INTERIM GEOLOGIC MAPS OF THE CRANDALL CANYON AND HIDDEN LAKE QUADRANGLES SUMMIT COUNTY, UTAH

by
Michael D. Bradley
Department of Geography and Geology
Eastern Michigan University
Ypsilanti, Michigan 48197

OPEN FILE REPORT 382
UTAH GEOLOGICAL SURVEY
a division of
UTAH DEPARTMENT OF NATURAL RESOURCES

May 2001

UTAH GEOLOGICAL SURVEY

TABLE OF CONTENTS

ABSTRACT

The Crandall Canyon quadrangle, Summit County, Utah is about 25 miles (40 km) due east of Salt Lake City, Utah at the northwestern boundary of the Uinta Mountains. The quadrangle is just east of the Weber River between Rockport Lake and Hoytsville, Utah. The Hidden Lake quadrangle is adjacent to and just east of the Crandall Canyon quadrangle.

Pennsylvanian to Tertiary sedimentary rocks, Oligocene volcanic rocks, Miocene intrusive rocks, and Tertiary and Quaternary sediments are exposed within the Crandall Canyon and Hidden Lake quadrangles. Sedimentary rocks include the Pennsylvanian and Permian Weber Formation (1,725 feet [526 m]); the Permian Park City Formation (910 feet [277 m]); the Triassic Woodside (707 feet [215 m]), Thaynes (735 feet [222 m]), and Ankareh (1,281 feet [360 m]) Formations; the Jurassic Nugget (1,293 feet [394 m]), Twin Creek (1,379 feet [420 m]), Preuss (1,700 feet [518 m]), Stump (0-223 feet [0-68 m]), and Morrison (0-250 feet [0-76 m]) Formations; the Cretaceous Kelvin (2,700 feet [823 m]), Aspen (525 feet [160 m]), Frontier (7,350-7,580 feet [2,240-2,310 m]), and Henefer (4,300 feet [1,311 m]) Formations; the Cretaceous and Tertiary Evanston (2,900+ feet [884+ m]) Formation; and the Tertiary Wasatch Formation (0-2,600 feet [0-792 m]). Oligocene Keetley volcanic rocks, exposed in the western part of the area, consist of a lower tuff unit (0-840 feet [0-256 m]) and an upper rhyodacite to andesite breccia unit (0-1,000 feet [0-305 m]). A few small lamprophyre dikes are exposed in the southeastern part of the Crandall Canyon quadrangle and the southwestern part of the Hidden Lake quadrangle. Tertiary and Quaternary surficial deposits include scattered boulders associated with a post-Keetley volcanics erosional surface, terrace gravels deposited along the larger drainages, colluvium on slopes, alluvium presently being deposited in the channels and flood planes of the larger streams, mass wasting deposits, and, in the Hidden Lake quadrangle, glacial deposits.

Structurally, the Crandall Canyon and Hidden Lake quadrangles lie at the intersection of the Idaho-Wyoming-Utah salient of the Sevier thrust belt and the Laramide foreland Uinta Mountain uplift. Several thrusts associated with each system are exposed in this area. The oldest thrusts are associated with the Sevier orogeny. These thrusts trend northeast and dip northwest and include the Cherry Canyon, Dry Canyon, Crandall Canyon, and Rockport thrusts. The major activity on these thrusts in this area was post-middle Turonian to pre-Maastrichtian. Thrusts associated with the Laramide uplift of the Uinta Mountains are the Perdue Creek, Big Piney and Mahogany Hills thrusts. These thrusts are imbricates of the south-dipping North Flank thrust system which lies along the north flank of the Uintas. Movement on these thrusts occurred in Maastrichtian to Paleocene in the Crandall Canyon/Hidden Lake area. Displacement on the North Flank thrust system decreases westward of the Bridger Lake area (T. 3N., R. 14E. Salt Lake Meridian) with surface offset dying out within the Crandall Canyon quadrangle. Throughout the southern parts of the Crandall Canyon and Hidden Lake quadrangles folding on the Uinta arch rotated Cretaceous and older rocks, and Sevier thrusts to steep northwest dips to locally overturned and dipping steeply southeast.

Landslides and flooding are the more common geologic hazards within the Crandall Canyon and Hidden Lake quadrangles. The landslides most commonly initiate in the Tertiary Wasatch Formation or Upper Cretaceous strata. Though no evidence of active faulting within the Crandall Canyon and Hidden Lake quadrangles was observed, Quaternary sediments are offset near the mouth of Seymour Canyon (SW1/4 section 22, T. 1S., R. 6E.) in the adjacent Kamas quadrangle. The Bear River, East Canyon, and Wasatch faults are all within 25 miles (40 km) and are capable of generating large magnitude earthquakes. Earthquakes associated with these faults could trigger landslides on some slopes within the area, especially when the soil is water saturated, such as during a wet Spring.

INTRODUCTION

The Crandall Canyon quadrangle, Summit County, Utah, lies just east of the Weber River between Rockport Lake and Hoytsville (figure 1). Though not considered part of the Uinta Mountains, the southern half of the quadrangle is dominated by Uinta structures and could structurally be considered part of the range. The northern part of the quadrangle is dominated by Sevier-age thrusts. Elevations range from a low of 6,052 feet (1,845 m) along the Weber River in the southwestern corner of the quadrangle (section 10, T. 1S., R. 5E.) to 9,377 feet (2,858 m) on Elkhorn at the eastern edge of the quadrangle (section 22, T. 1N., R. 6E.).

The Hidden Lake quadrangle is adjacent to and just east of the Crandall Canyon quadrangle. Structurally, the Hidden Lake quadrangle is similar to the Crandall Canyon quadrangle with the northern part of the quadrangle dominated by Sevier structures and the southern part of the quadrangle extending into the Uinta Mountains. The two quadrangles were mapped together because the major structures (faults and folds) cross both quadrangles. Elevations within the Hidden Lake quadrangle range from a low of 6,800 feet (2,073 m) along the Weber River in the southern part of the quadrangle (section 12, T. 1S., R. 6E.) to 10,002 feet (3,049 m) on an unnamed peak along the southeastern border of the quadrangle (section , T. 1S., R. 7E.).

Most of the land within the Crandall Canyon and Hidden Lake quadrangles is privately owned with access through locked gates by permission only. The area is primarily used to graze sheep and cattle. The northern part of the area includes the Lodgepole oil and gas field discovered in 1976. The trend of oil and gas fields along the leading edge of the Absaroka thrust extends through the Crandall Canyon quadrangle and has been a target for exploration drilling.

The earliest geologic work in the area was performed by Stanton (1893) who described the Cretaceous Aspen Formation that crops out along the Weber River just north of Peoa. Schultz (1918) identified faults in Crandall and Dry Canyons and associated them with the system of south-dipping thrusts along the north flank of the Uinta Mountains. Thomas and Krueger (1946) measured and described the Triassic and Jurassic stratigraphy in the Mahogany Hills (figure 1) and along the Weber River just north of Peoa. Five Master's theses at the University of Utah, Hooper (1951), Larson (1951), O'Toole (1951), Mount (1952), and Morris

(1953) provided the first geologic mapping within the area. Crittenden (1974) revisited the faults in Crandall and Dry Canyons and concurred with Larson (1951) that these faults are not part of the system of thrusts along the north flank of the Uintas as proposed by Schultz (1918) but are associated with the Sevier thrust belt. Ryer (1976) measured and described the Frontier Formation where it crops out along the Weber River. Bradley (1988) mapped part of the area at a scale of 1:24,000 as part of a Ph.D. dissertation at the University of Utah; this work extends the dissertation mapping. Bryant (1990) mapped both the Crandall Canyon and Hidden Lake quadrangles at a scale of 1:100,000 as part of the Salt Lake City 30' x 60' quadrangle.

To assist the reader in locating folds, faults, measured sections, drill holes, etc., discussed in the text, spot locations are given in an abbreviated form. For example, 1280 FNL 1280 FWL 27-1N-5E means 1280 feet from the northern boundary line and 1280 feet from the western boundary line of section 27 in Township 1 North, Range 5 East based upon the Salt Lake Meridian. Note that some of the locations are outside of the Crandall Canyon and Hidden Lake quadrangles.

STRATIGRAPHY

Permian

Permian rocks are exposed on the north-facing slope of the Uinta Mountains (figure 1). The Permian sequence is represented by the upper part of the Weber Formation and the Park City Formation.

Weber Sandstone (PlPw)

The oldest rocks within the mapped area are from the upper part (Permian) of the Pennsylvanian and Permian Weber Sandstone exposed on the northwest-facing slope of the Uinta Mountains in the southeastern part of the Hidden Lake quadrangle (plate 1, Hidden Lake quadrangle). The Weber consists of resistant, massive, fine to medium-grained, white- and rust-colored, quartz arenite with discontinuous lenses of limestone in the lower and middle parts of the formation. Bissell (1964) measured 1,725 feet (526 m) of the entire Weber Sandstone in Pullem Creek (1S-7E).

Park City and Phosphoria Formations (Ppc)

These formations are exposed on the northwest-facing slope of the Uinta Mountains in the southeastern part of the Hidden Lake quadrangle where the Park City conformably overlies the Weber Formation (plate 1, Hidden Lake quadrangle). Here, the Park City Formation can be divided into two members: the basal Grandeur and overlying Franson Members, separated by the Meade Peak Phosphatic Shale Tongue of the Phosphoria Formation. The Grandeur Member consists of calcareous sandstone and arenaceous limestone. The Meade Peak Shale consists of black phosphatic shale, sandstone, and limestone containing abundant chert. The Franson

Member consists of dense to finely crystalline, light gray to bluish gray, cherty limestone. Hooper (1951) measured 910 feet (277 m) of Park City Formation in Piñon Canyon (formerly Franson Canyon, 14 & 22-1S-6E).

Triassic

Triassic rocks are exposed along the northwest-facing slope of the Uinta Mountains in the southeastern part of the Hidden Lake quadrangle (plate 1, Hidden Lake quadrangle) and along the southeast-facing slope of Mahogany Hills (figure 1). The Triassic includes, in ascending order, the Woodside, Thaynes, and Ankareh Formations.

Woodside Formation (TRw)

The Woodside Formation conformably overlies the Park City Formation. The Woodside Formation is a series of nonresistant thin-bedded, reddish-brown shales, siltstones, and sandstones. The sandstones are more resistant to erosion and crop out as ledges along otherwise uniform slopes. The contacts with adjacent units are seldom exposed but are readily identifiable by the changes to non-resistant slope, reddish soil color, and vegetation. The Woodside Formation is 707 feet (215 m) thick in Piñon Canyon (14-1S-6E; Morris, 1953).

Thaynes Limestone (TRt)

The Thaynes Limestone conformably overlies the Woodside Formation. The Thaynes is 704 feet thick (215 m; Hooper, 1951) and can be divided into three lithologic units: a lower carbonate, a middle clastic, and an upper carbonate unit. The lower carbonate unit consists of buff to bluish-gray, arenaceous limestone, interbedded with thin, calcareous sandstones, which locally exhibit cross stratification, and sandy shale lenses. This resistant unit forms prominent ridges and hogbacks along the northwestern slopes of the Uintas, where it is 225 feet (69 m) thick. The middle clastic unit consists of thin-bedded, fine-grained, red, calcareous sandstone, siltstone, and shale. The clastic unit is incompetent, seldom exposed, and 185 feet (53 m) thick along the southeast-facing slope of the Mahogany Hills. The upper carbonate unit consists of interbedded dark-gray limestone and thin-bedded, buff-colored, arenaceous limestone, sandstone, and sandy shale. The upper carbonate is 294 feet (90 m) thick along the southeast-facing slope of the Mahogany Hills.

Ankareh Formation (TRa)

The Ankareh Formation is 1,180 feet (360 m) thick along the southeast-facing slope of the Mahogany Hills. The Ankareh Formation consists of three members, the Mahogany, Gartra Grit, and Stanaker Members.

Mahogany Member (TRam): The Mahogany Member of the Ankareh Formation conformably overlies the Thaynes Formation. The Mahogany Member consists of nonresistant, thin-bedded, purple to brick-red, fine- to medium-grained, calcareous siltstone, shale, and soft sandstone. The

Mahogany Member is 761 feet (232 m) thick along the South Fork of the Weber River (12-1S-6E and 7-1S-7E; Morris, 1953).

Gartra Grit Member (TRag): The Gartra Grit Member of the Ankareh Formation disconformably overlies the Mahogany Member. The Gartra consists of light- to medium-gray, fine-grained, well-indurated, sandstone to well-rounded pebble conglomerate with occasional discontinuous lenses of siltstone and shale. The Gartra is a ledge former which crops out over large lateral distances. The Gartra has rapid lateral thickness variations, with thicknesses varying from 33 feet (10 meters; Thomas and Krueger, 1946) to 60 feet (18 m; Hooper, 1951) within a 3.1 mile (5 km) continuously exposed section along the southeast-facing slope of the Mahogany Hills.

Stanaker Member (TRas): The Stanaker Member of the Ankareh Formation (Popo Agie Formation of High and others, 1969), conformably overlies the Gartra Member. The Stanaker consists of nonresistant, reddish-purple to reddish-brown, silty to sandy mudstone, with lenses of conglomeratic sandstone. Yellowish-brown, earthy, silty mudstone is common near the top of the unit. The Stanaker is 360 feet (110 m) thick along the southeast-facing slope of the Mahogany Hills (Morris, 1953).

Jurassic

The Jurassic system, in ascending order, is represented by the Nugget, Twin Creek, Preuss, Stump, and Morrison Formations. The thickness of Jurassic strata varies from 3,447 to 4,682 feet (1,051 to 1,427 m) thick within the area.

Nugget Sandstone (Jn)

The Lower Jurassic Nugget Sandstone is exposed along the southeast-facing slope of the Mahogany Hills in the southwestern part of the Hidden Lake quadrangle (plate 1, Hidden Lake quadrangle). The Nugget disconformably overlies the Triassic Stanaker Member of the Ankareh Formation within the Hidden Lake quadrangle. The ridge-forming Nugget consists of reddish-orange, fine- to medium-grained, well-sorted sandstone grading to white sandstone in the top 10 to 20 feet (3 to 6 m) of the formation. Planar beds in the lower part of the formation give way to large-scale cross stratification in the upper part of the formation. The Nugget Sandstone is an important oil reservoir in the Lodgepole field. Thomas and Krueger (1946) measured 1,293 feet (394 m) of Nugget in the Mahogany Hills, but subsequent workers (Morris, 1953; Hooper, 1951) stated a thickness of about 900 feet (274 m) in the Mahogany Hills. The Nugget is 910 feet (277 m) thick near Peoa, Utah (Morris, 1953).

Twin Creek Limestone (Jtc)

The Middle Jurassic Twin Creek Limestone crops out in the Mahogany Hills (plate 1, Hidden Lake quadrangle), White's Basin, and the north-facing slope of Maple Ridge (plate 1, Crandall Canyon quadrangle). The Twin Creek Formation is subdivided into five mappable units within the Crandall Canyon and Hidden Lake quadrangles: a lower unit consisting of Imlay's (1967) Gypsum Spring and Sliderock Members, the Rich Member, the Boundary Ridge Member, the Watton Canyon Member, and an upper unit consisting of the Leeds Creek and Giraffe Creek Members. The Twin Creek is 1,379 feet (420 m) thick along the Weber River near Peoa (figure 1) approximately one mile south of the Crandall Canyon quadrangle (Imlay, 1967).

Gypsum Spring and Sliderock Members (Jtgs): The middle Bajocian age (Imlay, 1967) Gypsum Springs Member of the Twin Creek Limestone disconformably overlies the Nugget Sandstone. The Gypsum Springs Member consists of red, salmon, and yellow silty sandstone and sandy sandstone. The lower part of the member appears to be reworked Nugget Sandstone. The top of the member contains a light-greenish tuff a few inches thick. The Gypsum Springs Member is 22 feet (7 m) thick along the southeast-facing slope of Mahogany Hills (Imlay, 1967).

The late Bajocian age (Imlay, 1967) Sliderock Member of the Twin Creek disconformably overlies the Gypsum Springs Member. The Sliderock Member consists of medium-gray, fossiliferous, oolitic limestone. *Livingstonensis* sp, *Prorokia fontenellensis, Pleuromya subcompressa,* and *Pholadomya kingi* have been identified in the Sliderock Member exposed in the Mahogany Hills where the member is 47 feet (14 m) thick (Imlay, 1967).

Rich Member (Jtr): The late Bajocian age (Imlay, 1967) Rich Member of the Twin Creek Limestone conformably overlies the Sliderock Member. The Rich Member consists of medium-bedded, medium-gray, shaly limestone with pervasive pencil cleavage at a high angle to bedding. *Quenstedia sublevis* and *Pleuromya subcompressa* have been identified in the Rich Member exposed along the southeast slope of the Mahogany Hills where the member is 125 feet (38 m) thick (Imlay, 1967).

Boundary Ridge Member (Jtbr): The Bathonian age Boundary Ridge Member of the Twin Creek Limestone conformably overlies the Rich Member. The Boundary Ridge Member consists of thin-bedded, yellowish-gray, sandy limestone and brownish-red siltstone. The Boundary Ridge Member is 107 feet (33 m) thick near Peoa (Imlay, 1967).

Watton Canyon Member (Jtwc): The Callovian age (Imlay, 1967) Watton Canyon Member of the Twin Creek Limestone conformably overlies the Boundary Ridge Member. The Watton Canyon Member consists of resistant, medium-gray, medium-bedded limestone. Oolitic beds occur throughout the member. Blocky joints are common making the Watton Canyon Member an important oil reservoir in the Lodgepole field. The Watton Canyon Member is 220 feet (67 m) thick near Peoa (Imlay, 1967).

Leeds Creek and Giraffe Creek Members (Jtlg): The Callovian age (Imlay, 1967) Leeds Creek Member of the Twin Creek Limestone conformably overlies the Watton Canyon Member.

The Leeds Creek Member consists of nonresistant, light-gray, shaly limestone with pervasive pencil cleavage at a high angle to bedding. Occasional resistant sandy limestone beds are present in the upper half of the member. The Leeds Creek Member is 776 feet (227 m) thick near Peoa (Imlay, 1967).

The Callovian age (Imlay, 1967) Giraffe Creek Member of the Twin Creek conformably overlies the Leeds Creek Member. The Giraffe Creek Member consists of nonresistant, gray, shaly limestone with occasional thin, sandy limestone beds. The Giraffe Creek Member is 82 feet (25 m) thick near Peoa (Imlay, 1967).

Preuss Sandstone (Jp)

The Middle Jurassic Preuss Sandstone crops out in the core and along the northern limb of the White's Basin anticline, in the hanging wall adjacent to the Crandall Canyon thrust, and in the hanging wall adjacent to the Cherry Canyon thrust. The Preuss disconformably overlies the Twin Creek Limestone. The Preuss consists of thin-bedded, dull reddish-brown to red, incompetent siltstone, shale, and silty sandstone. Salt has been encountered, in the lower part of the formation, in drill holes throughout the area. Salt flowage locally thickens the Preuss (Bryant, 1990). The Preuss is 1,196 feet (365 m) thick along the Weber River one mile (1.6 km) northwest of Peoa (Thomas and Krueger, 1946). In the Amoco #464B-1 Champlin well (23-1N-5E), on the hanging wall of the Dry Canyon thrust, the Preuss is about 1,700 feet (518 m) thick.

Stump Formation (Js)

The Stump Formation is exposed in the northern limb of the White's Basin anticline and in Crandall Canyon on the hanging wall of the Crandall Canyon thrust where it is thin and mapped together with the Morrison Formation (Jms). The Stump Formation conformably overlies the Preuss Sandstone. The Stump Formation can be divided into three distinct lithologies. The lower part of the formation consists of 41 feet (12 m) of light gray to yellowish, medium-grained sandstone. The middle unit consists of 142 feet (43 m) of incompetent reddish to buff-colored shales, sandy shales, and thin sandstones. The upper unit consists of 40 feet (12 m) of greenish-gray, calcareous and arenaceous limestone, locally glauconitic, and containing numerous conglomeratic lenses. The upper part of the Stump contains *Belemnites densus* (Morris, 1953). The Stump Formation is 223 feet (68 m) thick along the Weber River 1.1 miles (1.8 km) northwest of Peoa (Thomas and Krueger, 1946). The Stump thins westward and is not present in the Wasatch Mountains. There also is no Stump Formation in the hanging wall of the Crandall Canyon thrust at Rockport Lake, but just east of the lake discontinuous exposures up to 30 feet (9 m) thick are present. Continuing eastward, the Stump Formation appears in continuous outcrop reaching a thickness of nearly 130 feet (40 m) 2.8 miles (4.6 km) up Crandall Canyon where the formation crosses the creek (23-1N-5E).

Morrison Formation (Jm)

The Morrison Formation crops out along the northern limb of the White's Basin anticline.

The Morrison Formation conformably overlies the Stump Formation. The Morrison Formation consists of nonresistant, white to purple, soft sandstone interbedded with variegated siltstone. A gray, nodular limestone is present at the base of the formation, a distinctive bright orangish-red, silty sandstone is present in the middle of the formation, and a few discontinuous lenses of chert-pebble conglomerate are present near the top of the formation. The Morrison is 258 feet (79 m) thick along the Weber River 1.2 miles (1.9 km) northwest of Peoa (Mount, 1952). The Morrison thins westward and is not present in the Wasatch Mountains west of the Crandall Canyon area. There also is no Morrison Formation in the hanging wall of the Crandall Canyon thrust at Rockport Lake, but east of the lake thin discontinuous exposures of Morrison appear at the top of the Stump. In the hanging wall of the Crandall Canyon thrust, the Morrison gradually increases in thickness eastward reaching a few tens of feet thick in 25-1N-5E

Cretaceous

The Cretaceous sequence, in ascending order, is represented by the Kelvin, Aspen, Frontier, and Henefer Formations, and the Hams Fork Member of the Evanston Formation. Cretaceous strata range from 13,392 to 13,622 feet (4,082 to 4,152 m) thick.

Kelvin Formation (Kkp, Kk)

The Kelvin Formation crops out along the northern limb of the White's Basin anticline and in the hanging walls of the Crandall Canyon and Cherry Canyon thrusts. In the footwall of the Crandall Canyon thrust the Kelvin Formation conformably overlies the Morrison Formation. Here the Kelvin Formation can be divided into two distinct lithologies. The lower unit contains two to four prominent pebble to cobble conglomerate beds separated by red silty shale and sandstone. Conglomerate clast size ranges from 1 to 8 inches (2.5-20 cm) in diameter along the Weber River approximately one-half mile (0.8 km) south of the Crandall Canyon quadrangle. The clasts are mainly Paleozoic sediments eroded from the Willard thrust plate (DeCelles, 1994). The conglomerate beds progressively decrease in chert content up section and become mainly coarse-grained sandstone with a few limestone boulders included. There are four conglomeratic beds along the Weber River north of Peoa, but only two in the White’s Basin area (35-1N-6E).

The upper unit consists of gray to dark-red, silty sandstone and shale. The late Albian to early Cenomanian bivalve, *Inoceramus dunveganesis*, occurs near the top of the formation (Ryer, 1976). The Kelvin Formation is approximately 2,700 feet (823 m) thick along the Weber River 1.2 miles (2 km) northwest of Peoa in the footwall of the Crandall Canyon and Rockport thrusts (Morris, 1953).

Parley's Member of the Kelvin Formation (Kkp): In the hanging wall of the Crandall Canyon thrust the basal unit of the Kelvin Formation is the Parley's Member. The Parley's Member consists of bright-red to white siltstone (figure 2) and marl with nodules and concretions of very light-gray to white, pedogenic limestone and local lenses of coarse conglomerate (figure 3). The Parley's Member is about 250 feet (76 m) thick at Rockport Lake and thins eastward.

Aspen Shale (Ka)

The Albian Aspen Shale (Cobban and Reeside, 1952) crops out along the northern limb of the White's Basin anticline where it conformably overlies the Kelvin Formation. The Aspen consists of thin-bedded, medium-gray to black, siliceous shales with some silty shale near the top of the formation. Teleost fish scales are abundant in the Aspen making for easy identification of this incompetent unit (figure 4). The Aspen Shale is 525 feet (160 m) thick along the Weber River 1.9 miles (3 km) northwest of Peoa in the footwall of the Crandall Canyon and Rockport thrusts (Morris, 1953).

Frontier Formation

Along the Weber River where exposures are good, it is possible to divide the Frontier Formation into several members. But, within the majority of the Crandall Canyon and Hidden Lake quadrangles, exposures are poor making member subdivision tenuous at best. Within the Crandall Canyon and Hidden Lake quadrangles, the Frontier Formation is divided into three mappable units, in ascending order, a lower member, the Oyster Ridge Sandstone Member, and an upper member.

Lower member (Kfl): The lower member of the Frontier Formation crops out throughout the southern parts of the Crandall Canyon and Hidden Lake quadrangles. The lower member of the Frontier Formation includes, in ascending order, the Longwall, Spring Canyon, Chalk Creek, Coalville, and Allen Hollow Members of Hale (1960). This sequence of rocks consists of interbedded sandstone, conglomeratic sandstone, shale, silty shale, carbonaceous shale, and occasional thin coal. The total thickness of the lower member is about 4,000 feet (1,219 m).

Along the Weber River, in the footwall of the Rockport thrust (10-1S-5E), Hale's (1960) Longwall Member lies conformably on the Aspen Shale. At this location the Longwall Member is about 50 feet (15 m) of resistant, upward-coarsening, shallow marine sandstone (Ryer, 1976). Near Wanship Dam, in the hanging wall of the Dry Canyon thrust, the Longwall Member lies disconformably on the Kelvin Formation. Here the Longwall Member is about 250 feet (76 m) thick (Ryer, 1976).

The Spring Canyon Member conformably overlies the Longwall Member. The Spring Canyon Member consists of nonresistant carbonaceous shale, siltstone, and discontinuous sandstone with occasional thin beds of oyster coquina. The Spring Canyon Member is about 66 feet (20 m) thick near Wanship Dam (Ryer, 1976).

The Chalk Creek Member consists of interbedded medium-grained to conglomeratic sandstone and claystone. The Chalk Creek is about 2,493 feet (760 m) thick along the Weber River in the footwall of the Rockport thrust (Ryer, 1976).

The Coalville Member is truncated by the Rockport thrust so does not crop out within the Crandall Canyon or Hidden Lake quadrangles. In Three Mile Canyon near the Utelite mine (8-1S-5E), the Coalville Member is present but poorly exposed. Ryer (1976) estimated the thickness of the Coalville Member in the vicinity of the Utelite mine to be 164 feet (50 m).

The Allen Hollow Member disconformably overlies the Coalville Member. The Allen Hollow Member consists of incompetent, dark-gray, marine shale containing *Mytiloides opalensis* in the lower part (Ryer, 1976). A complete section of the Allen Hollow Member is not exposed in the Crandall Canyon or Hidden Lake quadrangles. The Allen Hollow Member is truncated in the footwall of the Rockport thrust and folded in the hanging wall; coupled with the general lack of exposure of this incompetent unit, the thickness of the Allen Hollow Member is difficult to determine. Ryer (1976) estimated the thickness of the Allen Hollow Member in the Pine Creek area to be 1,181 to 1,378 feet (360 to 420 m) but he did not recognize the presence of the Rockport thrust. Just northeast of Coalville in Allen Hollow (4-2N-5E), the Allen Hollow Member is 787 feet (240 m) thick (Hale, 1960).

Oyster Ridge Sandstone Member (Kfo): The Oyster Ridge Sandstone Member of the Frontier Formation is present only in the Crandall Canyon quadrangle in the footwall of the Crandall Canyon thrust, eastward it is truncated by the Big Piney thrust. The basal part of the Oyster Ridge Member contains a 66 to 82 feet (20 to 25 m) thick, resistant, ridge-forming, locally pebbly sandstone which is overlain by 200+ feet (61+ m) of interbedded sandstone, siltstone, and shale. The Oyster Ridge Member contains the early middle Turonian ammonite, *Collignoniceras wollgari* (Trexler, 1966).

Upper member (Kfu): The upper member of the Frontier Formation crops out in the footwall adjacent to the Crandall Canyon thrust and along the extension of this trend into the Hidden Lake quadrangle where it lies in the footwall adjacent to Big Piney thrust. The upper member consists of nonresistant, interbedded sandstone, conglomeratic sandstone, shale, silty shale, carbonaceous shale, and occasional thin coal and is rarely exposed within the Crandall Canyon and Hidden Lake quadrangles. Identification of this unit is commonly made by stratigraphic position and by palynomorphs collected from isolated outcrops. The upper member probably correlates with Hale's (1960) Dry Hollow and, perhaps in part, the Grass Creek Members of the Frontier Formation.

Henefer Formation (Kh)

The Henefer Formation crops out in the southeastern part of the Crandall Canyon quadrangle and the southwestern part of the Hidden Lake quadrangle. The Henefer Formation, is the onshore (westward) equivalent of the marine Hilliard Shale of southwestern Wyoming which is Coniacian near the base and Santonian in the upper part (Nichols, 1979). In the Crandall Canyon and Hidden Lake quadrangles the Henefer consists of siltstone, shale, sandstone, and occasional conglomeratic sandstone. Most of the unit is incompetent and rarely exposed. The Henefer Formation is identified by an angular unconformity with the underlying Frontier Formation and by palynomorphs collected from isolated outcrops. Due to the general lack of exposure and the possibility of repetition on imbricates of the North Flank thrust system, the thickness of the Henefer is difficult to determine. The estimated thickness of the Henefer

Formation in the Perdue and Neil Creek drainages (plate 1, Hidden Lake quadrangle) is over 4,300 feet (1,311 m) thick.

Evanston Formation

The Evanston Formation can be divided into two members, the Hams Fork Member and the main body of the Evanston. The Hams Fork Member has been dated as Maastrichtian in Cherry Canyon (Royse and others, 1975). The main body of the Evanston Formation in the Coalville anticline, 3 miles (4.8 km) north of the Crandall Canyon quadrangle, is Paleocene. Palynomorphs show a 4 million year hiatus between the Hams Fork Member and the main body of the Evanston Formation (Jacobson and Nichols, 1982).

Hams Fork Member of the Evanston Formation (Ke): The Hams Fork Member of the Evanston Formation consists of light-gray to brown, friable sandstone interbedded with medium-gray to black shale. A 10 to 50 feet (3 to 15 m) thick, cobble to boulder conglomerate locally crops out at the base of the formation (figure 5). Throughout the region clasts in this basal conglomerate are largely Cambrian Tintic and Proterozoic Mutual and Big Cottonwood Formations eroded from the Paris-Willard thrust sheet (Crawford, 1979; DeCelles, 1994), however locally, Cretaceous clasts are present. The Hams Fork Member is 2,117 feet (645 m) thick in Cherry Canyon (Larson, 1951).

The Hams Fork Member of the Evanston Formation overlies the Frontier Formation with a marked angular unconformity near the head of Dry Canyon (26-1N-5E; figure 6). The angular unconformity diminishes to zero 1.7 miles (3 km) westward at the Weber River. In the upper parts of Crandall Canyon (plate 1, Crandall Canyon quadrangle) and in the Neil Creek drainage (plate 1, Hidden Lake quadrangle) the Hams Fork Member overlies the Henefer Formation with a marked angular unconformity.

Tertiary

The Tertiary sequence is represented by the main body of the Evanston Formation, the Wasatch Formation, the Keetley volcanics, gravel deposits associated with older erosional surfaces, and some intrusive rocks.

Main body of the Evanston Formation (Te)

There is an angular discordance between the Hams Fork Member of the Evanston Formation and the overlying rocks in the Neil Creek drainage (23 & 24-1N-6E; plate 1, Hidden Lake quadrangle). Bryant (1990) interprets this angular discordance as a south-dipping imbricate of the north flank thrust system which repeats the Hams Fork Member. The 4 million year hiatus between deposition of the Maastrichtian Hams Fork Member and the Paleocene main body of the Evanston Formation was a period of active tectonics throughout the area. Therefore, without further evidence of thrusting, I interpret the angular discordance of bedding in the Neil Creek drainage as an angular unconformity between the Hams Fork Member and the main body of the

Evanston Formation. There are no outcrops of the main body of the Evanston Formation in the Neil Creek drainage from which to collect samples for palynological analysis. Float reveals these rocks to be light-gray to brown, friable sandstone and medium-gray to black shale. The exposed thickness of the main body of the Evanston Formation in Neil Creek is 800+ feet (244+ m).

Wasatch Formation (Tw)

The Wasatch Formation crops out through out the northern half of both the Crandall Canyon and Hidden Lake quadrangles. The Wasatch Formation overlies all older formations with a marked angular unconformity. The Wasatch consists of yellowish-brown, massive, cobble to boulder conglomerate interbedded with red, buff to gray sandstone and red to gray to purple shale. The Wasatch Formation is 0 to 2,600 feet (0 to 792 m) thick in the northern parts of the Crandall Canyon and Hidden Lake quadrangles. Palynomorphs collected within the Crandall Canyon quadrangle (appendix; plate 1, Crandall Canyon quadrangle) show the Wasatch Formation to be late Paleocene (Bryant, 1990).

Keetley Volcanics

Keetley Volcanic rocks are exposed along the southern border of the Crandall Canyon quadrangle. The Keetley volcanics are divided into two mappable units, the tuff member and the Silver Creek member.

Tuff member (Tkt): The basal unit of the Keetley Volcanics is a tuff which unconformably overlies older formations. The tuff member consists of buff-colored, fine to coarse-grained, partially water-reworked tuff, lapilli tuff, and thin lahars. The tuff member is an eastward extension of Bromfield and Crittenden's (1971) mapping in the Park City East quadrangle. The tuff member, in part, is equivalent to the Peoa Tuff of Willes (1962). The tuff member is 0 to 840 feet (0 to 256 m) thick in the Crandall Canyon quadrangle.

Silver Creek member (Tksc): The Silver Creek member of the Keetley Volcanics overlies the tuff member. The Silver Creek member consists of rhyodacite to andesite flow breccias and laharic breccias (figure 7) extruded 33 to 35 Ma (Woodfill, 1972) from vents 3 miles (5 km) northeast of Keetley, Utah (Bromfield, 1968). The Silver Creek member is an eastward extension of Bromfield and Crittenden's (1971) mapping in the Park City East quadrangle. The Silver Creek Member ranges from 600 to 1,000 feet (183 to 305 m) thick in the southern part of the Crandall Canyon quadrangle.

Gravel Deposits (Tg)

An unconsolidated, well-rounded boulder to cobble gravel occurs on Maple Ridge (9-1S-6E) in the Crandall Canyon quadrangle. The gravel contains boulders derived from the Wasatch Formation and locally from the Keetley Volcanics. The gravel is a lag deposit associated with an erosional surface that developed throughout the area, most likely during Oligocene or Miocene.

Lamprophyres (Tlam)

Several small lamprophyre dikes and pods crop out in Whites Basin and vicinity. In hand specimen, these rocks contain phlogopite phenocrysts in a dark aphanitic matrix. Thin section analysis by Morris (1953) shows the major constituents to be nepheline (40%), phlogopite (28%), and augite (25%). $^{40}Ar/^{39}Ar$ age determinations on phlogopites by Mitchell and Berman (1991) show these rocks to have been intruded 13.9-14.8 Ma.

Quaternary

Stream alluvium (Qal)

This unit consists of unconsolidated gravel, sand, silt, and clay deposited in channels and floodplains of larger streams. The deposits are Holocene in age and are generally less than 15 feet (5 m) thick.

Mixed alluvial and colluvial deposits (Qac)

Mixed alluvial and colluvial deposits occur as unconsolidated gravel, sand, silt, and clay deposited along the sides and valley bottoms of the larger secondary drainages. The deposits are generally less than 10 feet (3 m) thick and are interpreted as late Pleistocene to Holocene in age.

Colluvial deposits (Qc)

Colluvial deposits consist of unconsolidated, silt to boulder size debris carried by slope wash and deposited along the slopes of some ridges. These deposits generally occur in areas of gentler slope directly below areas of steeper slope. The deposits are commonly less than 10 feet (3 m) thick occurring as a veneer over other units and are interpreted as late Pleistocene to Holocene in age.

Terrace alluvium (Qat, Qat_1, Qat_2, Qat_3, Qat_4)

Older alluvial deposits are in terraces along the Weber River and the South Fork of Chalk Creek where they lie above the modern floodplain. The terrace alluvium consists of unconsolidated deposits of gravel, sand, silt, and clay up to 100 feet (30 m) thick. In areas where there are multiple terraces, the terraces are numbered consecutively with the youngest (lowest) terrace designated Qat_1. There are four levels of terraces in the Weber River valley and three levels of terraces along the South Fork of Chalk Creek in the Hidden Lake quadrangle (plate 1, Hidden Lake quadrangle). Qat_1 is approximately 20 feet above the current stream level, Qat_2 is approximately 40 feet above the current stream level, Qat_3 is approximately 80 feet above the current stream level, and Qat_4 is approximately 120 feet above the current stream level. There is only one level of terrace exposed within the Crandall Canyon quadrangle so this terrace is labeled Qat. The terrace in the Crandall Canyon quadrangle is not equivalent to any of the terraces in the Hidden Lake quadrangle. The terrace deposits represent former valley floor levels and are interpreted as late Pleistocene to Holocene in age.

Alluvial-fan deposits (Qaf)

Alluvial fan-deposits occur as unconsolidated gravel, sand, silt, and clay deposited where smaller streams with more constricted valleys enter into the wider valleys of higher order streams such as the Weber River valley. The deposits range from a thin veneer to about 10 feet (3 m) thick. Modern alluvial fans (Holocene) are designated Qaf_1. There is one older (late Pleistocene to early Holocene) inactive remnant of an alluvial fan at the mouth of Shingle Mill Creek designated Qaf_2.

Landslide deposits (Qmsy, Qmso)

Mass-wasting deposits are common through out the Crandall Canyon and Hidden Lake quadrangles. The majority of the mass-wasting deposits are debris slumps, slides, or flows in which rock, soil, trees, etc. moved downslope. The deposits are characterized by chaotic blocks of various sizes. Most of the mass-wasting deposits are interpreted to be late Pleistocene to early Holocene in age, these "older" deposits are labeled Qmso. Younger deposits (Qmsy) ranging in age from a few years to perhaps a few hundred years are also present throughout the area. Mass wasting deposits are generally less than 100 feet (30 m) thick, but some of the deposits are quite large exceeding a few square miles in area.

Talus deposits (Qmt)

This unit consists of unconsolidated angular blocks, boulders, and smaller fragments deposited on some of the steeper slopes in the Uinta Mountains in the Hidden Lake quadrangle. The deposits are Pleistocene to Holocene in age and range from a thin veneer to about 20 feet (6 m) thick.

Glacial deposits (Qgo, Qgy)

Glacial deposits are present in the southern part of the Hidden Lake quadrangle in the Nobletts Creek and Shingle Mill Creek (figure 8) drainages in the Uinta Mountains and in the northeastern part of the quadrangle in the upper reaches of the South Fork of Chalk Creek (10 & 11-1N-7E; figure 9). The glacial deposits consist of poorly sorted bouldery till that forms lateral, terminal, and recessional moraines up to a few tens of feet thick in the Nobletts and Shingle Mill Creek drainages and hummocky moraines in the South Fork of Chalk Creek drainage. There are two distinct ages of moraines in the Noblett's Creek drainage, an older (Qgo) more extensive glaciation that extended downslope to an elevation of about 8,000 feet (2,438 m) and a younger (Qgy) period of glaciation that extended downslope to an elevation of about 8,600 feet (2,621 m). The glacial deposits in Shingle Mill Creek and the South Fork of Chalk Creek correlate to the older period (Qgo) of glaciation in Noblett's Creek. The glacial deposits are most likely Pinedale age (Oviatt, 1994).

STRUCTURE

Thrust Faults

The Crandall Canyon and Hidden Lake quadrangles lie at the northwestern edge of the Uinta Mountains and along the southeastern margin of the Utah-Idaho-Wyoming salient of the Sevier overthrust belt. The southern edge of Sevier thrust sheets were folded about the Uinta arch and subsequent erosion has exposed four of these thrusts in the Crandall Canyon quadrangle. These northwest-dipping thrust faults exposed in the Crandall Canyon quadrangle are, from north to south, the Cherry Canyon, Dry Canyon, the Crandall Canyon, and Rockport thrusts (plate 1, Crandall Canyon quadrangle).

There are three south-dipping thrust faults associated with North Flank thrust system of the Uinta Mountains (Bradley, 1988) exposed in the Crandall Canyon and Hidden Lake quadrangles. These thrusts, from south to north, are the Mahogany Hills, Big Piney, and Perdue Creek thrusts.

Cherry Canyon Thrust

Along the south-facing slope of Cherry Canyon near the mouth of the canyon (15-1N-5E), the Cherry Canyon thrust can be seen dipping about 55° to the northwest. At this location, the Jurassic Preuss Formation is thrusted over the Maastrichtian Hams Fork Member of the Evanston Formation. North of Cherry Canyon, the thrust cuts Paleocene Wasatch Formation in the footwall. The Cherry Canyon thrust is cut by a normal fault (2-1N-5E) but continues in the subsurface north of the Crandall Canyon quadrangle into the Chalk Creek area where the Coalville anticline formed as a large hanging wall anticline on the Cherry Canyon thrust or a blind imbricate associated with it.

To the west of the Crandall Canyon quadrangle, 0.6 miles (1 km) up Bridge Hollow (30-1N-5E), the Cherry Canyon thrust is buried beneath Oligocene Keetley volcanic rocks, but re-emerges in a window in the volcanic cover in a small unnamed canyon along Interstate Highway 80 (35-1N-4E). The westernmost exposure of the Cherry Canyon thrust is at the mouth of Tollgate Canyon (35-1N-4E; I-80 Ranch Exit) where the Preuss Formation is still thrust against the Hams Fork Member of the Evanston Formation. West of Tollgate Canyon the fault is once again buried under Keetley volcanic rocks.

The geometry of the Cherry Canyon thrust surface is partially revealed in the exposures from Tollgate Canyon on the west to Pecks Canyon on the east. From Tollgate Canyon to about where the thrust crosses Cherry Canyon, a distance of about 5.5 miles (8.8 km), the Cherry Canyon thrust remains on a hanging wall flat. From Cherry Canyon to Hixon Canyon (15-1N-5E), a distance of about 1 mile (1.6 km), the thrust ramps (hanging wall) from the Jurassic Preuss Formation to the lower part of the Cretaceous Kelvin Formation where the thrust once again enters a hanging wall flat. Along the hanging wall ramp the Cherry Canyon thrust rises about 2,000 feet (610 m) in stratigraphic section over a distance of about 5,000 feet (1,529 m) for a ramp dip of about 22°. The corresponding footwall equivalents of these ramps and flats would lie west of Tollgate Canyon, most likely buried beneath the Oligocene Keetley volcanics.

The major displacement on the Cherry Canyon thrust is interpreted as Late Cretaceous based upon the Maastrichtian Hams Fork Member of the Evanston Formation lying directly on the Lower Cretaceous Kelvin Formation on the hanging wall of the thrust in Spring Canyon. The truncation of the Wasatch Formation north of Cherry Canyon is interpreted as a minor Paleocene reactivation.

Dry Canyon Thrust

The Dry Canyon thrust is exposed over a distance of 5 miles (8 km) in Dry Canyon and Kent Canyon (Crandall Canyon and Wanship quadrangles). In Kent Canyon, the trace of the Dry Canyon fault emerges from beneath the Oligocene Keetley volcanic cover of The West Hills (6-1S-5E), crosses Rockport Lake, and continues up Dry Canyon (figure 1). At the head of Dry Canyon (25-1N-5E), the fault is buried beneath the younger Maastrichtian Hams Fork Member of the Evanston Formation. In Dry Canyon, the Dry Canyon thrust dips steeply to the northwest and places the lower Frontier Formation over the Kelvin Formation. The steep dip and younger over older relationship on the Dry Canyon fault led Larson (1951) to interpret the fault as a normal fault, but regional work shows this fault to be a thrust emplaced at a shallow angle and later folded to a steep dip about the Uinta arch. As can be seen in structural cross section A-A' (plate 2, Crandall Canyon quadrangle), the Frontier Formation in the hanging wall of the Dry Canyon thrust corresponds to the Frontier Formation in the footwall of the Crandall Canyon thrust, not the Frontier Formation in the hanging wall of the Crandall Canyon thrust which has been eroded away, thus the "younger" over "older" relationship at the surface is misleading. Bryant (1990) correlated the Dry Canyon thrust with the Medicine Butte thrust, but this correlation is tenuous and not used in this report.

Crandall Canyon Thrust

The Crandall Canyon thrust places the Jurassic Preuss Formation over the Cretaceous Frontier Formation throughout most of its 5.9 mile (9.5 km) exposed length in the Crandall Canyon and adjacent Wanship quadrangles (figure 10). In The West Hills (7-1S-4E, Wanship quadrangle) 1.6 miles (2.6 km) up Three Mile Canyon, the Crandall Canyon thrust emerges from under Oligocene Keetley volcanics. At the mouth of Three Mile Canyon (5-1S-5E, Wanship quadrangle) the Crandall Canyon thrust dips 60° northwest and truncates the upper half of the early middle Turonian (Cobban and Reeside, 1952; Trexler, 1966) Oyster Ridge Member of the Frontier Formation. The thrust dip steepens eastward, overturning to the southeast in 35-1N-5E. The major transport direction on the Crandall Canyon thrust is eastward at a small to moderate angle to the trace of the thrust. The present geometry of the thrust is a consequence of folding about the Uinta arch.

The Crandall Canyon thrust is a major thrust that should be regionally correlatable but the specific correlation is not straight forward because the thrust is buried beneath Oligocene volcanic rocks to the west and Tertiary sedimentary rocks to the east. Based upon seismic surveys, drill hole data, and surface mapping the Crandall Canyon thrust most likely correlelates with the Absaroka thrust in southwestern Wyoming (Lamerson, 1982).

To the west, the Crandall Canyon thrust correlates with the Mount Raymond thrust in the Wasatch Mountains (figure 1; Mount, 1952; Crittenden, 1974; Lamerson, 1982; Bradley and Bruhn, 1988). There are two splays of the Mount Raymond thrust at the mouth of Neffs Canyon (1-2S-1E) along the Wasatch Front (Crittenden, 1965a). The stratigraphically lowest splay lies within the Cumbrian Ophir Formation. Both splays ramp up stratigraphic section to the east along the footwall, reaching Triassic strata by the location where the two splays rejoin 13 kilometers east of the Wasatch Front (Crittenden 1965b, 1966). The easternmost exposure of the Mount Raymond thrust is near Snyderville, Utah where the Mount Raymond thrust is folded around the Dutch Draw syncline. In the Dutch Draw syncline the Mount Raymond thrust is on a footwall flat in the Jurassic Twin Creek Formation. Between the easternmost exposure of the Mount Raymond thrust and the westernmost exposure of the Crandall Canyon thrust in Three Mile Canyon, the thrust ramps (footwall) from the Jurassic Twin Creek Formation to the lower part of the Cretaceous lower member of the Frontier Formation. In the easternmost exposures, the Crandall Canyon thrust is on a footwall flat in the upper member of the Frontier Formation. So, the Mount Raymond/Crandall Canyon thrust ramps from Cambrian strata at the Wasatch Front to Upper Cretaceous strata in Crandall Canyon. Much of this system of ramps and flats is exposed which presents an excellent opportunity to study the three-dimensional geometry of a major Sevier overthrust, the Absaroka thrust.

Rockport Thrust

The Rockport thrust is a footwall imbricate of the Crandall Canyon thrust, rejoining the Crandall Canyon thrust at the Utelite Mine in Three Mile Canyon (8-1S-5E). The Rockport thrust was unrecognized by early workers in the area because the trace of the thrust lies within incompetent shales and sandstones of the Allen Hollow Member (lower member) of the Frontier Formation. The presence of the Rockport thrust is clearly shown by the hanging wall deformation and the angular discordance in bedding across the trace of the thrust (figure 11). The name Rockport thrust is proposed for this fault because of its proximity to the former town of Rockport, Utah.

Mahogany Hills Thrust

The Mahogany Hills thrust, an imbricate of the North Flank thrust of the Uintas, emerges from beneath Quaternary sediments in the Weber River valley at the mouth of Perdue Creek (31-1N-7E). The thrust bifurcates creating a horse in White's Basin for a distance of about 1.5 miles (2.4 km). Displacement on the Mahogany Hills thrust rapidly diminishes westward and dies out beneath Oligocene Keetley volcanic cover on Maple Ridge (9-1S-6E). The name Mahogany Hills thrust is proposed for this fault because much of its exposed trace is in the Mahogany Hills.

Big Piney Thrust

The Big Piney thrust, an imbricate of the North Flank thrust, emerges from beneath Quaternary sediments in the Weber River valley at the mouth of Perdue Creek (31-1N-7E) and extends along the north-facing slope of Big Piney Mountain. The position of the thrust is marked by a change in the vegetation from forest to grassy meadow (figure 12). Across the fault there is an abrupt change in the dip of bedding. In the Crandall Canyon quadrangle, beds in the hanging wall adjacent to the thrust commonly have moderate northwest dips, whereas beds in the footwall are overturned, dipping steeply to moderately to the southeast (plate 1, Crandall Canyon quadrangle). At the mouth of Perdue Creek, Jurassic Preuss Formation is thrusted over the upper member of the Cretaceous Frontier Formation (plate 1, Hidden Lake quadrangle). Displacement rapidly diminishes westward of Perdue Creek so that by the time the Big Piney thrust reaches the Crandall Canyon thrust no displacement exists. The name Big Piney thrust is proposed for this fault because much of its exposed length is on the northwest-facing slope of Big Piney Mountain.

Perdue Creek Thrust

The Perdue Creek thrust, another imbricate of the North Flank thrust, emerges from beneath Quaternary cover in the Weber River valley in 32-1N-7E and extends north of and subparallel to the Big Piney thrust (plate 1, Hidden Lake quadrangle). Along much of its trace, the position of the thrust is marked by an angular discordance between the upper member of the Frontier Formation and the Henefer Formation. The Perdue Creek thrust joins the Big Piney thrust in 28-1N-6E (plate 1, Crandall Canyon quadrangle). The name Perdue Creek thrust is proposed for this fault because of its proximity to Perdue Creek.

Normal Faults

Several normal faults with trace lengths greater than one mile are exposed in the Crandall Canyon quadrangle. Three normal faults of note lie in the hanging wall of and subparallel to the trace of the Cherry Canyon thrust (plate 1, Crandall Canyon quadrangle). These faults offset strata as young as Paleocene Wasatch Formation. Another normal fault lies in Pine Creek subparallel to the trace of the Rockport thrust. This fault is truncated by the thrust and appears to be associated with it. A northwest-trending normal fault offsets the Big Piney and Rockport thrusts (36-1N-5E). Displacement on this fault is relatively minor, amounting to only a few hundred feet. Lastly, a normal fault in White's Creek shows minor offset that dies out northward. There is no evidence of Quaternary activity on any of these faults. However, it should be noted that a north-trending, down to the west, normal fault that extends along the east side of Kamas (formerly Rhodes) valley (figure 1) offsets Quaternary sediments at the mouth of Seymour Canyon just 2 miles (3.4 km) south of the Crandall Canyon quadrangle.

Small-scale normal faults with trace lengths of less than a mile are common throughout the quadrangles. Many of these faults strike northwest and appear to have formed in response to tensional stresses during uplift of the area. There is no evidence that any of these faults have been active in the Quaternary.

Folds

The largest fold in the area is the White's Basin anticline which extends from the southeastern part of the Crandall Canyon quadrangle into the southwestern part of the Hidden Lake quadrangle. There are also folds in the hanging walls of the Cherry Canyon, Dry Canyon, Crandall Canyon, Rockport, and Mahogany Hills thrusts. The Coalville anticline is a large hanging wall anticline developed on the Cherry Canyon thrust but lies north of the Crandall Canyon quadrangle so will not be further discussed here.

The White's Basin anticline is an open, upright, moderately (east) plunging fold. The southeastern limb of the White's Basin anticline is truncated by the Mahogany Hills thrust making the anticline pre- to early synkinematic with displacement on the Mahogany Hills thrust.

The Dry Canyon anticline, named by Morris (1953), in the hanging wall of the Dry Canyon thrust is exposed at Wanship Dam (29-1N-5E) and continues eastward into the Crandall Canyon quadrangle. The Dry Canyon anticline is an open, steeply inclined, gently northeast and east plunging, northwest verging fold with an amplitude of 0.9 miles (1.5 km). Both limbs of the anticline are truncated against the Dry Canyon fault (Wanship quadrangle); showing that this fold predates the Dry Canyon thrust. The anticline is overlapped by the Maastrichtian Hams Fork Member of the Evanston Formation showing that the anticline is older than Maastrichtian. The Amoco #1 WI (Rockport Reservoir) well (21-1N-5E) tested the Dry Canyon anticline for hydrocarbons. The Amoco #464B-1 Champlin well (23-1N-5E) tested the extension of the Dry Canyon anticline beneath the Evanston Formation. Both wells were drilled through the Dry Canyon thrust to the Jurassic Nugget Formation and declared dry holes. The southeastern limb of the anticline is folded into a syncline which approximately parallels the trend of the anticline (27, 28, and 33-1N-5E). The syncline is truncated by the Dry Canyon fault to the southwest and an unnamed normal fault to the northeast, so has a more limited aerial extent than the Dry Canyon anticline.

There is a syncline-anticline pair of folds on the hanging wall of the Crandall Canyon thrust (25, 26, and 27-1N-5E). The folds are close, steeply inclined, and steeply plunge to the northwest. Both folds are truncated by both the Crandall Canyon and Dry Canyon thrusts; showing that these folds predate major movement on the Crandall Canyon and Dry Canyon thrusts.

An anticline in the hanging wall of the Rockport thrust can be traced over a lateral distance of nearly 1.25 miles (2 km) (2 & 3-1S-5E). The incompetency of the strata comprising the Allen Hollow Member of the lower Frontier Formation and the consequent lack of outcrop in this area hinder any attempt to clearly define this fold. The fold appears to be a gentle, upright anticline which gently plunges to the east. The northern limb of the anticline is truncated by a high angle normal fault that lies in Pine Creek.

There is an anticline-syncline pair of folds in the Mahogany Hills on the hanging wall of the Mahogany Hills thrust. Five members of the Twin Creek Formation were mapped in this area to help define these folds.

ECONOMIC GEOLOGY

Oil and Gas

Part of the Lodgepole field is within the quadrangles and other oil and gas exploration wells have been drilled in the area (see appendix). In 1976, American Quasar completed the 35-1 UPRR well in the Twin Creek Formation with an initial potential of 128 barrels of oil per day (BOPD) and 76 thousand cubic feet of gas per day (MCFGPD). The 35-1 well, the discovery well for the Lodgepole field, has produced about 46,000 barrels of 34° API gravity oil through July, 1997. The porosity of the Twin Creek Formation in the Lodgepole Field averages 3 percent (Benson, 1993). Production is from numerous fractures in the Watton Canyon, and to a lesser extent the Leeds Creek and Giraffe Creek Members of the Jurassic Twin Creek Formation.

In 1977, American Quasar completed the 34-1 Judd well in the Jurassic Nugget Formation in the Lodgepole field with an initial potential of 1046 BOPD and 437 MCFGPD. The 34-1 well has produced 233,946 barrels of 43° API gravity oil and 118,516 MCFG through July, 1997. The porosity in the Nugget Formation averages 10 percent and the permeability averages 229 millidarcies (md) (Benson, 1993).

Advances in directional drilling technology and production, largely through ubiquitous vertical fractures, made the Twin Creek Formation a prime target for horizontal drilling. There are four horizontal wells in the Lodgepole field. The Union Pacific Resources 34-1H Judd well was drilled 3,587 feet (1,093 m) horizontally (bottom hole location: 4088 FSL 1761 FWL 34-2N-6E). The well had an initial potential of 160 BOPD, 40 MCFGPD, and 30 barrels of water per day (BWPD) from the Watton Canyon Member of the Twin Creek Formation. The Union Pacific Resources 35-2H well has two horizontal laterals one 2,900 feet (884 m) to the east-northeast and the other 2,000 feet (610 m) to the south. The well had an initial potential of 722 BOPD of 42° API gravity oil, 140 MCFGPD, and 262 BWPD from the Watton Canyon Member of the Twin Creek Formation. The Union Pacific Resources 4-1H Judd well has a 3,700 feet (1,128 m) lateral to the southwest. The well had an initial potential of 308 BOPD, 59 MCFGPD, and 41 BWPD from the Watton Canyon Member of the Twin Creek Formation.

Total production from the Twin Creek and Nugget Formations in the Lodgepole field through July, 1997 has been 1,788,000 barrels of oil, 686,000 MCFG, and 4,120,000 barrels of water.

In 1978, Colorado Energetics completed the 33-11 UPRR-Gilmore well in the Kelvin Formation with an initial potential of 370 MCFGPD, which “discovered” the Lodgepole South field. However, no commercial production has been recorded from this field.

The Lodgepole field is on trend with the Pineview and Elkhorn fields. The trend of these fields continues southwestward into the Crandall Canyon quadrangle and two wells have been drilled on this trend. In 1982-83, Amoco drilled the 464B-1 Champlin (23-1N-5E) well to a total depth of 12,725 feet (3,879 m) along the trend of the Dry Canyon anticline, which is on trend with the Lodgepole, Elkhorn, and Pineview fields. The well tested the Jurassic Nugget Formation and was plugged and abandoned. In 1983 Exxon drilled the 9-1 UPRR (9-1N-6E) well to a total depth of 15,183 feet (4,628 m; plate 2). The well tested the Jurassic Nugget Formation and was plugged and abandoned.

A few other dry holes are of note because they help to define the structure of the area (plates 1 and 2). The Amoco 33-11 UPRR-Gilmore well encountered the Absaroka thrust at an elevation of 5,611 feet (1,710 m) below sea level. The Amoco 494-A1 well reached a total depth of 6,035 feet (1,839 m) in the Henefer Formation and was plugged and abandoned. The Amoco 495-A1 well reached a total depth of 5,174 feet (1,577 m) in the Henefer Formation and was plugged and abandoned.

Phosphate

Phosphorite is present in the Meade Peak Tongue of the Phosphoria Formation in the quadrangle, but the Phosphoria hasn't been mined in this area. Analyses of the Meade Peak Tongue in Fransen (Pinon) Canyon in the Hoyt Peak quadrangle (14-1S-6E) are reported in Cheney and others (1953).

Sand and Gravel

The gravel pits on the Hidden Lake topographic quadrangle are in the Twin Creek Limestone (1-1S-6E, 6-1S-7E). The Twin Creek is used locally as road metal in northern Utah because abundant fractures produce rock fragments that, on weathering, are the right size for road gravel. The Utah Department of Highways (1967) provided analyses for material from one of these pits and another gravel pit, possibly in a Weber River terrace (SESESE 31-1N-7E).

WATER RESOURCES

Surface

Historical daily streamflow data is available for four wells in the Crandall Canyon and Hidden Lake quadrangles. The Weber River streamflow has been monitored continuously since 1905. Crandall Creek, Shingle Mill Creek, and the South Fork of the Weber River are no longer monitored but present streamflows are probably comparable to historic averages. Figure 13 shows the historical discharge for each of these streams. Table 1 provides a more detailed look at the average monthly discharge in each of the four streams. As can be seen from table 1, there is a dramatic increase in discharge due to Spring runoff during the months of May and June and to a lesser extent during the latter part of April and the first part of July.

Ground Water

Most of the water wells within the Crandall Canyon and Hidden Lake quadrangles produce from Quaternary sediments in the Weber River valley, which is where most of the housing development has occurred. These sediments exhibit good porosity and permeability and are good water producers with minimal draw down. The best estimate to the depth of the local water table in the Quaternary sediments of the Weber River valley is at the elevation of the surface water in the Weber River at a location closest to the well. A well drilled at 2400 FSL 2670 FWL 27-1N-7E in July, 1987 is a good example of a well producing from the Quaternary sediments in the Weber River valley. This well produces 42 gallons per minute (GPM) from perforations at 58 to 76 feet (18 to 23 m) below the ground surface.

Table 1. Average monthly streamflow data during a typical year for Crandall Creek, Shingle Mill Creek, South Fork of the Weber River, and the Weber River near Oakley. Discharge is given in cubic feet per second (CFS) and gallons per minute (GPM). Data from the U. S. Geological Survey

	Crandall Creek (1971)		Shingle Mill Ck. (1967)		S. Fork Weber (1968)		Weber River (1995)	
	CFS	GPM	CFS	GPM	CFS	GPM	CFS	GPM
JAN	1.2	547	2.3	1,022	8.8	3,935	51.2	22,992
FEB	1.4	611	2.3	1,012	8.8	3,664	60.6	27,202
MAR	1.9	860	2.9	1,306	8.9	3,974	104.3	46,809
APR	11.0	4,925	5.3	2,383	10.5	4,726	151.7	68,073
MAY	27.0	12,104	50.8	22,801	43.0	19,314	477.4	214,266
JUN	9.8	4,387	99.7	44,749	123.5	55,416	1355.0	608,181
JUL	1.9	847	30.3	13,614	29.8	13,378	823.6	369,678
AUG	1.2	521	5.8	2,606	17.8	7,978	178.5	80,138
SEP	0.4	184	3.8	1,704	12.7	5,700	131.1	58,842
OCT	0.8	356	3.3	14,623	11.1	4,966	118.9	53,353
NOV	0.9	391	2.7	1,207	10.9	4,907	72.3	32,451
DEC	0.9	395	2.4	1,092	9.8	4,400	61.9	27,770

There are very few wells that produce from bedrock within the Crandall Canyon or Hidden Lake quadrangles. One well located at 1090 FNL 2510 FEL 6-1S-7E (near Hidden Lake) produces 33 GPM from perforations in the Jurassic Nugget Formation at 115 to 119 feet (35 to 36 m) and 200-235 feet (61 to 72 m) below the ground surface. Another well, in Crandall Canyon (660 FSL 1150 FEL 34-1N-5E) in June, 1998, encountered the water table at 29 feet (9 m; at about the elevation of the surface water in Crandall Creek) and produced 10 GPM from perforations at depths of 160 to 180 feet (40 to 55 m) and 200-240 feet (61 to 73 m) from conglomerates in the upper member of the Frontier Formation. This well, however, had 180 feet (55 m) of draw down during a four hour pumping test; indicating that the aquifer has relatively low permeability.

GEOLOGIC HAZARDS

Landslides

There are several mass-wasting (landslide) deposits of various sizes on Elkhorn Divide and vicinity which involve the Wasatch Formation. The reasons for this are that the slopes are steep in this area and that the Wasatch has numerous horizons that are not very well-indurated. The largest deposits are debris slumps that are interpreted to have been most active during the late Pleistocene. These slumps can be quite large involving areas up to 3 square miles (9 square kilometers); the slump in 1, 11, & 12-1N-6E (plate 1, Hidden Lake quadrangle) and the slump in 10 & 15-1N-6E (plate 1, Crandall Canyon quadrangle) being good examples. These slump blocks have hummocky surfaces with locally poor drainage which sets them up for reactivation during wet years. In 1995 or 1996 a debris slide occurred along the northern edge of the debris slump in SW 8-1N-7E. Older debris slides and flows involving the Wasatch formation are also present in the Crandall Canyon. An example is in 22, 23, & 24-1N-5E (plate 1, Crandall Canyon quadrangle). Aerial photographs taken in 1978 (USDA 40 49043 178-213, 8-24-78) show movement on the slide in 20, 21, & 29-1N-6E that is not present in aerial photographs taken in1962 (DRU-2BB 129, 7-21-62).

Most other smaller mass-wasting deposits initiate on steep slopes in incompetent units within Cretaceous strata. Examples of these deposits can be seen along the south-facing slope of Big Piney Mountain (plate 1, Crandall Canyon quadrangle) and in the Perdue Creek drainage (plate 1, Hidden Lake quadrangle).

Several housing developments are built on mass-wasting deposits along the Weber River in the Hidden Lake quadrangle. No evidence of current movement was present but since reactivation of landslides is common throughout the area these areas should be considered at risk.

Flooding

There are several houses within the floodplain of the Weber River, commonly being only a few feet in elevation above the present stream level. These houses are at risk of being flooded during high runoff years. The floodplain of the Weber River is identifiable as Quaternary alluvium on the geologic maps.

ACKNOWLEDGMENTS

I would like to thank Jon King for his lessons in mapping surficial deposits and his thoughtful reviews of the geologic maps and the manuscript. I would also like to thank Doug Sprinkel for his assistance in identifying the members of the Twin Creek Formation. This research was supported by grants from the Utah Geological Survey and Eastern Michigan University.

REFERENCES CITED

Benson, A.K., 1993, Lodgepole field, *in* Hill, B.G. and Bereskin, S.R., editors, Oil and gas fields of Utah: Utah Geological Association Publication 22, unpaginated.

Best, M.G., Henage, L.F. and Adams, J.A.S., 1968, Mica peridotite, wyomingite, and associated potassic igneous rocks in northeastern Utah: American Mineralogist, v. 53, p. 1041-1048.

Bissell, H.J., 1964, Lithology and petrography of the Weber Formation, in Utah and Colorado, *in* Sabatka, E.F., editor, Guidebook to the geology and mineral resources of the Uinta Basin, Utah's hydrocarbon storehouse: Intermountain Association of Petroleum Geologists, 13th Annual Field Conference, p. 67-91.

Bradley, M.D., 1995, Timing of the Laramide rise of the Uinta Mountains, Utah and Colorado, *in* Jones, Richard, editor, Resources of southwest Wyoming: Wyoming Geological Association 1995 Field Conference Guidebook, p. 31-44.

Bradley, M.D., 1988, Structural evolution of the Uinta Mountains, Utah, and their interaction with the Utah-Wyoming salient of the Sevier overthrust belt [Ph.D. dissertation]: Salt Lake City, Utah, University of Utah, 178 p., scale 1:24,000

Bradley, M.D., 1986, Thrust splay correlation in the Absaroka thrust system of north central Utah: Geological Society of America Abstracts with Programs, v. 18, no. 5, p. 343.

Bradley, M.D. and Bruhn, R.L., 1988, Structural interactions between the Uinta arch and the overthrust belt, north central Utah - Implications of strain trajectories and displacement modeling, *in* Schmidt, C.A. and Perry, W. J., Jr., editors, Interaction of the Rocky Mountain foreland and the frontal Cordilleran thrust belt: Geological Society of America Memoir 171, p. 431-445.

Bromfield, C.S., 1968, Source of Keetley volcanic field: U.S. Geological Survey Professional Paper 600-A, p. A33.

Bromfield, C.S. and Crittenden, M.D., Jr., 1971, Geologic map of the Park City East Quadrangle, Summit and Wasatch Counties, Utah: U.S. Geological Survey Geologic Quadrangle Map GQ-852, scale 1:24,000.

Bryant, Bruce, 1990, Geologic map of the Salt Lake City 30' x 60' quadrangle, north-central Utah, and Uinta County, Wyoming: U.S. Geological Survey, Miscellaneous Investigations Series Map I-1944, scale 1:100,000.

Cheney, T.M., Smart, R.A., Waring, R.G., and Warner, M.A., 1953, Stratigraphic sections of the Phosphoria Formation in Utah, 1949-1951: U.S. Geological Survey Circular 306, p. 18-21.

Cobban, W.A. and Reeside, J.B., Jr., 1952, Frontier Formation, Wyoming and adjacent areas: American Association of Petroleum Geologists Bulletin 36, no. 10, p. 1913-1961.

Crawford, K.A., 1979, Sedimentology and tectonic significance of the Late Cretaceous-Paleocene Echo Canyon and Evanston synorogenic conglomerates of the north-central Utah thrust belt: Madison, Wisconsin, University of Wisconsin, M. S. thesis, 143 p.

Crittenden, M.D., Jr., 1974, Regional extent and age of thrusts near Rockport Reservoir and relation to possible exploration targets in northern Utah: American Association of Petroleum Geologists Bulletin, v. 58, no. 12, p. 2428-2435.

Crittenden, M.D., Jr., Calkins, F.C. and Sharp, B.J., 1966, Geologic map of the Park City West

quadrangle: U.S. Geological Survey Quadrangle Map GQ-535, 1:24,000.
Crittenden, M.D., Jr.,1965a, Geology of the Sugar House quadrangle: U.S. Geological Survey Quadrangle Map GQ-380, 1:24,000.
Crittenden, M.D., Jr.,1965b, Geology of the Mount Aire quadrangle: U.S. Geological Survey Quadrangle Map GQ-379, 1:24,000.
Forrester, J.D., 1937, Structure of the Uinta Mountains: Geological Society of America Bulletin, v. 48, p. 631-666.
Hale, L.A., 1960, Frontier Formation, *in* McGookey, D. P. and Miller, D. N., Jr., editors, Overthrust belt of southwestern Wyoming and adjacent areas: Wyoming Geological Association, 15th Annual Field Conference Guidebook, p. 136-146.
High, L.R., Hepp, D.M., Clark, T. and Picard, M.D., 1969, Stratigraphy of Popo Agie Formation (Late Triassic), Uinta Mountain area, Utah and Colorado. *in* Lindsay, J. B., editor, Geologic guidebook of the Uinta Mountains - Utah's maverick range: Intermountain Association of Geologists, 16th Annual Field Conference, p.181-192.
Hooper, W.G., 1951, Geology of the Smith and Morehouse-South Fork area, Utah: Salt Lake City, Utah, University of Utah, M. S. thesis, 55 p., scale 1:31,600.
Imlay, R.W., 1967, Twin Creek Limestone (Jurassic) in the western interior of the United States: U.S. Geological Survey Professional Paper 540, 105 p.
Jacobson, S.R. and Nichols, D.J., 1982, Palynological dating of syntectonic units in the Utah-Wyoming thrust belt - The Evanston Formation, Echo Canyon Conglomerate, and Little Muddy Creek Conglomerate, *in* Powers, R.B., editor, Geologic studies of the Cordilleran thrust belt: Rocky Mountain Association of Geologists, v. 2, p. 735-750.
Lamerson, P.R., 1982, The fossil basin and its relationship to the Absaroka thrust system, Wyoming and Utah, *in* Powers, R.B., editor, Geologic studies of the Cordilleran thrust belt: Rocky Mountain Association of Geologists, v. 1, p. 279-340, plate 1-B scale 1:200,000.
Larson, K.W., 1951, The areal geology of the Rockport-Wanship area: Salt Lake City, Utah, University of Utah, M. S. thesis, 46 p., scale 1:31,680.
McCormick, C.D. and Picard, M.D., 1969, Petrology of Gartra Formation (Triassic), Uinta Mountain area, Utah and Colorado: Journal of Sedimentary Petrology, v. 39, no. 4, p. 1484-1508.
Morris, E.C., 1953, Geology of the Big Piney area, Summit County, Utah: Salt Lake City, Utah, University of Utah, M. S. thesis, 66 p., scale 1:31,680.
Mount, D.L., 1952, Geology of the Wanship-Park City Region, Utah: Salt Lake City, Utah, University of Utah, M. S. thesis, 35 p., scale 1:31,680.
Nichols, D.J., 1979, Applications of palynology to stratigraphic and structural interpretations in the thrust belt of Wyoming and Utah [abstract], *in* Update on the Wyoming-Idaho-Utah thrust belt: Geological Survey of Wyoming, Public Information Circular 10, p. 21.
O'Toole, W.L., 1951, Geology of the Keetley-Kamas volcanic area: Salt Lake City, Utah, University of Utah, M. S. thesis, 38 p. scale 1:31,680.

Oviatt, C.G., 1994, Quaternary geologic map of the upper Weber River Basin drainage, Summit County, Utah: Utah Geological Survey Map 156, 10 p., scale 1:50,000.

Royse, Frank, Jr., Warner, M.A. and Reese, D.L., 1975, Thrust belt structural geometry and related stratigraphic problems, Wyoming-Idaho-Northern Utah, *in* Bolyard, D. W., editor, Symposium of deep drilling frontiers in the Central Rocky Mountains: Rocky Mountain Association of Geologists, p. 41-54.

Ryer, T.A., 1976, Cretaceous stratigraphy of the Coalville and Rockport areas, Utah: Utah Geology, v. 3, no. 2, p. 71-83.

Schultz, A.R., 1918, A geologic reconnaissance of the Uinta Mountains, northern Utah, with special reference to phosphate: U.S. Geological Survey Bulletin 690-C, p. 31-94.

Stanton, T.W., 1893, The Colorado Formation and its invertebrate fauna: U.S. Geological Survey Bulletin 106, 288 p.

Thomas, H.D. and Krueger, M L., 1946, Late Paleozoic and Early Mesozoic stratigraphy of Uinta Mountains, Utah: American Association of Petroleum Geologists Bulletin, v. 30, no. 8, p. 1255-1293.

Trexler, D.W., 1966, The stratigraphy and structure of the Coalville area, northeastern Utah: Colorado School of Mines Professional Contributions no. 2, 69 p. [same as 1955 Ph.D. dissertation at Johns Hopkins University].

Williams, N.C. and Madsen, J.H., Jr., 1959, Late Cretaceous stratigraphy of the Coalville area, Utah, *in* Williams, N.C., editor, Guidebook to the geology of the Wasatch and Uinta Mountains transition area: Intermountain Association of Petroleum Geologists, 10th Annual Field Conference p. 122-125.

Willes, S.B. 1962, The mineral alteration products of the Keetley-Kamas volcanic area, Utah: Brigham Young University Geology Studies, v. 9, part 2, p. 3-29, figure 9 scale 1:68,500.

Woodfill, R.D., 1972, A geologic and petrologic investigation of a northern part of the Keetley volcanic field, Summit and Wasatch Counties, Utah: Lafayette, Indiana, Purdue University, Ph.D. dissertation, 168 p., scale 1:24,000.

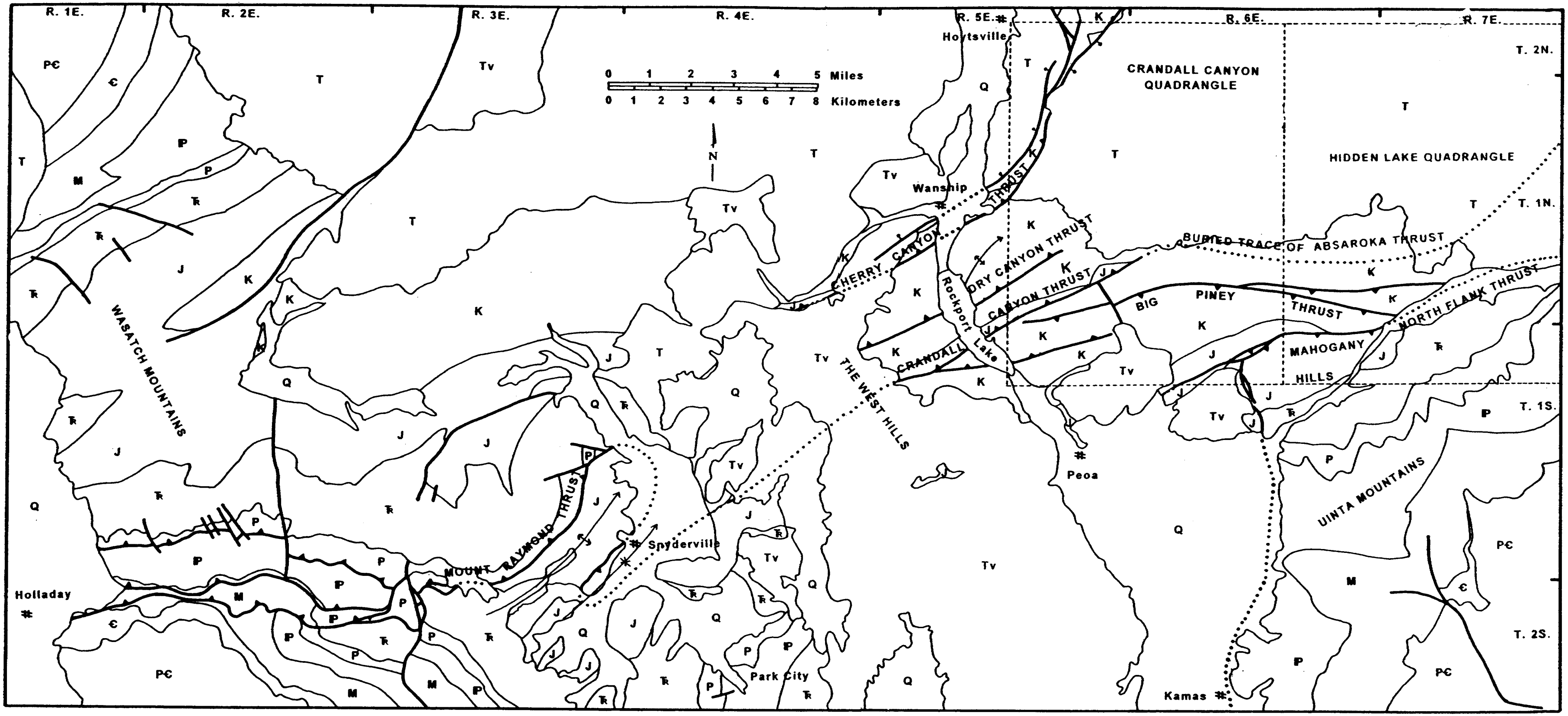


Figure 1. Generalized geologic map of the Crandall Canyon area. PC-Precambrian rocks, C-Cambrian rocks, M-Mississippian rocks, IP-Pennsylvanian rocks, P-Permian rocks, TR-Triassic rocks, J-Jurassic rocks, K-Cretaceous rocks, T-Tertiary rocks, Tv-Tertiary volcanic rocks, Q-Quaternary rocks. Modified from Bryant (1990).

Figure 2. The soft siltstones within the Cretaceous Parley's Member of the Kelvin Formation occasionally erodes into interesting shapes.

Figure 3. Interbedded very light gray to white pedigenic limestone nodules, overlain by bright red and white siltstone, which intern is overlain by lenses of cobble conglomerate of the Parley's Member of the Kelvin Formation. The outcrop is along the east shore of Rockport Lake and is underwater when the lake is high. Note hammer for scale.

Figure 4. Teleost fish scales in the Albian Aspen Formation.

Figure 5. Basal conglomerate of the Hams Fork Member of the Maastrichtian Evanston Formation exposed in Spring Canyon. Note hammer for scale.

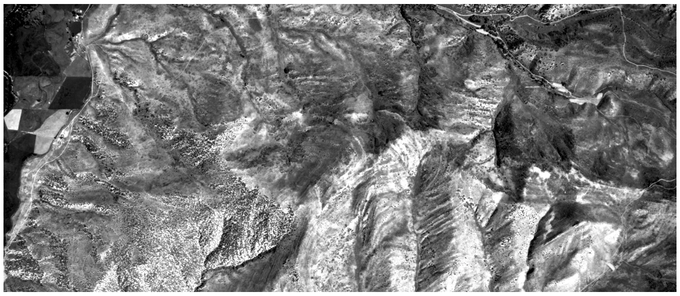


Figure 6. U. S. Department of Agriculture aerial photograph DRU-2HH-15 (7-10-67) showing the angular unconformity between the lower member of the Frontier Formation and the Hams Fork Member of the Evanston Formation along the ridge between Dry Fork and Cherry Canyon.

Figure 7. Silver Creek Member of the Oligocene Keetley volcanics. Outcrop is one mile southwest of Wanship, Utah. Note hammer for scale.

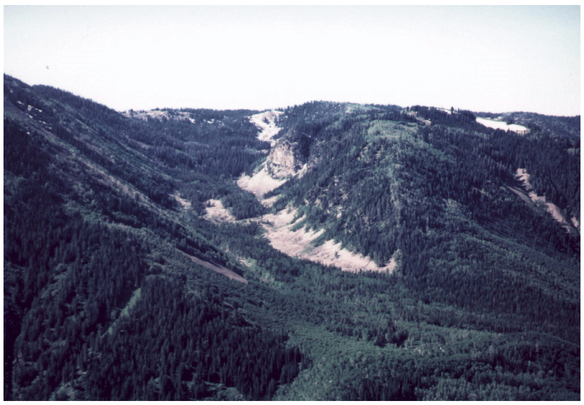


Figure 8. Glacial moraines in Shingle Mill Creek.

Figure 9. Glacial deposits in the upper reaches of the South Fork of Chalk Creek.

Figure 10. Looking eastward across Rockport Lake towards Big Piney Mountain. The Crandall Canyon thrust demarcates the reddish-brown siltstones of the Jurassic Preuss Formation (darker rocks) on the hanging wall of the thrust from the footwall tan sandstones of the Cretaceous Frontier Formation (lighter rocks).

Figure 11. Looking southwest towards Pine Creek from a helicopter above 35-1N-5E. The pattern of vegetation clearly delineates the anticline in the hanging wall of the Rockport thrust.

Figure 12. Looking southwest from Elkhorn towards Big Piney Mountain. The trace of the Big Piney thrust is marked by the linear grassy meadow. Strata on the hanging wall (left) dip moderately to the northwest. Strata in the footwall are overturned dipping moderately to steeply to the southeast.

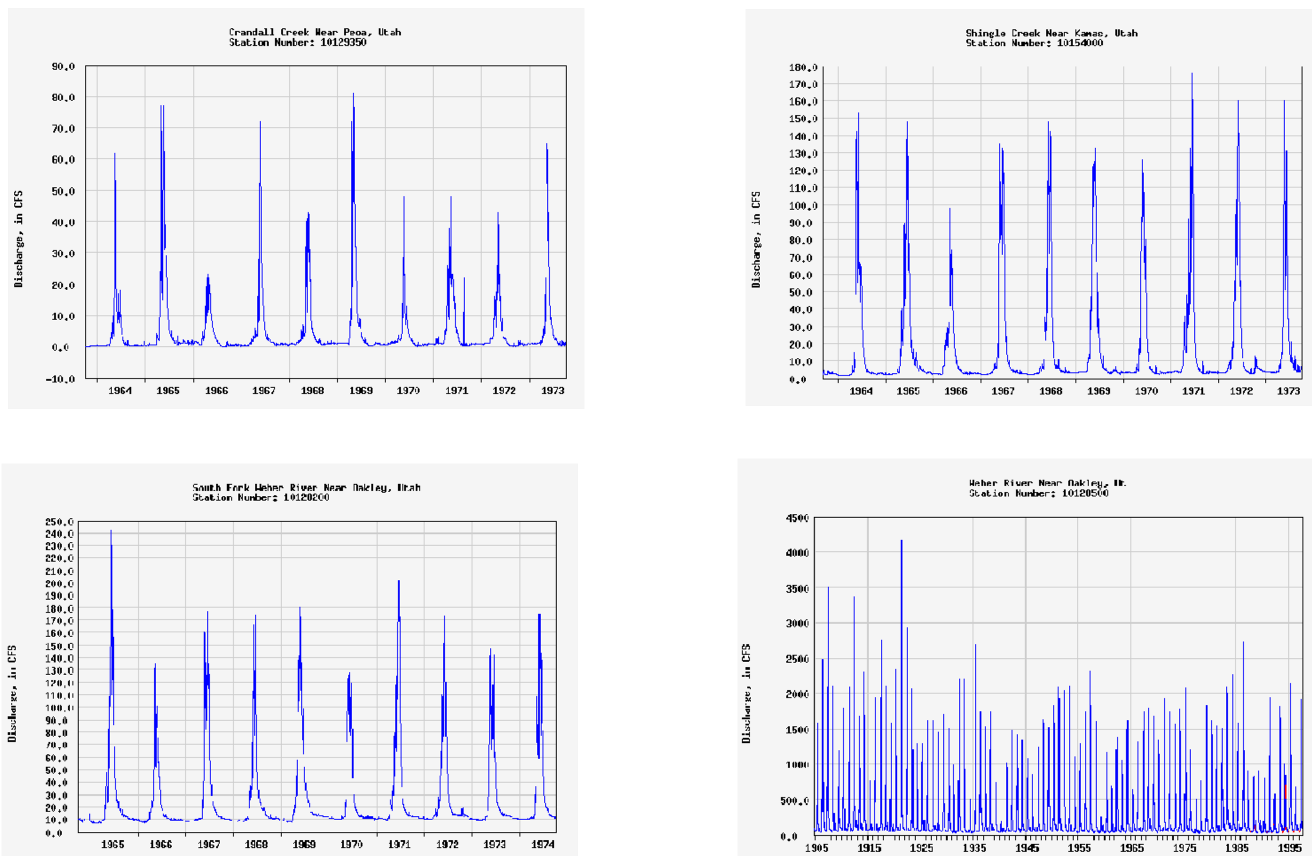


Figure 13. Historical streamflow data for a. Crandall Creek, b. Shingle Mill Creek, c. the South Fork of the Weber River, and d. the Weber River near Oakley. Discharge is in cubic feet per second. Data from the U.S. Geological Survey.

APPENDICES

Palynological Data

Several palynological samples were collected by the author (Bradley, 1988) and analyzed by S. Nelson and S.R. Jacobson, Chevron, USA. These samples are labeled P# on plate 1. Samples from Bryant (1990), labeled D# on plate 1, and Jacobson and Nichols (1982), labeled ME# on plate 1, are also included; see these references for details. For a given palynological zone, the stages listed here are from Bryant (1990); they are not those of Nichols (1994).

P6: (1650 FWL, 700 FNL, 33-1N-5E) Wanship quadrangle
Cretaceous, Turonian, Upper Frontier Formation. Correlation based on a palynomorph assemblage including *Palaeohystrichophora infusorioides*, *O. verrucosum*, and *Tanyosphaeridium* sp.

P7: (1750 FWL, 2850 FNL, 30-1N-6E) Crandall Canyon quadrangle
Upper Cretaceous, Upper Frontier-Lower Henefer Formation. Sample contains a nonmarine palynomorph assemblage including *Microreticulatisporites* sp. 1 and 2, *Cicatricosisporites* spp., and abundant *Quadripollis krempii*. Here mapped as Henefer Formation.

P14: (1550 FWL, 1150 FSL, 33-1N-6E) Hidden Lake quadrangle
Cretaceous. Sample dated Cretaceous based on a single specimen of *Gleicheniidites* sp.

P15: (1600 FWL, 500 FSL, 27-1N-6E) Hidden Lake quadrangle
Upper Cretaceous, upper Frontier Formation. Sample contains a long ranging Cretaceous assemblage including *Oligosphaeridium* sp., *Spiniferites* spp., *Gleicheniidites* sp., *Appendicisporites matesovae*, and abundant *Quadripollis krempii*. The presence of abundant *Quadripollis krempii* and absence of *Proteacidites* sp. suggest an upper Frontier-lower Hilliard Formation equivalent age.

P18: (1650 FEL, 250 FSL, 26-1N-7E) Hidden Lake quadrangle
Upper Cretaceous, Henefer Formation. Sample contains a diagnostic nonmarine assemblage with *Quadripollis krempii*, *Appendiscisporites* sp. 7, and *Ornamentifiera* sp. 2. *Proteacidites* sp. certifies Coniacian as an oldest limit. The presence of spores and absence of advanced pollen supports a Henefer Formation correlation for this sample.

P19: (1450 FEL, 700 FNL, 35-1N-7E) Hidden Lake quadrangle
Upper Cretaceous, upper Frontier Formation. Sample contains a predominantly marine assemblage with *Paleohystrichophora infusorioides*, *Dinogymnium* sp., *Chatangiella* spp., and the nonmaine components *Appendisporites* spp. 6, 10, and *Quadripollis krempii*. These forms are generally characteristic of the Hilliard Formation at Hilliard Flats, Wyoming. Although these forms could be found in the Adaville Formation, forms diagnostic of the Adaville in Chevrons references sections are absent. Location corrected to 700 FNL.

P20: (1300 FEL, 2300 FSL, 36-1N-7E) Hidden Lake quadrangle
Upper Cretaceous, upper Frontier Formation. Sample contains a marine assemblage with *Deflanrea* sp. 16 and *Palaeohystrichophora infusorioides*. The latter form defines the upper Frontier Formation as the oldest correlation and the diagnostic *Deflandrea* sp. 16 show a pre-Coniacian upper Frontier equivalence as the youngest limit.

P22: (2000 FEL, 2200 FNL, 31-1N-5E) Hidden Lake quadrangle
Cretaceous, Turonian, upper Frontier Formation. Correlation based on a palynomorph assemblage including *Palaeohystrichophora infusorioides*, *O. verrucosum*, and *Tanyosphaeridium* sp. 2. (Location actually 2800 FEL 1000 FNL).

D6305: (SWSE 2-1N-5E) Crandall Canyon quadrangle
upper Paleocene, P5-P6, Wasatch Formation. Age diagnostic palynomorphs present.

D6308: (NENE 11-1N-5E) Crandall Canyon quadrangle
upper Paleocene, P5-P6, Wasatch Formation. Age diagnostic palynomorphs present.

D6589: (NW corner 28-1N-6E) Crandall Canyon quadrangle
Cretaceous, Coniacian-Santonian, upper Frontier Formation. *Chatangiella* zone. Age diagnostic palynomorphs present. Age puts this as post Frontier Formation, and if it’s a conglomerate it could be Coalville or Echo Canyon age equivalent. Here mapped as Hams Fork Member of Evanston Formation.

D6590: (SW corner 21-1N-6E) Crandall Canyon quadrangle
Cretaceous, Cenomanian-Coniacian (age inferred), upper Frontier Formation. *Nyssapollenites* zone. Age inferred. With D6589 and D6591, age puts this as post Frontier Formation, and if it’s a conglomerate it could be Coalville or Echo Canyon age equivalent. Here mapped as Hams Fork Member of Evanston Formation.

D6591: (SW corner 21-1N-6E) Crandall Canyon quadrangle
Cretaceous, Coniacian-Santonian, upper Frontier Formation. *Chatangiella* zone. Age diagnostic palynomorphs present. Age puts this as post Frontier Formation, and if it’s a conglomerate it could be Coalville or Echo Canyon age equivalent. Here mapped as Hams Fork Member of Evanston Formation.

D6592: (NWNENW 29-1N-6E) Crandall Canyon quadrangle
Upper Cretaceous, late Campanian-early Maastrichtian, Hams Fork Member of the Evanston Formation. *Aquilapollenites quadrilobus* zone. Age diagnostic palynomorphs present.

D6611: (SWSWNE 31-1N-7E) Hidden Lake quadrangle
Cretaceous, Cenomanian to Coniacian, lower Frontier Formation. *Nyssapollenites* zone. Age inferred. Mapped here as upper Frontier.

D6652: (center N1/2 31-1N-7E) Hidden Lake quadrangle
Cretaceous, Turonian, lower Frontier Formation. *Alterbia* sp. A zone. Characteristic assemblage present. Mapped here as upper Frontier.

D6653: (SENENW 31-1N-7E) Hidden Lake quadrangle
Cretaceous, Turonian, lower Frontier Formation. *Alterbia* sp. A zone. Characteristic assemblage present. Mapped here as upper Frontier.

D6655: (NWNENE 24-1N-6E) Hidden Lake quadrangle
Cretaceous, Coniacian-Santonian (age inferred), Adaville and Hilliard formations. *Proteacidites retusus* zone. Age inferred, may be early Campanian. Mapped here as Henefer Formation.

D6657: (SENESE 26-1N-6E) Hidden Lake quadrangle
Cretaceous, Coniacian-Santonian, Adaville and Hilliard formations. *Chatangiella* zone. Age inferred, marine sample. Mapped here as Henefer Formation.

D6658A: (NWNWSE 26-1N-6E) Hidden Lake quadrangle
Cretaceous, Coniacian-Santonian, Adaville and Hilliard formations. *Proteacidites retusus* zone. Age diagnostic palynomorphs present. Mapped here as Henefer Formation.

D6658B: (NWNWSE 26-1N-6E) Hidden Lake quadrangle
Cretaceous, Coniacian-Santonian, Adaville and Hilliard formations. *Proteacidites retusus* zone. Age diagnostic palynomorphs present. Mapped here as Henefer Formation.

ME-34: (NWNE 22-1N-5E)
Cretaceous, upper Campanian-Maestrichtian, Hams Fork Member of the Evanston Formation.

ME-42: (NWNW 22-1N-5E)
Cretaceous, upper Campanian-Maestrichtian, Hams Fork Member of the Evanston Formation.

ME-45: (SESW 23-1N-5E)
Cretaceous, upper Campanian-Maestrichtian, Hams Fork Member of the Evanston Formation.

ME-46: (SENESE 23-1N-5E)
Cretaceous, upper Campanian-Maestrichtian, Hams Fork Member of the Evanston Formation.

ME-47: (center NW 23-1N-5E)
Cretaceous, upper Campanian-Maestrichtian, Hams Fork Member of the Evanston Formation.

Oil and Gas Well Data

Production and exploration wells in and near the Crandall Canyon and Hidden Lake quadrangles.

Name/ Company	**Location** (sec-T-R) (ft from sec. line)	**Completion Date/Status**	**Tests/Logs**	**TD** (feet)	**Unit Tops** (feet)	
PLOTTED ON CRANDALL CANYON PLATE 1						
UPRR 33-1	NWSESE 33-T2N-R6E	6-01-84	produced	13047	DOGM	
Conoco	990fsl, 990fel	water disposal	logs		1055	"Echo Canyon"
					1617	"Evanston"
					2709	"Dry Hollow"
					2768	Frontier, lower
					4972	Aspen
					5300	"Bear River"
					5452	Kelvin
					8900	Stump
					9257	Preuss
					10522	salt
					10640	base of salt
					10728	Giraffe Creek
					11064	Leeds Creek
					11377	Watton Canyon
					11630	Boundary Ridge
					11686	Rich
					11942	Slide Rock
					12020	Gypsum Spring
					12060	Nugget
Judd 34-2	SENW 34-T2N-R6E	5-26-79	produced	11817	DOGM	
American Quasar	1979fnl, 2163fwl	P&A	logs	LOG	surf	Wasatch
				697	818	Echo Canyon
				1404	1404	Evanston/u. Frontier
				2633	2623	"Current Ck"/Dry H.
				2814	2814	Frontier/l. Frontier
				4677	4522	Aspen
				4860	4866	"Bear River"
				5072	5196	Kelvin
				7868		Stump?
				8440	8400	Stump
				8808	8808	Preuss
				10150		salt
				10208	10206	Giraffe Creek
				10680		Leeds Creek
				11008		Watton Canyon
				11253		Boundary Ridge
				11304		Rich
				11570		Slide Rock
				11652		Gypsum Spring
				11700	11698	Nugget
Judd 34-3	SESW 34-T2N-R6E	1-14-80	produced	12084	DOGM	
Am Quasar?/UP Res.	652fsl, 2008fwl	shut-in	fiche logs		surf	Wasatch
			At DOGM		1318	"Echo Canyon"
					1940	Frontier
					4808	Aspen
					5124	"Bear River"
					5325	Kelvin
					8630	Stump
					8962	Preuss
					10311	Twin Creek
					11820	Nugget
*Judd 34-1H	NWSWSW 34-T2N-R6E	8-30-95	producing	16087 md		

UP Resources	711fsl, 552fwl		logs	LOG tvd		
	two laterals			8711		Stump
				8997		Preuss
				10383		salt
				10422		Giraffe Creek
				10900		Leeds Creek
				11230		Watton Canyon
				11480		Boundary Ridge
				11487		Rich
				11492		Boundary R., fault?
				11483		Rich
				11640md	Rich	
					TD	Twin Creek
*Judd 4-1H	NENE 4-T1N-R6E	10-20-96	producing	14980 md		
UP Resources	596fnl, 629fel		logs	LOG tvd		
	horizontal			8547 md		Stump
				9074 md		Preuss
				10346		salt
				10475		Giraffe Creek
				10898		Leeds Creek
				11252		Watton Canyon
				11459		Boundary Ridge
				11541		Rich
				11693		Rich?
*3-1H Judd (UPRR?)	NWNE 3-T1N-R6E	not drilled				
UP Resources	554fnl, 1757fel					
UPRR (9-)1	SENESW 9-T1N-T6E	3-12-85		15183	DOGM, UGS	
Exxon	1723fsl, 2095fwl	D&A	logs		surf	Wasatch?
			x-section		3450	Evanston, est.
					5110	Frontier
					6090	Aspen
					6300	"Bear River"/Kelvin
					6810	Kelvin/"Gannett"
					9740	Stump
					10100	Preuss
					12135	Twin Creek
					13868	Gypsum Spring?
					13915	Nugget
Champlin 464-B	NWSW 23-T1N-R5E	2-19-83		12725	DOGM md	
Amoco	1620fsl, 929fwl	D&A	logs		surf	"Wanship"[Evanston]
			x-section		1000	Frontier
					4189	Kelvin
					8183	Preuss
					10121	salt
					10205	Giraffe Creek
					11088	Leeds Creek
					11280	Watton Canyon
					11838	Rich
					12600	Nugget
PLOTTED ON HIDDEN LAKE PLATE 1						
Blonquist 26-1 (A?)	SESW 26-T2N-R6E	10-20-78		11914	DOGM	
American Quasar	600fsl, 1997fwl	D&A	logs	LOG	650	Echo Canyon
					1448	"Wanship"[Evanston]
					2726	Frontier
					4068	Aspen
					4418	"Bear River"
					4730	Kelvin
				7995	8093	Stump
				8218	8257	Preuss
				9762		salt
				10065	10093	Giraffe Creek

				10595		Leeds Creek?
				10775		Watton Canyon
				10973		Boundary Ridge
				11085		Rich
			11695?	11250		Slide Rock
Blonquist 26-3	SESW 26-T2N-R6E	11-03-83	produced	12088	DOGM	
Jake Hamon	739fsl, 1983fwl	shut-in	logs		4200	Aspen
					4414	“Bear River”
					4700	Kelvin
					8032	Stump
					8226	Preuss
					9750	salt
					10008	Giraffe Creek
					10520	Leeds Creek
					10982	Watton Canyon
					11670	Boundary Ridge
					11738	Rich
					11802	Slide Rock
					12080	Gypsum Spring
UPRR 27-1	SESE 27-T2N-R6E	7-20-79 (1-27-83)	produced	12188	DOGM/UGS	
Am Quasar/UP Res.?	659fsl, 654fel	P&A 10-15-91	fiche logs		surf	Wasatch
			at DOGM		1180	“Echo Cyn”
					1790	Evanston, est
					2943	“Dry Hollow”
					3142	Frontier
					4866	Aspen
					5234	“Bear River”/Kelvin
					5546	Kelvin
					8856	Stump
					9226	Preuss
					10540	salt
					10599	base of salt
					10608	Giraffe Creek
					11122	Leeds Creek
					11394	Watton Canyon
					11651	Boundary Ridge
				12048	12034	Gypsum Spring
				12098	12100	Nugget
*UPRC 27-1H	SESE 27-T2N-R6E	11-17-95		12662 md		
UP Resources	904fsl, 578fel	D&A	logs	LOG tvd		
				10529		salt
				10682		Giraffe Creek
				11112		Leeds Creek
				11511		Watton Canyon
				11920 md		Boundary Ridge
				TD		Twin Creek
Judd 34-1	SENE 34-T2N-R6E	2-19-78	produced	11806	DOGM	
American Quasar	1980fnl, 660fel	shut-in	logs	LOG	surf	Wasatch
				848		“Echo Canyon”
				1603		“Evanston”
				2828		“Current Creek”
				2995	3016	Frontier
				4350	4426	Aspen
				4620?	4632	“Dakota”/“Bear River”
				4970	4825	Kelvin
				7665	7666	Stump
				8450	8456	Preuss
				9840	9840	salt
					10154	base of salt
				10180	10188	Giraffe Creek
				10678	10650	Leeds Creek

					10924	Watton Canyon
				11185	11165	Boundary Ridge
				11235	11219	Rich
				11495	11491	Slide Rock
				11590	11580	Gypsum Spring
				11632	11625	Nugget
UPRR 35-1	SESENW 35-T2N-R6E	9-27-76	produced	17053		
American Quasar etc.	1969fnl, 1988fwl	D&A	logs			
	3311fsl, 1988fwl?	TAZ?	X-section	DOGM	UGS	
	2110fnl, 2040fwl?		LOG		surf	Wasatch
			1525			“Wanship”[Evanstn?]
			1840	1798	1673	“Frontier”/Evanston
			2780	3110		cong./Current Ck.
			3300	3317	3317	Frontier, lower
			~4240	4146	4035	Aspen
			~4370	4360	4360	Kelvin
				~7100		fault
			7460	7460		Morrison?
			~8540	8305	8305	Stump
			~8750	8723	8723	Preuss
				9940		salt
			~10430 or10404			Twin Creek?
			10504	10500	10413	Giraffe Creek
			10898			Leeds Creek
			11200			Watton Canyon
			~11460 or 11433			Boundary Ridge
			11498			Rich
			11771			Slide Rock
			~11830 or 11836		11818	Gypsum Spring
			11882-8	11887	11887	Nugget
			13356-8	13360	13360	Ankareh
			13506?		13540	Gartra Grit
			14002	13998		Gartra Grit?
					13600	Mahogany mbr
			14300?	14300		Mahogany mbr?
			~14300 or 14830?	14830	14320	Thaynes
			~15300 or 15280			Thaynes?
			~15580 or 15722	15580	15644	Woodside
			~15996 or 15980	15982	15982	Absaroka thrust
			15980	15982	15982	Aspen?
			16352 or 16342	16340	16340	“Bear R.”/Kelvin
UPRC-C 2	SESENW 35-T2N-R6E	7-27-91	oil in “Bear River”	16969?		
Exxon	2110fnl, 2040fwl	D&A				
	re-entry of 35-1?		Fiche log at DOGM			
UPRC-C 1	SWNESW 35-T2N-R6E	2-09-90		15401	DOGM	
Exxon	1962fsl, 1680fwl	D&A	logs	LOG		
				3240		conglomerate
				3448		Frontier
				~4800		Kelvin
				~8580		Stump?
				~9280		Preuss
				~10570		salt
				~11800	11195	Twin Creek
				~12870	12874	Nugget
				14520	14510	Ankareh
*UPRR 35-2H	NWNW 35-T2N-R6E	11-24-94	producing	14505	DOGM md?	
UP Resources	1058fnl, 645fwl			md	8070	Stump
	two laterals		some logs		10088	Twin Creek
					10638	Leeds Creek
Champlin 494-A1	SWNW 5-T1N-R7E	11-24-77		6035	DOGM	
Amoco	1958fnl, 554fwl	D&A	logs		surf	Wasatch

			add x-section		2500	"Adaville", Henefer
					4250	Frontier
Summit 1-4	SENE 4-T1N-R7E	9-19-91		8225	DOGM	
Belco Pet. Corp.	1502fnl, 601fel	D&A	logs		surf	Wasatch
					2710	Echo Canyon
					3886	Frontier
					5435	Kelvin
					7880	Stump
					8037	fault, Frontier
UPRR (Gilmore) **33-11**	NWSE 11-T1N-R6E	9-05-78	gas in Kelvin	15015	DOGM	
Colorado Energetics/	1980fsl, 1980fel	D&A	logs	LOG	surf	Tertiary[Wasatch]
Amoco			x-section	1177		"Echo Canyon"
					3268	"Ft. Union"[Evanston]
				4955		"Current Ck"[cong]
				5195	5211	Kelvin
				7268	7292	Stump
				7655	7665	Preuss
				7985	8300	fault, ?
				8645	8600	Stump
				9110	9112	Preuss
					9625	fault?
				10420	10435	fault?, Stump
					10955	Preuss
				11875		Twin Creek?
				12105		Stump?
				12385	12258	Preuss
				13835		Twin Creek?
					13835	fault, Cretaceous
				14043	14045	fault, Cretaceous
Champlin 550-A1	SWSWSW 11-T1N-R6E	11-11-82		7650	DOGM	
Amoco	640fsl, 535fwl	D&A	logs		3314	Evanston
			x-section		5229	Kelvin
					7326	Stump
					7507	Preuss
Champlin 495-A1	SENW17-T1N-R7E	11-17-77		5174	DOGM	
Amoco	1972fnl, 2109fwl	D&A	logs		surf	Wasatch
			x-section		1486	"Adaville"[Evanston]
					2827	Hilliard [Henefer]
IN UPTON QUADRANGLE						
Blonquist 26-2	NWSW 26-T2N-R6E	7-11-81		10736	DOGM	
American Quasar	1763fsl, 872fwl	D&A	logs	LOG	2635	Dry Hollow
					2830	Frontier
				4460	4496	Aspen
				4550	4860	"Bear River"
				~5800	5780	Kelvin
				~8600		Stump
				8840	8880	Preuss
				10110		salt
				10592		Twin Creek
Blonquist 26-4	SESENW 26-T2N-R6E	4-26-85		12027	DOGM	
Jake Hamon	2100fnl, 2100fwl	water disposal	logs	LOG		Aspen
				4516	4500	"Bear River"
				4931	4926	Kelvin
				8436	8424	Stump
				8712	8712	Preuss
				10180	10172	salt
					10490	base of salt
				10582	10570	Giraffe Creek
				11012	11030	Leeds Creek

				11322	11310 Watton Canyon
				11576	11560 Boundary Ridge
				11602	11594 Rich
				11860	11843 Sliderock
				11942	11920 Gypsum Spring
				11970	11950 Nugget
*UPRC (Blonquist) 26-1H	NENE 26-T2N-R6E	9-21-96		14206	DOGM md
UP Resources	585fnl, 731fel	shut in			3590 Aspen
					3802 “Bear River”
					3920 Kelvin
					4230 “Gannett”
					7332 Stump
					7880 Preuss
				9581-6	9610 salt
					9830 base of salt
					9913 Giraffe Creek
			tvd 10934		11886 Boundary Ridge
IN WANSHIP QUADRANGLE					
Champlin 464 A	SWSW 7-1N-5E	12-05-77		4005	DOGM
Amoco	1870fnl, 749fwl	D&A	logs		surf Wasatch
					488 Frontier
					1822 Dry Hollow mbr
					3028 Oyster Ridge mbr
					3697 Coalville mbr
Rockport Res 1	SWSE 21-T1N-R5E	10-20-79	gas show	12274	DOGM, UGS
Amoco	569fsl, 1870fel	D&A	logs		surf Frontier
					2000 Aspen
					2300 “Bear River”/Kelvin
					2500 Kelvin
					8350 Stump
					8606 Preuss
					10302 Twin Creek
					12115 Gypsum Spring?
					12175 Nugget
*27-1 UPRR	SENWNW 27-T1N-R5E	location abandoned			
Exxon	829fnl, 1204fwl				
IN TURNER HOLLOW QUADRANGLE					
Champlin 390 A 1	NWNW 29-T2N-R6E	4-14-77		4500	DOGM
Amoco	660fnl, 678fwl	D&A	logs		surf Wasatch
					540 Cret. [Evanston]
					2070 Hilliard[Henefer]

NE-NE1/4, NW-NW1/4, SE-SE1/4, SW-SW1/4, C-center
fsl-feet from south line, fnl-feet from north line, fwl-feet from west line, fel-feet from east line
P&A-plugged and abandoned, D&A-drilled and abandoned
TD-total depth
md-measured depth in deviated hole
tvd-total vertical depth in deviated hole
surf-surface
DOGM-Unit tops from Utah Division of Oil, Gas and Mining well files
LOG-Unit Tops interpreted from well logs
UGS-Unit Tops from Utah Geological Survey files

Abbreviations
sec-section, T-Township, R-Range, N-North, W-West

DESCRIPTION OF MAP UNITS
CRANDALL CANYON AND HIDDEN LAKE QUADRANGLES

Qal Stream alluvium (Holocene) - Clay through boulder-size clastics deposited in channels and floodplains of larger streams.

Qac Mixed alluvial and colluvial deposits (Holocene) - Unconsolidated gravel, sand, silt, and clay deposited along the sides and valley bottoms of the larger secondary drainages.

Qc Colluvial deposits (late Pleistocene to Holocene) - Unconsolidated silt to boulder size debris carried by slope wash and deposited along the slopes of some ridges; generally occur in areas of gentler slope directly below areas of steeper slope.

Qaf Alluvial-fan deposits (Pleistocene to Holocene)- Unconsolidated gravel, sand, silt, and clay deposited where smaller streams with more constricted valleys enter into the wider valleys of higher order streams such as the Weber River valley; in areas where there are multiple fan deposits, the fan deposits are labeled consecutively with the youngest deposit designated Qaf_1.

Qms Landslide deposits (Holocene and Pleistocene) - Clay through boulder size masses of bedrock units that have moved downslope. Qmso - Older deposits, (Pleistocene to early Holocene). Qmsy - Younger deposits (Holocene).

Qmt Talus deposits (Pleistocene to Holocene) - Unconsolidated angular blocks, boulders, and smaller fragments deposited along the base of some of the steeper slopes.

Qg Glacial deposits (late Pleistocene) - Poorly sorted bouldery till of Pinedale age in the Hidden Lake quadrangle that forms lateral, terminal, recessional, and/or hummocky moraines. Qgo - Older, more extensive glaciation. Qgy - Younger, less extensive glaciation.

Qat Terrace alluvium (late Pleistocene to Holocene) - Unconsolidated deposits of gravel, sand, silt, and clay up to 100 feet (30 m) thick. In areas where there are multiple terraces, the terraces are labeled consecutively with the youngest terrace (lowest) designated Qat_1.

Tlam Lamprophyres (Miocene) - Contain phlogopite phenocrysts in a dark aphanitic matrix of nepheline and augite (Morris, 1953); $^{40}Ar/^{39}Ar$ age of phlogopites is 13.9-14.8 Ma.

Tg Gravel deposits (Oligocene or Miocene?) - Associated with older erosional surfaces; unconsolidated pebble to boulder gravel commonly derived from erosion of the Wasatch Formation but locally contains clasts of reworked Keetley Volcanics.

Keetley Volcanics

Tksc Silver Creek member (Oligocene) - Chiefly rhyodacite to andesite flow beccias and laharic breccias originating from vents 3 miles (5 km) northeast of Keetley, Utah; K-Ar dated at 33, 34, and 35 Ma.

Tkt Tuff member (Oligocene) - Buff colored, fine- to coarse-grained, partially water-reworked tuff, lapilli tuff, and thin lahars.

Tw Wasatch Formation (Eocene and Paleocene) - Yellowish-brown, massive, cobble-to boulder conglomerate interbedded with red, buff to gray sandstone and red to gray to purple shale.

Evanston Formation

Te Main body (Eocene) - Light-gray to brown, friable sandstone and medium gray to black shale.

Ke Hams Fork Member (Upper Cretaceous) - Light-gray to brown, friable sandstone interbedded with medium-gray to black shale; 10-50 feet (3-15 m) thick, cobble to boulder conglomerate locally crops out at the base of the member.

Kh Henefer Formation (Upper Cretaceous) - Interbedded claystone, siltstone, sandstone, and conglomerate.

Frontier Formation

Kfu Upper member (Upper Cretaceous) - Interbedded sandstone, conglomeratic sandstone, siltstone, shale, silty shale, carbonaceous shale, and occasional thin coal.

Kfo Oyster Ridge Sandstone Member (Upper Cretaceous) - Mostly sandstone with interbedded siltstone and shale.

Kfl Lower member (Upper Cretaceous) - Includes Longwell Sandstone, Spring Canyon, Chalk Creek, Coalville, and Allen Hollow Shale Members of Hale (1960); interbedded sandstone, conglomeratic sandstone, siltstone, shale, silty shale, carbonaceous shale, and occasional thin coal.

Ka Aspen Shale - (Lower Cretaceous) - thin-bedded, medium-gray to black, siliceous shales with some silty shale near the formation top, contains abundant teleost fish scales.

Kk Kelvin Formation (Lower Cretaceous) - Interbedded pink to gray, friable, sandstone, siltstone, and shale with a pebble conglomerate at base of formation. The sandstone is usually massive and cross bedded.

Kkp Parley's Member of Kelvin Formation (Lower Cretaceous) - Bright-red to white siltstone and marl with nodules and concretions of white limestone and local lenses of coarse conglomerate at base of formation in Crandall Canyon quadrangle.

Jms Morrison and Stump Formations, undifferentiated (Upper and Middle Jurassic) - Used where both units are thin in Crandall Canyon quadrangle.

Jm Morrison Formation (Upper Jurassic) - White to purple, soft sandstone interbedded with variegated siltstone; a few discontinuous lenses of pebble conglomerate are present near the top of the formation; thins to west and north.

Js Stump Formation (Upper and Middle Jurassic) - Light-buff to tan, calcareous and arenaceous limestone, locally glauconitic, and containing numerous conglomeratic lenses.

Jp Preuss Sandstone (Middle Jurassic) - Thin-bedded, dull reddish-brown to red, incompetent siltstone, shale, and silty sandstone; salt in subsurface.

Jtc Twin Creek Limestone, undivided (Middle Jurassic)

Jtlg Giraffe Creek and Leeds Creek Members - Giraffe Creek Member consists of nonresistant, gray, shaly limestone with occasional thin, sandy limestone beds. Leeds Creek Member consists of nonresistant, light-gray, shaly limestone with pervasive pencil cleavage at a high angle to bedding.

Jtwc Watton Canyon Member - Resistant, medium-gray, medium-bedded limestone; oolitic beds occur throughout the member; blocky jointed.

Jtbr Boundary Ridge Member - Thin-bedded, yellowish-gray, sandy limestone and brownish-red siltstone.

Jtr Rich Member - Medium-bedded, medium-gray, shaly limestone with pervasive pencil cleavage at a high angle to bedding.

Jtgs Sliderock and Gypsum Springs Members - Sliderock Member consists of medium-gray, fossiliferous, oolitic limestone. Gypsum Springs Member consists of red, salmon, and yellow, silty sandstone and sandy sandstone.

Jn Nugget Sandstone (Lower Jurassic) - Ridge-forming, reddish-orange colored, fine- to medium-grained, thin- to very thick-bedded sandstone containing large-scale cross-stratification; exposed in Hidden Lake quadrangle.

TRa Ankareh Formation, undivided (exposed in Hidden Lake quadrangle)

TRas Stanaker Member (Upper Triassic) - Reddish-purple to reddish-brown, silty to sandy mudstone, with lenses of conglomeratic sandstone overlain by yellowish-brown, earthy, silty mudstone and argillaceous dolomite.

TRag Gartra Grit Member (Middle Triassic) - Ledge-forming, light-to medium-gray, fine-grained sandstone to well-rounded pebble conglomerate with occasional discontinuous lenses of siltstone and shale.

TRam Mahogany Member (Lower Triassic) - Non-resistant, thin-bedded, purple to brick-red, fine- to medium-grained, calcareous siltstone, shale and soft sandstone.

TRt Thaynes Limestone (Lower Triassic) - Interbedded dark-gray limestone and thin-bedded, buff, arenaceous limestone, sandstone, and sandy shale at top; underlain by non-resistant, thin-bedded, fine-grained, red, calcareous sandstone, siltstone, and shale; and basal, resistant, buff to bluish-gray, arenaceous limestone, locally exhibiting cross stratification, interbedded with thin, calcareous sandstones and sandy shale lenses; exposed in Hidden Lake quadrangle.

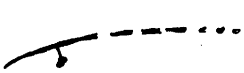
TRw Woodside Formation (Lower Triassic) - Nonresistant, thin-bedded, reddish-brown shales and siltstones; exposed in Hidden Lake quadrangle.

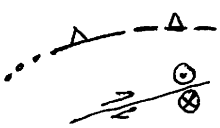
Ppc Park City and Phosphoria Formations (Permian) - Dense to finely crystalline, light-gray to bluish-gray, cherty limestone; underlain by black, phosphatic shale, sandstone, and limestone containing abundant chert; and basal calcareous sandstone and arenaceous limestone; exposed in Hidden Lake quadrangle.

PIPw Weber Sandstone (Permian and Upper Pennsylvanian) - resistant, massive, fine- to medium-grained, white- and rust-colored, quartz arenite with discontinuous lenses of limestone in the lower and middle parts of the formation; exposed in Hidden Lake quadrangle.

MAP AND CROSS SECTION SYMBOLS

 Contact - Dashed where approximately located on map.

 High-Angle Fault - Dashed where approximately located, dotted where covered; bar and ball on downthrown side; on cross section arrows show relative displacement in the plane of the cross section.

 Thrust Fault - Dashed where approximately located, dotted where covered; sawteeth on upper plate. On cross section arrows show relative displacement in the plane of the cross section, cross in circle and dot in circle indicate movement into and out of the plane of the cross section, respectively.

 Anticline - Line shows axial trace, arrow points in the direction of plunge.

 Syncline - Line shows axial trace, arrow points in the direction of plunge.

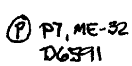
Strike and dip of bedding

 Horizontal

 Inclined

 Vertical

 Overturned

 Palynomorph sample locality

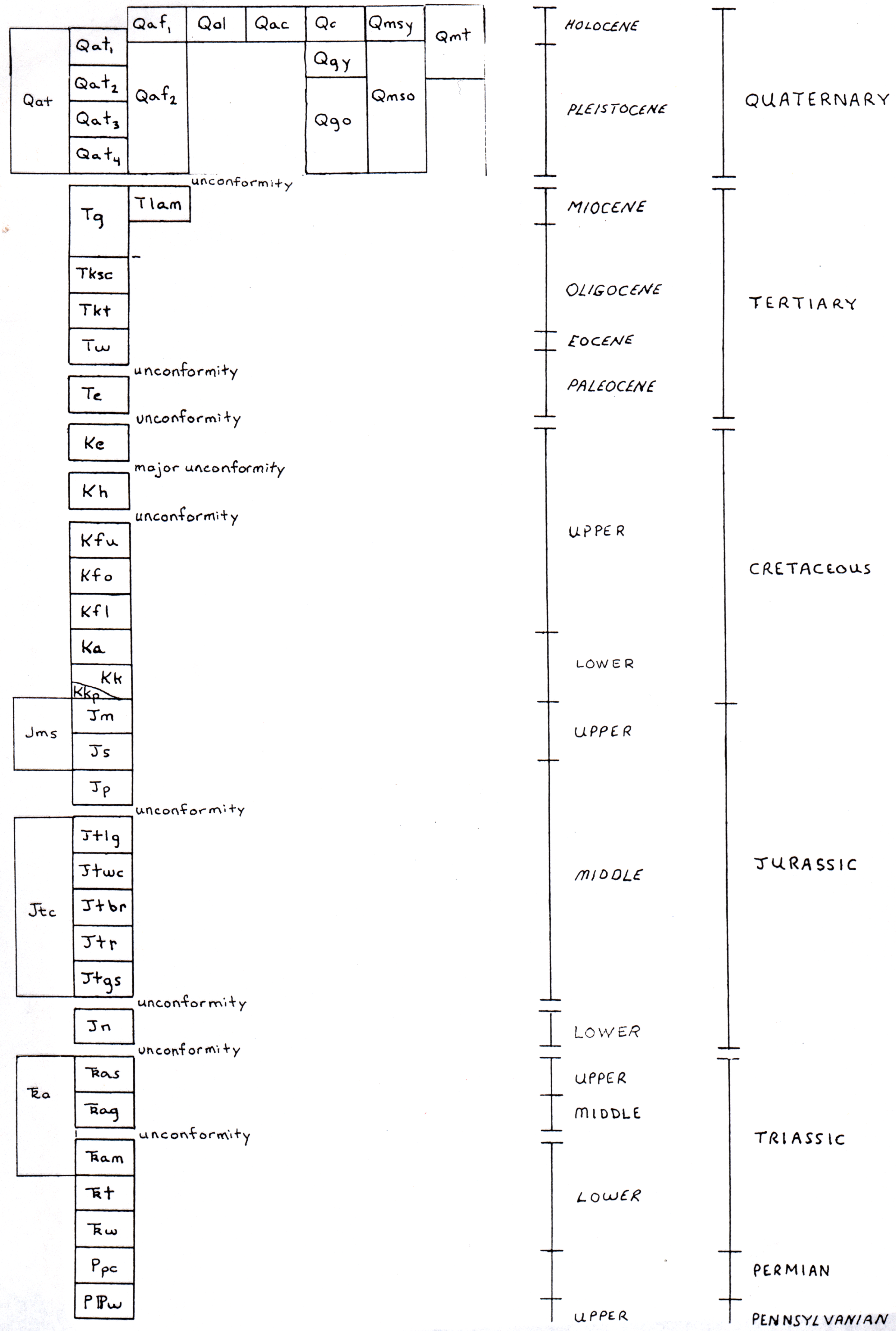
Oil and Gas well

 Oil

 Gas

 Dry Hole

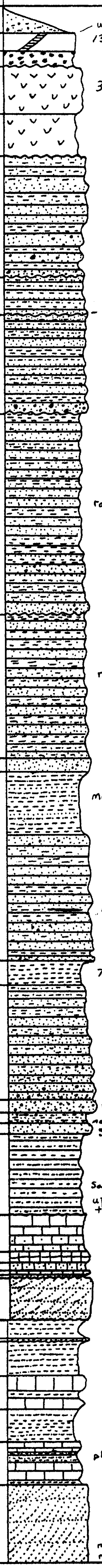
PLATE 2a. CORRELATION OF MAP UNITS



Michael D. Bradley
10/98 (WKK)

PLATE 2b. STRATIGRAPHIC COLUMN

Period	Epoch	Formation	Member	Map Symbol	Thickness Feet (Meters)	Lithology
Quat.		Surficial Deposits		Q	0-100 (0-30)	unconformity 13.9-14.8 Ma
Tertiary	Miocene	Lamprophyre		Tlam		
		Gravel Deposits		Tg	0-300 (0-91)	
	Oligocene	Keetley Volcanics	Silver Creek mbr.	Tksc	0-1000 (0-305)	33-35 Ma
			Tuff mbr.	Tkt	0-840 (0-256)	
	Eocene / Paleocene	Wasatch Fm.		Tw	0-2600 (0-792)	
		Evanston Fm.	Main body	Te	800+ (244+)	4 Ma HIATUS
Cretaceous	Upper		Ham's Fork Mbr.	Ke	2117 (645)	
		Henefer Fm.		Kh	4300 (1311)	rarely exposed
		Frontier Fm.	Upper mbr.	Kfu	3050-3280 (930-1000)	rarely exposed
			Oyster Ridge Ss.	Kfo	300 (91)	
			Lower mbr.	Kfl	4000 (1219)	marine shale; coal
	Lower	Aspen Shale		Ka	525 (160)	teleost fish scales
		Kelvin Fm.		Kk	2700 (823)	
			Parley's Mbr.	Kkp	0-250 (0-76)	white limestone concretions
Jurassic	Upper	Morrison Fm.		Jm	0-258 (0-79)	nodular limestone at base
		Stump Fm.		Js	0-223 (0-68)	glauconitic
	Middle	Preuss Sandstone		Jp	1196 (365)	Salt in lower Preuss up to 1700 feet (518 m) thick in subsurface
		Twin Creek Limestone	Leeds Creek & Giraffe Creek Mbrs.	Jtlg	858 (252)	
			Watton Canyon Mbr.	Jtwc	220 (67)	
			Boundary Ridge Mbr.	Jtbr	109 (33)	
			Rich Mbr.	Jtr	125 (38)	
			Gypsum Spring & Sliderock Mbrs.	Jtgs	69 (21)	
	Lower	Nugget Ss.		Jn	900 (274)	eolian
Triassic	Upper	Ankareh Fm	Stanaker Mbr.	TRas	360 (110)	
	Middle		Gartra Grit Mbr.	TRag	0-33 (0-10)	
			Mahogany Mbr.	TRam	761 (232)	
	Lower	Thaynes Ls.		TRt	704 (215)	
		Woodside Fm.		TRw	707 (215)	
Permian		Park City and Phosphoria Fms.		Ppc	910 (277)	phosphate
Pennsylvanian	Upper	Weber Ss.		PIPw	1725 (526)	eolian; middle + lower part not exposed

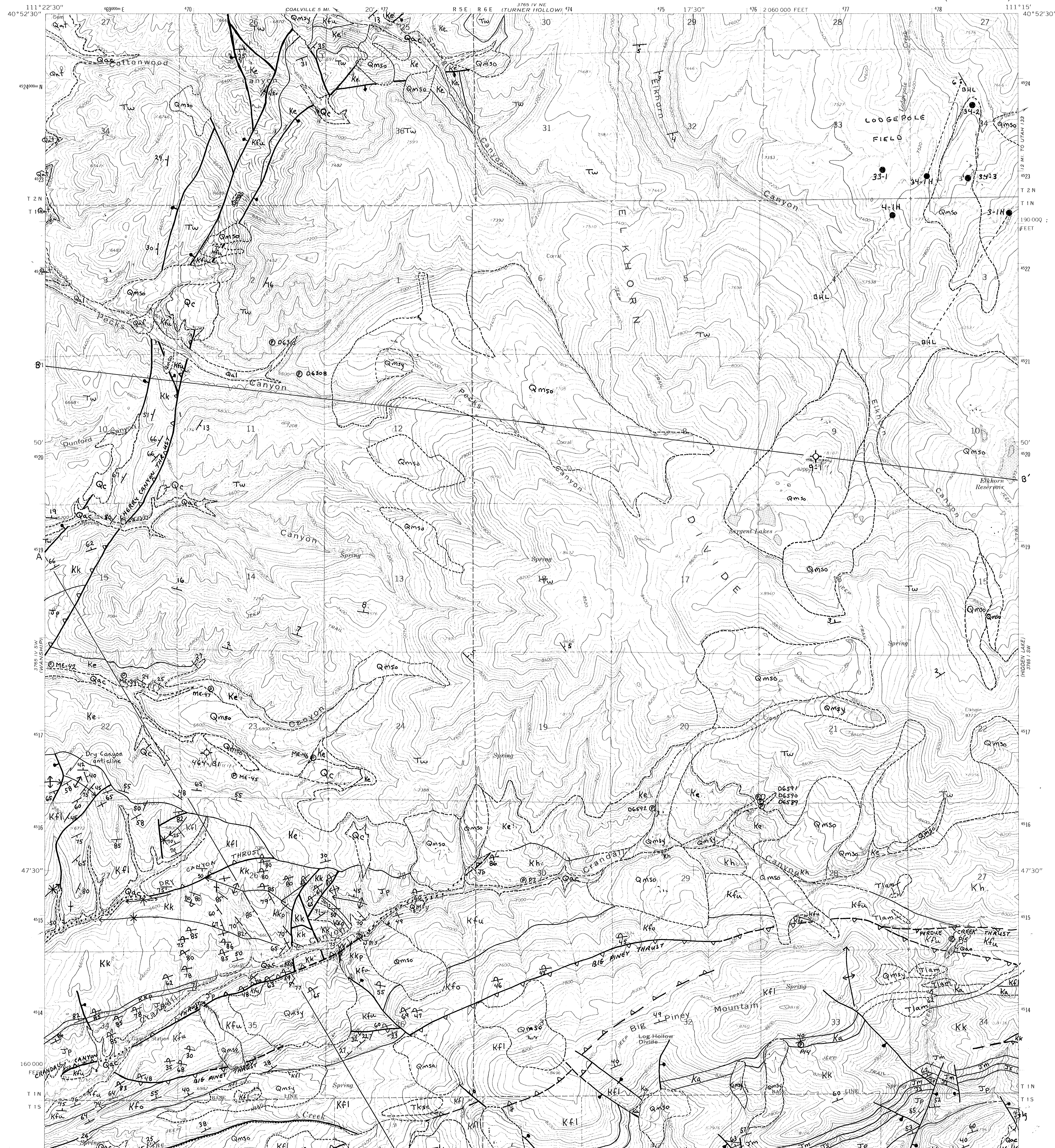


Michael D. Bradley
10/98 (JKK)

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

PLATE I GEOLOGIC MAP OF THE CRANDALL CANYON QUADRANGLE
by
MICHAEL D. BRADLEY

CRANDALL CANYON QUADRANGLE
UTAH—SUMMIT CO.
7.5 MINUTE SERIES (TOPOGRAPHIC)



Mapped, edited, and published by the Geological Survey

Control by USGS and USC&GS

Topography by photogrammetric methods from aerial photographs taken 1963. Field checked 1967

Polyconic projection. 1927 North American datum
10,000-foot grid based on Utah coordinate system, north zone
1000-meter Universal Transverse Mercator grid ticks, zone 12, shown in blue

Fine red dashed lines indicate selected fence lines

Areas covered by dashed light-blue pattern are subject to controlled inundation

There may be private inholdings within the boundaries of the National or State reservations shown on this map

UTM GRID AND 1967 MAGNETIC NORTH DECLINATION AT CENTER OF SHEET

SCALE 1:24 000

CONTOUR INTERVAL 40 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929

THIS MAP COMPLIES WITH NATIONAL MAP ACCURACY STANDARDS
FOR SALE BY U. S. GEOLOGICAL SURVEY, DENVER, COLORADO 80225, OR RESTON, VIRGINIA 22092
A FOLDER DESCRIBING TOPOGRAPHIC MAPS AND SYMBOLS IS AVAILABLE ON REQUEST

UTAH
QUADRANGLE LOCATION

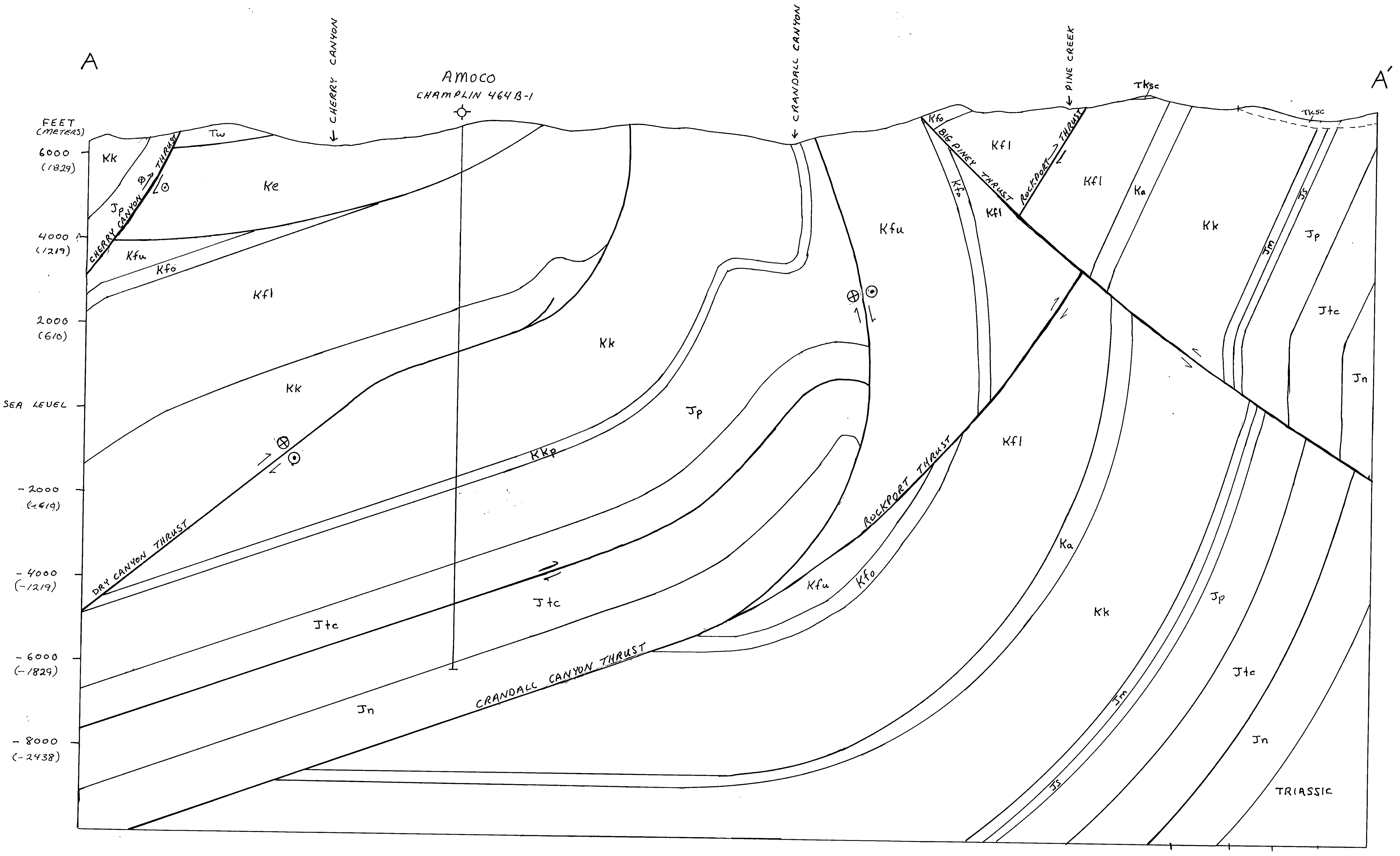
ROAD CLASSIFICATION
Medium-duty Light-duty
Unimproved dirt
U. S. Route

(OCTOBER) 1998

CRANDALL CANYON, UTAH
N4045—W11115/7.5
1967

DMA 3765 IV SE—SERIES V897

PLATE 2: STRUCTURAL CROSS SECTIONS. CRANDALL CANYON QUADRANGLE.



NO VERTICAL EXAGGERATION (HORIZONTAL SCALE = VERTICAL SCALE)

SURFICIAL DEPOSITS TOO THIN TO SHOW

MICHAEL D. BRADLEY
10/1998

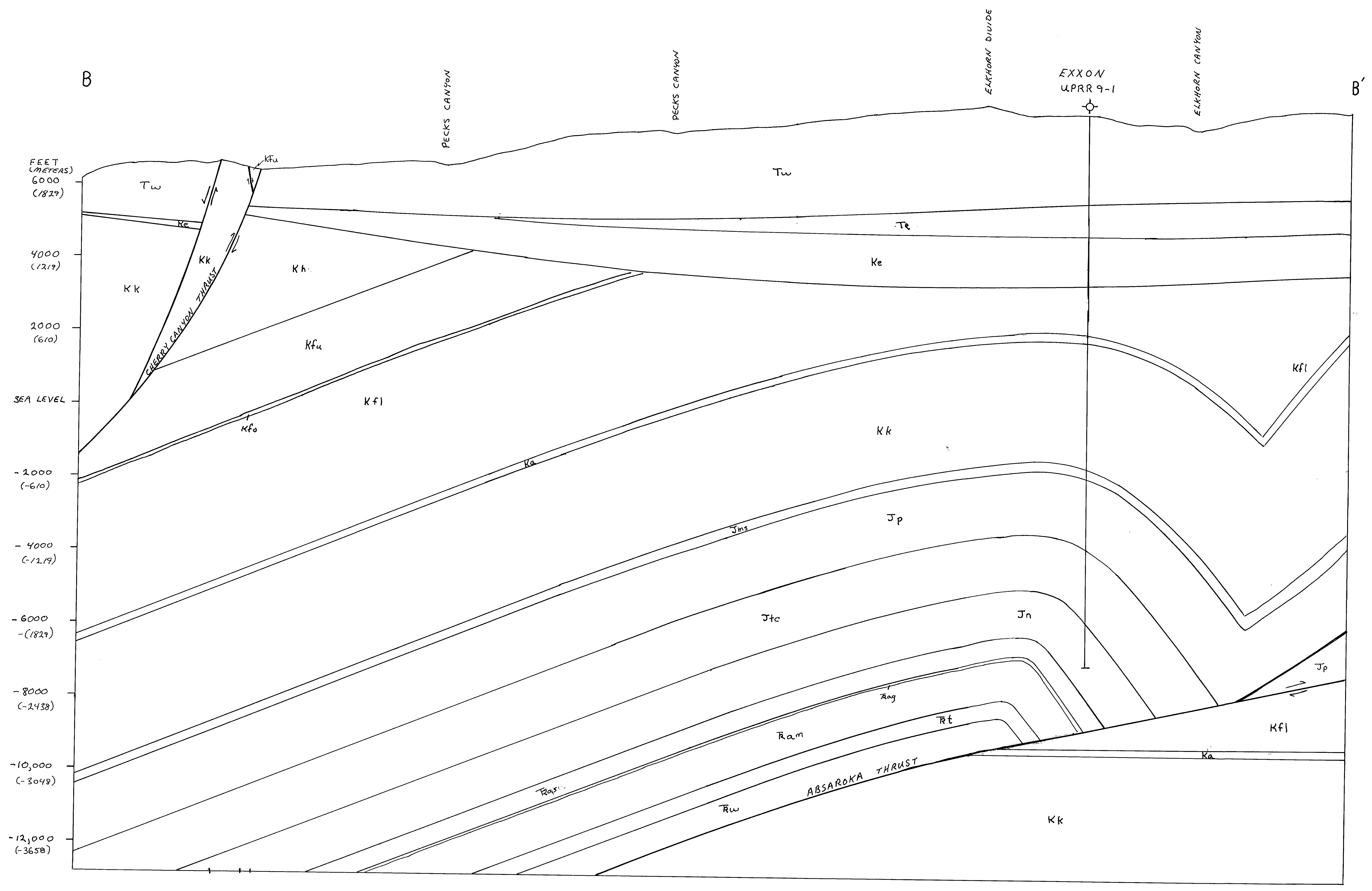


PLATE 1: GEOLOGIC MAP OF THE HIDDEN LAKE QUADRANGLE
by
MICHAEL D. BRADLEY

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

HIDDEN LAKE QUADRANGLE
UTAH—SUMMIT CO.
7.5 MINUTE SERIES (TOPOGRAPHIC)

Mapped by the U. S. Forest Service
Edited and published by the Geological Survey

Control by USGS, USC&GS, and U. S. Forest Service

Topography by photogrammetric methods from aerial photographs taken 1967. Field checked by USGS 1972.

Projection and 10,000-foot grid ticks: Utah coordinate system, north zone (Lambert conformal conic) 1000-meter Universal Transverse Mercator grid ticks, zone 12, shown in blue. 1927 North American datum

Fine red dashed lines indicate selected fence lines

UTM GRID AND 1972 MAGNETIC NORTH DECLINATION AT CENTER OF SHEET

SCALE 1:24 000

CONTOUR INTERVAL 40 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929

THIS MAP COMPLIES WITH NATIONAL MAP ACCURACY STANDARDS
FOR SALE BY U.S. GEOLOGICAL SURVEY, DENVER, COLORADO 80225, OR RESTON, VIRGINIA 22092
A FOLDER DESCRIBING TOPOGRAPHIC MAPS AND SYMBOLS IS AVAILABLE ON REQUEST

QUADRANGLE LOCATION

ROAD CLASSIFICATION

Primary highway, hard surface — Light-duty road, hard or improved surface
Secondary highway, hard surface — Unimproved road
Interstate Route — U. S. Route — State Route

OCTOBER 1998

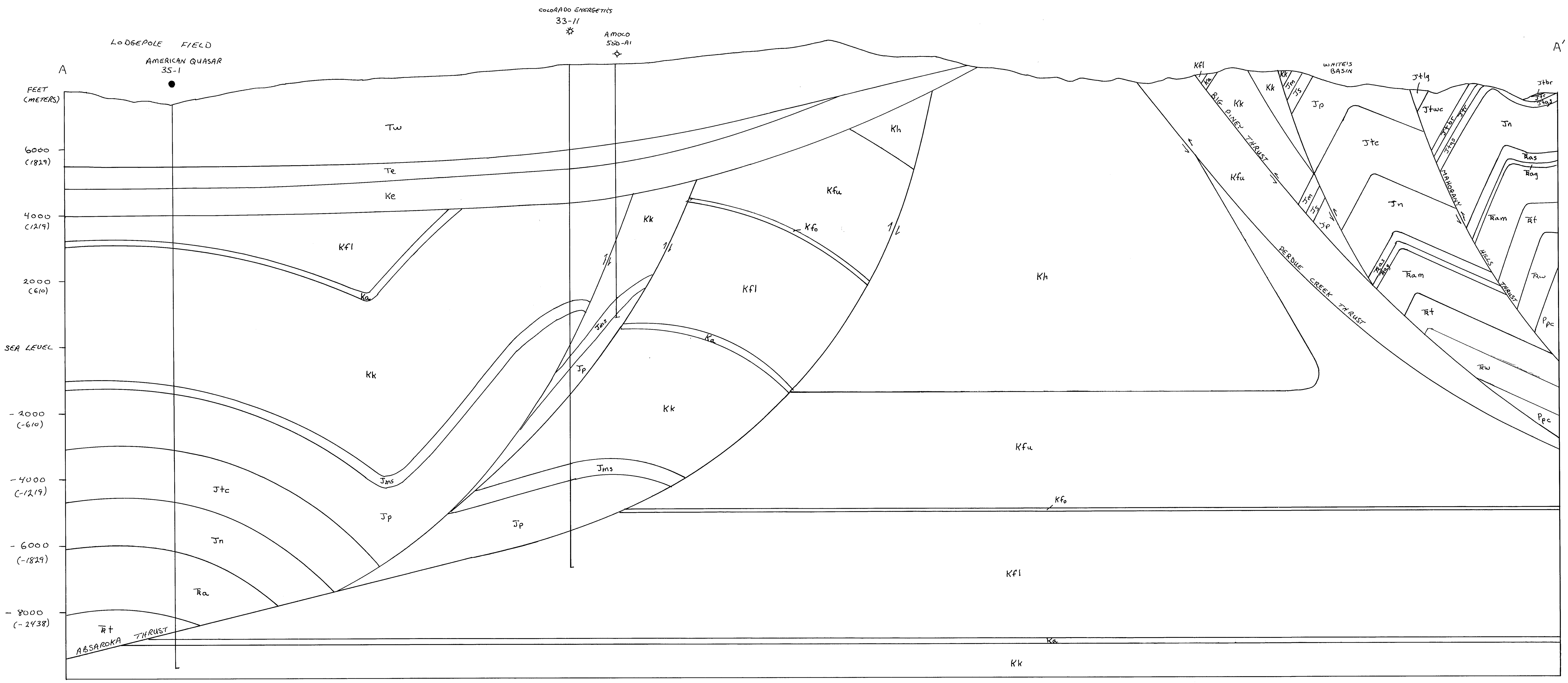
HIDDEN LAKE, UTAH
N4045—W11107.5/7.5

1972

AMS 3765 I SW—SERIES V897

ISBN 0-607-00544-0

PLATE 2: STRUCTURAL CROSS SECTIONS. HIDDEN LAKE QUADRANGLE.



NO VERTICAL EXAGGERATION (HORIZONTAL SCALE = VERTICAL SCALE)

SURFICIAL DEPOSITS TOO THIN TO SHOW

MICHAEL D. BRADLEY
10/98 JKK 4/01