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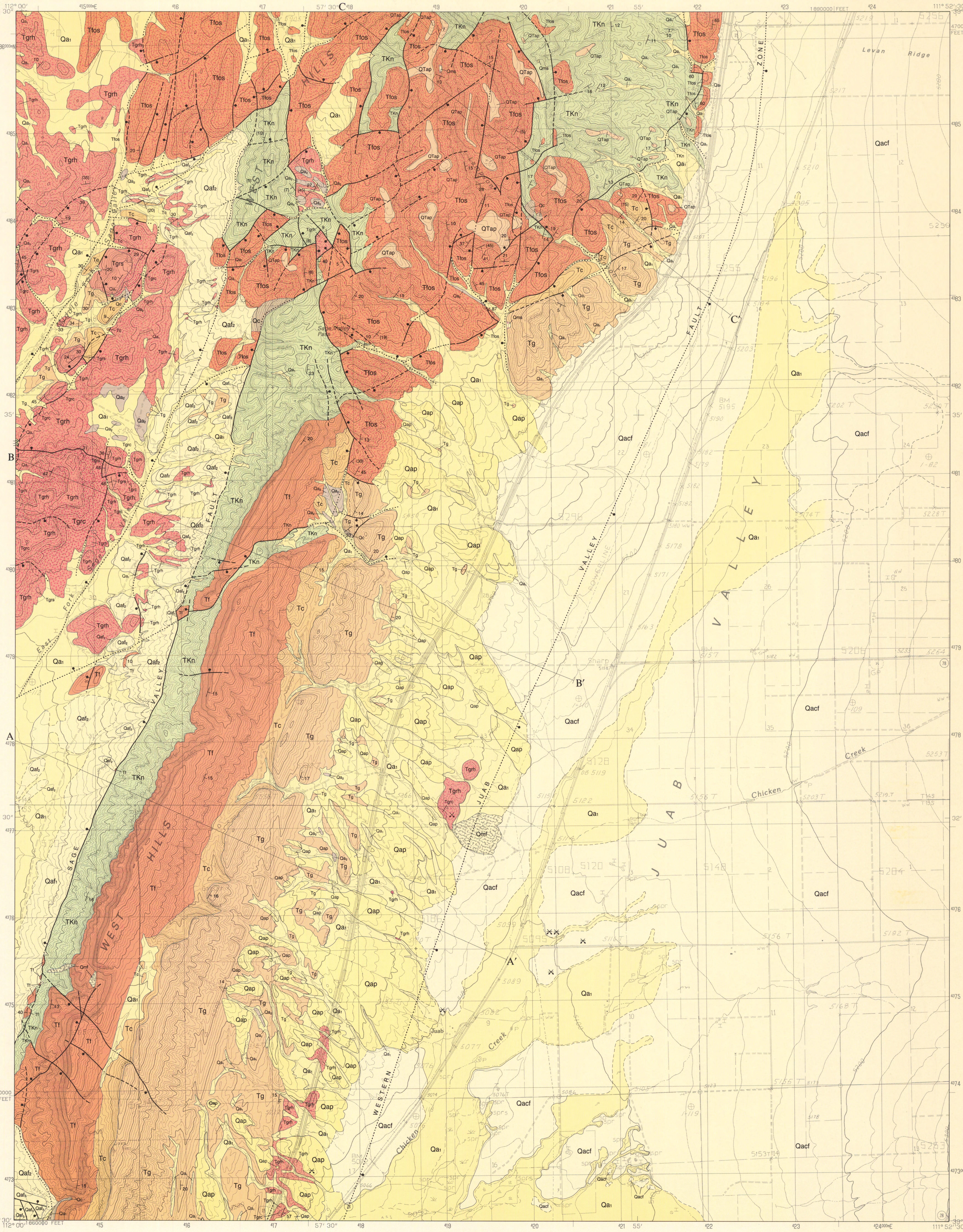

Provisional base map from U.S. Geological Survey, Juab Quadrangle, 1983

SCALE 1:24 000

MILES

FEET

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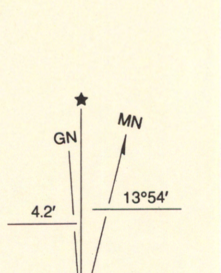
METERS

CONTOUR INTERVAL 20 FEET

Malcolm P. Weiss, Thesis Chairman
J.W. Parker, Cartographer



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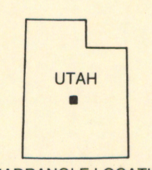
PROVISIONAL GEOLOGIC MAP OF THE JUAB QUADRANGLE, JUAB COUNTY, UTAH

by

Donald L. Clark

1990



QUADRANGLE LOCATION

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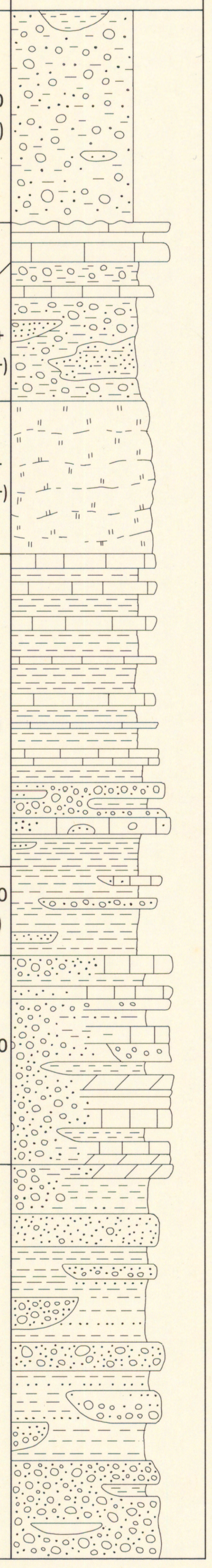
DESCRIPTION OF MAP UNITS

- **Qa₁** — Younger alluvium — *Clay- to boulder-sized detritus, locally derived and deposited along intermittent streams.*
- **Qa₂** — Older alluvium — *Deposits incised by younger alluvium and of similar composition.*
- **Qaf₁** — Younger alluvial fans — *Clay- to boulder-sized debris derived from local bedrock, composing coalescing fan system overlying Qaf₂.*
- **Qaf₂** — Older alluvial fans — *Dissected alluvial apron formed of a coalesced series of fans.*
- **Qaf₃** — Oldest alluvial fan — *Dissected and faulted, solitary fan containing Flagstaff debris, higher than Qaf₂.*
- **Qacf** — Coalesced alluvial fans — *Extensive coalescing alluvial fan systems (bajadas) of Juab Valley; clay- to boulder-sized material.*
- **Qap** — Younger pediment alluvium — *Thin, gently sloping mantle of clay- to boulder-sized material overlying a truncated bedrock surface.*
- **QTap** — Older pediment alluvium — *Mostly clay, silt, and sand; higher and more dissected than Qap.*
- **Qc** — Colluvium — *Slope cover composed of fallen blocks, talus, boulders, and surficial debris.*
- **Qmf** — Mass movement flow deposits — *Debris flows consisting of North Horn and Flagstaff materials developed on steep slopes; mudflow containing Green River and Flagstaff debris.*
- **Qms** — Mass movement slump deposits — *Small rotational slumps developed on steep slopes in the Green River, Orme Spring Conglomerate, and North Horn Formation.*
- **Tgr** — Goldens Ranch Formation (undifferentiated) — *Shown only on cross sections.*
- **Tgrs** — Sage Valley Limestone Member of the Goldens Ranch Formation — *Yellowish-gray to light-olive-gray limestone with plant remains, chert, vugs, gastropods; interbedded clays.*
- **Tgrh** — Hall Canyon Conglomerate (Meibos, 1983) — *Gray-colored volcanic conglomerate and conglomerate, volcaniclastic sandstone and siltstone, tuffaceous sandstone, tuff, and bentonitic clay.*
- **Tgrc** — Chicken Creek Tuff Member of the Goldens Ranch Formation — *Light-gray to grayish-pink ash-flow tuff with biotite, pumice lapilli; K/Ar dated.*
- **Tg** — Green River Formation — *Interbedded moderate-greenish-yellow and gray mudstone, and platy yellowish-gray fossiliferous limestone, bentonitic at top; orange, brown, and gray conglomerate, mudstone, sandstone, siltstone; green mudstone, yellowish-gray to light-olive-gray limestone.*
- **Tc** — Colton Formation — *Moderate-reddish-orange and brown, and pale-red mudstone, sandstone, conglomerate; mottled carbonates.*
- **Tf** — Flagstaff Formation — *Pastel-colored limestone and dolomite; multicolored mudstone and siltstone, sandstone, conglomerate. Exposures in southern and central portions of the quadrangle.*
- **Tfos** — Orme Spring Conglomerate — *Pink and white conglomerate, mudstone, and lesser siltstone and calcareous sandstone. Exposures in northern portion of the quadrangle.*
- **TKn** — North Horn Formation — *Moderate-reddish-orange and brown conglomerate, mudstone, sandstone, siltstone; oncolites and gastropods.*

Kpr (Price River Formation) and Ki (Indianola Group) shown on cross section only.

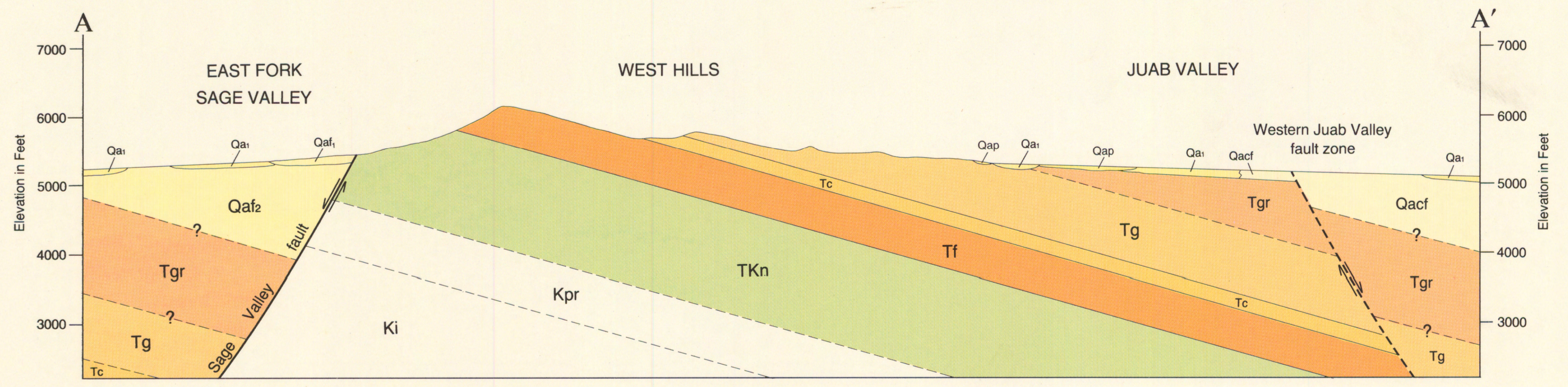
CORRELATION OF MAP UNITS

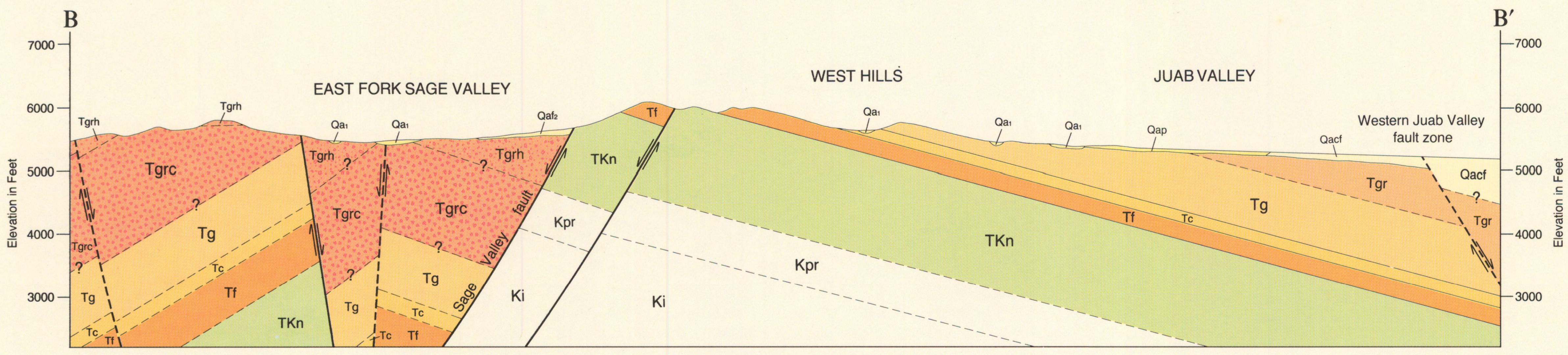
SYSTEM	SERIES (STAGE)	FORMATION		SYMBOL	THICKNESS Feet (Meters)	LITHOLOGY
QUATERNARY	Holocene Pleistocene	surficial deposits		Q	0-3000 (0-915)	
TERTIARY	Oligocene	Goldens Ranch Formation	Sage Valley Limestone Member	Tgrs	0-100 (0-31)	
			Hall Canyon Conglomerate Member	Tgrh	0-400+ (0-122+)	
			Chicken Creek Tuff Member	Tgrc	0-640+ (0-195+)	
	? Eocene	Green River Formation		Tg	900 ± (274±)	
		Colton Formation		Tc	214-260 (65-79)	
	?	Orme Spring Conglomerate	Flagstaff Formation	Tfos Tf	482-650 (147-198)	
	Paleocene	North Horn Formation		TKn	1120+ (342+)	
? CRET.	? (Maas.)					

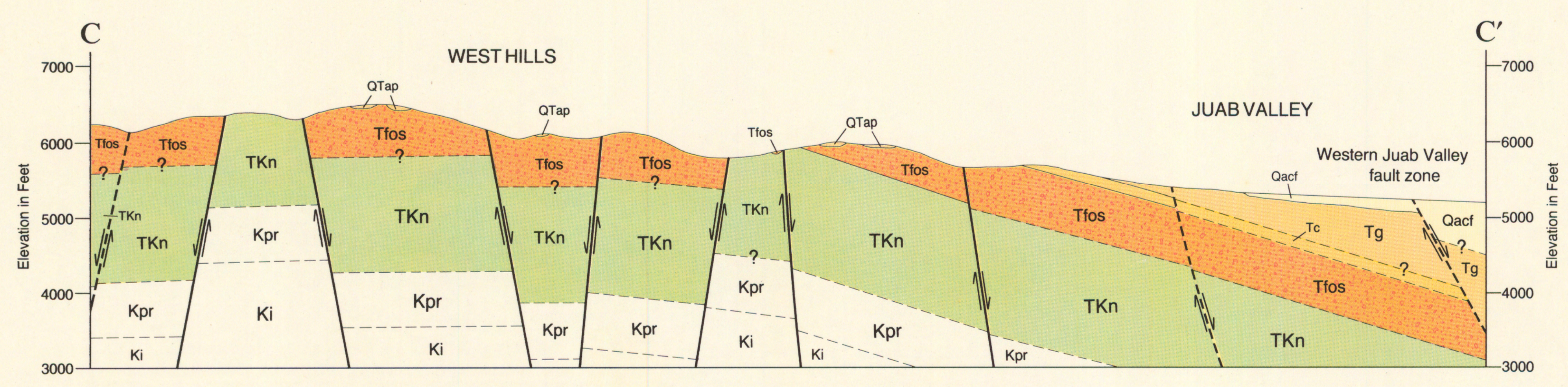


MAP SYMBOLS

- CONTACT — Dashed where approximate.
- NORMAL FAULT — Dashed where inferred, dotted where concealed; bar and ball on downthrown side.
- SPRING
- STRIKE AND DIP OF BEDDING — In parentheses where approximate. (5 / (5))
- GRAVEL PIT
  - active
  - abandoned
- OPEN PIT

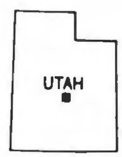






PROVISIONAL GEOLOGIC MAP OF THE JUAB QUADRANGLE JUAB COUNTY, UTAH

by Donald L. Clark
Department of Geology
Northern Illinois University



MAP 132 **1990**
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PROVISIONAL GEOLOGIC MAP OF THE JUAB QUADRANGLE JUAB COUNTY, UTAH

by Donald L. Clark[1]

ABSTRACT

The Juab 7.5-minute quadrangle lies along the eastern margin of the Basin and Range physiographic province in central Utah, and it encompasses portions of the West Hills, and Juab and Sage Valleys. The geology has been mapped at a scale of 1:24,000.

A succession of Late Cretaceous (?) to Oligocene strata crops out in the quadrangle, and well data indicate that older Mesozoic and Paleozoic units exist in the subsurface. The oldest exposed rock unit, the North Horn Formation (Maastrichtian[?] - Paleocene), consists of clastics deposited in piedmont fans along the eastern margin of the Sevier orogenic belt. The overlying late Paleocene-early Eocene Flagstaff Formation developed in the Lake Flagstaff lacustrine-alluvial complex. Nearness to the lake's western margin is indicated by the northward transition from lacustrine and fluvial lithofacies to a piedmont lithofacies (the Orme Spring Conglomerate). Partial infilling of Lake Flagstaff is recorded by the mostly fluvial Colton Formation (early and/or middle Eocene). The overlying Green River Formation was deposited in the southern arm of Lake Uinta in central Utah during the late Eocene to earliest Oligocene. The Green River Formation in the quadrangle contains a mudstone, a coarse clastic, and a mudstone-micrite lithofacies. Three members of the Oligocene Goldens Ranch Formation occur, in ascending order: Chicken Creek Tuff, Hall Canyon Conglomerate, and Sage Valley Limestone. The lower two members contain pyroclastic and water-laid debris, probably derived from the East Tintic volcanic field; the upper member is a localized lacustrine deposit. Quaternary surficial deposits including pediments, alluvial fans, mass-movement deposits, colluvium, and alluvium locally overlie the bedrock units.

The quadrangle has been affected by Basin and Range extensional faulting. The West Hills horst is bounded by the Sage Valley fault (west) and the western Juab Valley fault zone (east), and cut by numerous other high-angle, normal faults of lesser displacement. The map area also lies near the eastern limit of large-scale thrusting that occurred during the Sevier orogeny. Subsurface information reveals that major thrust faults and folds occur at depth.

The principal economic resources of the quadrangle include sand and gravel, carbonate rock, and ground water. Exploration for hydrocarbons in the area has resulted in gas and oil shows, but no production.

Earthquakes and mass movements are geologic hazards that could potentially cause damage, injury, or loss of life in the area.

INTRODUCTION

The Juab quadrangle is located in central Utah approximately 6 miles (9.6 km) southwest of Nephi and 0.5 mile (0.8 km) west of Levan. Interstate Highway 15 crosses the central part of the quadrangle.

The quadrangle area lies along the eastern margin of the Basin and Range physiographic province and encompasses portions of the West Hills, and Juab and Sage Valleys. In the quadrangle, the West Hills consist of three distinct physiographic segments: 1) a series of cuestas dipping east-southeast (south), 2) rounded, elongated hills and adjacent valleys (north), and 3) low rounded hills between the forks of Sage Valley (northwest). Juab and Sage Valleys are broad, alluviated valleys that flank the West Hills to the east and west, respectively. The topography varies from an elevation of 6622 feet (2018 m) at the Cedar triangulation station, located at the northern border of the map area, to 5050 feet (1539 m) at the Chicken Creek Reservoir, along the southern border.

The first detailed mapping of the area was performed by Muessig (1951); his study included the greater part of both the West Hills and Long Ridge, from south of Mills Gap to Goshen. Lambert (1976) measured three stratigraphic sections of the Flagstaff Formation exposed in the cuesta bordering Sage Valley. Vorce (1979) also measured stratigraphic sections on the cuestas bordering Sage Valley, including two sections of the North Horn and Flagstaff Formations in the Juab quadrangle. A preliminary geologic map of the Nephi 30 x 60-minute quadrangle has been prepared by Witkind and Weiss (1985). Also see Clark (1987).

[1]Department of Geology, Northern Illinois University

STRATIGRAPHY

A conformable succession of late Cretaceous (?) to Oligocene strata, nearly 4100 feet (1250 m) in thickness, crops out in the Juab quadrangle. Older Mesozoic and Paleozoic units are exposed in the vicinity, and well data indicate they underlie the map area.

The oldest exposed rock unit is the North Horn Formation (Maastrichtian[?]-Paleocene), which developed in a foreland basin east of the Sevier orogenic belt during a time of waning deformation (Stanley and Collinson, 1979; Fouch and others, 1983). The deep red clastics that comprise the unit were deposited by alluvial fans flanking the Sevier highland (Muessig, 1951; Vorce, 1979).

The Flagstaff Formation (late Paleocene-early Eocene) was deposited in the Lake Flagstaff lacustrine-alluvial complex in the final phase of subsidence and infilling of the foreland basin (Stanley and Collinson, 1979). In the Juab quadrangle, interbedded carbonates and clastics, as well as a facies change (northward) to the Orme Spring Conglomerate, indicate the proximity to the lake's western margin.

Colton (early and/or middle Eocene) strata record a change from dominantly lacustrine to fluvial conditions, as a northward prograding alluvial plain system partially infilled Lake Flagstaff (Marcantel and Weiss, 1968; Stanley and Collinson, 1979; Volkert, 1980; Zawiskie and others, 1982). The abundant clastics and lesser carbonates of the Colton Formation represent mixed fluvial and local shallow lacustrine depositional environments.

The Green River lacustrine beds encroached upon the Colton Formation, as Lake Uinta extended southward into central Utah (Spieker, 1949; Ryder and others, 1976), where the unit is locally Eocene-earliest Oligocene rather than strictly Eocene, as it is to the northeast. The lithofacies of the Green River Formation in the map area are indicative of shallow lacustrine and minor alluvial conditions.

The deposition of the Goldens Ranch Formation is largely related to early Oligocene eruptive episodes in the nearby East Tintic volcanic field (Morris, 1975; Morris and Lovering, 1979). The lower two members of the formation (Chicken Creek Tuff and Hall Canyon Conglomerate) contain pyroclastic and water-laid debris, while the upper Sage Valley Limestone Member is a localized lacustrine deposit.

The bedrock units of the Juab quadrangle are covered locally by unconsolidated Quaternary surficial deposits. Eleven Quaternary units were differentiated and include several types and ages of pediment alluvium, alluvial fans, mass-movement debris, colluvium, and alluvium.

SUBSURFACE PALEOZOIC AND MESOZOIC ROCK UNITS

Paleozoic and Mesozoic rock units are exposed in the vicinity of the quadrangle and have been logged in nearby Placid Oil Company wells (Howard #1A, #2; State #1, #2; Monroe #13-7; Barton #1). The subsurface units of the Juab quadrangle include (in descending order) the Price River Formation, Indianola Group, Cedar Mountain Formation, Twist Gulch Formation, Arapien Shale, Twin Creek Limestone, Navajo Sandstone, Chinle Formation, Moenkopi Formation and several Paleozoic and Proterozoic formations (Hintze, 1973).

CRETACEOUS(?)-TERTIARY SYSTEMS

North Horn Formation (Maastrichtian[?]-Paleocene)

The North Horn Formation of the West Hills is characterized by its deep red color and highly clastic nature. The rock types, in decreasing order of abundance, include conglomerate, mudstone, sandstone, siltstone, and carbonate.

North Horn conglomerates in the study area are bimictic, polymodal, and clast supported. The clasts are mostly quartzite and carbonate; the quartzite clasts are white, very pale orange, grayish yellow, and pale reddish brown, and are commonly banded and appear to be from Cambrian and Precambrian sources; the medium-dark-gray carbonate clasts appear to be derived from Paleozoic rocks. Quartzite is the dominant clast type, comprising about 75 to nearly 100 percent of the total clasts, while carbonate clasts make up a few to 25 percent of the total. The poorly sorted conglomerates exhibit a clast size range from 0.5 inch to 2.5 feet (1.3-76 cm) (pebbles to boulders), but the majority of clasts are pebbles and cobbles. Clasts range from well rounded to subrounded, with rounded and well-rounded clasts predominating. The matrix of the conglomerates, approximately 30 percent of the rock, is moderate reddish orange and reddish brown, very sandy, and calcareous. The moderately consolidated North Horn conglomerates form slopes, ledges, and small cliffs. Often, exposures are limited to rounded hills of deep red soils strewn with quartzite boulders. Individual conglomerate units can be fairly continuous, but most are discontinuous and have an irregular base.

Moderate-reddish-orange mudstones are the second most abundant rock type of the North Horn Formation. These weakly indurated mudstones form slopes and are often poorly exposed. Bedding is poorly developed, ranging from thinly laminated to very thinly bedded. The mudstones also contain various percentages of silt and sand.

Sandstones of the formation are also moderate reddish orange and moderate reddish brown due to the presence of hematite. The sandstones generally are fine to coarse grained and frequently contain pebbly and conglomeratic lenses. Grains are mostly subangular to subrounded; sorting is moderate to poor. The moderate- to well-indurated sandstone is attributed to a calcareous (calcite and dolomite) cement and a silty to muddy matrix. Sandstone units are medium to thickly bedded and develop ledges; some of them contain small- to large-scale trough cross bedding. Discontinuous lenses of sandstone also occur within the North Horn conglomerate.

The North Horn sandstone of the quadrangle is classified as sublitharenite and lithic arenite. Monocrystalline quartz is the most abundant constituent, but the polycrystalline variety is also present. Carbonate rock fragments are the dominant type of sedimentary rock fragments. Chert constitutes a small percentage of the sandstone, and feldspars are not present in amounts exceeding 1 percent. Accessory minerals include powdery hematite, muscovite, tourmaline, and zircon.

Siltstones have the same characteristic red colors, are calcareous and often sandy (to medium grain size), are crudely bedded (thickly laminated to thinly bedded), and weather into blocks. Oncolites up to 1.5 inches (3.8 cm) in diameter and gastropods were collected from two silty horizons.

Carbonates are sparse in the North Horn of the West Hills. A carbonate unit at the top of the formation is a mottled sandy dolomicrite and records the gradational nature of the North Horn-Flagstaff contact. Two other carbonates of very limited extent were noted: a pale-reddish-brown intramicrudite and a moderate-reddish-orange, silty, sandy, oncolitic biointramicrudite; both have the conspicuous hematitic staining common to other North Horn rocks.

The North Horn Formation was deposited in one or more foreland basins that lay between the Sevier orogenic belt on the west and the San Rafael Swell and other anticlines east of the belt. This setting allowed for the development of a variety of continental depositional environments ranging from mountain front (alluvial) fan to lacustrine, and, in turn, to a variety of lithofacies (Stanley and Collinson, 1979; Fouch and others, 1983).

Mudstone appears to have been deposited by mudflows, particularly as sheetflows, while conglomerate and sandstone deposition occurred through streamflow. With the development of streamflow on the alluvial fans, channels cut into the underlying sediment and were filled; the channels appear to have been straight or slightly meandering. Probable root casts occur in a fine-grained sandstone. Gastropods indicate both land and shallow freshwater affinities (La Rocque, 1960). The oncolites formed in ponds or streams that developed on the piedmont. A western sediment source is suggested for the North Horn of the West Hills. Well-developed channel surfaces and imbricated conglomerate clasts indicate paleocurrent directions to the southeast and east, respectively (Vorce, 1979). Lithic quartz sandstone and quartzite-carbonate conglomerate reflect a Precambrian, Paleozoic, and Mesozoic sedimentary source terrain in the Sevier orogenic belt (Stanley and Collinson, 1979; Vorce, 1979).

The thickness of the North Horn Formation in central Utah is quite variable. The base of the North Horn Formation in the Juab quadrangle is not exposed, but Muessig (1951) measured nearly 1120 feet (341 m) just south of Sage Valley Pass, which may be the maximum exposed thickness. Thicknesses of 1500 and 1700 feet (457 and 518 m) are reported in the Placid Oil Howard #1A and State #1 wells, located approximately 1 mile (1.6 km) north and south of the quadrangle, respectively.

In the northern West Hills, Meibos (1983) mapped the Conglomerate of Spring Canyon, which he considered equivalent to the upper part of the Indianola Group or Price River Formation. He stated that the Conglomerate of Spring Canyon lies disconformably below the Red Narrows Conglomerate (North Horn equivalent) (figure 1). The Price River Formation has been recognized in the Placid Oil Howard #1A and State #1 wells. The Flagstaff Formation conformably overlies the North Horn over much of the region. In general, the contact is gradational, and the units are distinguished from each other by the red beds in the North Horn Formation and the much less clastic nature of the Flagstaff Formation.

The North Horn Formation, at the type section in the Wasatch Plateau, is regarded as late Cretaceous to Paleocene in age (Spieker, 1946, 1949). Spieker (1949) and Fouch and others (1982, 1983) have indicated that occurrences of the unit farther west may be younger. Fossils found in the quadrangle include *Bulimulus?* sp., *Helix? riparia* White, *Oreohelix* sp. and *Viviparus trochiformis?* Meek and Hayden. Because of their long ranges, these gastropods are not useful for age determination. Therefore, until additional evidence can be found, the age of the North Horn Formation is listed as Maastrichtian?-Paleocene for the Juab quadrangle, although the unit may be entirely Paleocene here.

TERTIARY SYSTEM

Flagstaff Formation (late Paleocene-early Eocene)

The Flagstaff Formation is present in the West Hills as two distinct facies: a southern lacustrine and fluvial facies, and a northern piedmont facies (Muessig, 1951). The transition between the two facies occurs in the Juab quadrangle and in the next quadrangle to the north (Sugarloaf). Meibos (1983, p. 45) formally named the piedmont (conglomeratic) facies the Orme Spring Conglomerate, which will be used in this report. The term Flagstaff Formation is also used here to indicate the limestone and conglomerate natures of the Flagstaff.

In the southern part of the quadrangle, the Flagstaff consists of pastel-tinted limestones, dolomites, mudstones, sandstones, conglomerates, and siltstones. To the north, it consists of pinkish conglomerates and pink and white mudstones expressed topographically as rounded hills. The transition between the southern lacustrine and fluvial facies, and the northern piedmont facies, occurs in a 0.5-mile (0.8 km) area in N ½ Section 20, T. 14 S., R. 1 W. The nature of this transition is shown in figure 2.

Lacustrine and fluvial facies—About 50 percent of this facies is composed of various types of carbonate rock. Limestones and dolomites occur both as micrites and sparites and commonly contain various amounts of sand, intraclasts, pellets, and ooids. The bedding is thin to massive and the rocks are resistant, commonly forming ledges and cliffs. Fracturing, jointing, and karst features are common; vugs and dark-yellowish-brown and medium-light-gray chert are present, especially in the upper part of the unit.

The other 50 percent of the facies includes mudstone and siltstone, sandstone, and conglomerate in decreasing order of abundance. The mudstones and siltstones are found in light shades of gray, green, and pink, contain varying amounts of sand, and are slope formers. The mudstones are thinly laminated, while the siltstones are very thin to thinly bedded.

The multi-colored Flagstaff sandstones range from fine to coarse grained and may contain pebbly lenses. These rocks are poorly to well sorted with subangular to subrounded grains, and are moderately to well indurated. Compositionally, the sandstones are classified as quartz arenite, sublitharenite, and lithic arenite. Quartz is the dominant mineral grain; smaller amounts of sedimentary rock fragments, mostly carbonates and chert, are also present. Feldspar occurs in trace amounts. The thin to thickly bedded sandstones are generally more continuous than North Horn sandstones, but some channel-form sandstones are also present. Other distinctive features are cross beds and ripple marks.

Pale-red and grayish-yellow-green channel-form conglomerate is also present. The clasts are almost exclusively well-rounded

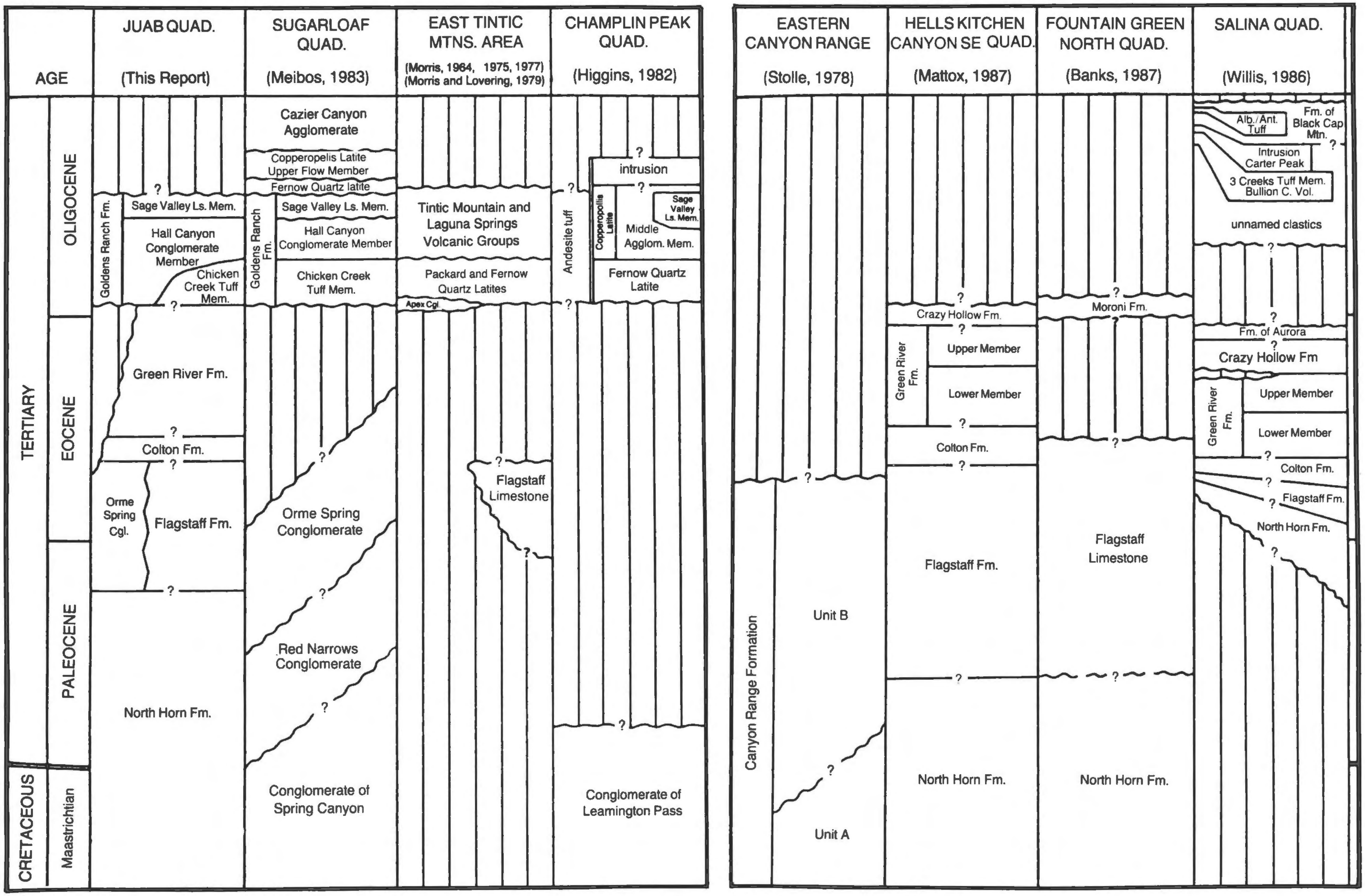

Figure 1. *Correlation chart of selected stratigraphic columns in central Utah.*

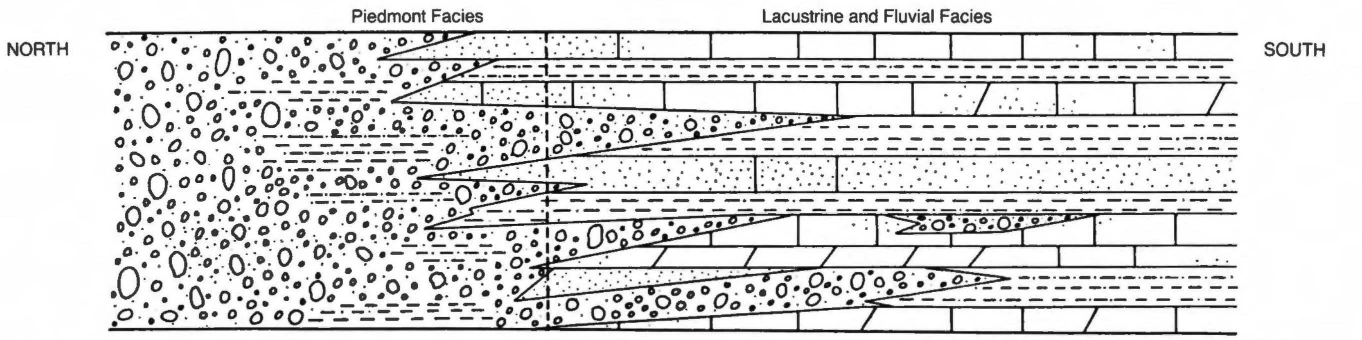

***Figure 2.** Representation of the northward transition of Flagstaff facies from the lacustrine and fluvial to the piedmont (Orme Spring Conglomerate).*

quartzite averaging 1 to 2 inches (2.5-5 cm) in diameter, and can be found up to 8 inches (20 cm) in diameter. The conglomerate is clast supported and has a sandy matrix.

Piedmont facies or Orme Spring Conglomerate— This lithofacies is dominated by conglomerate and mudstone, and it contains lesser amounts of siltstone and calcareous sandstone. The conglomerate is bimictic, polymodal, and clast supported. Clasts of Paleozoic carbonates and Cambrian quartzite are present, with carbonate clasts comprising 70 percent and quartzite clasts about 30 percent of the total. Conglomerate sorting is poor and, although clasts range in size from nearly 0.5 inch to 2 feet (1.3-60 cm), most clasts are pebble and cobble sized. The clasts are angular to well rounded, but most are subangular to subrounded. About 10 to 20 percent of the rock is an orange-pink, pale-red, and very-light-gray, sandy, calcareous matrix. The conglomerate is generally moderately well consolidated, and the rock is exposed as ledges and rounded hills.

Moderate-orange-pink and white mudstone retains the light coloration characteristic of the Flagstaff Formation throughout the quadrangle. This mudstone is mostly a poorly exposed slope former and locally contains pale blotches where iron has been reduced, perhaps by included organic debris.

Siltstone and calcareous sandstone constitute a relatively small percentage of the Orme Spring Conglomerate. The siltstone is often grayish pink, contains varying amounts of sand, and forms slopes. Very light-gray calcareous sandstone is poorly sorted and contains pebbly and conglomeratic lenses, channeling features, small-scale trough cross bedding, and bone fragments. The sandstone is classified as a sublitharenite.

Significant facies changes occur within the Orme Spring Conglomerate itself. All rock varieties of the piedmont facies are present in exposures in the eastern Sage Valley and Lampson Canyon, but to the northwest the facies is almost exclusively conglomerate.

Central Utah was once occupied by the basin of early Cenozoic Lake Flagstaff, which lay between the Sevier orogenic thrust belt to the west and Laramide basement uplifts to the east (Stanley and Collinson, 1979). The West Hills and the Juab quadrangle lie along the west depositional edge of this lake, at the east edge of the Sevier orogenic belt. Expansion and contraction of the lake resulted in a lateral shifting of facies and an intertonguing of alluvial and lacustrine rocks (Muessig, 1951; Lambert, 1976; Vorce, 1979).

A complete section of the Flagstaff Formation is exposed across the southern and central portions of the quadrangle. Measurements indicate that the unit ranges from 480 to 650 feet (146-200 m) in thickness. Vorce (1979) measured a section of 809 feet (246.6 m) in the quadrangle that appears a bit thick and may be duplicated by faulting.

The Colton Formation overlies the Flagstaff throughout most of central Utah. This boundary is conformable, gradational, locally intertonguing (Spieker, 1946, 1949) and, in this quadrangle, marked by a change from light-colored resistant carbonate and mudstone to mostly slope-forming deep-red mudstone, shale, and sandstone.

Fossils collected from the Flagstaff Formation of the Juab quadrangle are not diagnostic in age. Studies defining the age of the Flagstaff have been offered by Muessig, 1951; La Rocque, 1960; Newman, 1974; Fouch and others, 1982, 1983. The Flagstaff is usually considered to be late Paleocene to early Eocene in age. It is correlated with the Wasatch (Knight) Formation of the northern and central Wasatch Mountains, and the Claron and Cedar Breaks Formations of southwestern Utah (Hintze, 1973, 1975).

Colton Formation (early-middle Eocene)

The Colton Formation forms a conspicuous red swath in the saddle between the two prominent cuestas of the quadrangle. Differentiating the Colton from the Orme Spring Conglomerate in the northern part of the quadrangle (Sections 10, 15, and 16, T. 14 S., R. 1 W.) is difficult because of the fluviatile nature of both units. The Colton Formation is dominated by mudstone, with subordinate amounts of carbonate, sandstone, conglomerate, and siltstone, shale, and claystone.

Over half the unit consists of moderate-reddish-orange and brown, and pale-red mudstone; some of these rocks contain pale reduced spots and various amounts of silt and sand. The poorly to moderately indurated mudstones are thinly laminated to very thinly bedded, generally break into small blocks or chips, and weather to slopes.

Mottled carbonates of the Colton are generally pale red, moderate reddish orange, and white. Mottling and reduction spots can be attributed to the former presence of organic material. Most carbonates are sandy and dolomitic and all are micritic. They are well indurated, thin to thickly bedded (most beds are 1 to 3 feet; 0.3-0.9 m), and are not laterally extensive.

The sandstone is pale red, moderate reddish orange, pale reddish brown, and very light gray. Sand size ranges from fine to coarse, with some gritty and pebbly lenses. The generally subangular grains are poorly to well sorted, but are mostly moderately sorted. Bedding ranges from very thin to thick; some trough cross beds occur. Sandstone induration varies from poor to good, depending on the amount of clay matrix and calcite cement present. Compared to the Flagstaff sandstone, this sandstone has a slightly higher percentage of mica, feldspar, and clay. Monocrystalline quartz is the dominant constituent, with lesser amounts of polycrystalline quartz, chert, and sedimentary rock fragments, of which carbonate and argillaceous rock fragments are the predominant types.

Moderate-reddish-orange and pale-red conglomerate is bimictic, polymodal, and clast supported. Carbonate and quartzite clasts occur in equal amounts, from pebble to boulder sizes. The clasts are subangular to well rounded, and poorly sorted. Sandy matrix comprises approximately 15 to 20 percent of the rock. The conglomerate units are discontinuous laterally and rarely extend more than tens to hundreds of feet in length. Small amounts of this formation are also composed of slope-forming moderate-reddish-orange sandy siltstone, and pale-red shale and claystone.

Lateral variations in beds and sets of beds are conspicuous. Colton exposures are generally poor in the north, attributable to a greater amount of mudstone and a lesser amount of carbonate in the section. Conglomerate lenses are present throughout the lateral extent of the unit but are relatively abundant at Mills Gap, to the south.

The lithologies of the Colton in the West Hills indicate that sediments were deposited in shallow, freshwater lakes or ponds, with marginal mudflats, developed on flood or delta plains (Volkert, 1980; Zawiskie and others, 1982). Red mudstone, so prevalent in the quadrangle, is interpreted as a well-drained floodplain deposit, while the coarser clastics represent channel and overbank deposits. The thin, discontinuous carbonate layers in the unit suggest intermittent shallow lacustrine conditions as well. Paleocurrent directions and the mineralogy of the Colton sandstone indicate a source, or sources, differing from that of the North Horn and Flagstaff sediments. Colton sediments were largely derived from the southeast, south, and southwest (Peterson, 1976; Stanley and Collinson, 1979). Proposed source areas include arkosic sandstone (Cretaceous) of the Monument uplift in Utah, Precambrian crystalline rocks of the Laramide uplifts in Colorado, the Upper Cretaceous-Tertiary volcanic pile in the San Juan Mountains of Colorado, and sedimentary rocks of southeastern Utah (Stanley and Collinson, 1979; Volkert, 1980). Locally, however, sediment may also have been derived from the Sevier orogenic belt as indicated by Marcantel and Weiss (1968).

The Colton Formation is completely exposed in the Juab quadrangle and ranges from 214 to 260 feet (65-79 m) in thickness. Like the Flagstaff-Colton boundary, the Colton-Green River succession is regionally conformable. In the quadrangle, the boundary is conformable and distinctly marked by a change from deep-red mudstones to calcareous green-colored mudstones, and oolitic and algal carbonates. No evidence indicative of the age of the Colton Formation was found in the Juab quadrangle. Because the upper Flagstaff is early Eocene in the Gunnison and Wasatch Plateaus, the Colton in the quadrangle is probably early and/or middle Eocene in age. Hintze (1973, 1975) correlates the Colton with part of the Wasatch Formation of the Uinta Basin, Uinta Mountains, and northern Utah.

Green River Formation (late Eocene-early Oligocene?)

The Green River Formation in the Juab quadrangle can be divided into three vertically successive lithofacies which, from the base of the unit, are: 1) mudstone, 2) coarse clastic, and 3) mudstone-micrite. The lithofacies are persistent and extensive in the area.

Mudstone facies — The mudstone facies is dominated by light-greenish-gray, grayish-yellow-green, and dusky-yellow-green mudstone, which is thinly laminated to very thinly bedded, and weathers to form slopes. The mudstone also contains small lenses of sandy dolomite (a few inches thick) and laminated calcareous nodules. Carbonates that cap and comprise nearly 30 percent of the mudstone facies are yellowish-gray to light-olive-gray sparites and micrites. Some of these rocks contain sand, pebbles, ooliths, chert, and stromatolites. The stromatolites occur as laterally linked hemispheroids and were identified by Muessig (1951) as containing *Chlorellopsis.* The carbonates are thinly bedded to massive, well indurated, often fractured, and are ledge to cliff formers. Discontinuous lenses of channel-form conglomerate also occur in this facies and are generally light olive gray with mostly well-rounded quartzite clasts.

Coarse-clastic facies — The middle or coarse-clastic facies consists of 46 percent conglomerate, 31 percent mudstone, 17 percent sandstone, and 6 percent siltstone. Moderate-reddish-orange and brown conglomerate is bimictic, as are the older conglomerates. Approximately 70 to 75 percent of the rock is composed of quartzite and carbonate clasts. About 60 percent of the clasts are quartzite in shades of white, purple, gray, and orange, while some are banded. Carbonate clasts are medium gray and some are fossiliferous. Rounded to subrounded clasts are pebble to boulder sized (to 1 foot; 30 cm). The conglomerates are clast supported and have a sandy, calcareous matrix. The often poorly exposed nature of the rock bespeaks its generally poor to moderate induration but, in places where it is better consolidated, small ledges are developed. Sandstone lenses, present in the conglomerate units, range from medium to coarse grained and exhibit trough cross bedding and channeling features.

Mudstones of this facies are mostly shades of brown and are thinly laminated to thinly bedded. These slope-forming rocks contain varying amounts of silt and sand and, locally, small sandy lenses a few inches in thickness.

Red, orange, and gray sandstones contain silt to medium sand that is moderately to well sorted and subangular to subrounded. Some pebbly and gritty lenses occur. The bedding is very thin to very thick, and some beds contain poorly developed, small-scale trough cross stratification. Induration is moderate or better; the more strongly indurated sandstones possess a greater percentage of calcareous cement.

Siltstone is very thinly to thinly bedded, moderately indurated, and constitutes a relatively small amount of the coarse-clastic facies.

Mudstone-micrite facies— Repetitively interbedded mudstone and micrite constitute most of mudstone-micrite facies, although minor amounts of sandstone and bentonitic clay also occur. The mudstones are green, yellow, and gray, and total over 50 percent of the facies. Bedding is often indistinct, but the slightly more indurated units are thinly laminated to very thinly bedded. These rocks weather and erode easily.

Yellowish and grayish micrite beds are moderately to well indurated and range from thinly laminated to thickly bedded, but they are commonly platy and develop small ledges. Also present in the carbonates are calcite stringers, chert, patches of limonite, and fossils such as pelecypods, gastropods, ostracodes, and plant fragments. The shell-bearing fossils are locally quite abundant, so that certain beds might be classified as coquinas.

Sandstone is yellowish gray and grayish yellow and made of well-sorted and subrounded medium to fine grains. Silt is also present. The thinly bedded sandstone units develop small, weakly cemented ledges. Some of the sandstone of the exposures in Sage Valley is coarser grained and contains thin, pebbly and gritty lenses.

Bentonitic clays, although poorly exposed, are present near the top of the mudstone-micrite facies. The gray and white clays characteristically weather to ashy powder and are interbedded with the micrites and mudstones.

Following Colton fluvial deposition, lacustrine conditions returned to central and northeastern Utah. Green River strata were deposited in and near Lake Uinta, which filled a basin bounded by tectonic elements similar to those that outlined Lake Flagstaff. Mudstone of the lower facies was probably deposited adjacent to the lake on carbonate mudflats, while the sandy, oolitic, and stromatolitic carbonates that cap the facies are indicative of shallow lacustrine conditions. The coarse-clastic facies was deposited in an alluvial or delta plain (Millen, 1982). The mudstone-micrite lithofacies was deposited in freshwater lake and carbonate flat environments.

A complete, nearly 900-foot-thick (274 m) section of the Green River Formation crops out near the southern border of the Juab quadrangle. To the north, the formation may be slightly thinner. The upper contact of the Green River Formation with the overlying Goldens Ranch Formation is thought to be conformable and gradational. Poor exposures and lack of bedding in the lower part of the Goldens Ranch Formation make description of the contact difficult. However, along the Middle Fork of Sage Valley, concordance between the units is evident, and southwest of Chicken Creek Reservoir (near Mills Gap) the top of the Green River intergrades with the Chicken Creek Tuff (lower Goldens Ranch Formation) (Everenden and James, 1964).

Mollusk fossils collected in the Green River Formation in the Juab quadrangle include *Sphaerium, Gyraulus,* and *Hydrobia.* These are not useful enough to make age determinations. The specific age of the Green River has not been constrained in the Juab quadrangle area, but radiometric dates obtained for the overlying unit indicate the Green River is mostly late Eocene and possibly earliest Oligocene in age.

Goldens Ranch Formation (Oligocene)

The Goldens Ranch Formation in the Juab quadrangle can be divided into three members. These three members, in ascending order, are the Chicken Creek Tuff, the Hall Canyon Conglomerate, and the Sage Valley Limestone, following the usage of Meibos (1983).

Chicken Creek Tuff Member— This member consists of a light-gray to grayish-pink latitic, ash-flow tuff. In hand samples, biotite, pumice lapilli, and lithics are conspicuous. The pumice lapilli, present in various abundances in the rock, are found to 1.5 inches (3.8 cm) long and some appear slightly flattened. Lithics, although not everywhere present, include quartzite, carbonate, and volcanic types, up to pebble sizes. The moderately to well-indurated tuff commonly effervesces in hydrochloric acid. The unit is crudely layered, yet locally the layering is distinct and may be as thin as a few inches. Exposures of the Chicken Creek Tuff generally develop rounded knobs or ledges.

About 30 percent of the rock is composed of crystals and the remaining 70 percent is groundmass or matrix. Plagioclase, sanidine, quartz, biotite, iron oxide, and basaltic hornblende often occur as broken fragments. Plagioclase is the most abundant mineral, making up about two-thirds of the 30 percent. Clear sanidine and quartz each comprise about 2 to 4 percent of the rock, well-formed biotite constitutes about 1 or 2 percent, and iron oxides and basaltic hornblende each 1 percent or less. Some of the crystals are embayed and have glassy crusts, particularly the feldspars and quartz. Lithic fragments of quartzite, volcanics, and possible carbonate also occur in limited abundance. The groundmass of the Chicken Creek Tuff consists of 40 to 50 percent glassy fragments embedded in 25 to 30 percent calcite. The glassy component includes both pumice and glass shards, and gives the rock a vitriclastic texture. The presence of calcite is undoubtedly a secondary feature (not from the magma) and may be due to deposition of pyroclastic material in water or later percolation of calcium- and/or carbonate-rich waters through the porous rock.

Hall Canyon Conglomerate Member (Meibos, 1983)— Volcanic conglomerate and conglomerate are the most abundant rock types of the middle member of the unit. In overall color these rocks are shades of gray. Clasts of the conglomerates are volcanics, quartzites, and carbonates occurring in various percentages, but usually the volcanics, mostly of latite and andesite, predominate. The quartzite clasts are commonly white, pink, orange, and purple, while the carbonates are typically medium gray. Pebble- to boulder-sized clasts occur; however, pebbles and cobbles are most abundant. The largest clast noted in the quadrangle is about 4 feet (1.2 m) in diameter. Clasts are subangular to well rounded, but most are rounded, and sorting is poor to moderate. The matrix of the volcanic conglomerate and conglomerate is bentonitic and tuffaceous, consisting of clay- to sand-sized particles composed of volcanic and sedimentary debris. As a rule, these rocks are poorly consolidated and are only rarely seen in a consolidated exposure. Typical exposures of the conglomerate are low, rounded, rubbly hills littered with pebbles, cobbles, and boulders.

Other rock types in the Hall Canyon Conglomerate include volcaniclastic sandstone and siltstone, tuffaceous sandstone, tuff, and bentonitic clay. The volcaniclastic sandstone and siltstone are usually light bluish gray and grayish yellow green. Particles are silt to pebble sized, angular to rounded, and poorly to moderately sorted. Induration of these rocks is poor to moderate, and bedding is commonly poorly developed.

Medium-light-gray and light-olive-gray tuffaceous sandstone is composed of glassy material, volcanic, carbonate, and quartzite rock fragments, feldspar, quartz, biotite, magnetite, and hornblende. Glass often constitutes from less than 20 to 40 percent of the rock, occurring as pumice, glass shards, and fine vitreous material. Some pumice shards are flattened. Rock fragments, feldspar, and quartz are more prevalent than the other mineral constituents. Many volcanic rock fragments are glassy with contained microlites. Also, calcite is present as a cementing agent. The sandstone ranges from fine to very coarse grained and locally contains granular to pebbly material. Individual layers can vary in grain size. The grains are angular to rounded, and generally moderately sorted. Induration of the tuffaceous sandstone is greater than for the volcaniclastic sandstone; bedding varies from very thin to medium.

The ash and lapilli tuffs of the member are pinkish gray, very light gray, and light gray. Pumice and glass shards are the predominant constituents of these tuffs. Crystals comprise less than 30 percent of the rock and include feldspars and quartz, with minor amounts of biotite, magnetite, and basaltic hornblende. The crystals are commonly broken, and some are embayed and/or have glassy crusts. Volcanic rock fragments and secondary calcite are also present. Consolidation of the tuffs is moderate to good, but bedding is very crude. In some locations only very thin tuff layers (a few inches thick) are present.

Light-colored (white, gray, green) bentonitic clays are poorly exposed in the Hall Canyon Conglomerate.

Sage Valley Limestone Member— This member consists of limestone, clay, claystone, and shale. The limestone is yellowish gray to light olive gray, finely to coarsely crystalline (sparite), and is fractured, vuggy, and often weathers to a rough, pitted surface. It contains abundant plant fossil fragments and impressions, particularly of reed-like varieties, as well as leaves and stems. Locally, freshwater gastropods are present. Chert occurs in thin discontinuous layers and patches, and is medium light gray, moderate reddish brown, and white in color. This well-indurated limestone is thinly to thickly bedded and forms a series of ledges that often cap hills.

Whitish to orangish clay, claystone, and shale form poorly exposed slopes between limestone ledges. These rock types are calcareous and earthy, and some may contain a small amount of bentonitic material.

Volcanism in central Utah occurred toward the end of Green River deposition, as evidenced by the tuffaceous and bentonitic material in the upper parts of that formation in surrounding areas (Muessig, 1951; Sheliga, 1980; Millen, 1982). Oligocene volcanic activity was significant in parts of Utah. Deposition of the Goldens Ranch Formation is believed to have been largely related to the volcanic episodes of the nearby Tintic district (Morris, 1975; Morris and Lovering, 1979). Other volcanic sources for the unit may have existed locally.

The Chicken Creek Tuff has been described as an ash-flow tuff and is also referred to as an ignimbrite (Mackin, 1960; Meibos, 1983). It is probably the consequence of the first volcanic episode in the Tintic volcanic field. Initial eruptions are believed to have been voluminous and persistent (Morris, 1975). The Hall Canyon Conglomerate is almost certainly the volcanic outwash from the East Tintic volcanic field. The conglomerate and sandstone that comprise most of this member are water-laid; volcanic and sedimentary debris were carried by streams from the volcanic field, probably in alluvial-fan or alluvial-plain depositional systems. Due to the buildup of the volcanic pile, gradients were considerable at times, judging by the sizes of clasts in the rocks. Subordinate tuffs and bentonitic clays reflect deposition by ash flows or falls.

The Sage Valley Member is interpreted as a localized lacustrine deposit. The well-bedded limestone and interbedded clays formed in a lake or series of small lakes. Chert in the unit suggests that the body or bodies of water may have been somewhat saline.

In the Juab quadrangle, the Chicken Creek Tuff Member is discontinuous and is estimated to range from 0 to 640+ feet (0-195+ m) in thickness. The thickest exposure occurs in Sections 19 and 30, T. 14 S., R. 1 W. About 0 to 400 feet (0-120 m) of the Hall Canyon Conglomerate can be accounted for; it might be thicker, its base is not everwhere exposed. The thickness of the Sage Valley Limestone ranges from 0 to 100 feet (0-30 m) in the map area.

A conformable succession appears to exist between the three members of the Goldens Ranch Formation, even though the Chicken Creek Tuff is discontinuous and, in places, the Hall Canyon Conglomerate directly overlies the Green River. The Goldens Ranch Formation is the youngest rock unit in the Juab quadrangle and is locally overlain by Quaternary surficial deposits.

Direct evidence for the age of the Goldens Ranch Formation comes from various K/Ar dates (Everenden and James, 1964; Armstrong, 1970; Marvin, 1984), which range from 31 to 38 Ma, but mostly fall in the 32 to 34 Ma range. The age-dated samples were obtained near the Green River-Goldens Ranch contact, so that the ages nearly represent the time of initial deposition of the unit. The radiometric dating suggests that at least part of the unit is early Oligocene in age. The age of the upper part may extend into the late Oligocene. The Chicken Creek Tuff is thought to correlate with the Fernow and Packard Quartz Latite (Morris, 1964, 1975, 1977) (figure 1). The Hall Canyon Conglomerate Member is correlated with the Tintic Mountain and Laguna Springs volcanic groups. The Moroni Formation of the Cedar Hills, about 20 miles (32 km) northeast, was thought to be equivalent to the Goldens Ranch Formation based on lithology and stratigraphic position (Muessig, 1951; Witkind and Weiss, 1985), but K/Ar dating indicates that it is 35 to 38 Ma (Marvin, 1984). The Moroni ages are supported by the age of the Salt Creek dike (33.6± 1.4 Ma), which cuts the Moroni Formation (Banks, 1986). Correlation of the Goldens Ranch Formation and Chicken Creek Tuff with other units of the eastern Great Basin (eastern Nevada and western Utah) is presented by Fouch and others (1979).

QUATERNARY SYSTEM

A total of 11 surficial units were mapped—differentiated by morphology, composition, and relative age. They include two levels of pediment alluvium, four alluvial-fan levels, mass-movement flow and slump deposits, colluvium, and two ages of alluvium. The surficial material likely ranges from 0 to 3000 feet (0-915 m) in thickness, with the thicker areas confined to the east, beneath Juab Valley.

Features and deposits of Lake Bonneville have not previously been mapped in the Juab quadrangle and none were found, although their existence is implied by others (Gilbert, 1890; Muessig, 1951; Currey, 1982). A recent delineation of the Bonneville shoreline by Currey (1982) shows the lake extending into the southernmost portion of the Juab quadrangle (Chicken Creek Reservoir area) with the shoreline following the 5090-foot (1551 m) contour line. The mapped shoreline is indicated to be an erosional shoreline or a poorly developed or poorly preserved depositional shoreline. The area of the quadrangle, which might have Bonneville deposits, is of low relief, offering no good exposures. The material present there is mapped as alluvium. The possibility that Bonneville deposits are present in the subsurface cannot be excluded.

Pediment Alluvium

Older pediment level— A level of weathered pediment alluvium (QTap), older and higher than a younger level (Qap), caps several flat-topped ridges and hills in the northeastern part of the map area and slopes gently eastward. This pediment consists of unconsolidated earthy material composed of clay, silt, sand, and a few pebbles and cobbles. These sediments overlie the Orme Spring Conglomerate and the North Horn Formation. The pediment level likely reflects the existence of an old erosional surface which developed subsequent to relative uplift of the West Hills, but which is now dissected extensively and eroded because of still later uplift. The elevation and dissected nature of QTap suggests that it is older than Qap and may have initially developed in the late Tertiary.

Younger pediment level— A well-developed level of pediment alluvium (Qap) lies along the east flank of the West Hills and western margin of Juab Valley in the southern and central parts of the quadrangle. A thin mantle of alluvium lies on a gently sloping, truncated bedrock surface (mostly upper Green River and Goldens Ranch Formations), and against and lapping onto a series of low, eastward-dipping cuestas and small hills. The alluvial cover is pale yellowish brown, yellowish gray, very light gray, and is composed of poorly sorted clay, silt, sand, granules, pebbles, cobbles, and boulders that reflect local sources. These unconsolidated to poorly consolidated materials are massively to crudely bedded. The thickness of alluvial cover ranges from a few feet at the heads of the pediments to an uncertain thickness (possibly tens of feet) downslope.

Some of these features are fan-shaped in plan, while others are elongated northwest-southeast. There likely was once a more continuous pediment surface (pediplain), but it has been incised by stream action. The pediment surfaces are flat to slightly concave upward and slope about 2.5 degrees toward Juab Valley.

Alluvial Fans

Coalesced fans— The Juab Valley part of the quadrangle is dominated by coalescing alluvial fans (Qacf) which form two gently sloping alluvial aprons (or bajadas). The bajadas emanate from the West Hills and the adjacent Gunnison Plateau and merge in Juab Valley. Fans issue eastward from a series of small drainages in the West Hills; three extensive fans extend westward from major drainages of the Gunnison Plateau. The fans from the Gunnison Plateau are more extensive, as is expected from their much larger drainage basins, so that the line of convergence of the two fan systems is west of the center of the valley. Fans on the western side of the valley are steeper than their counterparts to the east and are differentiated from alluvium (Qa) based on morphology.

The coalesced fans remain active today. Chicken Creek has been trenched to keep it from meandering across the large fan in the east-central portion of the quadrangle. The surface of the fan system carries numerous streams and some water seeps; it is also extensively cultivated. In one location (Section 13, T. 14 S., R. 1 W.), patterned ground of uncertain origin was noted.

Fan deposits range in color from moderate reddish brown to moderate yellowish brown and light gray, and they are composed of poorly sorted clay- to cobble-sized material, with some boulders. Grain size generally decreases from the apices to the toes of the fans. The deposits are unconsolidated to poorly consolidated, and massively to crudely bedded. A section through the uppermost part of the fan extending west from Levan (in gravel pit NW Section 36, T. 14 S., R. 1 W.) reveals mostly pebbles and cobbles in a matrix of sand and silt. Clasts are rounded quartzite, carbonate, and sandstone. Sand and clay lenses and channeling features are also present. The upper parts of the fan material in Juab Valley are considered Quaternary in age, but underlying deposits may be Tertiary in age.

A gravity profile across Juab Valley, about 6 miles (10 km) to the north, indicates that the alluvial fill there is about 3900 feet (1188 m) thick. The fill thins to the south in Juab Valley onto a structural high that separates Juab and Sevier Valleys (Zoback, 1983). Wells drilled in Juab Valley have bottomed in valley deposits at depths measuring hundreds of feet (Meinzer, 1911; Bjorklund and Robinson, 1968). The maximum depth of alluvial fill in the quadrangle is estimated to be 3000 feet (914 m).

Fan levels 1, 2, and 3— Three levels of alluvial fans were mapped in eastern Sage Valley and are differentiated according to relative age. The oldest fan (Qaf_3) is a solitary fan near the mouth of a small canyon in the southwest corner of the quadrangle. This fan is much dissected, faulted, and higher in elevation than the next younger fan level (Qaf_2), which surrounds Qaf_3. The fan material is generally light brown, poorly sorted, subangular to subrounded, and clay to boulder sized. Most of the larger clasts are carbonates, probably from the Flagstaff Formation. Considering the composition of the fan and that the adjacent canyon is deeply incised into the Flagstaff Formation, the deposit may be of debris-flow origin. The fan appears to be at least 50 feet (15 m) in thickness.

The next younger fan level (Qaf_2) is extensive along the East Fork of Sage Valley. A series of fans have coalesced to form a broad, sloping, alluvial apron at the foot of the steep west side of the cuesta bordering Sage Valley. The apron is quite dissected, and patches of underlying bedrock are exposed. In some locations, the youngest fan level (Qaf_1) spills over Qaf_2. The level 2 fan system was derived from material shed from the North Horn and Flagstaff Formations, and in some places obscures the Sage Valley fault. The clay- to boulder-sized material is moderate reddish brown to moderate brown and is unconsolidated to semiconsolidated. The thickness ranges from 0 to tens of feet.

The youngest fan deposits (Qaf_1) also form a coalesced system, actively building along the western margin of the West Hills. Streams eroding the North Horn and Flagstaff Formations carry debris across the scarp of the Sage Valley fault and deposit the materials as alluvial fans. As individual fans continue to build and enlarge, adjacent fans overlap and interfinger. The moderate-reddish-brown fan deposits consist of clay- to boulder-sized materials. Consolidation and stratification are poor to nonexistent. Fan thickness ranges from 0 to tens of feet.

Mass-Movement Deposits

The number of mass-movement deposits in the study area are small compared to those of the nearby Gunnison Plateau which are locally quite abundant. Two types of mass movements, flows and slumps, were mapped in the Juab quadrangle.

Flows — Two varieties of flows (Qmf) are present: debris flows and a mudflow. Two debris flows (Varnes, 1958) involving the North Horn and Flagstaff Formations occur on the steep slopes in Section 12, T. 15 S., R. 1½ W. They consist of unsorted masses of rock fragments, soil, and mud. The flows are elongate with thin apices but widen downslope. They appear to be relatively old features, as their surfaces are vegetated with grasses and there is no evidence of scarps above. Considerable mass has been lost along the margins. The flows are surficial features, probably nowhere greater than 25 feet (7.6 m) in thickness. They originated as highly saturated material on oversteepened slopes. The debris flows may have developed during the Pleistocene, under the increased precipitation of that time (Schumm, 1965).

The single mudflow mapped (Section 4, T. 14 S., R. 1 W.) has a squarish to elongated shape and a steep and slightly lobate front edge. Its surface is somewhat dissected, generally flat, and slopes gently eastward. The mass is composed of granules, pebbles, cobbles, and boulders set in a pale yellowish-brown matrix of sand, silt, and clay. The majority of the deposit is fine-grained material. Sedimentary debris, notably Green River and Flagstaff material, is recognizable. Its thickness is uncertain but may be 10 feet (3 m).

Slumps — Three small rotational slumps (Qms) were observed. They are developed in the Orme Spring Conglomerate and the Green River and North Horn Formations in Sections 4 and 16, T. 14 S., R. 1 W. The slumps occur on steep slopes, and none have been displaced more than a few feet. Of the three slumps, only the one formed in the North Horn is relatively fresh.

Colluvium

A few small patches of colluvium (Qc) are present on slopes and at the bases of slopes in Sections 9, 18, and 29, T. 14 S., R. 1 W., and in Section 13, T. 15 S., R. 1½ W. These unconsolidated deposits are locally derived and were emplaced by gravity. The debris is clay to boulder sized, poorly sorted and angular, and only a few feet in thickness. At the dogleg in the Sage Valley fault, on the boundary of Sections 17 and 18, T. 14 S., R. 1 W., moderately sorted, subrounded to rounded, pebble- to boulder-sized material (mostly quartzite) covers the steep slope. The colluvial material is derived from the topographically higher ridge of North Horn Formation. The deposit partially covers the downdropped Orme Spring Conglomerate.

Alluvium

Two levels of alluvium are mapped; an older level (Qa_2) is of limited extent, higher in elevation, and is incised by the younger level (Qa_1). Alluvium occurs as flattened surfaces along most drainages, particularly in Juab and Sage Valleys. In some places, alluvium deposited by streams that dissect the coalesced fans is more finely dispersed than can readily be mapped.

The composition, size, and color of these surficial deposits reflect the local bedrock. The deposits are generally brown, gray, and red, and contain clay- to cobble-sized subangular to subrounded materials that are poorly to well sorted. Consolidation and stratification are nonexistent to poor. The alluvium ranges from 0 to tens, or possibly hundreds, of feet in thickness.

STRUCTURE

The Juab quadrangle lies in a region of complex geology along the eastern margin of the Basin and Range physiographic province. Surface structures are expressed as high-angle normal faults and minor folds. Major valley faults bound the West Hills horst, which itself is cut by faults of lesser displacement. Thrusts and major folds occur in the subsurface and salt diapirism may have influenced structural geometries.

Normal Faults

Sage Valley fault — A well-expressed normal fault bounds the western margin of the West Hills and the eastern margin of Sage Valley. The throw on the fault is at least 2900 feet (884 m). Alluvium and blocks of Flagstaff, Green River, and the Hall Canyon Conglomerate are downdropped adjacent to the North Horn Formation of the upthrown block in the East Fork of Sage Valley. A somewhat eroded set of triangular facets or faceted spurs express a fault-line scarp along the southern extent of the Sage Valley fault. No scarps were noted cutting the alluvium in the map area.

The Sage Valley fault trends N. 20° E. for a distance of 5.5 miles (8.8 km) before bending more easterly. The fault may continue northward to become the East Spring Canyon fault of the Sugarloaf quadrangle (Meibos, 1983). Each fault trends into a complexly disturbed area within the Juab quadrangle (Sections 8 and 17, T. 14 S., R. 1 W.), where many faults mask the relationship. The Sage Valley fault continues southwestward into the adjacent Sage Valley quadrangle for an additional mile (1.6 km) before it terminates against a horst of Flagstaff west of Mills Gap. Before reaching the horst, the fault cuts older alluvial-fan material and is itself dissected by the apex of an active fan.

Western Juab Valley fault zone— A zone of concealed down-to-the-east faults is believed to border the western margin of Juab Valley. Surface evidence for this fault zone is limited; tilted blocks of Orme Spring Conglomerate that occur in Section 2, T. 14 S., R. 1 W. seem to be truncated by a fault or faults to the east. Lengthy northeast-trending faults with a down-to-the-southeast displacement along the margin of the hills in the Lampson Canyon area suggest a step-like style of faulting along the upland-valley margin. The Western Juab Valley fault zone is buried by alluvium along its length, and although no scarps were noted, cultivation may have destroyed them. The existence of the zone is suggested by the relief of the West Hills above Juab Valley and indicated by geophysical investigations (gravity, seismic) (Cook and Berg, 1961; Zoback, 1983).

Other faults— Other normal faults mapped in the quadrangle are found cutting the cuestas, northern hills, and forks of Sage Valley. Few faults cut the principal cuestas. Several faults intersect near the squarish notch in Section 12, T. 15 S., R. 1½ W.; they trend northwest and northeast, with down-to-the-southwest and -northwest displacements, respectively. The displacements range from a few feet to about 100 feet (30 m). The longest of these faults cuts North Horn through Green River strata. To the north, a northeast-trending cross fault forms a slot in the cuestas nearly a mile (1.6 km) long. This fault mostly cuts the North Horn and Flagstaff Formations and drops strata on the northwest about 500 feet (152 m). Small subsidiary faults are associated with it. As the cuestas die out northward in Section 20, T. 14 S., R. 1 W., corresponding with the facies change of the Flagstaff Formation, faults become more abundant.

The area from Sage Valley Pass to the north and northeast (northern hills) contains the greatest density of normal faults in the quadrangle. The Orme Spring Conglomerate and the North Horn Formation dominate the surface geology. In the area of Sage Valley Pass, faults trend to the northwest and northeast. A mile-long (1.6 km) northwest-trending fault drops the Orme Spring Conglomerate on the northeast against the North Horn with an estimated displacement on the order of 200 to 300 feet (60-90 m). Lampson Canyon is abundantly faulted where the Orme Spring Conglomerate is best exposed and structures can readily be delineated. Fault trends are predominantly north to northeast and displacements range in the tens of feet. Westward, the Burnt Valley-Burnt Valley Wash area (Section 8, T. 14 S., R. 1 W.) is highly faulted. Of interest is a small north-trending graben with two downdropped blocks of the Hall Canyon Conglomerate near its southern end. A horst of North Horn and Orme Spring flanks the western margin of the graben.

The Goldens Ranch Formation dominates the area of the forks of Sage Valley. The eastern portion of Sage Valley is structurally a series of horsts and grabens. The East and West Forks of Sage Valley are probably structurally controlled by faults; their trend (about N. 20° E.) is similar to that of the Sage Valley fault. Between the east and west forks of Sage Valley, the large hill in Sections 19 and 30, T. 14 S., R. 1 W. is cut by east-west faults and is also faulted along its east side. Significant displacement has occurred along the northern and eastern sides. Northward, a fault that is continuous over a distance of 2 miles (3.2 km) drops the Hall Canyon Conglomerate on the southeast; the trend is similar to the forks of Sage Valley. This fault also partly bounds a horst composed of the Colton, Green River, and all members of the Goldens Ranch Formation.

Thrust Faults

The map area lies near the eastern limit of large-scale thrusting that occurred during the Sevier orogeny. Thrusts are exposed at Mt. Nebo and in the Canyon and Pavant Ranges. Thrust faults are projected to underlie the quadrangle at depths over approximately 8000 feet (2438 m). Discussions regarding thrust faults affecting the quadrangle can be obtained from Standlee (1982) and Villien (1984).

Folds

The trace of an anticlinal structure extends southward from the area near the Placid Oil Howard #1A well in the adjacent Sugarloaf quadrangle (Meibos, 1983) to a location near the Cedar triangulation station. In Section 8, T. 14 S., R. 1 W., the axial trace trends southwestward before turning back southward to follow the East Fork of Sage Valley. The structure is post-Goldens Ranch Formation in age.

ECONOMIC GEOLOGY

Sand and Gravel

Extensive alluvial material in Juab and eastern Sage Valleys consists of alluvial-fan, pediment alluvium, and colluvium deposits. The material is clay to boulder sized, often with lenses of sand, silt, and clay, which might be used for a variety of applications including road metal, riprap, and concrete production. Sorting and washing would be necessary for some applications. A small gravel pit in alluvial-fan deposits along Utah State Highway 78 provides road fill. Abandoned excavations near the south end of the quadrangle were used similarly.

A small hill of the Hall Canyon Conglomerate and Chicken Creek Tuff is excavated for use as gravel. Conglomerate in the North Horn, Flagstaff, Colton, and Green River Formations might also be used, if crushed and sorted. Boulder conglomerate of the North Horn and Hall Canyon in particular, and local colluvium, could be utilized for riprap. Boulders from the quadrangle area are used for riprap along some drainage ditches that pass under Interstate Highway 15.

Carbonate Rock

Carbonate rock is found in the Flagstaff, Colton, Green River, and Goldens Ranch Formations. The potential use of these rocks is for cement, building or dimension stone, and aggregate. Good carbonate rock for cement must be very pure limestone containing less than 5 percent $MgCO_3$. Carbonates of the Flagstaff and Colton Formations are quite dolomitic (Vorce, 1979); limestones of the Green River Formation and the Sage Valley Member of the Goldens Ranch Formation might be more suitable, but they are not as abundant.

The Flagstaff Formation carbonates are the best candidates for building stone. The rocks are well indurated and bedded, and beautifully colored. Unlike the Flagstaff exposures to the east, the unit is readily accessible in the Juab quadrangle. The limestones of the quadrangle are also suitable for crushing to be used as aggregate, including road metal. Large blocks of Green River carbonate are used for riprap along Interstate Highway 15.

Tuff ("Azomite")

Tuff in the Goldens Ranch Formation, from the Chicken Creek Tuff Member, has been quarried by the Azome Utah Mining Company in the Milky Wash and Painted Rocks areas, south of the quadrangle. The tuff has been crushed and marketed under the name "Azomite" and used as poultry grit, a soil mineralizer and conditioner, and a domestic animal feed additive (Vogel, 1957; Pratt and Callaghan, 1970). Exposures of the tuff in the Juab quadrangle might be used accordingly.

Petroleum

Exploration for oil and gas through seismic surveys and drilling has taken place in the vicinity of the quadrangle. The subsurface geology of this area indicates the presence of structural relations similar to the producing overthrust belt of Wyoming and northern Utah. Nearby wildcat tests have discovered oil and gas shows in the subsurface, and the region remains an interesting target for petroleum discovery.

Ground Water

Ground water occurs in the unconsolidated alluvium of southern Juab Valley and is present in some of the bedrock units in the Juab quadrangle. Recharge areas exist around the margins of the valley where coarse-grained alluvial-fan material is present. Artesian conditions occur in the central and lower parts of the valley where clays and silts are interbedded with coarser alluvial materials (Bjorklund and Robinson, 1968; Gates, 1982). The ground-water table slopes as the land surface does, but with less gradient, and is shallowest in the low, central part of Juab Valley. Water moves down gradient from the recharge areas to the vicinity of Chicken Creek Reservoir, where it discharges in pumped and flowing wells, springs, and seeps. The geology of the West Hills indicates that water from this area flows from west to east, toward Juab Valley. Water quality in southern Juab Valley is in the fresh to slightly saline range ($<$1000 to 3000 ppm dissolved solids) and poses no problems for its principal uses of irrigation or for watering livestock (Bjorklund and Robinson, 1968).

Springs — Only a few springs issue from the West Hills. One spring is shown on the topographic map in SESWSW Section 4, T. 14 S., R. 1 W., and three additional springs are located in one area along the western border in Section 19, T. 14 S., R. 1 W. The combined discharge from these three springs is not significant, probably not more than 1 gpm (3.78 l/m). All of the springs of the West Hills are believed to be related to faults.

Numerous springs and seeps occur along the northern portion of the Chicken Creek Reservoir and farther northward in central Juab Valley. Discharge from individual springs and seeps is often small and much is consumed by evapotranspiration, but a rough estimate indicates that 1300 acre-feet (1.6 hm^3) of water flows to the reservoir from them (Bjorklund and Robinson, 1968). The salinity of water discharging from the springs and seeps is similar to that discharging from the wells of the area.

GEOLOGIC HAZARDS

The potential hazards in the Juab quadrangle include earthquakes and mass movements. Recognition of potential hazards for planning purposes is essential to minimize damage to man-made structures and to prevent injury and loss of life.

Earthquakes

The Juab quadrangle lies in the Intermountain seismic belt, a zone of seismicity that follows the boundary between the Basin and Range, and Colorado Plateaus and Middle Rocky Mountains physiographic provinces. It is roughly centered on the Wasatch fault zone. Seismicity in this region is generally shallow and diffuse but locally intense (Arabasz and others, 1980). Cook and Smith (1967) cataloged earthquake data in Utah for the period 1850 to June 1967 and their findings indicate that, during the latter part of the reporting period, the West Hills area displayed above-normal earthquake activity.

The strongest earthquake recorded in the West Hills-Juab Valley area occurred on July 7, 1963, and was a 4.4 local magnitude event (McKee and Arabasz, 1982). The epicenter was located along the western side of the valley in the Juab quadrangle, Section 34, T. 14 S., R. 1 W., which suggests movement along the western Juab Valley fault zone. More recent epicenter maps show continued activity, and the seismic risk remains high. The greatest potential for destruction lies in ground shaking and surface rupture of the extensive alluvial cover. Other potential earthquake hazards include triggering of landslides, soil liquefaction, and differential ground settlement. Risk in the Juab quadrangle is low because the area is sparsely inhabited. Damage to structures such as Interstate Highway 15 and other roads, the Union Pacific Railroad, and power lines is most likely. Also, the potential for liquefaction is high in Juab Valley near the Chicken Creek Reservoir, where the water table is relatively shallow.

Mass Movements

Mass-movement deposits are not numerous in the Juab quadrangle, which suggests that the potential for future mass movements is small. Areas with steeper slopes and higher mud content or poorly consolidated material, particularly those areas that are sparsely vegetated, are most susceptible. Earthquake-triggered movements should also be considered. The greatest threat of possible damage from mass movements is to roads.

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REFERENCES CITED

Arabasz, W. J., Smith, R. B., and Richins, W. D., 1980, Earthquake studies along the Wasatch Front, Utah: Network monitoring, seismicity, and seismic hazards: Bulletin of the Seismological Society of America, v. 70, no. 5, p. 1479-1499.

Armstrong, R. L., 1970, Geochronology of Tertiary igneous rocks, eastern Basin and Range Province, western Utah, eastern Nevada, and vicinity, U.S.A.: Geochimica et Cosmochimica Acta, v. 34, no. 2, p. 203-232.

Banks, R. L., 1986, The geology of the Fountain Green North quadrangle, Sanpete and Juab Counties, Utah: Unpublished M. S. thesis, Northern Illinois University, 246 p.

Bjorklund, L. J., and Robinson, G. B., 1968, Ground-water resources of the Sevier River Basin between Yuba Dam and Leamington Canyon, Utah: U. S. Geological Survey Water-Supply Paper 1848, 79 p.

Clark, D. L., 1987, The geology of the Juab quadrangle, Juab County, central Utah: Unpublished M.S. thesis, Northern Illinois University, 324 p.

Cook, K. L., and Berg, J. W., Jr., 1961, Regional gravity survey along the central and southern Wasatch Front, Utah: U. S. Geological Survey Professional Paper 316-E, 89 p.

Cook, K. L., and Smith, R. B., 1967, Seismicity in Utah, 1850 through June 1965: Bulletin of the Seismological Society of America, v. 57, p. 689-718.

Currey, D. R., 1982, Lake Bonneville: Selected features of relevance to neotectonic analysis: U. S. Geological Survey Open-File Report 82-1070, 30 p.

Everenden, J. F., and James, G. T., 1964, Potassium-argon dates and Tertiary floras of North America: American Journal of Science, v. 262, p. 945-971.

Fouch, T. D., Hanley, J. H., and Forester, R. M., 1979, Preliminary correlation of Cretaceous and Paleogene lacustrine and related nonmarine sedimentary and volcanic rocks in parts of the eastern Great Basin of Nevada and Utah *in* Newman, G. W., and Goode, H. D., editors, Basin and Range Symposium: Rocky Mountain Association of Geologists and the Utah Geological Association, p. 306-312.

Fouch, T. D., Lawton, T. F., Nichols, D. J., Cashion, W. B., and Cobban, W. A., 1982, Chart showing preliminary correlation of major Albian to middle Eocene rock units from the Sanpete Valley in central Utah to the Book Cliffs in eastern Utah *in* Nielson, D.L., editor, Overthrust Belt of Utah: Utah Geological Association Publication 10, p. 267-272.

Fouch, T. D., Lawton, T. F., Nichols, D. J., Cashion, W. B., and Cobban, W. A., 1983, Patterns and timing of synorogenic sedimentation in upper Cretaceous rocks of central Utah and northeast Utah *in* Reynolds, M. W., Dolley, E.D., and Spearing, D.R., editors, Mesozoic Paleography of the West-Central United States, Rocky Mountain Paleogeography Symposium 2: Society of Economic Paleontologists and Mineralogists, p. 305-330.

Gates, J. S., 1982, Hydrology of the Gunnison-Fairview-Nephi area, central Utah *in* Nielson, D.L., editor, Overthrust Belt of Utah: Utah Geological Association Publication 10, p. 151-162.

Gilbert, G. K., 1890, Lake Bonneville: U. S. Geological Survey Monograph 1, 438 p.

Higgins, J. M., 1982, Geology of the Champlin Peak quadrangle, Juab County, Utah: Brigham Young University Geology Studies, v. 29, pt. 2, p. 40-58.

Hintze, L. F., 1973, Geologic history of Utah: Brigham Young University Geology Studies, v. 20, 181 p.

Hintze, L. F., 1975, Geologic highway map of Utah: Brigham Young University Geology Studies, Special Publication 3, 1 sheet.

Lambert, D.L., 1976, A detailed stratigraphic study of initial deposition of Tertiary lacustrine sediments near Mills, Utah: Brigham Young University Geology Studies, v. 23, pt. 3, p. 9-35.

La Rocque, A. L., 1960, Molluscan faunas of the Flagstaff Formation of central Utah: Geological Society of America Memoir 78, 100 p.

Mackin, J. H., 1960, Structural significance of Tertiary volcanic rocks in southwestern Utah: American Journal of Science, v. 258, p. 81-131.

Marcantel, E. L., and Weiss, M. P., 1968, Colton Formation (Eocene: fluviatile) and associated lacustrine beds, Gunnison Plateau, central Utah: Ohio Journal of Science, v. 68, no. 1, p. 40-49.

Marvin, R. F., 1984, unpublished data: U. S. Geological Survey.

Mattox, S.R., 1987, Provisional geologic map of the Hells Kitchen Canyon SE quadrangle, Sanpete County, Utah: Utah Geological and Mineral Survey Map 98, 17 p., 2 pl.

McKee, M. E. and Arabasz, W. J., 1982, Microearthquake studies across the Basin and Range-Colorado Plateau transition in central Utah *in* Nielson, D.L., editor, Overthrust Belt of Utah: Utah Geological Association Publication 10, p. 137-150.

Meibos, L. C., 1983, Structure and stratigraphy of the Nephi NW 7 ½ minute quadrangle, Juab County, Utah: Brigham Young University Geology Studies, v. 30, pt. 1, p. 37-58.

Meinzer, O. E., 1911, Groundwater in Juab, Millard, and Iron Counties, Utah: U. S. Geological Survey Water-Supply Paper 277.

Millen, T. M., 1982, Stratigraphy and petrology of the Green River Formation (Eocene), Gunnison Plateau, central Utah: Unpublished M. S. thesis, Northern Illinois University, 220 p.

Morris, H. T., 1964, Geology of the Eureka quadrangle, Utah and Juab Counties, Utah: U. S. Geological Survey Bulletin 1142-K, 29 p.

Morris, H.T., 1975, Geologic map and sections of the Tintic Mountain quadrangle and adjacent part of the McIntyre quadrangle, Juab and Utah Counties, Utah (1:24,000): U.S. Geological Survey, Miscellaneous Investigations Series Map I-883.

Morris, H. T., 1977, Geologic map and sections of the Furner Ridge quadrangle, Juab County, Utah: U. S. Geological Survey, Miscellaneous Investigations Series Map I-1045.

Morris, H. T., and Lovering, T. S., 1979, General geology and mines of the East Tintic mining district, Utah and Juab Counties, Utah: U. S. Geological Survey Professional Paper 1024, 203 p.

Muessig, S. J., 1951, Geology of a part of Long Ridge, Utah: Unpublished Ph. D. dissertation, Ohio State University, 213 p.

Newman, K. R., 1974, Palynomorph zones in early Tertiary formations of the Piceance Creek and Uinta Basins, Colorado and Utah *in* Murray, D.K., editor, Guidebook to the Energy Resources of the Piceance Creek

Basin, Colorado: Rocky Mountain Association of Geologists Guidebook, 25th Annual Field Conference, p. 47-55.

Peterson, A.R., 1976, Paleoenvironments of the Colton Formation, Colton, Utah: Brigham Young University Geology Studies, v. 23, pt. 1, p. 3-35.

Pratt, A.R., and Callaghan, Eugene, 1970, Land and mineral resources of Sanpete County, Utah: Utah Geological and Mineral Survey Bulletin 85, 69 p.

Ryder, R. T., Fouch, T. D., and Elison, J. H., 1976, Early Tertiary sedimentation in the western Uinta Basin, Utah: Geological Society of America Bulletin v. 87, p. 496-512.

Schumm, S. A., 1965, Quaternary paleohydrology *in* Wright, H. E., and Frey, D. G., editors, The Quaternary of the United States: Review Volume for the VII Congress of the International Association for Quaternary Research, p. 783-794.

Sheliga, C. M., 1980, Sedimentology of the Eocene Green River Formation in Sevier and Sanpete Counties, central Utah: Unpublished M. S. thesis, Ohio State University, 166 p.

Spieker, E. M., 1946, Late Mesozoic and early Cenozoic history of central Utah: U. S. Geological Survey Professional Paper 205-D, p. 117-161.

Spieker, E.M., 1949, The transition between the Colorado Plateau and the Great Basin in central Utah: Utah Geological Society Guidebook 4, 106 p.

Standlee, L. A., 1982, Structure and stratigraphy of Jurassic rocks in central Utah: their influence on tectonic development of the Cordilleran foreland thrust belt *in* Powers, R. B., editor, Geologic Studies of the Cordilleran Thrust Belt: Rocky Mountain Association of Geologists, p. 357-382.

Stanley, K. O., and Collinson, J. W., 1979, Depositional history of Paleocene-lower Eocene Flagstaff Limestone and coeval rocks, central Utah: American Association of Petroleum Geologists Bulletin, v. 63, p. 311-323.

Stolle, J. M., 1978, Stratigraphy of the lower Tertiary and upper Cretaceous (?) continental strata in the Canyon Range, Juab County, Utah: Brigham Young University Geology Studies, v. 25, pt. 3, p. 117-139.

Varnes, D.J., 1958, Landslide types and processes *in* Eckel, E.B., editor, Landslides and Engineering Practice: Washington Highway Research Board Special Report 544, p. 20-47

Villien, A., 1984, Central Utah deformation belt: Unpublished Ph.D. dissertation, University of Colorado, 283 p.

Vogel, J. W., 1957, The geology of the southernmost Juab Valley and adjacent highlands, Juab County, Utah: Unpublished M. S. thesis, Ohio State University, 152 p.

Volkert, D. G., 1980, Stratigraphy and petrology of the Colton Formation (Eocene), Gunnison Plateau, central Utah: Unpublished M. S. thesis, Northern Illinois University, 132 p.

Vorce, C.L., 1979, Sedimentary petrology and stratigraphic relationships of the North Horn Formation and the Flagstaff Limestone at Long Ridge, central Utah: Unpublished M. S. thesis, Ohio State University, 90 p.

Willis, G. C., 1986, Geologic map of the Salina quadrangle, Sevier County, Utah: Utah Geological and Mineral Survey Map 83, scale 1:24,000.

Witkind, I. J., and Weiss, W. P., 1985, Preliminary geologic map of the Nephi 30 x 60 minute quadrangle, Carbon, Emery, Juab, Sanpete, Utah, and Wasatch Counties, Utah: U. S. Geological Survey Open-File Report 85-466.

Zawiskie, J., Chapman, D., and Alley, R., 1982, Depositional history of the Paleocene-Eocene Colton Formation, north-central Utah *in* Nielson, D. L., editor, Overthrust Belt of Utah: Utah Geological Association Publication 10, p. 173-284.

Zoback, M. L., 1983, Structure and Cenozoic tectonism along the Wasatch fault zone, Utah *in* Miller, D.M. and others, editors, Tectonic and Stratigraphic Studies in the Eastern Great Basin Region: Geological Society of America Memoir 157, p. 3-27.