Springs—Castle Rock area, Front Range Urban Corridor, Colorado, by J. F. McCain and W. R. Hotchkiss. 1975. Lat 38” 37’30” to 39” 22′30″, long 104” 37’30” to about 105”. Scale 1:100,000. $1.25.

I-857-D. Map showing availability of hydrologic data published as of 1974 by the U.S. Environmental Data Service and by the U.S. Geological Survey and cooperating agencies, Colorado Springs--Castle Rock area, Front Range Urban Corridor, Colorado, by L. 0. Anna. 1975. Lat 38” 37’30” to 39” 22′30″, long 104” 37’30” to about 105”. Scale 1:100,000. $1.25.

I-857-E. Lakes in the Colorado Springs-Castle Rock area, Front Range Urban Corridor, Colorado., by D. B. Adams. 1976. Lat 38” 37’30” to 39” 22’30”. lone: 104” 37’30” to 105” 07’30”. Scale 1:100,000. $1.50.

I-869. Reconnaissance geologic map of the Royal Gorge quadrangle, Fremont and Custer Counties.. Colo.. by R. B. Taylor. G. R. Scott. R. A. Wobus, and R. C. Epis. 1975. Lat 38’ 15’ to 38” 30′, long 105° 15’ to 105” 30′. Scale 1:62,500. $1.50.

I-870. Reconnaissance geologic map of the Deer Peak quadrangle and southern part of the Hardscrabble Mountain quadrangle, Custer and Huerfano Counties, Colo., by R. B. Taylor. 1974 (1975). Lat 38” to about 38” 09′, long 105” 07’30” to 105” 15’. Scale 1:24,000. $1.50.

I-892. Reconnaissance geologic map of the Howard quadrangle, central Colorado, by R. B. Taylor, G. R. Scott, and R. A. Wobus. 1975. Lat 38” 15’ to 38” 30′, long 105” 45’ to 106”. Scale 1:62,500. $1.50.

I-900. Reconnaissance geologic map of the Cotopaxi 15-minute quadrangle, Fremont and Custer Counties, Colo., by R. B. Taylor, G. R. Scott, R. A. Wobus, and R. C. Epis. 1975. Lat 38” 15’ to 38” 30′, long 105” 30’ to 105” 45’. Scale 1:62,500. $1.50.

I-901. Geologic map of the lower Conejos River Canyon area, southeastern San Juan Mountains, Colo., by P. W. Lipman. 1975. Lat 37” to 37” 15′, long 106” to 106” 30’. Scale 1:48,000. $1.50.

MISCELLANEOUS INVESTIGATIONS SERIES-Continued

I-912. Magnetic inclination in the United States-Epoch 1975.0, by N. W. Peddie, W. J. Jones, and E. B. Fabiano. 1976. 2 sheets. Scale 1:5,000,000. $3.

I-913. Magnetic horizontal intensity in the United States-Epoch 1975.0, by E. B. Fabiano and W. J. Jones. 1976. 2 sheets. Scale 1:5,000,000. $3.

I-914. Magnetic vertical intensity in the United States-Epoch 1975.0, by W. J. Jones and E. B. Fabiano. 1976 (1977). Two sheets. Scale 1:5,000,000 (1 inch = about 80 miles). Sheet 33 by 47 inches. $3.

I-915. Magnetic total intensity in the United States-Epoch 1975.0, by E. B. Fabiano, N. W. Peddie, and W. J. Jones. 1976. 2 sheets. Scale 1:5,000,000. $3.

I-930. Historic trail maps of the Pueblo 1" x 2" quadrangle, Colorado, by G. R. Scott. 1975 (1976). Lat 38" to 39°, long 104" to 106". Scale 1:250,000. Accompanied by 9-page text. 2 sheets. $2.50 per set.

I-937. Geologic and biostratigraphic map of the Pierre Shale in the Canon City-Florence basin and the Twelvemile Park area, south-central Colorado, by G. R. Scott and W. A. Cobban. 1975 (1976). Lat 38" 12'30" to 38" 30', long 105" to 105" 15'. Scale 1:48,000. $1.25.

I-944. Geologic map of the Lamar quadrangle, COLORADO, and KANSAS, by J. A. Sharps. 1976. Lat 38" to 39", long 102" to 104". Scale 1:250,000 (1 inch = about 4 miles). Structure-contour interval 100 feet (30.5 m). Sheet 25% by 40 inches. $1.50.

I-952. Geologic map of the Del Norte area, eastern San Juan Mountains, Colorado, by P. W. Lipman. 1976. Lat 37" 30' to 37" 52'30", long 106" 07'30" to 106" 30'. Scale 1:48,000. $1.50.

I-962. Geologic map of the Lake City caldera area, western San Juan Mountains, southwestern Colorado, by P. W. Lipman. 1976 (1977). Lat 37" 45' to 38" 07'30", long 107" 15' to 107" 37'30". Scale 1:48,000 (1 inch = 4,000 feet). Sheet 39 by 58 inches. $1.50.

I-964. Preliminary map of landslide deposits in Colorado, by R. B. Colton, J. A. Holligan, L. W. Anderson, and P. E. Patterson. 1976. Lat 37" to 41". long 102" to 109". Scale 1:500,000 (1 inch = about 8 miles). Sheet 40 by 52 inches: $1.25.

I-965. Map showing nonmetallic mineral resources (except fuels) in bedrock, Front Range Urban Corridor. Colorado, by E. J. Crosby. 1976 (1977). Two sheets. Lat 38" 37'30" to 40° 37'30", long 104" 37'30" to 105" 22'30". Scale 1:100,000 (1 inch = about 1.6 miles). Sheet 1, 34 by 44 inches; sheet 2, 39 by 48 inches. $3 per set.

I-966. Geologic map of the South Fork area, eastern San Juan Mountains, southwestern Colorado, by P. W. Lipman and T. A. Steven. 1976. Lat 37" 30' to 37" 45', long 106 30' to 106° 45'. Scale 1:48,000 (1 inch = 4,000 feet). Sheet 28 by 30 inches. $1.50.

I-972. Geologic map of the Craig 1" by 2" quadrangle, northwestern Colorado, compiled by Ogden Tweto. 1976. Lat 40" to 41°, long 106" to 108". Scale 1:250,000 (1 inch = about 4 miles). Sheet 29 by 41 inches. $1.50.

I-973-A. Map showing types of bedrock and surficial deposits in the Telluride quadrangle, San Miguel, Ouray, and San Juan Counties, Colorado, by R. G. Luedke and W. S. Burbank. 1976 (1977). Lat 37" 52'30" to 38°, long 107" 45' to 107" 52'30". Scale 1:24,000 (1 inch = 2,000 feet). Sheet 28 by 28 inches. $1.50.

I-973-B. Map showing potential geologic hazards in the Telluride quadrangle, San Miguel, Ouray, and San Juan Counties, Colorado, by R. G. Luedke and W. S. Burbank. 1977. Lat 37" 52'30" to 38°, long 107" 45' to 107" 52'30". Scale 1:24,000 (1 inch = 2,000 feet). Sheet 29 by 30 inches. $1.50.

I-980. Engineering geologic map of the Indian Hills quadrangle, Jefferson County, Colorado, by R. D. Miller and Bruce Bryant. 1976 (1977). Lat 39" 30' to 39" 37'30", long 105" 07'30" to 105" 15'. Scale 1:24,000 (1 inch = 2,000 feet). Sheet 37 by 39 inches. $1.50.

I-1039. Energy resources map of Colorado, by U. S. Geological Survey and Colorado Geological Survey. 1977. Lat 37' to 41°, long 102" to 109". Scale 1:500,000 (1 inch = about 8 miles). Sheet 42 by 59 inches. $1.75.

MISSOURI BASIN STUDIES

1. Mineral resources of the Missouri Valley region, compiled by D. H. Dow, D. M. Larrabee, and S. E. Glabaugh. 1945-46. These maps cover the entire basin. They show the sedimentary and igneous rocks of different ages. Structure-contour lines are also given. Part 1 shows the metallic mineral resources, part 2, the nonmetallic mineral resources, part 3, fuel resources, and part 4, construction materials. Scale 1:2,500,000.

MISSOURI BASIN STUDIES-Continued

*2. Preliminary map showing sand and gravel deposits of Colorado, compiled by Helen Varnes and D. M. Larrabee. 1946. Scale 1:500,000.

*8. Map showing mineral deposits of Colorado, compiled by R. P. Fischer, Wilbur Burbank, Helen Cannon, and others. 1946. Scale 1:1,000,000.

* 10. Map showing construction materials and nonmetallic mineral resources of Colorado, compiled by D. M. Larrabee, S. E. Clabaugh, W. R. Griffitts, and others. 1947. Scale 1:500,000.

*MOSQUITO RANGE, COLO. Preliminary geologic map of west slope of Mosquito Range near Leadville, Colo. Geology, by G. H. Behre, Jr., assisted by E. N. Goddard, and A. E. Sandburg. 1939. Scale 1:12,000.

OIL AND GAS INVESTIGATIONS CHARTS

*7. Correlation of basal Permian and older rocks in southwestern Colorado, northwestern New Mexico, northeastern Arizona, and southeastern Utah, by N. W. Bass. 1945.

16. Mesozoic and Paleozoic stratigraphy in northwestern Colorado and northeastern Utah, by C. R. Thomas, F. T. McCann, and N. D. Ramon. 1945.2 sheets. $2.50 per set.

*39. Pre-Pennsylvanian rocks along the Front Range of Colorado, by J. C. Maher. 1950.

*OC-42. Subsurface geologic cross sections of Mesozoic rocks in northeastern Colorado, by R. W. Blair. 1951. 2 sheets.

OC-46. Correlation of Permian and Pennsylvanian rocks from western Kansas to the Front Range of Colorado, by J. C. Maher and J. B. Collins. 1952. 3 sheets. $3.75 per set.

OC-59. Stratigraphy of Paleozoic rocks in northwestern Colorado, by W. D. Hallgarth. 1959 (1960). $1.25.

OC-60. Stratigraphy of the Dakota group along the northern Front Range foothills, Colorado, by K. M. Waage. 1959. $1.25.

OC-63. Block diagram of the San Rafael Group and underlying strata in Utah and part of Colorado, by J. C. Wright and D. D. Dickey. 1963. $1.25.

OC-65. Chart showing correlation of selected key units in the organic-rich sequence of the Green River Formation, Piceance Creek basin, Colorado, and Uinta Basin, Utah, by W. B. Cashion and J. R. Donnell. 1972. $1.25:

OC-67. Chart showing correlation of selected restored stratigraphic diagram units of the Eocene Uinta and Green River Formations, east-central Piceance Creek basin, northwestern Colorado, by R. B. O'Sullivan. 1974. $1.25.

OC-68. Stratigraphic sections across Upper Cretaceous Mancos Shale-Mesaverde Group boundary, eastern Utah and western Colorado, by J. R. Gill and W. J. Hail, Jr. 1975. $1.25.

OC-69. Stratigraphic sections of some Triassic and Jurassic rocks from Douglas, Wyoming to Boulder, Colorado, by G. N. Pipiringos and R. B. O'Sullivan. 1976. $1.25.

OIL AND GAS INVESTIGATIONS MAPS

*7. Structure contour map of the exposed rocks in the Rangely anticline, Rio Blanco and Moffat Counties, Colo., by C. R. Thomas and others. 1944. Scale 1:31,680. (Superseded in part by Map 67.)

10. Map showing thickness and general character of the Cretaceous deposits in the western interior of the United States. bv J. B. Reeside, Jr. 1944. Scale 1:13,939,200. $1.25.

32. Geology of the Washakie Basin: Sweetwater and Carbon Counties, Wyo., and Moffat County, Colo., by W. H. Bradley. 1945. Scale 1:190,080. $1.25.

*41. Structure contour mans of the Raneely anticline, Rio Blanco and Moffat Counties, Colo., by C. R. Thomas and others. 1945. Scale 1:31,680. (Superseded by Map 67.)

*67. Subsurface maps of the Rangely anticline, Rio Blanco County, Colo., by N. W. Bass. 1948. Scale 1:31,680.

*68. Structure contour map of the surface rocks of the Model anticline, Las Animas County, Colo., by N. W. Bass. 1947. Scale 1:42,240.

*73. Map of Colorado showing dry holes and oil and gas fields, by F. K. Demok, H. R. Castor, and N. W. Bass. 1947. Scale 1:500,000. (Superseded by Map OM-116.)

*81. Geology of the southern part of Archuleta County, Colo., by G. H. Wood, V. C. Kelley, and A. J. MacAlphin. 1948. Scale 1:63,360.

*93. Geology of the Eguar-Gypsum Valley area, San Miguel and Montrose Counties, Colo., by W. L. Stokes and D. A. Phoenix. 1948. Scale 1:48,000.

94. Geology of Naval Oil Shale Reserves 1 and 3, Garfield County, Colo., by D. C. Duncan and N. M. Denson. 1949. Scale 1:31,680. 2 sheets. $2.50 per set.

OIL AND GAS INVESTIGATIONS MAPS-Continued

*96. Stratigraphy and geologic structure in the Piedra River Canyon, Archuleta County, Colo., by C. B. Read, G. H. Wood, A. A. Wanek, and Pedro Verastegui Mackee. 1949. Scale 1:48,000.

*101. Pre-Pennsylvanian geology of southwestern Kansas, southeastern Colorado, and the Oklahoma Panhandle, by J. C. Maher and J. B. Collins. 1949. Scale 1:1,013,760. 4 sheets.

109. Geology and coal resources of the Durango area, La Plata and Montezuma Counties, Colo., by A. D. Zapp. 1949. Scale 1:31,680. 2 sheets. $2.50. per set.

*OM-114. Geology of DeBeque oil-shale area, Garfield and Mesa Counties, Colo., by F. R. Waldron, J. R. Donnell, and J. C. Wright. 1951. Scale 1:62,500. 2 sheets.

*OM-116. Map of Colorado showing test wells for oil and gas, pipelines, oil, and gas fields, and areas of pre-Cambrian rocks, compiled by F. W. Walker and N. W. Bass. 1951. Scale 1500,000. 2 sheets.

OM-119. Geology and oil-shale resources of the eastern part of the Piceance Creek Basin, Rio Blanco and Garfield Counties, Colo., by D. C. Duncan and Carl Belser. 1950. Scale 1:96,000. $1.25.

OM-120. Geology of Dove Creek area, Dolores and Montezuma Counties, Colo., by E. A. Finley. 1951. Scale 1:48,000. $1.25.

*OM-134. Geology of the Cathedral Bluffs oil-shale area, Rio Blanco and Garfield Counties, Colo., by J. R. Donnell, W. B. Cashion, and J. H. Brown, Jr. 1953. Scale 1:62,500. (See Bulletin 1082-L.)

*OM-135. Permian and Pennsylvanian rocks of southeastern Colorado and adjacent areas, by J. C. Maher and J. B. Collins. 1953. Scale 1:1,143,180.

*OM-138. Geology of the Ignacio area, Ignacio and Pagosa Springs quadrangles, La Plata and Archuleta Counties, Colo., by Harley Barnes. 1953. Lat 37” 15’ to 37” 20′, long 107” 20’ to 107” 40’. Scale 1:63,360. 50¢.

*OM-146. Geology of the La Veta area, Huerfano County, by R. B. Johnson and J. G. Stephens. 1954. Lat 37” 30’30” to 37” 45′, long 104” 55’ to 105” 07’30”. Scale 1:31,680.

OM-149. Geology and fuel resources of the Red Mesa area, La Plata and Montezuma Counties, Colo., by Harley Barnes, E. H. Baltz, Jr., and P. T. Hayes. 1954. Lat 37” to 37” 20′, long 107” 52’30” to 108° 20’. Scale 1:62,500. $1.25.

*OM-152. Geologic map of the Mesa Verde area, Montezuma County, Colo., by A. A. Wanek. 1954. Lat 37” to 37” 20′, long 108” 20’ to 108” 45’. Scale 1:63,360. (See Bulletin 1072-M.)

OM-153. Geology of the Bonanza-Dragon oil-shale area, Uintah County, Utah, and Rio Blanco County, Colo., by W. B. Cashion and J. H. Brown, Jr. 1956. Scale 1:62,500. 2 sheets. $2.50 per set.

OM-161. Geologic map of the Walsenburg area, Huerfano County, Colo., by R. B. Johnson and J. G. Stephens. 1955. Scale 1:31,680. $1.25. (See Bulletin 1042-o.)

OM-174. Geology of the Trinidad-Aguilar area, Las Animas and Huerfano Counties, Colo., by R. L. Harbour and G. H. Dixon. 1956. Lat 37” 10’ to 37” 30′, long 104” 30’ to 104” 45’. Scale 1:31,680. $1.50. (See Bulletin 1072-G.)

OM-176. Preliminary structure contour map of the Colorado plains, by E. A. Finley, C. E. Dobbin, and E. E. Richardson. 1955 (1956). Lat 37” to 41°, long 102” to 105”. Scale 1500,000. $1.25.

OM-183. Preliminary geologic map of the northern part of the Raton Mesa region and Huerfano Park in parts of Las Animas, Huerfano and Custer Counties, Colo., by R. B. Johnson, G. H. Wood, Jr., and R. L. Harbour. 1958. Lat 37” 30’ to 37” 52′30″, long 104” 37’30” to 105” 22’30”. Scale 1:63,360. 2 sheets, $3 per set. (See Bulletin 1071-D.)

OM-184. Index map of central midcontinent region giving lines of sections that show detailed lithology of Paleozoic and Mesozoic rocks, by Jeannette Fox and M. G. Sheldon. 1957. Lat 33” to 46°, long 89” to 106°. Scale 1:2,500,000. $1.50.

GM-209. Preliminary structure contour map on top of salt in the Paradox member of the Hermosa Formation in the salt anticline region, Colorado and Utah, by D. P. Elston and E. M. Shoemaker. 1961. Lat 37” 45’ to 39°, long 108” to 110”. Scale 1:250,000. $1.25.

OM-216. Geologic map of the Thornburg oil and gas field and vicinity, Moffat and Rio Blanco Counties, Colo., by J. R. Dyni. 1966. Area lies in the vicinity of lat 40°15′, long 107° 40’. Scale 1:24,000. Accompanied by 7-page text. $1.25.

***PALEOCENE DEPOSITS OF THE ROCKY MOUNTAINS AND PLAINS,** by R. W. Brown. 1949. Shows the areas of outcrop of the earliest Tertiary (Paleocene) rocks from Montana and North Dakota south to Arizona and New Mexico. The upper and lower boundaries of the Paleocene deposits and their areal relations with Cretnceous and younger Tertiary rocks are indicated. A brief discussion of Paleocene formations is printed on the same sheet. Scale 1:1,000,000. (See Professional Paper 375.)

PIKES PEAK AND VICINITY, COLORADO. 1948-56 (1957). Text on the reverse side of the map discusses the geologic story of Pikes Peak and the surrounding region, by A. H. Koschmann. Available in contour or shaded relief editions. $1 each.

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Many of the publications listed herein may be consulted in the following libraries in Colorado:

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