STATE OF UTAH
DEPARTMENT OF NATURAL RESOURCES
UTAH GEOLOGICAL AND MINERAL SURVEY

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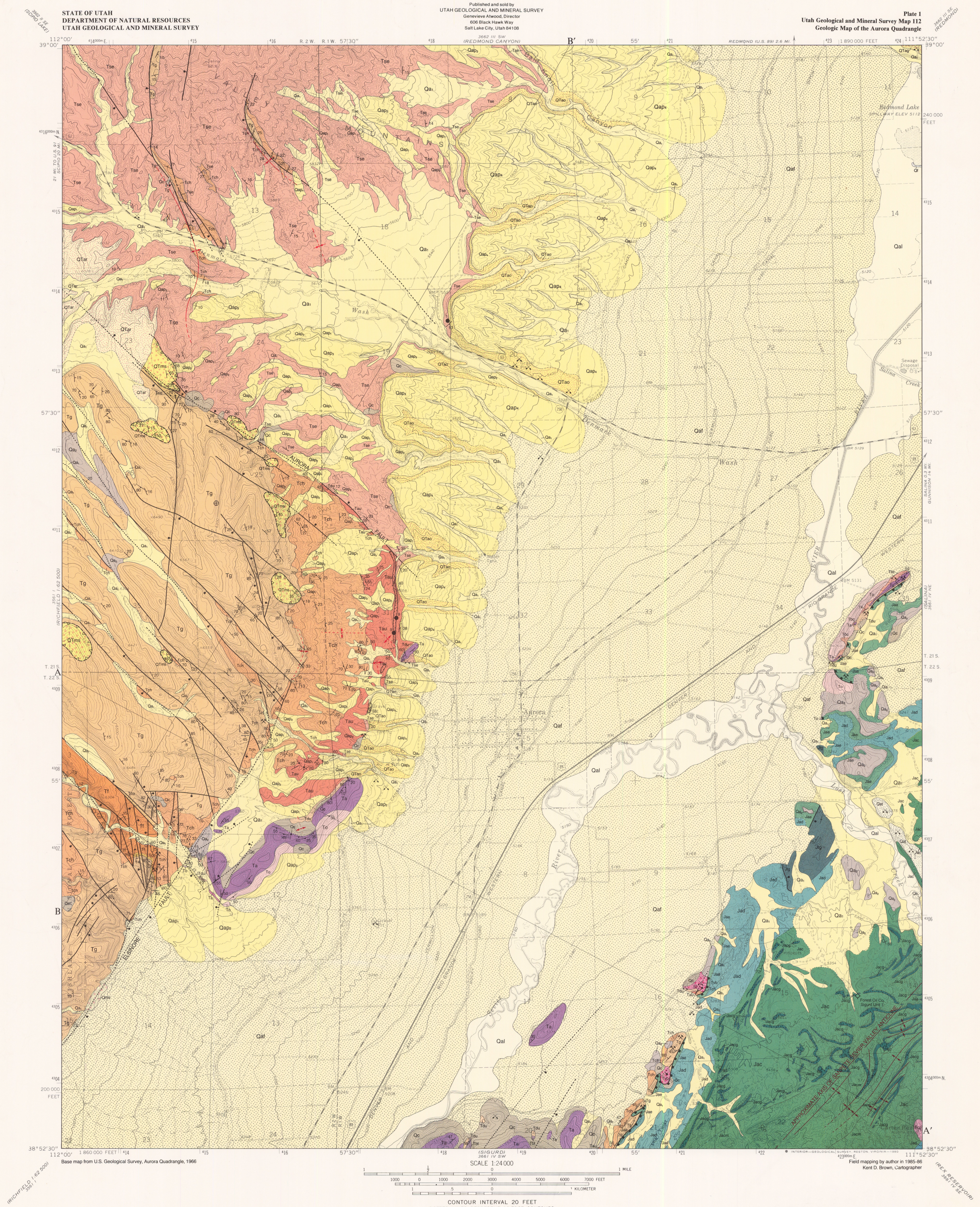


Base map from U.S. Geological Survey, Aurora Quadrangle, 1966

SCALE 1:24 000

CONTOUR INTERVAL 20 FEET
DOTTED LINES REPRESENT 10-FOOT CONTOURS
NATIONAL GEODETIC VERTICAL DATUM OF 1929

Field mapping by author in 1985-86
Kent D. Brown, Cartographer

UTM GRID AND 1966 MAGNETIC NORTH
DECLINATION AT CENTER OF SHEET

GEOLOGIC MAP OF THE AURORA QUADRANGLE SEVIER COUNTY, UTAH

by
Grant C. Willis
Utah Geological and Mineral Survey

1988

QUADRANGLE LOCATION

STATE OF UTAH
DEPARTMENT OF NATURAL RESOURCES
UTAH GEOLOGICAL AND MINERAL SURVEY

DESCRIPTION OF MAP UNITS

Qf Artificial fill—*Manmade dikes and dams.*

Qal Flood plain and channel deposits of Sevier River and Lost Creek—*Well to moderately well sorted sand, silt, mud, clay, gravel, and boulders.*

Qa₁ Younger alluvial deposits—*Sand, silt, mud, gravel, and boulders. Primarily ephemeral stream deposits in active depositional areas.*

Qa₂ Older alluvial deposits—*Sand, silt, mud, gravel, and boulders dissected or isolated by downcutting drainage systems.*

Qaf Alluvial fan and alluvial slope deposits—*Moderately to poorly sorted sand, silt, mud, gravel, and boulders.*

Qap_1–Qap_4 Pediment deposits—*Deposits on pediment surfaces isolated by downcutting drainage systems. Poorly to moderately sorted angular to subrounded boulders, cobbles, pebbles, sand and silt. Four relative ages are differentiated based on elevation above adjacent active drainage systems and adjacent pediments. Qap_1 is youngest; Qap_4 is oldest. Numerous intermediate levels are lumped into Qap_2 and Qap_3. Ages should only be considered valid relative to adjacent pediments.*

Qat Older alluvial terrace deposits along Lost Creek—*Gravel, sand, silt, clay, and boulders.*

Qc Colluvium—*Slope cover composed primarily of fallen blocks and talus, with minor fine-grained surficial deposits.*

Qms Landslide deposits—*Poorly sorted, surficial material transported and deposited by mass movement.*

QTag Gravel deposits of Redmond Hills—*Moderately well sorted gravel and sand with minor amounts of mud and clay.*

QTar Older alluvial deposits in the northwest part of the quadrangle—*gravel, sand, silt, mud and clay.*

QTao Older alluvial valley-fill deposits—*Moderately to well sorted gravel, sand, silt, and boulders primarily derived from Tertiary rocks to the west.*

QTms Slump blocks—*Large coherent blocks of Green River Formation that have detached along bedding planes and moved downslope.*

QTu Undifferentiated middle and upper Tertiary deposits—*Shown only on cross section.*

Tvb Volcanic breccia—*Moderately to intensely brecciated and deformed volcanic blocks and volcaniclastic sediment. Probably late Tertiary, age uncertain.*
UNCONFORMITY

Tse Sevier River Formation—*Mudstone, sandstone, conglomerate, and carbonaceous mudstone. Pale brownish- or reddish-gray. Contains volcanic clasts in the southern part. Forms lightly vegetated hills and intricately dissected slopes. Queried where identity of outcrop is less certain.*
UNCONFORMITY

To Osiris Tuff—*Light gray, but also reddish-brown, reddish-purple, or brownish-gray, densely welded, porphyritic, latitic tuff with conspicuous plagioclase and biotite, and minor sanidine and Fe-Ti oxides.*

Tbc Formation of Black Cap Mountain—*Bluish-gray volcaniclastic sandstone with minor conglomerate, air fall tuff, and breccia.*

Ta Tuff of Albinus Canyon and Antimony Tuff Member of Mount Dutton Formation, undifferentiated—*Dark reddish-brown, dark brownish-gray, or dark gray, densely welded, crystal-poor ash flow tuff of quartz latite composition with plagioclase, sanidine, pyroxene, and drawn-out vesicles and pumice lenticules.*

Tcp Intrusion of Carter Peak—*Greenish-gray to black and gray, fine-grained, holocrystalline diorite with plagioclase, clinopyroxene, pyroxene, biotite, hornblende, and accessory sphene and apatite.*

Tbt Three Creeks Tuff Member of Bullion Canyon Volcanics—*Pale gray to pinkish-gray latitic tuff with plagioclase, amphibole, biotite and minor accessory minerals.*
UNCONFORMITY

Tdu Dipping Vat Formation and unnamed sandstone, mudstone, and conglomerate beds, undifferentiated—*White to pale gray water-lain tuffaceous sandstone, mudstone, marlstone, and conglomerate. Conglomerate contains volcanic and sedimentary-derived clasts.*
UNCONFORMITY

Tau Formation of Aurora—*Pale gray interbedded mudstone, bentonitic shale, limestone, and sandstone with occasional pale reddish-orange beds. Has reworked pumiceous clay and tuff and pale gray volcaniclastic sandstone in the upper part.*

Tch Crazy Hollow Formation—*Dark orangish-red and light yellowish-gray "salt and pepper" sandstone, mudstone, siltstone, shale, and black chert-pebble-bearing conglomerate.*

Tg Green River Formation—*Pale yellow, massive, silicified limestone with chert nodules and interbedded greenish-gray or light brown shale in the upper part and greenish-gray thin-bedded to laminated shale, light brown calcareous sandstone, and light yellowish-gray chalky limestone in the lower part.*

Tco Colton Formation—*Dark reddish-brown mudstone. Poorly exposed, slope forming.*

Tf Flagstaff Formation—*Reddish-brown, cliff-forming sandstone, conglomerate, limestone, and minor siltstone.*

TKnh North Horn Formation—*Shown only on cross section.*
UNCONFORMITY

Ki Indianola Group—*Shown only on cross section.*
UNCONFORMITY

Jtg Twist Gulch Formation equivalent to Entrada Sandstone of the San Rafael Swell area—*Interbedded reddish-brown siltstone, mudstone, sandstone, and minor conglomerate.*

Ja Arapien Shale, undifferentiated—*Shown only on cross section.*

Jae Unit E of Arapien Shale—*Dark reddish-brown, salt-bearing, silty shale.*

Jad Unit D of Arapien Shale—*Interbedded, bluish-gray and reddish-gray gypsiferous shale, mudstone, and sandstone.*

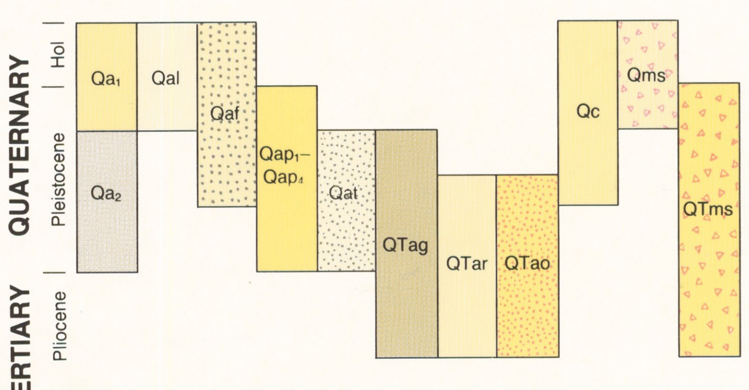
Jac Unit C of Arapien Shale—*Bluish-gray calcareous shale with gray thin-bedded calcareous sandstone, massive gray to white lenticular gypsum beds, and arenaceous limestone.*

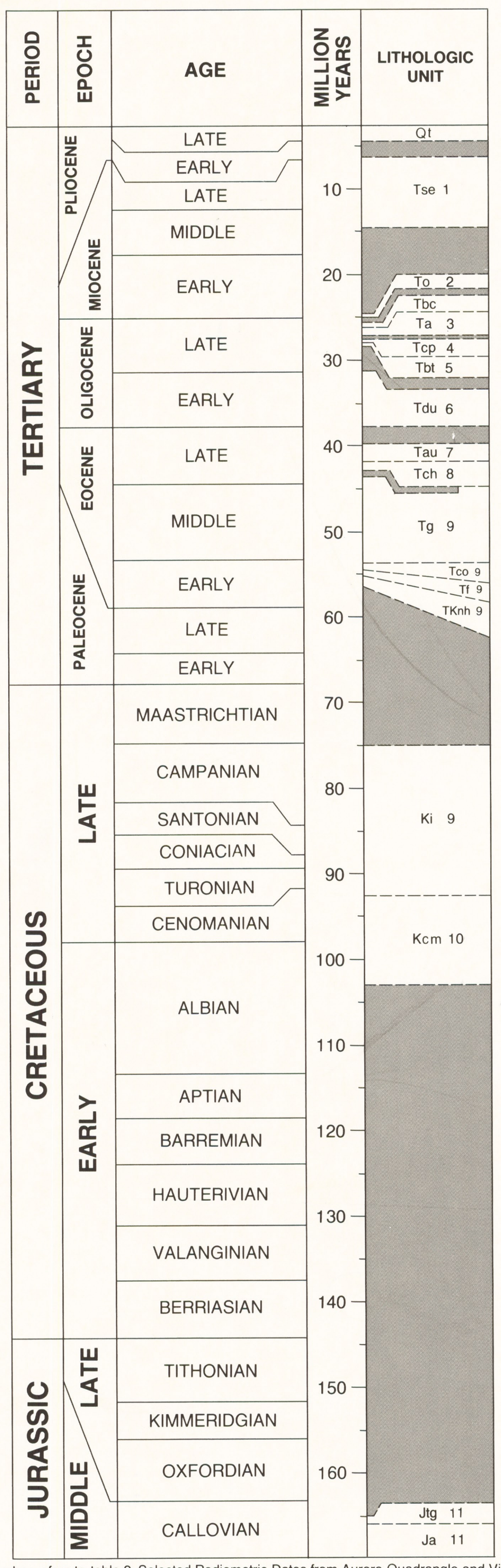
Jacg Lenticular beds of gypsum within unit C of the Arapien Shale—*Massive, pale gray to white mottled gypsum.*

Jacm Dark reddish-brown sandstone marker bed in unit C of the Arapien Shale.

Jaa Unit A of Arapien Shale—*Pale yellow and gray argillaceous, chippy limestone.*

CORRELATION OF MAP UNITS





(number refers to table 2, Selected Radiometric Dates from Aurora Quadrangle and Vicinity)

FORMATION		SYMBOL	THICKNESS Feet (meters)	LITHOLOGY
Surficial Deposits		Q, QT	0-300 (0-90)	
older alluvial valley-fill deposits		QTao	0-800 (0-240)	
Sevier River Formation		Tse	1500-2000 (450-600)	
Osiris Tuff		To	0-200 (0-60)	
Fm. of Black Cap Mountain		Tbc	0-100 (0-30)	
Tuff of Albinus Canyon		Ta	0-300 (0-90)	
Three Creeks Tuff		Tbt	0-200+ (0-60+)	
Dipping Vat Formation		Tdu	50-200 (15-60)	
Formation of Aurora		Tau	700-800 (210-240)	
Crazy Hollow Formation		Tch	900-1000 (270-300)	
Green River Formation		Tg	800-1100 (240-330)	
Colton Formation		Tc	50-300 (15-90)	
Flagstaff Formation		Tf		
North Horn Formation Indianola Group (undif.) Cedar Mountain Formation		Not exposed in outcrop		
Twist Gulch Formation		Jtg	1800-2000 (540-600)	
Arapien Shale	Unit E	Jae	200-400 (60-120)	
	Unit D	Jad	1000-3000 (300-900)	
	Unit C	Jac	1000-3000 (300-900)	
	Unit A	Jaa	20+ (6+)	

CONTACT

Dashed where approximate, dotted where covered

FAULT

High angle, dashed where location inferred; dotted where covered; queried where probable, bar and ball on downthrown side.

May be due to diapirism of mudstone and evaporate beds in the Arapien shale; teeth on diapiric material.

Low angle, bounding detached blocks

TRACE OF AXIAL SURFACE OF FOLD

Anticline — Syncline — Monocline

Arrows show direction of plunge; dotted where covered

STRIKE AND DIP OF BEDDING

Inclined — Horizontal — Vertical

STRIKE AND DIP OF VOLCANIC FOLIATION

STRIKE AND DIP OF JOINTS

Inclined — Vertical

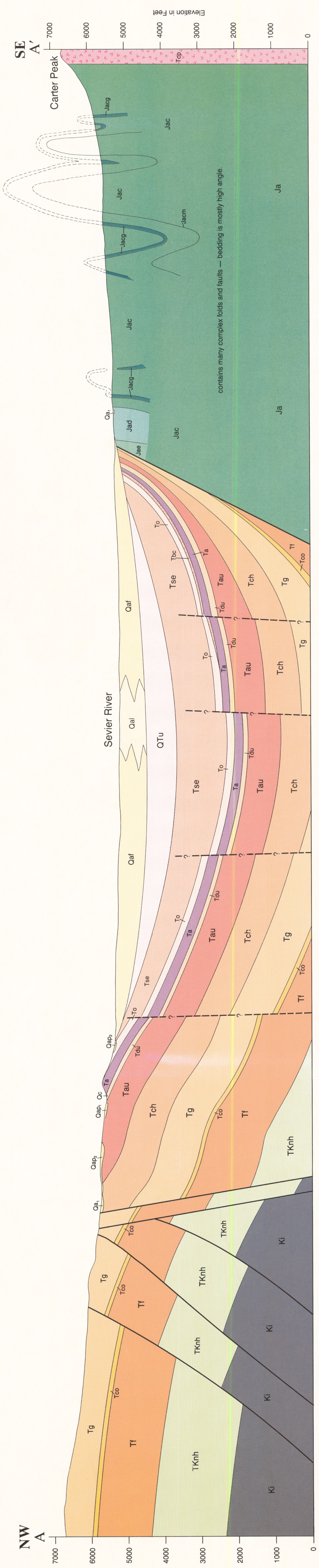
Prospect, small mine or pit; s-salt, c-calcite; gy-gypsum; no symbol-unknown

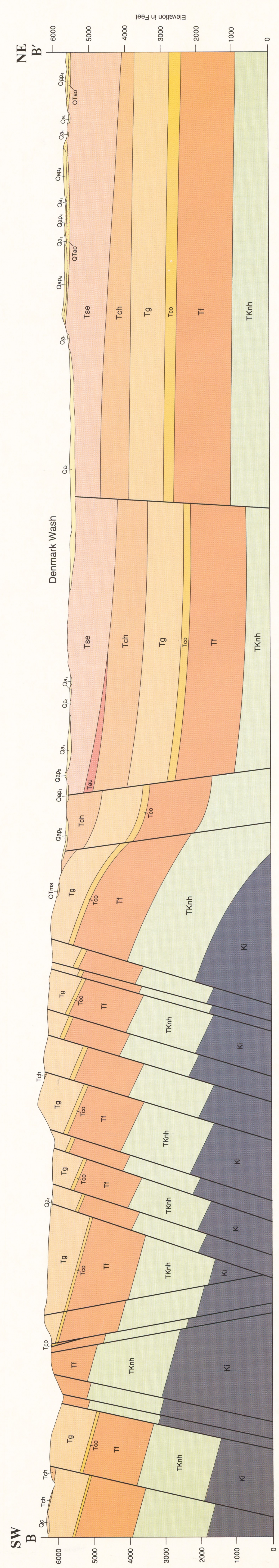
Open pit mine, gypsum or clay

Gravel or road-fill pit

Oil or gas well, dry

Location and sample number of radiometric ages (see table 2, Selected Radiometric Dates from Aurora Quadrangle and Vicinity)





GEOLOGIC MAP OF THE AURORA QUADRANGLE, SEVIER COUNTY, UTAH

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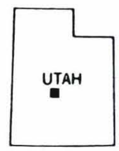

UTAH GEOLOGICAL AND MINERAL SURVEY
a division of
UTAH DEPARTMENT OF NATURAL RESOURCES
MAP 112 **1988**

UTAH GEOLOGICAL AND MINERAL SURVEY
606 Black Hawk Way
Salt Lake City, Utah 84108-1280

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GEOLOGIC MAP OF THE AURORA QUADRANGLE, SEVIER COUNTY, UTAH

by

Grant C. Willis

ABSTRACT

The Aurora quadrangle is located in the central Sevier Valley of Utah near Richfield. It contains more than 6000 feet (1800 m) of Jurassic rocks and as much as 7000 feet (2100 m) of exposed Tertiary and Quaternary rocks. No Cretaceous rocks are exposed due to a major angular unconformity. Rocks in the quadrangle can be divided into five groups: 1) marine, restricted marine, and marginal marine deposits that are Jurassic-Callovian in age, 2) Paleocene and Eocene fluvial-lacustrine rocks, 3) Oligocene and Miocene volcanic and volcaniclastic rocks, 4) Miocene to Holocene alluvial and lacustrine rocks with minor volcanic material, and 5) surficial deposits which range up to a few hundred feet thick.

Structurally and topographically the quadrangle consists of three distinct areas. The southeast part of the quadrangle includes part of the Sanpete-Sevier Valley anticline (SSVA). The central part is occupied by the Sevier Valley through which the Sevier River flows northward, and the northwestern part includes part of the east flank of the Valley Mountains and Pavant Range. The SSVA formed during the Late Cretaceous, severely deforming incompetent Jurassic rocks and folding more competent Jurassic and Cretaceous rocks into a complex anticline. A major period of erosion followed this deformation after which early Tertiary rocks onlapped and eventually covered the deformed units. Subsequent deformation, probably diapiric in nature, caused renewed upward movement of the incompetent core of the SSVA. The more competent flanking Jurassic and Cretaceous beds were not affected.

The subsurface structure of Sevier Valley is poorly known but it is probably a faulted syncline. The Valley Mountains and Pavant Range consist of gently to moderately inclined beds which dip toward the east. They are cut by a major northeast-trending fault (the Elsinore fault) and by numerous normal faults which trend northwest, oblique to the mountain front. Most of the northwest-trending faults curve to merge with the northeast fault and are down to the southwest, although a few have opposite displacement. The northwest fault system may be related to faults in Round Valley, a large graben valley to the northwest. The eastward tilt of the beds affects rocks as young as Quaternary. Primary economic resources are gypsum, clay or fuller's earth, and gravel and road fill. Gypsum is currently being mined in the quadrangle. Significant quantities of fuller's earth have been mined in the past. Potential geologic hazards include earthquakes, ground subsidence, floods and mud and debris flows.

INTRODUCTION

The Aurora 7 ½' quadrangle is located about 10 miles (16 km) northeast of Richfield in central Utah. U. S. Interstate 70, U. S. Highway 89, and State Route 26 cross the quadrangle. Sevier Valley occupies the central part of the quadrangle, the western part covers the southern end of the Valley Mountains and foothills of the Pavant Range, and the eastern part covers steep, low hills with sparse vegetation. The lowest elevation is in Sevier Valley with an altitude of 5100 feet (1554 m) and the highest is along the west border with an elevation of about 6760 feet (2060 m). Carter Peak in the southeast corner of the quadrangle is 6718 feet (2048 m) high. Annual precipitation ranges from 8-10 inches (20-25 cm) in the valley to 16-20 inches (40-50 cm) in the mountains (Covington and Williams, 1972). Vegetation is primarily grass and sagebrush in the lower areas with sagebrush, juniper, and pinyon pine in the higher areas. Aurora, with a population of 874 (1980 census), is the only community within the quadrangle; agriculture and gypsum mining are the primary occupations. Although previous studies mention the geology of the central Sevier Valley area, the geology was first described in detail by Spieker (1946; 1949) who named and defined many of the stratigraphic units and discussed the structure of the area. Subsequently smaller areas were studied in more detail by Ohio State University students under Spieker's direction including Gilliland (1951), Hardy (1952), Lautenschlager (1952), and McGookey (1960). More recently other important studies have been completed including Witkind (1982; 1983), Standlee (1982), Witkind and Page (1984), Lawton (1985), Arabasz (1986) and Anderson and Barnhard (1987). Hardy (1952) included part of the quadrangle in a small-scale map focusing on Jurassic units. Lautenschlager (1952) mapped the 15-minute quadrangle which includes the Aurora quadrangle. McGooky (1960) included the southeast part of the quadrangle in a geologic map of the northern Fish Lake Plateau. Williams and Hackman (1971) published a geologic map of the Salina 1 by 2-degree quadrangle (1:250,000) which includes the Aurora 7 ½' quadrangle. Witkind (1981) mapped the adjacent Redmond quadrangle. Steven and Morris (1983) mapped the Richfield 1 by 2-degree quadrangle which borders Aurora on the west.

STRATIGRAPHY

Exposed rocks in the quadrangle are divisible into five main sequences: 1) Jurassic rocks which are at least 6000 feet (1800 m) thick and which are exposed in the southeastern part of the quadrangle, 2) up to 4000 feet (1200 m) of early Tertiary fluvial-lacustrine rocks which unconformably overlie the Jurassic and Cretaceous rocks, 3) Oligocene and Miocene volcaniclastic and volcanic rocks which are up to 1000 feet (300 m) thick and which cap the earlier rocks, 4) late Tertiary alluvial and lacustrine deposits which unconformably overlie the volcanic units and which exceed 2000 feet (600 m) in places, and 5) surficial deposits, which are thick locally. About 10,000 feet (3000 m) of Cretaceous rocks occur in the subsurface but are not exposed in the quadrangle.

MIDDLE JURASSIC

Jurassic rocks in the quadrangle crop out along the NNE-trending Sanpete-Sevier Valley anticline (SSVA) in the southeast part of the quadrangle and include the Arapien Shale and Twist Gulch Formation. The Arapien Shale and Twist Gulch Formation were originally defined as the Twelvemile Canyon and Twist Gulch Members, respectively, of the Arapien Shale (Spieker, 1946, p.124-125). Hardy (1952) suggested upgrading the members to formational status without doing so, but usage has confusingly alternated between both nomenclatures (for example: Hardy, 1952; Witkind and Sprinkel, 1982; Standlee, 1982). Finally Witkind and Hardy (1984) officially changed the names to those used on this map.

Arapien Shale

The oldest unit exposed in the Aurora quadrangle is the Arapien Shale (Ja) of Middle Jurassic Callovian age (Sprinkel, 1982) (Table 1, plate 2). The Arapien was subdivided by Hardy (1952) into five mappable members, A to E in ascending order. I generally mapped units A, C, D, and E of the Arapien Shale in accordance with Hardy's work. Unit B is not present in the quadrangle and only a very small outcrop of unit A is exposed. The remaining three members may have a combined thickness of 4000-6000 feet (1200-1800 m) in the quadrangle although no complete section is available due to complex structure. Underlying unit A is the Twin Creek Limestone, which is probably considerably less than 1000 feet (300 m) thick in this area based on wells located farther north (Sprinkel, 1982). The Arapien Shale was deposited in a long, narrow seaway which opened to the north and which became hypersaline near the end of Arapien deposition. Fossils are rare except in a few beds and include only a few salt-tolerant forms; Hardy (1952) lists the fauna found in the Arapien. Current directions in the Arapien are unimodal to the north (Picard and Uygur, 1982.

Unit A (Jaa) is exposed in the core of a small anticline in the middle of the complex, larger Sanpete-Sevier Valley anticline (Willis, 1986). Only a small amount of the unit a few feet thick extends into the Aurora quadrangle in Section 14, T 22 S, R 1 W. It is composed of medium gray, thin-bedded, argillaceous limestone which weathers to angular brownish-yellow chips.

Unit C (Jac) is composed of bluish-gray calcareous shale with gray, thin-bedded, calcareous sandstone, massive gray to white lenticular to planar gypsum beds, and resistant layers of fossil-bearing arenaceous limestone. It forms steep, intricately dissected "badlands" topography which supports sparse vegetation. The contact between units C and D is gradational over a 1000-foot (300 m) zone in which beds range from uniform bluish-gray mudstone and minor sandstone of unit C to blotched red and gray mudstone with more sandstone common to unit D.

Unit C contains thick lenticular beds of massive, pale gray to white mottled gypsum which form resistant protruding ledges, and which were mapped separately (Jacg). These gypsum outcrops may have been deposited as part of a single bed that is repeated at the surface by folding and faulting. A distinctive marker bed stratigraphically below the gypsum bed (Jacm) is well expressed on aerial photographs and was mapped separately to aid in indicating fold structures. It consists of dark reddish-brown beds of mudstone 10 to 50 feet (3-15 m) thick and is occasionally interlayered with pale gray mudstone beds. It is mapped only in the central part of the anticline where it is more continuous.

Unit D (Jad) is composed of interbedded, bluish-gray and reddish-gray gypsiferous shale, mudstone, and sandstone. It is thin bedded to laminated with sparse, shaly, thin-bedded gypsum. Intense folding, highly contorted beds, and facies changes give the unit a blotched or streaked appearance. It also forms "badlands" topography which supports sparse vegetation.

Unit E (Jae) is composed of dark reddish-brown, salt-bearing, silty shale. The salt is generally dissolved at a depth of 5-20 feet (1.5-6 m), leaving a residual clay cover which forms distinctive dark red, steep, rounded hills with intricate drainage patterns and no vegetation. Patches of white "salt bloom" form on the surface of salt-cored hills. The salt, which is only exposed in fresh cuts along washes or in old mine workings, is massive with occasional secondary crystals and has a high clay content which gives it a mottled red color. Unit E, the uppermost member of the Arapien Shale and the only member having salt exposed at the surface, crops out along the flanks of the complex SSVA. Unit E is also exposed in parts of the Redmond Hills in adjacent quadrangles, and salt probably underlies the small gravel outcrop mapped in the northeast corner of the Aurora quadrangle as well.

Twist Gulch Formation

The Twist Gulch Formation (Jtg) is Callovian in age and probably represents a continuous depositional sequence with the Arapien Shale. It is composed of interbedded reddish-brown siltstone, mudstone, sandstone, gritstone, and minor conglomerate. It is generally thin-bedded but varies from sparse, thick beds to laminated bedding. No complete section is exposed in central Utah but the minimum estimated thickness is 1800 feet (540 m) (Willis, 1986). The basal contact of the Twist Gulch is sharp in the few places where it is exposed and is placed at the base of the lowest sandstone.

The type section of the Twist Gulch Formation is in the adjacent Salina quadrangle (Spieker, 1949, p. 36) where parts are recognizable as equivalents of the Entrada, Curtis, and Summerville Formations of the San Rafael Swell area (Willis, 1986). The outcrop exposed in the Aurora quadrangle is probably equivalent to the Entrada. The Aurora beds are generally coarser than corresponding beds in the San Rafael Swell area and contain a few grit and fine conglomerate beds of fluvial origin. The Twist Gulch Formation was deposited primarily in a tidal flat environment. The mudstone and glauconitic sandstone beds are shallow marine and shoreline deposits. The best exposure of Twist Gulch Formation in the quadrangle occurs in a road cut along U. S. Interstate 70 in the east-central part of the quadrangle. Beds of the Twist Gulch Formation that may be equivalent to the Curtis and Summerville Formations are undifferentiated on cross section A-A'.

UPPER JURASSIC AND CRETACEOUS

No Upper Jurassic rocks are recognized in the Sevier Valley area (Willis,1986). Earlier studies in the area (Spieker, 1949; Williams and Hackman, 1971) include rocks thought to be Upper Jurassic Morrison Formation, however, recent work has shown that these rocks are part of the Cretaceous Cedar Mountain Formation (Willis, 1986; Willis and Kowallis, in press).

No Cretaceous rocks are exposed in the Aurora quadrangle. Drill data and exposures in nearby Salina Canyon suggest that the Cedar Mountain Formation and Indianola Group (Sanpete Formation, Allen Valley Shale, Funk Valley Formation, and Sixmile Canyon Formation) underlie at least part of the quadrangle and have a combined total thickness of about 10,000 feet (3000 m) (Willis, 1986).

TERTIARY

Tertiary rocks in the quadrangle total more than 6000 feet (1800 m) and can be divided into four groups: 1) Paleocene and early Eocene fluvial-lacustrine formations of regional extent which include the North Horn, Flagstaff, Colton,and Green River Formations, 2) late Eocene fluvial-lacustrine deposits of localized extent that become increasingly volcanic upward which include the Crazy Hollow Formation and formation of Aurora, 3) volcanic and volcaniclastic rocks which include units from the unnamed sandstone to the Osiris Tuff, and 4) post-volcanic lacustrine and alluvial sediments. Paleocene and early Eocene formations in the quadrangle are parts of fluvial-lacustrine systems which covered much of the state while late Eocene deposits are more localized fluvial-lacustrine deposits that contain volcanic-derived sediments. Oligocene and Miocene deposits are primarily volcaniclastic sediments and welded ash-flow tuff deposits derived from the Marysvale volcanic field.

North Horn Formation

The North Horn Formation (Tnh) is not exposed in the quadrangle but is present in the subsurface. It is composed of fluvial-lacustrine deposits ranging up to coarse conglomerate. Where exposed east of the quadrangle, it directly overlies a major unconformity and represents a major change from mountain-building caused by Sevier thrusting to lacustrine basin development in the area.

Flagstaff Formation

The Flagstaff Formation (Tf) is composed of interbedded reddish-brown sandstone, conglomerate, siltstone, limestone and mudstone. Conglomerate clasts range to 1 foot (0.3 m) in diameter but average 1-6 inches (3-15 cm). It forms steep ledgy cliffs where exposed in a faulted block in the southwestern part of the quadrangle. Only a few hundred feet are exposed but it may be as much as 1500 feet (450 m) thick in the subsurface. Exposures in the quadrangle are primarily of coarse clastic rocks with a few limestone beds, in contrast to exposures on the east side of Sevier Valley near Salina which contain thick limestone beds. Thickness and clast size suggest the presence of significant highlands in the area to the west at the time of deposition (Stanley and Collinson, 1979).

Colton Formation

The Colton Formation (Tc) is composed of reddish-brown and purple mudstone, siltstone, and minor sandstone and forms a poorly exposed slope. The Colton,which is probably Eocene, is only about 50 feet (15 m) thick where exposed in the southern part of the Aurora quadrangle, however, it thickens northward in the subsurface and is probably about 300 feet (90 m) thick near the northern border. It pinches out to the south.

Green River Formation

The Green River Formation (Tg) is composed of greenish-gray to pale green, thin-bedded to laminated shale, light-brown calcareous sandstone, pale gray to pale yellowish-gray chalky limestone, dense silicified oolitic limestone, and cherty algal limestone. It forms slopes with low ledges held up by limestone and chert. Locally it forms steep cliffs up to 30 feet (10 m) high. It has a series of planar, dense, silicified oolitic limestone beds 1 to 4 feet (0.3-1 m) thick near the top which form important stratigraphic markers. It is a shallow lacustrine deposit.

The Green River Formation was divided into two informal map units in the adjacent Salina quadrangle, a lower green shale unit and upper yellow limestone and chert unit (Willis, 1986), but in the Aurora quadrangle the distinction is less pronounced so no subdivision is made. The upper part of the unit contains the most resistant beds in the quadrangle and caps many of the mountains. The carbonate rocks of the Green River Formation are highly silicic in some areas, forming platy slabs and irregular cherty algal mounds. The Green River Formation is early to late Eocene in age.

Crazy Hollow Formation

The Crazy Hollow Formation (Tch) is primarily brownish-red and orangish-red and, to a lesser extent, medium-gray and light yellowish-gray sandstone, mudstone, and siltstone. The sandstone has an immature "salt and pepper" texture. The unit generally has a basal conglomerate with distinctive dark gray to black chert pebbles ½ to 2 inches (1-5 cm) in diameter which are usually diagnostic of the formation. It is late Eocene in age.

The Crazy Hollow Formation forms dark, mottled, orange, red, and yellow hills with interspersed discontinuous ledges which make a sharp contrast with the pale yellow and green of the underlying Green River Formation. The contact is disconformable in most areas, however, the Green River and Crazy Hollow Formations interfinger in some areas where conglomeratic sandstone with dark chert pebbles interfingers with pale yellow siliceous limestone. The interfingering is interpreted as having occurred in an area of early Crazy Hollow fluvial discharge into the Green River lake prior to the basin being filled with Crazy Hollow sediments. The Crazy Hollow sediments were probably derived from Laramide uplifts to the southeast with minor amounts derived from the west (Norton, 1986). Norton measured 977 feet (298 m) northwest of Aurora.

Formation of Aurora (formerly Bald Knoll Formation)

The formation of Aurora (Tau) is composed of interbedded mudstone, bentonitic shale, limestone, and sandstone. It also contains a few thin beds of carbonaceous shale and coal. West of the town of Aurora it contains a distinctive conglomerate bed with primarily volcanic-derived clasts. It is white, pale gray, or pale orangish-gray with occasional pale reddish-orange beds. It is thin to massive bedded and forms clay-covered slopes. Bioturbation is common in the finer-grained units.

The upper part is composed primarily of reworked volcaniclastic sediments which range from pink, gray and white pumiceous tuff to conglomerate. A horizon in the tuff unit is altered to economic-grade clay which has been mined in the past. The formation is late Eocene in age: a K/Ar age on biotite from a rhyolite tuff in the formation of Aurora in the adjacent Salina quadrangle yielded an age of 40.5 ± 1.7 million years (table 2). Samples from the pumiceous tuff units near the top of the formation in the Aurora quadrangle yielded K/Ar ages of 39.6 ± 1.5 and 38.4 ± 1.5 my (table 2). This unit ranges from 0-800 feet (0-240 m) but was probably of uniform thickness at the time of deposition.

The formation of Aurora is primarily lacustrine with some fluvial channel deposits. The contact with the underlying Crazy Hollow Formation is gradational and occurs where beds change from dominantly reddish mudstone and thick channel sandstone to green or gray mudstone. The formation of Aurora is generally unconformably overlain by beds mapped as undifferentiated Dipping Vat Formation and unnamed sandstone, mudstone, and conglomerate. Where disconformable, the contact between the two units is difficult to identify, hence it has been shown as a dashed contact in the western part of the map.

The formation of Aurora is generally equivalent to the former Bald Knoll Formation of earlier workers (Gilliland, 1951; Lautenschlager, 1952; McGookey,1960). As mapped and defined by them, the Bald Knoll included pale gray beds which conformably overlie the Crazy Hollow Formation and underlie volcaniclastic deposits. Unfortunately, due to failure to recognize a fault which juxtaposes Bald Knoll beds against younger rocks of similar lilthology, the type section of the Bald Knoll Formation was established by Gilliland (1949) in exposures that I have subsequently identified as Sevier River Formation of Miocene-Pliocene age (Willis, in prep.) in Section 6, T 21 S, R 1 W (a few hundred meters north of the Aurora quadrangle). According to the North American Stratigraphic Code (North American Commission on Stratigraphic Nomenclature, 1983) the proper recourse is to abandon the name "Bald Knoll Formation" and establish a new name and type section. While this is in progress the unit is herein informally designated the "formation of Aurora."

***Table 1.** Sources of Ages for Correlation of Map Units on Plate 2 (compare with Table 2)*

1*— Fission track age on zircon 5.2 ± 0.4 my (sample AUXX-0701, Table 2) (sample locality shown on map).
2— Fleck et al., 1975, p. 56-57 (samples ES-1 and EM-1, Table 2) (adjusted according to Dalrymple, 1979)
3— based on unpublished K-Ar dates by H.H. Mehnert of the U.S. Geological Survey
4— K-Ar age on biotite 26.6 ± 1.1 my (sample SACP-0510, Table 2) (Willis, 1986)
5— Steven et al., 1981
6— Fission track age on zircon 29.7 ± my (sample SAUS-0101, Table 2)
K-Ar age on biotite 34.2 ± 1.4 my (sample RRDV-0101, Table 2) (Willis, 1986)
Fission track age on zircon 34.6 ± 1.6 my (sample AUBK-2001, Table 2) (sample locality shown on map).
K-Ar age on biotite 35.8 ± 1.4 my (sample SGXX-0103, Table 2)
Note: The unnamed sandstone unit and the Dipping Vat Formation are undifferentiated as map units. The unnamed sandstone unit is approximately 28-31 my old; the Dipping Vat Formation is 34-35 million years old.
7— K-Ar age on biotite 38.4 ± 1.5 my (sample AUBK-0112, Table 2) (sample locality shown on map) (Willis, 1986)
K-Ar age on biotite 39.6 ± 1.5 my (sample AUBK-1010, Table 2) (sample locality shown on map) (Willis, 1986)
K-Ar age on biotite 40.5 ± 1.7 my (sample SABK-1110, Table 2) (Willis, 1986)
8— age bracketed by 7 and by Nelson et al., 1983
9— Fouch et al., 1982
10— Fission track ages on zircon (Willis and Kowallis, in press; Willis, 1986)
11— Imlay, 1980
Sprinkel, 1982

**Numbers refer to the Correlation of Map Units on Plate 2*

Dipping Vat Formation and unnamed sandstone, mudstone, and conglomerate beds, undifferentiated

Overlying the formation of Aurora is a sequence of sandstone, mudstone, and conglomerate beds (Tdu). In the Aurora quadrangle the beds are as much as 200 feet (60 m) thick in the eastern part, but are as much as 600 feet (180 m) thick in the Salina quadrangle (Willis, 1986). They are white to pale gray fluvial tuffaceous sandstone, mudstone, conglomerate, marlstone and minor airfall tuff. The sandstone is composed primarily of volcanic material including glass shards (up to 80%), quartz, feldspar, biotite, magnetite, altered clay and pumice. The conglomerate beds range up to 6 feet (2 m) thick and contain rounded clasts up to 6 inches (15 cm) in diameter. Some of the conglomerate beds contain mostly volcanic rock clasts while others contain sedimentary-derived clasts. Bioturbation is common in the finer grained units.

In the Salina quadrangle, I did not apply a name to rocks in a similar stratigraphic position because of uncertain correlation. To the southeast, similar rocks are called the Dipping Vat Formation (McGookey, 1960). Near its type section the Dipping Vat Formation yielded radioisotope ages of 34.2 ± 1.4 and 35.8 ± 1.4 my (table 2). A sample from similar rocks in the Aurora quadrangle yielded an age of 34.6 ± 1.6 million years while a sample from the Salina quadrangle was dated at 29.7 ± 1.5 my. Because of the large age range, the difficulty in correlation, and the lack of a mappable contact, I have combined the unnamed unit and the Dipping Vat Formation into one undifferentiated map unit in the Aurora quadrangle. The abundance, size, and diversity of volcanic clasts suggest that the unit was derived from the Marysvale volcanic field to the south.

The undifferentiated beds unconformably overlie the formation of Aurora in some areas and the Arapien Shale in others. The unconformity between the Arapien and undifferentiated beds is angular, while it is disconformable with the formation of Aurora. An angular relationship between the beds and the formation of Aurora occurs in the Salina quadrangle to the east (Willis, 1986), suggesting that the undifferentiated rocks are more closely related to overlying volcanic and volcaniclastic rocks. Where the formation of Aurora and unnamed beds are parallel, the contact is difficult to locate and is dashed on the map.

Table 2. *Selected Radiometric Dates from Aurora Quadrangle and Vicinity*
(compare with Table 1)

SAMPLE #	GEOLOGICAL UNIT	LATITUDE	LONGITUDE	QUADRANGLE	MATERIAL	METHOD	AGE (Million yrs) ± 1 SD
AUXX-0701	Sevier River Formation	38°58′17″	111°56′36″	Aurora	Zircon	Fiss. trk.	5.2 ± 0.4
EM-1	Osiris Tuff	38°57′30″	111°48′12″	Salina	Biotite	K-Ar	22.4 ± 0.4
ES-1	Osiris Tuff	38°57′30″	111°48′12″	Salina	Biotite	K-Ar	22.9 ± 0.4
SACP-0510	Int. Carter Peak	38°52′34″	111°52′29″	Salina	Biotite	K-Ar	26.6 ± 1.1
SAUS-0101	Unnamed ss	38°56′25″	111°50′19″	Salina	Zircon	Fiss. trk.	29.7 ± 1.5
RRDV-0101	Dipping Vat Formation	38°47′29″	111°50′22″	Rex Res	Biotite	K-Ar	34.2 ± 1.4
AUBK-2001	Dipping Vat Formation	38°55′51″	111°57′03″	Aurora	Zircon	Fiss. trk.	34.6 ± 1.6
SGXX-0103	Dipping Vat Formation	38°48′30″	111°53′35″	Sigurd	Biotite	K-Ar	35.8 ± 1.4
AUBK-0112	Formation of Aurora	38°56′10″	111°57′04″	Aurora	Biotite	K-Ar	38.4 ± 1.5
AUBK-1010	Formation of Aurora	38°56′07″	111°57′05″	Aurora	Biotite	K-Ar	39.6 ± 1.5
SABK-1110	Formation of Aurora	38°53′10″	111°49′03″	Salina	Biotite	K-Ar	40.5 ± 1.7

Laboratory data on unpublished ages:
(see references for data on other ages)

SGXX-0103
Laboratory: KE=Krueger Enterprises, Inc., Cambridge, MA; 40*Ar (ppm)=0.01436; 0.01431 (40*Ar=radiogenic Argon 40)
%K=5.755; 5.681
40*Ar/Total 40Ar=0.463; 0.472
40K (ppm)=6.822

	Fossil Track Density		Induced Track Density		Neutron Fluence		Number
	trk/cm² (x10⁶)	track counts	trk/cm² (x10⁶)	track counts	n/cm² (x10¹⁴)	track counts	Grains
AUXX-0701	.0823	200	4.71	1145	9.97	2438	10
SAUS-0101	3.66	956	3.30	863	8.99	2438	5
AUBK-2001	5.26	1298	4.12	1016	9.08	2438	6

Fission track constants:
λ d=1.55 x 10^{-10}/yr
λ f=7.03 x 10^{-17}/yr
U^{235}/U^{238}=0.00725

Three Creeks Tuff Member of Bullion Canyon Volcanics

The Three Creeks Tuff Member of the Bullion Canyon Volcanics (Tbt) (Steven and others, 1979) is composed of pale gray to pinkish-gray latitic tuff and contains plagioclase, amphibole, biotite, and other accessory minerals. It erupted from the Three Creeks caldera in the southern Pavant Range about 40 miles (60 km) to the southwest and is about 27 my old. Table 3 gives representative modal analyses.

The Three Creeks Tuff Member occurs as small, poorly exposed outcrops in the southeast part of the quadrangle. The relationship to other volcanic units in the area is uncertain but it appears to directly underlie the formation of Black Cap Mountain in the southern part of the quadrangle.

Intrusion of Carter Peak

The intrusion of Carter Peak (Tcp) is greenish-gray to black and gray, fine-grained, holocrystalline diorite. It contains plagioclase, clinopyroxene, pyroxene, biotite, hornblende, and accessory sphene and apatite; table 3 gives representative modal analyses of selected samples. It has a sharp chilled contact with the Arapien Shale host. The intrusion was dated at 26.6 ± 1.1 my (table 2) but its relationship to other igneous units in the area is unknown.

The intrusion of Carter Peak occurs as an isolated, weathered outcrop which forms the core of a steep conical hill of Arapien Shale located in the southeast corner of the quadrangle. The exposed part of the intrusion consists of about 200 feet (60 m) of resistant holocrystalline diorite formerly mapped as "undifferentiated latite and basaltic andesite flows" by Williams and Hackman (1971). The intrusion has nearly vertical contacts with the Arapien on all sides where well exposed. The Arapien is baked in a zone up to 30 feet (9 m) wide next to the contacts while the intrusion has an aphanitic margin grading to phaneritic texture 5 to 20 feet (1.5-6 m) from the contact.

Table 3. *Modal Analyses of Volcanic Units from Aurora Quadrangle and Vicinity*
To-Osiris Tuff, Tda-Antimony Tuff Member of the Mount Dutton Formation, Ta-Tuff of Albinus Canyon, Tcp-Intrusion of Carter Peak, Tbt-Three Creeks Tuff Member of Bullion Canyon Volcanics, Tau-rhyolite tuff bed in formation of Aurora.

Sample	Unit	Counts	Latitude	Longitude	MTX	PLAG	SAN	BIOT	AMPH	PYX	FE-TI	SPH	APA	QTZ	LITH	OTHER
SATO-0702	To	600	38°51′11″	111°51′48″	80.6	14.3	2.3	1.5	—	0.8	0.5	—	—	—	—	—
SATO-1013	To	600	38°57′32″	111°50′5″	71.3	17.6	4.8	2.2	0.2	1.7	2.2	—	—	—	—	—
SATO-0104	To	650	38°56′26″	111°48′52″	78.9	11.1	3.4	1.7	—	1.8	0.8	—	tr	tr	2.3	—
AUTO-0206	To	700	38°55′42″	111°53′16″	78.0	15.7	3.1	1.6	—	0.7	0.9	—	tr	—	tr	—
SAAT-0806	Tda	760	38°56′11″	111°50′4″	88.8	6.6	2.6	—	—	0.3	1.4	—	0.3	—	—	—
SAAT-0810	Tda	765	38°56′11″	111°50′3″	91.2	4.4	2.8	—	—	0.5	1.1	—	tr	—	—	—
AUAT-0110	Tda	650	38°54′54″	111°57′37″	92.3	3.5	1.7	tr	0.3	0.6	1.1	—	tr	—	—	—
AUAT-0103	TaTda	700	38°54′31″	111°58′39″	87.3	6.7[1]	—[1]	—	—	1.0	0.3	—	tr	—	—	4.7[2]
AUAT-0105	TaTda	750	38°54′43″	111°58′37″	93.3	4.9[1]	—[1]	—	—	1.2	0.5	—	tr	—	—	—
SAAT-0801	Ta	708	38°56′9″	111°50′8″	90.1	4.4	—	—	—	0.7	1.9	—	0.1	0.1	2.7	—
SAAT-1172	Ta	650	38°56′13″	111°50′5″	84.6	2.0	0.3?	—	—	—	0.9	—	tr	—	—	12.2[3]
AUAT-0111	Ta	650	38°55′50″	111°57′2″	86.5	8.0	—	0.9	0.8	1.1	1.2	—	—	0.2	1.5	—
AUAT-0204	Ta	700	38°55′51″	111°53′13″	92.4	4.4	—	0.1	—	1.1	1.1	—	0.1	—	0.7	—
AUAT-0207	Ta	650	38°53′35″	111°54′24″	93.7	4.2	tr	—	—	0.9	0.9	—	tr	tr	—	—
AUAT-0208	Ta	700	38°53′20″	111°55′49″	90.0	5.7	—	—	—	3.0[4]	1.0	—	tr	—	0.3	—
SABT-0201	Tbt	700	38°53′22″	111°50′46″	59.6	23.6	—	1.7	13.0	—	1.9	—	0.1	tr	0.1	-
SABT-0204	Tbt	845	38°53′22″	111°50′46″	54.5	28.3	—	3.8	12.0	—	1.1	—	0.1	0.1	0.1	—
SACP-2501	Tcp	600	38°52′31″	111°52′22″	—	60.7	—	9.8	6.8	9.8	4.0	0.5	0.2	—	—	8.2[5]
SACP-2502	Tcp	600	38°52′31″	111°52′22″	—	72.4	—	5.8	10.0	7.8	2.8	0.7	0.5	—	—	—
SACP-2503	Tcp	500	38°52′32″	111°52′21″	9.9	36.1	—	—	0.4	16.8	1.2	0.4	0.2	—	—	35.0[6]
SACP-2504	Tcp	600	38°52′32″	111°52′21″	54.1	19.7	—	—	—	10.2	3.5	—	—	—	—	12.5[7]
SABK-1110	Tau	640	38°53′11″	111°49′3″	83.8	2.3	tr	0.1	tr	—	0.8	—	—	0.9	1.1[8]	10.8[9]
AUBK-0111	Tau	500	38°55′56″	111°57′3″	91.8	2.0	—	0.84	tr	—	tr	—	—	1.4	0.8	3.2[10]

[1]may include sanadine, [2]vesicles-4.7%, [3]vesicles-12.2%, [4]includes altered grains, [5]kaolinite-8.2%,
[6]kaolinite-31.2%, carbonate-2.6%, uralite-1.2%, [7]voids-12.3%, olivine-0.2%, [8]pumice present, but included in matrix count in thin section
[9]carbonate-10.8%, zircon-tr, [10]pumice-3.2%, zircon-tr

Tuff of Albinus Canyon and Antimony Tuff Member of Mount Dutton Formation, Undifferentiated

The tuff of Albinus Canyon (Steven, 1979) and Antimony Tuff Member of the Mount Dutton Formation (Anderson and Rowley, 1975) are undifferentiated (Ta) in the Aurora quadrangle because of similarity in lithology and the resulting lack of a mappable contact. Both tuffs are composed of dark reddish-brown, dark brownish-gray, or dark gray crystal-poor ash-flow tuff of quartz latite composition. They are brittle, densely welded, and commonly contain drawn-out vesicles and pumice lenticules. The Antimony Tuff rests directly on the tuff of Albinus Canyon and may best be differentiated in thin section on the basis of sanidine content (the Antimony Tuff has a relatively higher sanidine content) (P. D. Rowley, U. S. Geological Survey, personal communication, 1984). They are composed of 85-90% matrix, 4-9% plagioclase, 0-4% sanidine, and 1-2% pyroxene (table 3). Unpublished radiometric dates by H.H. Mehnert of the U.S. Geological Survey indicate an age of 25 my. The combined unit varies from 0 to 300 feet (0-90 m) thick.

The undifferentiated tuff unit overlies the unnamed sandstone, mudstone, and conglomerate except in the southern part of the quadrangle where it interfingers with the lower part of the formation of Black Cap Mountain. It underlies most of the formation of Black Cap Mountain where it is present and the Osiris Tuff where it is not. In the Aurora area, the Antimony Tuff member rests on the tuff of Albinus Canyon with only minor or no intervening beds. In the Monroe area, to the south, they are separated by thick local lava flows (Rowley and others, 1981).

Formation of Black Cap Mountain

The formation of Black Cap Mountain (Tbc) is composed of volcaniclastic sandstone with minor interbedded conglomerate, air-fall tuff, and breccia. It is nonresistant and poorly exposed, generally as a slope between more resistant welded tuffs, with a bluish-gray cast due to a weathered coating on individual grains. Clasts are primarily volcanilithic and poorly cemented. The grains, angular to rounded and fine to coarse grained, are generally well sorted but have occasional poorly sorted channel deposits with rare Paleozoic-derived cobbles (Willis, 1986). Occasional angular blocks up to 3 feet (0.9 m) in diameter derived from the tuff of Albinus Canyon/Antimony Tuff Member occur in the unit. It also has zones with abundant angular welded tuff and pumice fragments. The unit is between 23 and 25 million years old and about 100 feet (30 m) thick in the eastern part of the quadrangle; it is absent in the western part.

Osiris Tuff

The Osiris Tuff (To) is composed of densely welded porphyritic, latitic tuff, usually light gray, but also reddish brown, reddish purple, or brownish gray and has a dark gray to black basal vitrophyre. It contains 70-80% matrix, 10-20% plagioclase, 1-3% biotite, 2-5% sanidine, 0.5-2% pyroxene and minor Fe-Ti oxides. The biotite, which weathers copper-brown, and the plagioclase are particularly conspicuous in handsamples. The Osiris typically erodes into large rounded blocks which form steep hills and ledges and weather to granular fragments. It has a black basal vitrophere up to 5 feet (1.5 m) thick overlain by a grayish-red zone 0-30 feet (0-9 m) thick. The remainder of the unit, which locally exceeds 300 feet (90 m), is pale gray or pale brownish-gray. The Osiris Tuff overlies the formation of Black Cap Mountain in the southeastern part of the quadrangle and the tuff of Albinus Canyon/Antimony-Tuff in the southwestern part. The Osiris erupted from the Monroe Peak Caldera located 30 miles (50 km) to the south (Steven and others, 1984) about 23 million years ago (table 2) (Fleck and others, 1975).

Sevier River Formation

The Sevier River Formation (Tse) is a thick sequence of mudstone, sandstone, limestone, and conglomerate exposed in the northwest part of the quadrangle. It is poorly cemented, but occasional resistant beds, mostly conglomerate, form knolls with steep-walled washes. It is pale red to pale gray in outcrop and contains angular blocks up to 6 feet (2 m) in diameter in the lower part of the unit in the western exposures, becoming finer eastward and up section where clasts are seldom larger than 2 inches (5 cm). Volcanic clasts up to 4 inches (10 cm) in diameter, which occur in the southernmost exposures, rapidly decrease in quantity and size toward the north and rarely occur north of Denmark Wash. The volcanic clasts were probably derived in part from volcanic outcrops located in the southern part of the quadrangle. Other clasts are limestone, chert and sandstone that were derived primarily from the Green River and Flagstaff Formations exposed in highlands to the west. A partially reworked ash bed in the upper part of the formation that locally ponded up to about 40 feet (12 m) thick is exposed in several places north of Denmark Wash. It was dated by fission track methods at 5.2 $\pm$ 0.4 my (table 2). Steven and Morris (1983) report an age range of 7 to 15 my for the Sevier River Formation to the south. The outcrops of Sevier River Formation in the quadrangle were previously incorrectly mapped by earlier workers as Bald Knoll Formation and considered late Eocene or Oligocene in age (Lautenschlager, 1952; Gilliland, 1951; Williams and Hackman, 1971).

The formation consists of basin-fill deposits, but the basin configuration was not the same as the modern topography: the southern Valley Mountains were not present when the unit was deposited. The formation lies on an angular unconformity which increases in magnitude to the northwest. It apparently is cut into the formation of Aurora in the west-central part of the quadrangle (the unconformable contact is not exposed because of the Aurora fault), into the Crazy Hollow to the north, and into the Green River in the northwestern part of the map area.

Several small outcrops in the central part of the quadrangle are labeled with question marks (?) because of uncertain correlation with the Sevier River Formation north of the

Aurora fault. The queried outcrops consist of cemented gravel deposits that contain a small percentage of volcanic clasts and are tilted up to about 40° (figure 1). Only about 60 feet (20 m) of exposure occurs, but the unit may be thicker in the subsurface. The queried outcrops may more closely correlate with the older alluvial deposits (QTao) described below.

Volcanic Breccia

Two small, rounded hills in the east-central part of the quadrangle are capped by an intensely brecciated volcanic unit mapped as volcanic breccia (Tvb). The brecciation is intraformational, caused by faulting and deformation along an adjacent shear zone. The unit is composed primarily of the tuff of Albinus Canyon/Antimony Tuff but includes other units. Timing of brecciation is uncertain but it is considered late Tertiary.

Undifferentiated Middle and Upper Tertiary Deposits

Undifferentiated middle and upper Tertiary deposits (Tu) are shown on the accompanying cross section in the Sevier Valley area. They are at least partially equivalent to the previously described middle and upper Tertiary units exposed along the valley margins.

TERTIARY-QUATERNARY

Slump Blocks

Numerous blocks of Green River Formation in the west part of the map area are detached along bedding planes and have slumped down dip slopes (QTms). In some the footing had been weakened by the cutting of washes and canyons. The best exposed slump block is in the northeast ¼ of Section 36, T 21 S, R 2 W where it has been cut by a later stream (figure 2). The north end of the block deformed into an overturned fold while the south end detached along the lower surface and rode over itself, causing rotation within the block. Most blocks are poorly exposed and are recognized by anomalous bedding attitudes and hummocky topography.

Older Alluvial Valley-fill Deposits

Thick, partially consolidated gravel deposits (QTao) representative of an earlier period of valley filling are exposed in the central and north-central part of the quadrangle. The gravels are exposed only beneath several deeply dissected pediments and are unconformably overlain by a thin veneer of younger deposits associated with the later pediment development (figure 1). The unit is composed primarily of conglomerate interbedded with sandstone and mudstone. Pebble-sized clasts are moderately well sorted, poorly consolidated or uncemented, and moderately well rounded. Significantly, most of the clasts in the southern and central exposures are from the Flagstaff and older units even though the Green River Formation is the major unit presently exposed above the deposits. Only rare volcanic clasts occur in the unit, indicating a western primary source for the deposit. The partially consolidated gravel deposits are probably younger than nearby faults that cut the Sevier River Formation, but they have been tilted in some places; they are probably Pliocene or Pleistocene in age.

The unit was deposited during a period of major aggradation in Sevier Valley and unconformably overlies several older units including the Sevier River Formation. Unlike the Sevier River Formation, it apparently conforms approximately with the present basin configuration. Several small outcrops west and southwest of Aurora mapped as Sevier River Formation(?) may actually more closely correlate with this unit. Lautenschlager (1952) mapped this unit and the overlying pediment veneer as Axtell Formation, a name established on the east side of Sevier Valley to the northeast. I have chosen to not use that term until more precise correlation with the type section has been documented, though they are likely of similar age.

Reddish Older Alluvial Deposits

Reddish alluvial deposits (QTar) have been isolated up to 200 feet (60 m) above present drainage systems in the northwest part of the quadrangle. They are composed primarily of moderately to poorly sorted cobbles, pebbles, sand, silt, and clay eroded from the North Horn and Flagstaff Formations exposed in the Pavant Range to the west and southwest, and they may be a western extension of the older valley-fill deposits (QTao) described above. They appear to be older, at least in part, than the pediment surfaces exposed in the central part of the quadrangle.

Gravel Deposits of Redmond Hills

Poorly cemented or uncemented, moderately well sorted cobbles, pebbles, and sand with minor amounts of mud and clay cap the Redmond Hills in the northeast corner of the quadrangle (QTag). The beds generally tilt away from the center of the hills at 20 to 40°. Most of the gravel deposits are well sorted but occasional lenses of poorly sorted materials with subangular clasts are also present. Cobbles in the gravels resemble local sedimentary and volcanic bedrock units exposed to the south. The age of these deposits is considered to be Pleistocene but may be late Tertiary.

Figure 1. *Tilted alluvial valley-fill deposits beneath old pediment deposits southwest of Aurora. The steeply tilted beds near the left side are probably Sevier River Formation (Tsr(?)), and the moderately tilted beds near the right center are older alluvial valley-fill deposits (QTao). The hills in the background are composed primarily of Green River Formation and are flanked on the east side by Sevier River Formation. Intermittent eastward rotation of the valley mountains has probably been occurring since Pliocene time.*

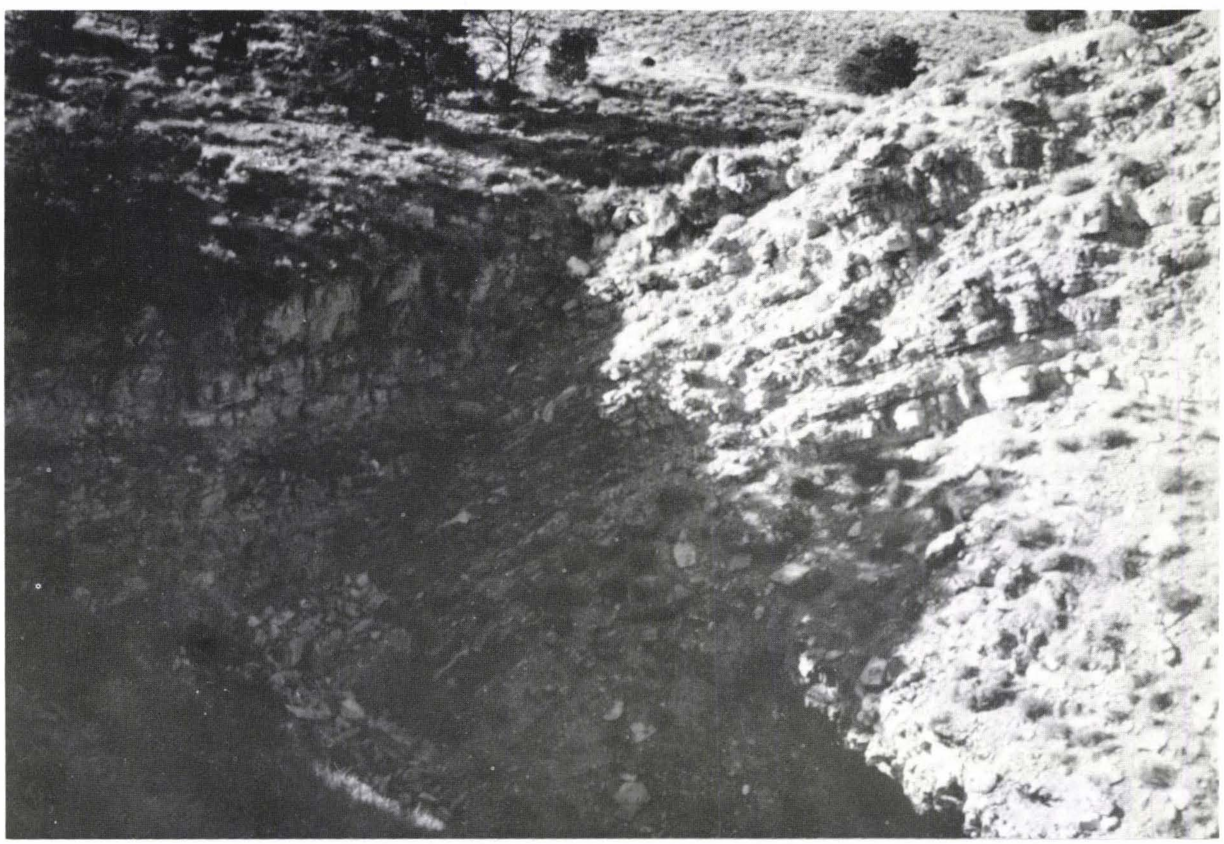

Figure 2. *View looking north at southern part of a slump block composed of the Green River Formation northwest of Aurora. The block detached along a bedding plane and moved along a ramp over equivalent attached beds (lower right part of photograph), moving forward about 300 feet (90 m), and rotating as it did so. The northern side of the block (not shown in photograph) moved only a few feet, forming an asymmetric fold.*

QUATERNARY

The only mapped landslide deposit (Qms), which occurs in the southwest part of the quadrangle, consists of poorly sorted, angular, broken blocks of Green River Formation that have slid down a faceted spur oversteepened by faulting.

Colluvium (Qc) consists of fallen blocks, talus, and surface cover on slopes that were derived from adjacent and topographically higher bedrock. It is locally gradational with alluvial deposits and bedrock.

Terrace deposits (Qat) composed of moderately well sorted alluvial material occur along Lost Creek in the southeast part of the quadrangle. They consist of gravel, sand, silt, clay, and boulders of primarily volcanic origin. The deposits range from 75 feet (22 m) to 150 feet (45 m) above the present drainage and contain volcanic boulders that were transported in an earlier phase of Lost Creek. They may be equivalent in part to nearby "older alluvial deposits" (described below) that are similar in composition and in elevation but that do not have a preserved terrace morphology.

Several levels of pediment surfaces mantled by a thin layer of alluvial deposits occur in the central and northwestern part of the quadrangle (Qap1-Qap4) (figure 1). Veneered by poorly sorted, angular boulders, cobbles, pebbles, and fine-grained material, the deposits are mapped on the basis of geomorphic form and relative elevation above present drainage systems. Although numerous intermediate levels occur, all pediments are grouped into four levels in which surfaces with minor elevation differences are lumped together to make mapping of the deposits feasible. Qap_1 are the youngest and lowest deposits, ranging up to about 50 feet (15 m) above present drainage systems, with successive numbers indicating older deposits. Relative age should only be considered valid for adjacent pediment levels. The oldest level (Qap_4) is the most prominent, forming a line of beheaded pediments that exceed 200 feet (60 m) above present drainages and that continues across most of the quadrangle. The pediments cut into, and overlie, primarily the formation of Aurora, the Sevier River Formation, and the "older alluvial valley fill deposits." The pediment mantle is generally less than 30 feet (9 m) thick.

A large part of the Sevier Valley has been mapped as alluvial fan deposits (Qaf). The fans are composed of sand, silt, clay, gravel, cobbles, and boulders in poorly to moderately sorted sinuous deposits. Several smaller, isolated fan deposits are included with "younger alluvial deposits" and several older dissected alluvial fans are included with "older pediment surfaces."

Older alluvial deposits (Qa_2) consisting of sand, silt, clay, gravel, and boulders occur in several areas. They are primarily locally derived and include deposits that have been dissected or isolated by downcutting of modern drainage systems. They also include stream alluvium, alluvial fan deposits,and deposits on old pediment surfaces. They locally are gradational with colluvial and other alluvial deposits.

Younger alluvial deposits, extensive in the quadrangle (Qa_1), consist of locally derived sand, silt, clay, gravel, and boulders. They vary from poorly sorted to well sorted and include stream alluvium, alluvial fan deposits, slope wash, and young stream terrace deposits. They tend to be gradational with colluvial and other alluvial deposits.

Fluvial deposits along Sevier River and Lost Creek have been mapped as flood-plain and channel deposits (Qal). They are composed of boulders, gravel, sand, silt, mud, and clay. Poorly to moderately well sorted near Lost Creek, they are moderately well sorted in the Sevier River flood plain.

STRUCTURE AND GEOLOGIC HISTORY

The Aurora quadrangle is located in the transition zone between the Colorado Plateau and Basin and Range geologic provinces and has structural characteristics of both. In addition, it is near the center of the Arapien Shale depositional basin and may be influenced by possible diapirism of the Arapien Shale. The quadrangle area, located near the leading edge of the Sevier thrust belt, has been influenced by thrust deformation. The Sanpete-Sevier Valley anticline (SSVA) occurs in the eastern part of the quadrangle, the Sevier Valley occupies the center, and the Valley Mountains occupy the western part.

SANPETE-SEVIER VALLEY ANTICLINE AREA

The Sanpete-Sevier Valley anticline (SSVA), named by Gilliland (1963), is about 40 miles (65 km) long and has a structural relief of as much as 20,000 feet (6000 m). It trends north-northeastward along the east side of the Sevier and Sanpete Valleys and crosses the southeastern part of the Aurora quadrangle. The Aurora quadrangle is about 15 miles (25 km) north of the southernmost exposure, where the structure either terminates or plunges beneath volcanic deposits.

Intensely folded, faulted, and structurally thickened Arapien Shale occupies the core of the SSVA. Despite the large structural relief, no older unit is exposed; drill data indicate that the underlying Navajo Sandstone and Twin Creek Limestone and older beds are minimally affected by uplift associated with the anticline. Evidence in the area suggests that the anticline originally formed during the Late Cretaceous or early Tertiary. In Salina Canyon beds as young as the Late Cretaceous Indianola Group were steeply tilted, and in some places overturned, during the formation of the structure. The steeply tilted beds were beveled off and in turn were overlain by early Tertiary strata. Following this deposition, the SSVA then underwent additional localized deformation.

I believe the SSVA was formed by thrust deformation as part of the Sevier orogeny during the Late Cretaceous and possibly the early Tertiary. This deformation folded relatively competent rock (Twist Gulch Formation through Indianola Group) into a large anticlinal structure and intensely deformed and thickened the less competent core of Arapien Shale. The fold was rooted to a detachment surface located near the base of the Arapien, above the underlying Twin Creek Limestone and Navajo Sandstone. Later, diapirism deformed Tertiary rocks and complicated much of the evidence for the thrusting event. Alternatively, Witkind (1982) proposed that all the major episodes of deformation were caused by diapirism and that thrusting had little or no affect.

Original Episode of Deformation

Conclusive evidence in the Aurora quadrangle to support the original episode of deformation is lacking; better evidence is present in the Salina quadrangle (Willis, 1986). It is difficult to relate specific structural features in the Aurora quadrangle to this event, however, the dominant north-northeast trend of the SSVA and many of the subsidiary folds in the Arapien Shale shown on the map and cross section probably formed at this time. Nevertheless, this episode deformed both the Arapien Shale and over 10,000 feet (3000 m) of overlying rocks, including the Twist Gulch Formation, the Cedar Mountain Formation, and the Indianola Group. During thrusting the competent rocks formed a large fold and the incompetent rock was crumpled and thickened inside the fold by internal folding and imbricate thrust faulting (Lawton, 1985). Later the upper part of the anticline was eroded off. Subsequent episodes of deformation had little or no effect on the remaining competent rock adjacent to the structure. Later, the mudstone and evaporites of the Arapien moved diapirically upward through the weaker linear gap bounded by the competent rock.

The SSVA is dominated by numerous internal folds and faults on both a large and a small scale. The internal folds and faults trend generally northeast in the Aurora quadrangle but are highly variable in the Salina quadrangle to the east (Willis, 1986). The contorted nature of mapped gypsum outcrops, which likely are all part of the same bed repeated at the surface, reveal part of this structure. Most smaller structures were not separately mapped due to the involved complexities.

Following the original episode of deformation, the crest of the SSVA was eroded down to near the regional base level. Some topographic relief, perhaps enhanced by early diapirism, persisted into the Tertiary. The North Horn and Flagstaff Formations were deposited on the flanks of the structure to a thickness of 2000 feet (600 m) but did not overlap the crest. The Colton Formation was probably the first to cover the SSVA. The younger Green River and Crazy Hollow Formations were deposited across the structure with little or no thinning. The Green River and Crazy Hollow Formations are very thin in the southeast part of the Aurora quadrangle adjacent the SSVA, a combined thickness of less than 100 feet (30 m), versus over 2000 feet (600 m) normally, but this thinning is due to later structural deformation.

Later Deformation

The flanking Jurassic and Cretaceous rocks folded in the original deformation were not generally affected by subsequent episodes of deformation on the SSVA. In the Salina quadrangle, the flanking beds, which are steeply tilted and bevelled off, are overlain by undeformed Tertiary rocks (Willis, 1986). Where these same Tertiary beds overlie the Arapien Shale they are intensely folded and deformed. Evidence for the later events falls into three categories: 1) a sheared and striated contact between the Arapien Shale and adjacent units, 2) the Arapien is exposed at a higher elevation than the nearby unconformable surface to which it was bevelled without a significant high-angle fault in between, and 3) deformation of Tertiary, and possibly Quaternary, rocks adjacent to the SSVA.

Contact between the Arapien Shale and adjacent units

Wherever exposed, the contact between the Arapien and any adjacent rock is sheared and striated. Clay is common along the contact and it usually shows foliated "fish scales," glossy, smooth, striated surfaces, and sometimes contains remnants of rock sheared from adjacent beds. The fragments of sheared rock, which range from a few inches to several feet thick, may represent more than a thousand feet of rock that has been removed by structural deformation (figure 3). The attitude of the shear plane is variable but generally is between 45 and 90 degrees. This sheared surface was probably produced in large part by diapiric movement of the mudstone beds of the Arapien Shale but may be due to other causes as well. Anderson and Barnhardt (1987) have documented a similar surface in the Annabella area to the south that they believe is not due to diapirism but is related to a subhorizontal detachment surface in which the Arapien moved west relative to the overlying Tertiary rock. In that area the contact is usually inclined less than 45°.

Elevation of exposures of the Arapien Shale

The erosional surface that formed following the original episode of deformation in the Late Cretaceous is well exposed in Salina Canyon at an elevation of 5600 feet (1700 m) (Willis, 1986). Since the Arapien is a nonresistant unit it should have been eroded down to that surface as well. Presently however, it is exposed at elevations in excess of 6400 feet (1950 m) in spite of considerable erosion. There is no fault other than the sheared surface at the top of the Arapien Shale to account for the upward movement.

Deformation of Cenozoic rocks

Tertiary rocks of Eocene to Quaternary age are tilted, sheared, and brecciated wherever exposed near the Arapien Shale. Two and possibly three or more episodes of deformation have been identified in these rocks. The first occurred after deposition of the formation of Aurora and prior to deposition of the undifferentiated Dipping Vat Formation and unnamed sandstone, mudstone, and conglomerate beds, a second deformed the "undifferentiated" beds and overlying volcanic units, and a third presently may be deforming unconsolidated surficial deposits. The later deformation may be the result of diapirism, dissolution and collapse, or both.

In several localities in the Aurora and adjacent quadrangles the "undifferentiated" beds are deposited directly on the Arapien Shale. Exposures in Salina Canyon and elsewhere indicate that about 3000 feet (900 m) of Colton Formation through formation of Aurora rocks must have been removed, probably by erosion. A striated and sheared surface is present along the contact, and it is likely that part of these rocks were removed structurally. These beds were removed prior to deposition of the "undifferentiated" beds only from over the SSVA, elsewhere they are still present. Where the Colton through formation of Aurora beds are still present, the "undifferentiated" beds were deposited on them without discordance. Thus at least 3000 feet (900 m) of diapiric uplift of the Arapien Shale occurred between deposition of the formation of Aurora 38-40 million years ago and deposition of the "undifferentiated" beds 30-35 million years ago.

A row of hogbacks composed of the Flagstaff Formation and younger Tertiary units extends along the west flank of the SSVA for more than 20 miles (36 km). In the Aurora quadrangle some of the hogbacks are composed of the Green River through volcanic units and others of just the volcanic units. They strike parallel to the SSVA with a moderate to vertical dip and were probably tilted by more than one episode of diapirism. Evidence in the Salina quadrangle indicates that the Green River through formation of Aurora beds were tilted prior to deposition of the unnamed beds (Willis, 1986). Elsewhere, the volcanic units were tilted together with the Green River and related beds in one or more episodes.

Rocks in the hogbacks are invariably highly fractured and brecciated and in some cases are structurally thinned or attenuated to only a fraction of their original thickness. In Section 16, T 22 S, R 1 W, the Green River Formation is missing while the overlying Crazy Hollow and formation of Aurora are less than a tenth of their normal thickness (figure 3). Just to the south, in Section 21, the Green River is present but is less than 100 feet (30 m) thick as opposed to a normal thickness of over 1000 feet (300 m). The thinning definitely is not stratigraphic but occurred well after deposition. In some cases shattered remnants of the missing rocks are preserved. Thus at least 1000 to 2000 feet (300 to 600 m) of rock have been structurally removed. In that area the sheared surface is oriented at 60-90°.

A third episode of deformation, which is probably still occurring, is necessary to account for tilted and deformed surficial deposits which occur in several areas along the flank of the SSVA. Diapirism of the mudstone and evaporite beds of the Arapien Shale and salt dissolution and subsequent collapse of overlying rocks are the likely causes.

Brecciation of Volcanic Rocks

In Sections 16 and 21, T 22 S, R 1 W, a unit mapped as volcanic breccia overlies the steeply tilted hogbacks composed of the Green River Formation and related beds including the Arapien. The breccia is composed in large part of the tuff of Albinus Canyon/Antimony Tuff which are also involved in the hogbacks. The breccia may be a gravity slide or similar feature that was displaced from the rising diapiric mass to rest on the hogbacks. It probably does not represent a separate episode of diapirism.

Block of Twist Gulch Formation

A block of Twist Gulch Formation about a mile long is exposed in Section 10 in the east central part of the quadrangle near the margin of the SSVA. Significantly, Arapien Shale is faulted against at least two sides of the block. The outcrop of Twist Gulch Formation is probably a detached block that has become incorporated in the internal deformation of the SSVA.

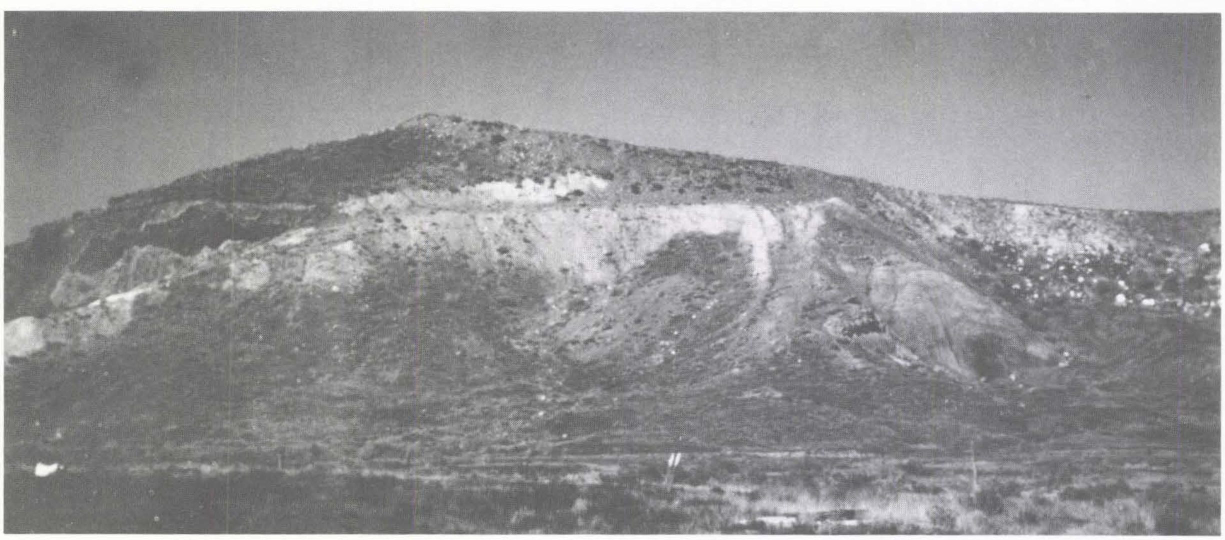

Figure 3. View to the north of an exposure located in Section 16, T 22 S, R 1 W on the east side of Sevier Valley showing westwardly tilted beds of Tertiary sedimentary and volcanic units. The beds have been intensely brecciated, faulted, and thinned by shearing. Shearing has completely removed the Green River Formation; the Crazy Hollow and formation of Aurora are recognizable (near center of photograph), but are only a fraction of their original thickness. The volcanic units are less sheared but are intensely brecciated. The exposure has been modified by recent bulldozer activity.

History of the Sanpete-Sevier Valley Anticline

The tectonic forces which formed the structural features associated with the Sanpete-Sevier Valley anticline and adjacent structures has been controversial since first studied by geologists. Spieker (1946, 1949) explained the complex structures of the area by a series of 14 "crustal movements." Stokes (1952, 1982) said many of the features were caused by salt diapirism. Gilliland (1963) attributed the SSVA to a combination of compression and salt and shale flowage. More recently Witkind (1982) and Witkind and Page (1984) have extended the diapirism concept, using a model of repeated episodes of diapirism to explain the complex structures, structural thinning, unconformities, sedimentary thinning and other features in the area. Standlee (1982) renewed the controversy by suggesting that diapirism was minimal and that most features were related to Sevier thrusting and later backthrusting. Willis (1984) claimed major features in the area were formed by thrusting and later modified by diapirism and salt dissolution. Lawton (1985) cited additional evidence supporting thrusting in the area, proposing a model similar to Standlee's but using the "triangle zone" concept of Jones (1982). Anderson and Barnhard (1987) suggest that at least part of the deformation is related to low-angle detachment surfaces separate from diapirism.

I believe that the Sanpete-Sevier Valley anticline was formed by thrusting during the Sevier orogeny and that diapirism was a significant but local secondary event. The thrust detachment surfaces and most of the thrust deformation occurred in the Arapien Shale. This deformation probably doubled or even tripled the original thickness of the Arapien and folded more competent Jurassic and Cretaceous rocks overlying the Arapien into a large anticline. The flanks of the anticline provided a natural linear "conduit" or zone of weakness for diapiric material to follow.

After formation of the SSVA by thrusting, it was eroded down to a topographic surface of low relief. This was followed by deposition of thick early Tertiary fluvial and lacustrine sediments which first lapped up against and later covered the SSVA. The loading of these sediments, possibly combined with regional structural forces, may have rendered the previously thickened mudstone and evaporite bodies unstable, causing diapirism during the late Eocene or Oligocene. The resulting diapirism created part of the hogbacks in the southeast part of the quadrangle, resulted in the erosion of the Eocene cover from the SSVA, and also masked some of the original effects of thrusting. Since the Miocene, the Arapien has undergone episodic diapiric movement affecting immediately adjacent rocks. This tilted, brecciated, and thinned or "sheared out" the overlying and adjacent volcanic units, forming the hogbacks in the southeast part of the quadrangle. Salt dissolution and subsequent collapse of overlying rocks may have further complicated features in the area. Thus, episodes of diapirism are documented after deposition of the formation of Aurora and prior to the deposition of the unnamed sandstone beds, after deposition of the welded tuff units and prior to at least part of the surficial deposits and possibly recently. There may have been intervening episodes as well.

REDMOND HILLS

Diapirism has also occurred outside of the SSVA. A linear chain of small hills which deflects the Sevier River begins near the center of Sevier Valley in the extreme northeast corner of the Aurora quadrangle and continues northward for several miles. Projected southward, this trend intersects an area of particularly complex folding in the SSVA. Most of the hills are capped by unconsolidated gravel similar to modern Sevier River deposits that generally dip away from the center of the hills. Salt is being, or has been, mined in several of the hills. I believe the hills to be active diapiric structures. The nonresistant caps and the location of the hills in the active flood plain suggest that they would not stand as topographic highs unless they were actively being elevated. The linear trend of the hills suggests control by a fault or linear zone of weakness.

SEVIER VALLEY

The structural nature of rocks underlying the Sevier Valley is largely unknown due to sparse subsurface control. However, I believe the Tertiary and Quaternary formations exposed along the east and west sides of the valley (and probably Cretaceous rocks as well) are present beneath Sevier Valley and form a shallow syncline. They may be cut by numerous faults, creating poor seismic reflectors. Circumstantial evidence to support the presence of the Tertiary and earlier rocks and the synclinal fold include:

-the westward dip of the hogbacks on the east side of Sevier Valley north of Salina flattens from east to west. The beds dip about 60° on the east side and about 45° on the west, suggesting that they may flatten out under the valley (Willis, 1986).

-early Tertiary rocks equivalent to those forming the hogbacks are exposed on the west side of the Sevier Valley. They have a shallow eastward dip and project beneath the valley at a low to moderate angle.

-blocks of Tertiary rocks are exposed in the Redmond Hills north of the quadrangle (Willis, in prep). I believe that the blocks were recently pushed up by diapirism (indicating that early Tertiary rocks are present elsewhere beneath the valley). The lower elevation of these Tertiary rocks, compared to exposures a few miles to the southeast, suggests that the valley has been dropped down by faulting.

-the Gunnison Plateau, which has a synclinal form, lies on trend with Sevier Valley to the north.

-a drill hole near Sigurd (Champlin No. 13-31 USA; NW, SW, Section 31, T 22 S, R 1 W), on the west side of the SSVA, penetrates a complete early Tertiary section before passing into the Twist Gulch Formation and the Arapien Shale.

-the hogbacks along the flank of the SSVA are too linear and unbroken to be considered strip thrusts (Billings, 1933) or detached blocks.

The Sevier Valley may have formed by Basin and Range extensional faulting. In areas south of the quadrangle, and to the north in Sanpete and Sevier Valleys, young high-angle

Figure 4. View west toward the Elsinore fault near the southwest border of the quadrangle. Offset on the fault is in excess of 4000 feet (1200 m) and rapidly decreases toward the north. the Green River Formation is exposed at the right; the Flagstaff Formation to the left and in the background; the low hills at the foreground are Miocene volcanic units dropped down by the Elsinore fault.

normal faults occur along the valley margins, creating straight mountain fronts characteristic of the Basin and Range. Similar faults have not been recognized in the Aurora area, however, the Redmond Hills follow a linear trend, suggesting fault control. The syncline may be of similar age or be older. The valley form may have been accentuated by complementary thinning of Arapien Shale related to the diapirism in the adjacent SSVA. In an alternative opinion, Witkind (1981) shows the surficial valley fill to be entirely underlain by diapiric Arapien Shale.

VALLEY MOUNTAINS-PAVANT RANGE

The hills in the quadrangle southwest of Denmark Wash are geographically part of the Pavant Range, however geologically they are part of the Valley Mountains. As used in this text all the area west of Sevier Valley that falls within the Aurora quadrangle is considered part of the Valley Mountains. Herein the "Pavant Range" refers to the mountain range 2 to 3 miles (4-6 km) south and west of the quadrangle which is topographically higher and is composed mostly of early Tertiary and older rock.

The Valley Mountains have a different structural style from the east part of the quadrangle and were probably not significantly affected by diapirism. The oldest rocks exposed are Eocene Flagstaff Formation, thus all structural events represented are younger than the Flagstaff and are probably younger than the Osiris Tuff, much younger than the early history of the SSVA. The dip of beds is to the east, southeast, or northeast at low to moderate angles. The beds are folded by a north-trending monocline and by a gentle east-west fold. They are cut by several northwest-trending faults, most of which are down to the southwest, and by a related major north-northeast-trending fault (Elsinore fault) which is down to the southeast. Most of the northwest faults curve into and join with the Elsinore fault.

Bedding Attitudes

Generally, beds near the west-central margin of the quadrangle strike northwest and dip 15° to 20° northeast. Near the Elsinore fault the bedding attitude makes a rapid change from northwest to northeast and attains dips commonly from 40° to 80°. The change in attitudes is due in part to fault drag but it also reflects monoclinal folding which is probably associated with faulting. The monocline extends north beyond the terminus of the Elsinore fault where its trend curves around to the northwest, matching the pattern of the northwest-trending faults in the area. The zone of curvature coincides with the east-west fold described later.

North and east of the Elsinore fault, beds generally strike north to northeast and dip 10° to 40° east to southeast except where deflected by localized structures. One such structure occurs in the southern part of Section 31, T 21 S, R 1 W as indicated on the map by the bedding attitudes. A gentle fold occurs in Section 24, T 21 S, R 1 W which locally reverses bedding attitudes.

Elsinore Fault

The northern end of the Elsinore fault, which enters the quadrangle near the southwest corner and trends northeast, is the most prominent fault in the quadrangle (figure 4). The southern part within the quadrangle is a young fault that has cut off the front of the Pavant Range, leaving prominent faceted spurs, a straight mountain front, and drainage systems that are not adjusted to topography. A few small outcrops of volcanic rock located just south of the quadrangle indicate that offset on this portion probably exceeds 4000 feet (1200 m). Some of the offset may be incorporated in a monoclinal fold which roughly parallels the mountain front.

Offset on the fault decreases rapidly toward the north. From near Dry Red Canyon northward bedrock units are exposed on the down-faulted side of the fault and increasingly less section is cut out toward the north. The fault completely dies out in Section 1, T 22 S, R 2 W, changing into a tight monocline which in turn dies out to the north. The area of rapid decrease in offset coincides with the area in which the northwest-trending faults apparently merge with the Elsinore fault. The northwest faults subtract from the offset on the Elsinore fault, which would otherwise decrease in offset even more dramatically towards the northeast.

Northwest Fault Set

The west part of the quadrangle is anomalous to the Valley Mountains to the north and the Pavant Range to the south in that it is cut by a series of northwest-trending faults not found in those areas. These faults all lie within a similar northwest-trending complex graben, the bounding faults of which lie just outside the quadrangle to the north and south. The graben and bounding faults project into the Round Valley graben which continues to the north-northwest. The northwest-trending faults exposed in the Aurora quadrangle may underlie the alluvial fill in Round Valley as well. Within the quadrangle, younger units, including the Sevier River Formation which has been dated at 5.2 my (table 2), are preserved within the graben and older units are down-dropped relative to the same units exposed in the bounding blocks outside of the graben. Some folding, possibly caused by fault drag, is also associated with the faults.

Most of the northwest-trending faults are down to the southwest and have offsets that exceed 500 feet (150 m) in places. Most of these faults appear not to cross the Elsinore fault, instead they curve to merge with it. Joint patterns, which coincide well with the trend of the faults, also suggest that the northwest faults curve to merge with the Elsinore fault. Thus the two fault systems may be partly contemporaneous and related. Anderson and Barnhard (1987) suggest that the northwest-trending faults may be of a different age and may in fact extend east of the Elsinore fault, but as of yet are unrecognized in that area. This is possible since the exposed units east of the Elsinore fault are the Crazy Hollow Formation and formation of Aurora, units typified by poor exposures and a lack of marker beds needed to recognize faults. However, I believe the bedding and joint attitudes shown on the map support the contemporaneous relationship I propose above. However, small-scale folding of the volcanic outcrop in Section 12, T 22 S, R 2 W, and in the formation of Aurora, Section 31, T 21 S, R 1 W lend support to the theory that the northwest-trending faults (or related folds) extend east of the Elsinore fault. I have been unable to develop reliable data on the rake of the Elsinore fault because of poor exposures.

Notable exceptions to the down-to-the-southwest faults are faults in Dry Red Canyon and a major fault northwest of Aurora (Aurora fault), which are down to the northeast. The fault in Dry Red Canyon is part of an area of complex faulting described below. The Aurora fault may be unrelated to the others in that it occurs north of the terminus of the northeast-trending Elsinore fault and extends well east of it.

Aurora Fault

A few of the northwest-trending faults are down to the northeast. One occurs northwest of Aurora and is here named the Aurora fault. The Aurora and Elsinore faults may not be related since the Elsinore fault dies out south of the Aurora fault. The Aurora fault has as much as 2000 feet (600 m) of offset and juxtaposes the Sevier River Formation against the formation of Aurora, Crazy Hollow and Green River Formations. It is covered by the older red alluvium in the northwest part of the map area but is exposed at the north end of the open clay pit northwest of Aurora where it trends N. 50° W., dips 80° east, and has a rake of 75° northwest.

Faulting Near Dry Red Canyon

Near Dry Red Canyon numerous faults splay off of the main northeast-trending Elsinore fault. Parts of the area are so shattered that faults are difficult to recognize. It is likely that even more faults are present than have been mapped. The complexity of this area may be due to wrenching associated with interacting northwest and northeast systems. One or more of the northwest faults may cross the Elsinore fault in this area. A small isolated outcrop of Osiris Tuff occurs south of the wash that is offset to the southwest and is best explained by a large-displacement fault that is down to the southwest; however the fault is not exposed.

Just to the north, on the southeast side of the Elsinore fault, an outcrop of volcanic rocks is probably cut by several down-to-the-mountain normal faults which are the cause of the unusually wide outcrop width of the volcanic units. A similar pattern of down-to-the-mountain faulting has been described to the south in Sevier Valley (Anderson and Barnhard, 1987).

East-Trending Fold

A broad gentle fold with an east-west axis which plunges east occurs east and northeast of the Elsinore fault with its axis approximately in the southern part of Section 31. It is best revealed by bedding attitudes in the Crazy Hollow Formation and formation of Aurora. The fold does not persist west of the Elsinore fault where bedding consistently dips to the northeast. The relationship of this fold to other structures is unknown.

Smaller Structural Features

Numerous small-displacement faults occur in the quadrangle which were infeasible to map separately. Several are well exposed in the small wash in the north-central part of Section 1, T 22 S, R 2 W. These trend northeast approximately parallel to the larger fault and occur in the axis of the monocline. Most are down to the northwest. Some can be seen to die out up or down section. I believe these are related to the monoclinal folding and are adjustment faults for small offsets and deformation caused by folding.

A few other small faults are exposed in the open clay pit near Aurora. It is assumed that many more occur elsewhere in the incompetent or poorly exposed units. These faults are probably related to larger structural features. Two small asymmetric folds occur near Aurora, one in the south-central part of Section 31, T 21 S, R 1 W, and the other in Sections 1 and 12, T 22 S, R 2 W. They may be evidence that the structural influence of the northwest-trending faults extends east of the Elsinore fault.

Eastward Tilting

Apart from the previously described deformation, rocks in the western partof the quadrangle dip eastward at 10° to 15°. Older alluvial valley-fill deposits beneath the major pediments (QTao) and possibly the older pediments (Qap_{2-4}) are affected. Where several levels of pediments occur in the quadrangle, the older pediment surfaces consistently have a steeper dip than progressively younger levels. This inclination appears to be related to tilting rather than original depositional angle. The oldest pediments may be graded to the Pavant Range on the west side of Round Valley or to rocks that have subsequently been faulted down within Round Valley. Accurate attitudes are difficult to obtain in the poorly bedded and partially consolidated deposits but it does suggest Quaternary tilting of this part of the range.

Detachment Blocks

Numerous detached slump blocks occur on and adjacent to the outcrops of Green River Formation in the west central part of the quadrangle (figure 2). The blocks are composed primarily of Green River Formation but may involve small amounts of Crazy Hollow Formation. They are generally less than 100 feet (30 m) thick but locally may exceed that amount and are generally less than 1000 feet (300 m) long. Most are broken and brecciated but still remain internally coherent. They are slump blocks that have detached along bedding planes in areas where the topographic slope coincides with the bedding angle. They have moved down slope a few feet to a few hundreds of feet to where a decrease in slope allowed them to stabilize. Most of the larger blocks have been mapped separately (QTms). Topography is generally the same as at the time they moved, but some of the blocks have been cut by small washes up to 100 feet (30 m) deep indicating that they are probably older Quaternary features. No evidence of Holocene movement was found.

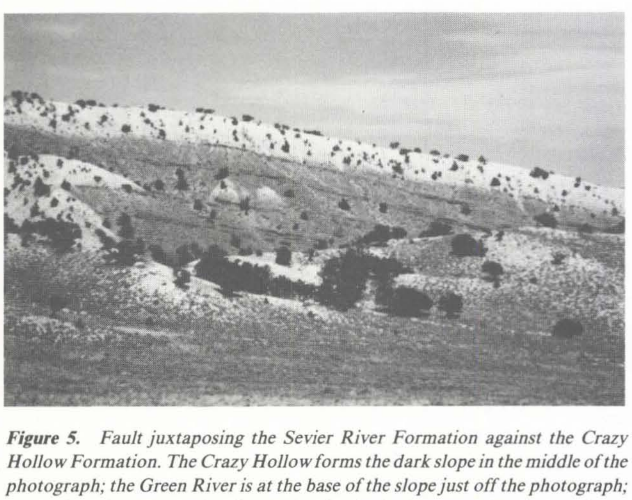

Figure 5. *Fault juxtaposing the Sevier River Formation against the Crazy Hollow Formation. The Crazy Hollow forms the dark slope in the middle of the photograph; the Green River is at the base of the slope just off the photograph; the Sevier River Formation forms the hills in the foreground and unconformably overlies the Crazy Hollow Formation along the ridge crest. Offset on the fault is estimated to be in excess of 200 feet (60 m). More than 2000 feet (600 m) of beds may have been eroded from the unconformable surface prior to deposition of the Sevier River Formation. There is a slight angularity along the unconformable contact with the hiatus increasing to the northwest.*

Causes and Timing of Deformation

Apparently all major structural features present in the western part of the quadrangle are younger than the Osiris Tuff and may be younger than the Sevier River Formation. Except for a minor disconformity between the Green River and Crazy Hollow Formations, all formations from the Flagstaff through the Aurora are parallel and conformable. Thus, it appears that from the late Paleocene through the late Eocene the area had low relief and was not significantly affected by structural events. Small unconformities, representing hiatuses of a few million years, exist between the formation of Aurora and the overlying volcaniclastic and volcanic units. The volcanic and volcaniclastic rocks deposited afterwards, which are as young as 23 my, are still approximately parallel with the older Tertiary rocks and do not reflect any large intervening structural deformation. Thus the major structural events reflected in rocks exposed in the Valley Mountains are probably younger than 23 million years.

A significant unconformity occurs between the Osiris Tuff and the next younger unit preserved in the quadrangle, the Sevier River Formation, at least the upper part of which has been dated at 5 million years (table 2). The Sevier River Formation, preserved only in the northern part of the quadrangle, sits with slight angular unconformity on the Green River and Crazy Hollow Formations and the formation of Aurora (figure 5). All major faults exposed in that area cut the Sevier River Formation. Thus, it is possible that all rocks in the area were subhorizontal and undeformed as recently as the Pliocene. Unfortunately, most of the down-to-the-southwest faults in the central part of the quadrangle do not come in contact with the Sevier River Formation, but if the northern and central faults are related then all are younger than five million years.

The next unit younger than the Sevier River Formation, the older alluvial valley-fill deposits (QTao), overlies older rocks in an angular unconformity. Due to poor exposures, it is difficult to determine if the alluvial deposits are cut by faults but no significant offset was recognized, suggesting that major faulting occurred previously. However, locally the alluvial deposits have been tilted as much as 20° to 25°. There may have been eastward tilting during the late Tertiary and Quaternary. To the northwest, faults bounding Round Valley on both sides have Holocene fault scarps. No Holocene scarps were recognized in the quadrangle but structures may still be active.

I believe most of the faults and folds in the western part of the quadrangle are genetically and temporally related. They probably formed in response to a Basin and Range style of block faulting associated with the formation of Sevier Valley and Round Valley to the northwest. Round Valley is bounded on both sides by high-angle normal faults which trend generally northward. Near the southern end, in the Aurora quadrangle, the faults curve to merge with the Elsinore fault and Sevier Valley. The complex structure is probably due to the interacting of different stress regimes associated with the intersection of Round Valley and Sevier Valley in a manner that is not well understood.

ECONOMIC DEPOSITS

GYPSUM

Several kinds of geologic resources occur in the Aurora quadrangle and gypsum, clay and gravel have been produced. Others show potential for future production. Gypsum is the most important and is presently being mined. All minable gypsum deposits are located in the southeast part of the quadrangle in the vicinity of Lost Creek and in adjacent quadrangles. Two companies, United States Gypsum Company and Georgia-Pacific Corporation, presently control the reserves and both are actively mining. Important deposits (mapped as Jacg) occur in unit C of the Arapien Shale. The deposits are planar to lenticular with the thickest parts generally being concentrated in the apex of folds. The deposits, which are probably part of a single bed repeated at the surface by faulting and folding, are usually 20 to 100 feet (6-30 m) thick but are locally missing. Bounding rock is shaly limestone, gypsiferous shale, siltstone, or sandstone. The gypsum is more resistant to erosion and forms linear ridges.

Typical composition of the gypsum deposit is gypsum-93.5%, SiO_2-3.64%, other inert rock material-1.62%, and $CaCO_3$-1.60%. Minor constituents are KCl-13.9 ppm (parts per million), NaCl-10.9 ppm, Na_2SO_4-8.7 ppm, $MgSO_4$-65.1 ppm, and $MgCl_2$-0.2 ppm (R.J. Beckman, U.S. Gypsum Co., written communication, 1984). The gypsum is recovered entirely by strip mining and is primarily used as sheetrock wall board. Less pure, uncalcined gypsum is used as a soil conditioner. An estimate of reserves is unavailable but as of 1986, about half the recoverable gypsum in the quadrangle had been mined. The approximate extent of mined-out areas is shown on the map.

SALT

Salt was the first mineral resource produced in Sevier Valley. Because it is soluble, salt is rarely exposed at the surface but typically forms the core of steep, dark red, vegetation-free hills of unit E of the Arapien Shale. Thus hills that appear to be composed of dark reddish-brown clay may be salt cored. Major outcrops in the quadrangle are near the east border. Salt is exposed immediately north of the quadrangle in the Redmond Hills and probably underlies the quadrangle in that area as well.

Salt has been produced in small amounts from the aforementioned localities. Total production from the quadrangle is unknown but is presumed small, most for local usage. None is presently being commercially produced but some salt is being mined in the Redmond quadrangle to the northeast. Salt deposits usually occur as large, structureless masses, often with secondary crystals in excess of 6 inches (15 cm) in length. Residual bedding is sometimes present. Unevenly dispersed dark red clay gives the salt a mottled appearance. Typical analysis of salt from the Redmond Hills area is halite 95.6%, silica 2.16%, sulfate 1.1%, calcium 0.51%, iron and aluminum oxide 0.04%, magnesium 0.04%, and iodine 0.03% (Pratt and others, 1966). Smaller deposits typically have higher quantities of clay.

It is difficult to estimate the size of salt bodies or reserves due to their highly contorted, discontinuous nature and unknown depth. The Redmond Hills deposit is estimated to be about 1000 feet (300 m) across and at least 1000 feet (300 m) deep (Pratt and others, 1966). The Chevron USA #1 Salina Unit well penetrated in excess of 1000 feet (300 m) of salt in Section 33, T 22 S, R 1 W, less than one-half mile (0.8 km) south of the quadrangle, however, wells drilled in Sections 31 and 32 nearby encountered much less salt (Standlee, 1982, p. 366). Other wells throughout Sevier Valley also penetrated highly variable thicknesses.

CLAY

The upper part of the formation of Aurora contains beds of clay up to 50 feet (15 m) thick exposed west of Aurora where they have been open-pit mined. Most of the easily accessible deposits are exhausted and none is presently being mined. The clay is derived from volcanic dacite ash. Crawford and Cowles (1932) determined mineralogic content of the deposits as feldspar (Al_7An_3) 2.25%, gypsum 0.69%, titanite 0.59%, rutile 0.16%, biotite 12.03%, quartz 1.5%, zeolites 16.15%, fuller's earth ($Al_2O_3{\cdot}SiO_2{\cdot}7H_2O$) 67.58%, and hygroscopic moisture 0.11%. A chemical analysis reported a composition of 64.5% silica, 2.5% ferric oxide, 12.7% aluminum oxide, 5.4% calcium oxide, 2.3% magnesium oxide, 8.7% loss on ignition (volatiles), 1.5% sodium oxide, 1.6% potassium oxide, 0.03% phosphorus pentoxide, and 0.19% sulfur (Neal J. Mortensen, Western Clay Co., written communication). I am not aware of any X-ray analyses of the clay. The feldspar and biotite are remarkably fresh and unaltered, suggesting that the conversion to fullers earth was probably not a post-depositional weathering effect. Crawford and Cowles (1932) describe the primary constituent as "fuller's earth," a product of variable composition which contains various clay minerals. Fuller's earth is used to filter, clean and de-color oil products. Fire testing reveals little potential for products as the clay cracked and showed shrinkage up to 40% (Van Sant, 1964, p. 99).

GEOTHERMAL POTENTIAL

The Aurora quadrangle lies in an area categorized as "favorable for discovery and development of local sources of low-temperature (less than 90°C (195°F)) water" (Utah Geological and Mineral Survey, 1983). However, no discoveries have been made and no exploration is known to be in progress.

GRAVEL AND ROAD METAL

The Aurora quadrangle contains significant deposits of gravel suitable for highway construction, concrete production, riprap, and other uses. Deposits are of three types. Thick, older pediment deposits along the east side of the Valley Mountains are composed of unconsolidated or poorly consolidated gravel and conglomerate. The deposits are typically moderately well sorted and consist of quartzite, dense sandstone, limestone, and dense siltstone pebbles which range from

½ to 2 inches (1-5 cm) in diameter. Locally, however, they are poorly sorted, ranging from boulder to clay. Deposits typically contain thin interfingering beds of sandstone or mudstone and minor iron oxide makes a pale red or orange color. Unwashed or unscreened, the deposits are generally not suitable for concrete or asphalt production but have been used extensively for road fill and similar uses. The Utah Department of Transportation tested eight pits and potential fill sites in the quadrangle and found six suitable for cement aggregate or use as surface gravel. One site was suitable for borrow fill while insufficient data was available for the other (Utah Department of Transportation, 1966).

Volcanic colluvium from slopes adjacent to volcanic rock in the southeast part of the quadrangle has been quarried for road fill. Major quarries were developed for the road base of U. S. Interstate 70 which crosses the quadrangle. Stream-deposited gravel and sand occur along Lost Creek and in many parts of Sevier Valley, particularly the Redmond Hills. The deposits are moderate- to well-sorted cobbles, pebbles, and sand with little or no silt or clay-sized material. Some may be suitable for concrete production without washing. Deposits near Lost Creek were also used as road fill for Interstate 70. Deposits within the quadrangle in the Redmond Hills are small, however, extensive deposits with major quarries are in the adjacent Redmond quadrangle.

LIMESTONE AND BUILDING STONE

Dense algal and oolitic limestone of the upper Green River Formation has been quarried for building stone in various parts of the Sanpete and Sevier Valleys because of its intrinsically pleasing golden yellow color and well-indurated nature. The Green River Formation is exposed in much of the Aurora quadrangle but no quarrying is known to have occurred although it has been used locally for decorative landscaping. Parts of the Green River and Crazy Hollow Formations are flaggy to thin-bedded and could be used as flagstone or ashlar. Some beds in the Flagstaff Formation, which vary from a few inches to a few feet thick, are blocky and well indurated and could be used for building stone.

HYDROCARBONS

Sevier County has been the scene of moderate hydrocarbon exploration in the past and shows good potential for the future (Stark and Gordon, 1982). One well, the Forest Oil Company Sigurd Unit #1 in the NW ¼, NW ¼, SW ¼, Section 14, T 22 S, R 1 W, was drilled in the quadrangle but no shows were reported. Several wells have been drilled near the quadrangle. No production has been achieved but minor shows of oil and gas were reported. Britt and Howard (1982) summarize potential source beds and reservoir rocks in the area. Source beds that underlie or are close to the quadrangle, followed by a regional average of total organic content, are the Mississippian Great Blue and Deseret Limestones (0.61%), Mississippian Chainman and Manning Canyon Shales (0.98%), Permian Park City Formation (1.26%), Jurassic Twin Creek Limestone and Arapien Shale (0.27%), and the Cretaceous Mancos Shale and Mesa Verde Formation (1.52%). Possible reservoir rocks occur in several formations.

WATER RESOURCES

As in most desert areas, water is the most valuable resource in the Sevier Valley area. Agriculture has been developed in the valley since about 1850 and surface-water rights are fully appropriated. The Sevier River crosses the eastern part of the quadrangle and has an average annual flow of 73,100 acre-feet. This is much less than upstream near Marysvale (165,800 acre-feet) because of irrigation use. The water table is within 10 feet (3 m) of the surface in most of the valley and artesian conditions are common (Young and Carpenter, 1965).

Lost Creek is the only other perennial stream in the quadrangle. Average annual flow is about 4400 acre-feet (Young and Carpenter, 1965). Three springs occur in the quadrangle, all of which occur along a major northeast-trending fault. All have been developed, one is a major water supply for the town of Aurora. The high country is dry most of the year.

GEOLOGIC HAZARDS

EARTHQUAKE HAZARDS

The Aurora quadrangle is in the one of the more seismically active parts ofthe state. Recent work by Anderson and Barnhardt (1987) has correlated part of this seismicity with several complex structural elements in addition to discrete faults. The Elsinore fault, which extends into the southwest corner of the quadrangle and is the principle Quaternary fault, may have been the source of several seismic events in historic time. No Quaternary scarps have been recognized in the quadrangle but they are numerous to the south in Sevier Valley and to the west and northwest in Round Valley (Anderson and Miller, 1979). Several small, potentially active faults cross the quadrangle and the Wasatch Fault occurs within 50 miles (80 km) to the north. Several large earthquakes (over 4.0 on the Richter scale) with epicenters within 50 miles (80 km) of the quadrangle have occurred since 1850 when records were first kept (Arabasz and others, 1979; Richins and others, 1981).Several were 20 to 30 miles (32-48 km) to the south along the Elsinore fault. Shock waves from a quake in the area have the potential to do significant damage in the Aurora quadrangle.

The Aurora quadrangle is located in high risk zone U-3 (on a scale of 1 to 4 with 4 being the highest; 3 is similar to 4 except without added stringency of building inspections) (Seismic Safety Advisory Council of Utah, 1979) and in Uniform Building Code zone 3. There is some risk of liquefaction in the Sevier River flood plain. Aurora and the surrounding agricultural community have numerous older structures of unreinforced masonry that present the greatest hazard for injury or property damage in the event of a significant earthquake.

FLOODING, MUDFLOWS, DEBRIS FLOWS

The Sevier River meanders across a broad flood plain through most of the quadrangle but is confined to a straight, diked channel in the northern part. Meandering of the silt-laden river during spring runoff has caused damage to the channel but the flood plain is mostly undeveloped marshland and pasture, and monetary damage has been limited.

Heavy runoff from spring melting or heavy rain has the potential to generate mud or debris flows in many of the canyons. There is evidence of this having occurred recently in Dry Red Canyon. Many areas are sparsely vegetated with thick, unconsolidated cover and are especially vulnerable. The major threat is to primary and secondary roads.

LANDSLIDES AND SLUMP BLOCKS

No large landslides were recognized in the quadrangle but the Green River Formation is susceptible to landslides in adjacent quadrangles and might develop slides in the Aurora quadrangle. A small landslide was mapped in Section 14, T 22 S, R 2 W. Risk to property is low as potential slide areas are free of structures or cultural improvements. Several large slump blocks were mapped in the hills west of Aurora. They probably last moved during the Pleistocene and present little threat.

EXPANDING CLAY, SALT

Many of the formations in the Sevier Valley area, particularly the Arapien Shale and the formation of Aurora, contain expanding clays which present potential problems for buildings, roads, and other structures. Recent freeway construction required an extra thick base to compensate for these potential problems. Older buildings have been damaged by expanding clays. Salt deposits with thin overburden occur in several localities in the quadrangle. Settling due to salt dissolution has occurred, both historically and prehistorically, but the potential for catastrophic collapse is probably low. The primary area of salt dissolution is near the mouth of Lost Creek. Potential contamination of culinary and agricultural water supplies by dissolved salt is possible.

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