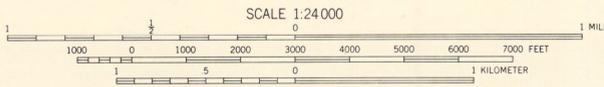


Base from U.S. Geological Survey Redmond Canyon 7.5' Quadrangle, 1966



CONTOUR INTERVAL 40 FEET  
DATUM IS MEAN SEA LEVEL

### GEOLOGIC MAP OF THE REDMOND CANYON QUADRANGLE, SANPETE AND SEVIER COUNTIES, UTAH

by  
Grant C. Willis  
1991



Cartography by J. Parker

DESCRIPTION OF MAP UNITS

- Qa<sub>1</sub>** Younger alluvial deposits. Poorly to moderately sorted, clay- to boulder-sized material deposited in active washes, ephemeral stream channels and small mountain valleys. Commonly gradational with other deposits. Generally less than 100 feet (30 m) thick, except in valley areas where thickness is unknown.
- Qa<sub>2</sub>** Older alluvial deposits. Poorly to moderately sorted clay- to boulder-sized material deposited in washes, ephemeral stream channels, and small mountain valleys. Isolated and being eroded by downcutting of nearby drainage systems. Commonly gradational with other deposits. Generally less than 100 feet (30 m) thick.
- Qaf** Younger alluvial-fan deposits. Poorly to moderately sorted, locally derived, boulders through clay, with some loess, deposited in fan-shaped lobes at slope changes near the mouths of streams and washes. Generally fine-grained away from the mountain front. Thickness unknown.
- Qaf<sub>1</sub>** Older alluvial-fan deposits. Poorly to moderately sorted, boulders through clay, with some loess, deposited in fan-shaped lobes at slope changes near the mouths of streams and washes. Similar to the younger alluvial-fan deposits (Qaf), but have been uplifted or tilted by diapirism in the Redmond Hills. Thickness unknown.
- Qms** Mass-movement/landslide deposits. Poorly sorted, boulder- to clay-sized material; hummocky-surfaced; deposited in lobate mounds by landsliding and slumping. Involve colluvial material and weathered rock of the Colton Formation. Moved most recently from 1983 to 1985. Generally less than 50 feet (15 m) thick.
- Qapv** Pediment deposits containing volcanic clasts. Deposits on pediment-cut surfaces that contain volcanic clasts derived from "gravel deposits of Redmond Hills" (QTag). Pediment surfaces are continuous with adjacent pediments (Qap) and the deposits are similar in composition except for the volcanic clasts. Generally less than 30 feet (9 m) thick.
- Qap<sub>2</sub>, Qap<sub>4</sub>** Pediment deposits. Poorly sorted, boulder- to clay-sized material deposited as a thin veneer on pediment surfaces. Generally less than 40 feet (12 m) thick. Locally gradational with, or includes, other deposits to facilitate mapping. The numbering scheme is a continuation of numbering applied in the Aurora quadrangle to the south (Willis, 1988). "Qap<sub>2</sub>" deposits are the highest and oldest. "Qap<sub>4</sub>" deposits are of the intermediate level. "Qap<sub>1</sub>" and "Qap<sub>3</sub>" deposits are not differentiated in the Redmond Canyon quadrangle.
- QTag** Gravel deposits of Redmond Hills. Moderately well-sorted cobbles, pebbles, and sand with minor amounts of mud and clay that cap and flank the Redmond Hills. In many places, beds are tilted away from the center of the hills at 20 to 40 degrees. Probably 0 to 500 feet (0-150 m) or more thick. Late Tertiary or Quaternary in age.
- QTao** Older alluvial valley-fill deposits. Poorly to moderately sorted, conglomerate with interbedded mudstone and sandstone. Underlie, and commonly covered by, pediment deposits. Derived from Tertiary rocks to the west. Difficult to distinguish from the Sevier River Formation in some places. Ranges from 0 to more than 2,000 feet (0-600 m) in thickness. Late Tertiary or early Quaternary in age.
- Tse** Sevier River Formation. Pale-gray, yellow or greenish-gray, poorly to moderately sorted and bedded mudstone, sandstone, conglomerate, and carbonaceous mudstone. Generally, lower part is coarsest and most poorly sorted. Contains a few reworked ash beds in upper part; in the Aurora quadrangle, to the south, one such bed yielded a fission-track age of 5.2 ± 0.4 million years (Willis, 1988). Some outcrops near southern border of quadrangle were previously mapped by Gilliland (1951) and Witkind and others (1987) as Eocene or Oligocene Bald Knoll Formation (now formation of Aurora — see text discussion) but map relationships and fission track dating confirm that the beds are Sevier River Formation. Probably more than 600 feet (180 m) thick. (Note: on the cross section this unit may include other Tertiary rocks present beneath Sevier Valley).
- To** Osiris Tuff. Densely welded porphyritic, latic tuff. Light-gray, purplish-gray, or brownish-gray; 70-80% matrix, 10-20% plagioclase, 1-3% biotite, 2-5% sanidine, 0.5-2% pyroxene and minor Fe-Ti oxides. The biotite and plagioclase are particularly conspicuous in hand samples. Has a distinct basal vitrophyre. Derived from Monroe Peak caldera and is about 23 million years old (Fleck and others, 1975; Steven and others, 1984). Occurs in one small outcrop along eastern border where it is about 50 feet (15 m) thick.
- Trc** Clay and sandstone deposits in Redmond Hills. Gray, white, yellow, red, purple, and green bentonitic clay deposits with interbedded fluvial sandstone, minor conglomeratic sandstone, and travertine. A potassium-argon isotopic determination yielded an age of 25.8 ± 1.0 million years for the volcanic source of this unit, but the age of deposition may be younger. Thickness is unknown but may exceed 1,000 feet (300 m).
- Trt** Travertine deposits in Redmond Hills. Yellow to reddish-yellow, thin- to medium-bedded travertine deposits interbedded with the clay deposits described above. Ranges up to about 200 feet (60 m) thick. Numerous thin travertine beds are not differentiated on the map.
- Tch** Crazy Hollow Formation. Brownish-orange to reddish-brown mudstone and siltstone, locally bentonitic, and pale gray or yellow, lenticular, medium- to coarse-grained sandstone. The sandstone has a "salt-and-pepper" appearance due to dark-colored chert and lithic grains. Unit generally has a basal conglomerate or conglomeratic sandstone; however, unit interfingers with the upper Green River Formation in several areas (Willis, 1986). About 150 feet (45 m) thick in the southern part of the quadrangle. Absent in the central and northern part. Late Eocene in age.
- Tg** Green River Formation. Greenish-gray to pale-green, thin-bedded to laminated shale, light-brown calcareous sandstone, and mudstone in the lower part; and pale yellow to brownish-yellow, chalky limestone, oolitic limestone, dense silicified limestone and chert in the upper part. About 950-1,100 feet (285-330 m) thick. Eocene in age.
- Tco** Colton Formation. Reddish-brown, gray, purple, white and green, bentonitic mudstone, siltstone, and sandstone with local calcareous beds. Grades upward into the more calcareous Green River Formation. Easily eroded and generally forms a strike valley. Overall, thins from about 400 feet (120 m) near the northern border to 350 feet (105 m) near the southern border. About 250 feet (75 m) thick near Redmond Canyon.
- Tfu** Upper member of the Flagstaff Formation. Pale-gray, and to a lesser extent, pale-reddish-gray or reddish-yellow, thick-bedded to massive, micritic limestone, and lesser sandy limestone, mudstone, and carbonaceous shale. Bedding is indistinct and partially destroyed by rooting and bioturbation. 250 to 550 feet (75-165 m) thick. Eocene in age.

- Tfm** Middle member of the Flagstaff Formation. Generally dark-reddish-brown, poorly bedded limestone, sandstone, calcareous mudstone, and minor conglomerate. Member thickens southward at the expense of the underlying and overlying units from 160 to about 400 feet (50-120 m) thick. Clastic content increases southward; member is primarily sandstone, mudstone, and conglomerate near the southern border. Some small outcrops are difficult to distinguish from underlying and overlying members.
- Tfl** Lower member of the Flagstaff Formation. Interbedded pale-gray, yellowish-gray, and reddish-gray micritic limestone, argillaceous limestone, mudstone, and sandstone. Generally has a thick micritic limestone bed near the top. Lower part is sandy and gradational with the underlying North Horn Formation. 700 to 1,100 feet (210-330 m) thick. Eocene in age.
- TKnh** North Horn Formation. Interbedded brown and brownish-yellow sandstone and yellow, gray, and brown siltstone, sandstone, and mudstone. Sandstone beds form resistant, lenticular ledges and the mudstone and siltstone form slopes. Gradational with the overlying Flagstaff Formation. About 1,450 feet (435 m) are exposed; however, thickness is probably well over 2,000 feet (600 m) in the quadrangle. Probably Eocene in age, but lower part may be as old as Cretaceous.
- Ku** Cretaceous rocks, undifferentiated. Shown only on the cross section. Probably includes the Cedar Mountain Formation, Indianola Group, and Price River Formation. Thickness is unknown.
- Jae** Unit E of the Arapien Shale (of Hardy, 1952). Dark-reddish-brown, featureless siltstone with local white patches of "salt-bloom" on the surface. Mostly massive salt in the subsurface. Only a few feet are exposed in a very small area near the east border of the quadrangle, but in subsurface, may be in diapiric pods that exceed 1,000 feet (300 m) in thickness. Bedded thickness is much less.

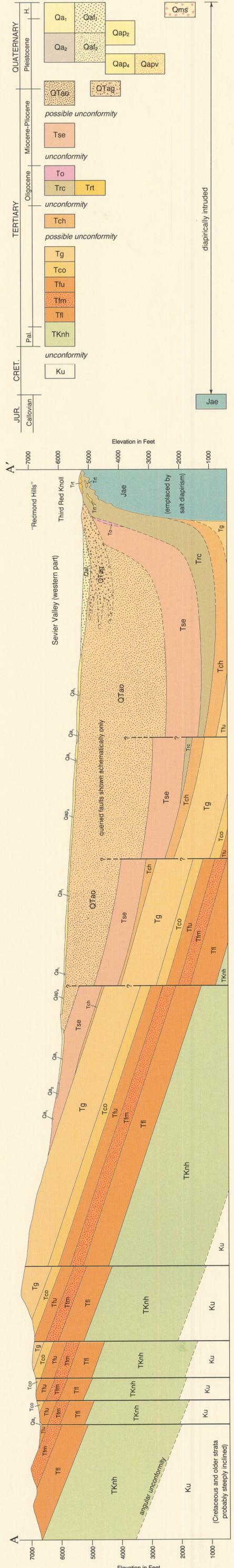
MAP SYMBOLS

- Contact — dashed where approximately located
- - - - - Fault — dashed where location inferred, dotted where concealed; queried where probable; bar and ball on downthrown side
- ↗<sup>25</sup> ↘<sup>80</sup> Strike and dip of bedding — inclined, vertical, overturned
- ↗<sup>80</sup> ↘ Strike and dip of joints — inclined, vertical
- x Prospect pit — tr = travertine
- Open-pit clay mine — hachures show approximate disturbed area
- x Gravel or road-fill pit
- ★ Radiometric age determination/sample location

LITHOLOGIC COLUMN

PERIOD	EPOCH	UNIT	SYMBOL	THICKNESS (feet, meters)	LITHOLOGY
QUAT.	Pleist.	Surficial deposits	Q	0-100 (0-30)	
		Gravel deposits of Redmond Hills	QTag	0-500+ (0-150)	
Pliocene		Older alluvial valley-fill deposits	QTao	0-2000+ (0-600+)	
		Sevier River Formation	Tse	0-600+ (0-180+)	
Miocene		Osiris Tuff	To	0-50 (0-15)	
		Bentonitic clay and sandstone (Trc) — and — travertine (Trt) deposits of the Redmond Hills	Trc Trt	0-1000+ (0-300+) 0-200 (0-60)	
Oligocene		Crazy Hollow Formation	Tch	0-150 (0-45)	
		Green River Formation	Tg	950-1100 (285-330)	
		Colton Formation	Tco	250-400 (75-120)	
Eocene	Flagstaff Formation	Upper Member	Tfu	250-550 (75-165)	
		Middle Member	Tfm	160-400 (50-120)	
		Lower Member	Tfl	700-1100 (210-330)	
Pal.		North Horn Formation	TKnh	1450+ (435+)	
		Undifferentiated Cretaceous rocks	Ku	3000+ (900+)	in subsurface only — not exposed
JUR.	Middle	Arapien Shale — Unit E	Jae	1000+ (300+)	

CORRELATION OF MAP UNITS



# **GEOLOGIC MAP OF THE REDMOND CANYON QUADRANGLE, SANPETE AND SEVIER COUNTIES, UTAH**

*by*  
*Grant C. Willis*  
*Utah Geological Survey*



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# GEOLOGIC MAP OF THE REDMOND CANYON QUADRANGLE, SANPETE AND SEVIER COUNTIES, UTAH

by  
*Grant C. Willis*  
*Utah Geological Survey*

## ABSTRACT

The Redmond Canyon quadrangle is in the transition zone between the Colorado Plateau and the Basin and Range physiographic provinces, and includes parts of the Valley Mountains and the adjacent Sevier Valley. Small knolls, known locally as the "Redmond Hills" occur along the eastern border of the quadrangle. Consolidated strata exposed in the Valley Mountains are over 4,000 feet (1,200 m) thick, and include the North Horn Formation, which may be Paleocene or Eocene in age; the Flagstaff, Colton, Green River, and Crazy Hollow Formations, which are probably Eocene in age; and the Sevier River Formation of Miocene to Pliocene age. Small outcrops of Jurassic Arapien Shale and Miocene Osiris Tuff, and larger exposures of bentonitic clay and travertine of probable Oligocene age crop out in the Redmond Hills. The bentonitic clay may be correlative with the formation of Black Cap Mountain, exposed in the Salina area. Extensive late Tertiary and Quaternary unconsolidated and surficial sediments also occur in the quadrangle. The unconsolidated and surficial deposits consist of thick fluvial and alluvial-fan deposits and thinner alluvial-channel, pediment-mantle, colluvial, and mass-movement deposits. Earlier workers mapped large exposures of Jurassic Arapien Shale in the Redmond Hills; however current mapping and potassium-argon (K-Ar) dating has shown that most of these outcrops are the Tertiary bentonitic clay deposits.

Structurally, rocks in the quadrangle occur in three groups: (1) faulted and rotated strata of the Valley Mountains, which generally dip eastward at 15 to 35 degrees, (2) slightly rotated and deeply dissected pediments that flank the Valley Mountains and that conceal faulted and slightly folded bedrock, and (3) complexly deformed strata of the Redmond Hills. At least some of the faulting and folding in the Valley Mountains and the Redmond Hills postdate the Sevier River Formation and are late Tertiary and possibly Quaternary in age. Faults in the Valley Mountains are high-angle normal faults. Most trend northward or eastward, intersecting roughly at right angles, and have displacements of as much as 2,000 feet (600 m). One fault in the southwest part of the quadrangle has displacement exceeding 2,500 feet (760 m).

Unconsolidated deposits cover most of the eastern part of the quadrangle; however, the structure of the concealed bedrock is

probably similar to that exposed in the Valley Mountains. The Redmond Hills trend northward along a possible buried fault and consist of moderately to steeply dipping, complexly deformed, late Tertiary and Quaternary deposits that flank a diapiric core of salt-bearing Arapien Shale that pushed up the Redmond Hills.

Primary geology-related, economic resources in the quadrangle include bentonitic clay, salt, and gravel. Geologic hazards of concern include expanding and contracting soils, landslides, debris flows, flash floods, rock falls, and active faults.

## INTRODUCTION

The Redmond Canyon quadrangle is about 6 miles (10 km) southwest of Gunnison and 6 miles (10 km) northwest of Salina in central Utah (figure 1). U.S. Highway 89 runs north-south through Sevier Valley about 3 miles (5 km) east of the quadrangle and U.S. Highway 50 passes through Round Valley about 2 miles (3 km) to the west. Several gravel and dirt roads provide access to the quadrangle from Sevier and Round Valleys.

The Valley Mountains, which form the highest part of the quadrangle, range from about 6,000 to 8,436 feet (1,830-2,571 m) in elevation and are moderately steep and rugged. They form a northward-trending range about 30 miles (50 km) long and 4 to 8 miles (6-12 km) wide. All rocks exposed in the range are Tertiary, except for a small exposure of Cretaceous rocks about 10 miles (16 km) north of the Redmond Canyon quadrangle. With only minor exceptions, all strata in the range dip roughly east 15 to 40 degrees, and are cut by fault sets trending (1) generally north-south, and (2) southeast-northwest to east-west.

The lowest part of the quadrangle overlies cultivated alluvial fans in the northeast corner that have an elevation of 5,080 feet (1,548 m). A discontinuous chain of small hills about 8 miles (13 km) long, known locally as the "Redmond Hills," rises up to 150 feet (45 m) above the valley floor in the eastern part of the quadrangle.

Annual precipitation ranges from 8 to 10 inches (20-25 cm) in Sevier Valley to 16 to 20 inches (40-50 cm) in the higher elevations (Young and Carpenter, 1965; Covington and Williams, 1972). Natural vegetation is primarily grass, rabbit brush, and sagebrush

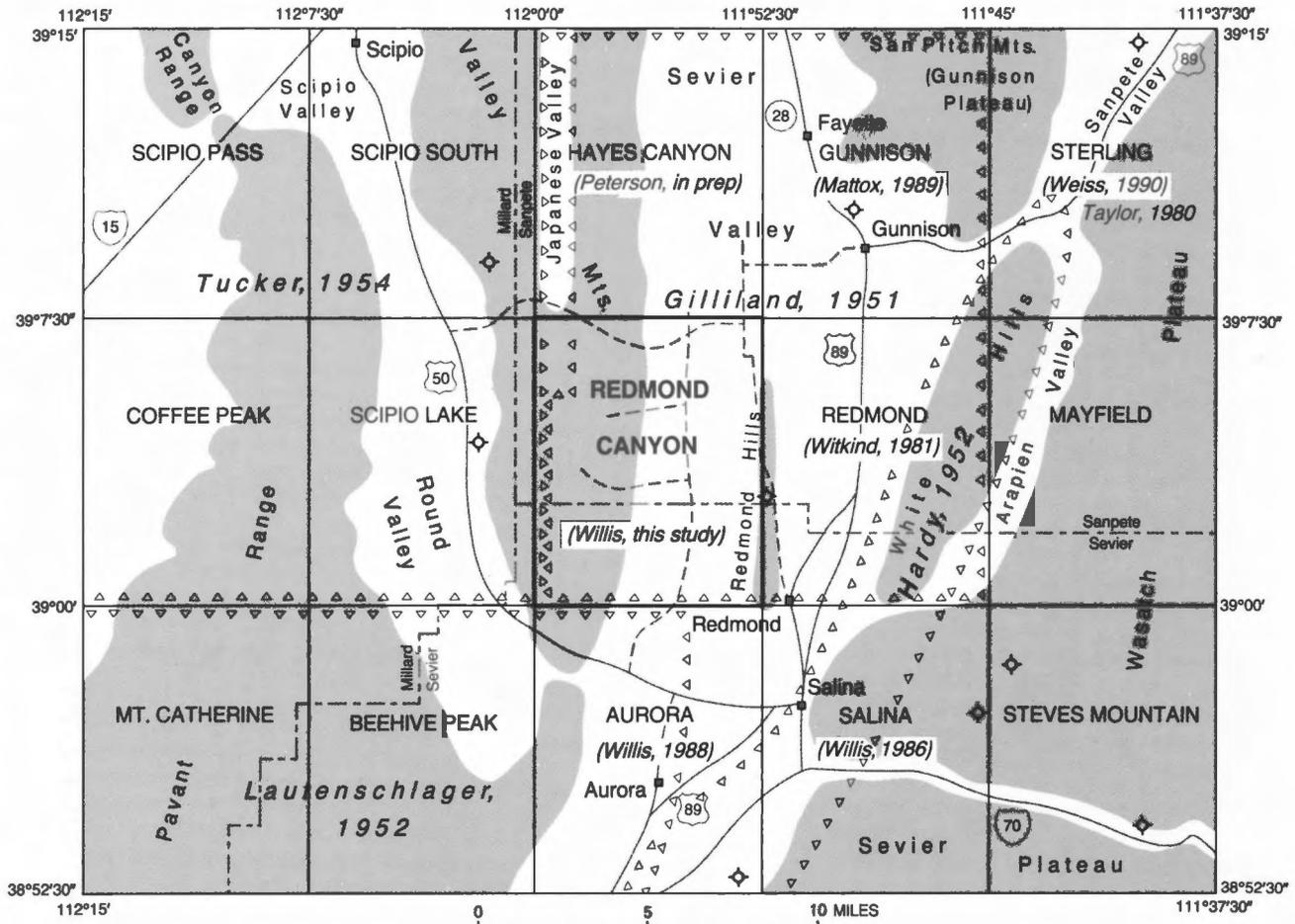


Figure 1. Index map showing the relationship of the Redmond Canyon quadrangle to selected highways, unimproved roads, drill holes, and topographic features of the area. Selected geologic maps that have been completed are indicated by author and date under quadrangle name; irregular study areas are outlined with triangle-line patterns.

in the lower elevations and juniper and pinyon pine in the intermediate and higher elevations. Douglas fir grows on the highest north-facing slopes.

Although the area is mentioned briefly in earlier papers, the first detailed report on central Sevier Valley geology was by Spieker (1946), who described most of the exposed formations. Later, he mentioned the stratigraphy of the Valley Mountains in his guidebook to the transition zone between the Basin and Range and Colorado Plateau provinces (Spieker, 1949). Gilliland (1949; 1951) mapped the geology and measured several stratigraphic sections in the Gunnison 15' quadrangle which includes the Redmond Canyon quadrangle (figure 1). Lautenschlager (1952) mapped the Richfield 15' quadrangle to the south, and Tucker (1954) mapped the Scipio 15' quadrangle to the west and an adjacent area that included a small part of the Redmond Canyon quadrangle.

More recently Witkind (1981) mapped the Redmond 7 1/2' quadrangle to the east and Mattox (1989), mapped the Gunnison quadrangle to the northeast (figure 1). Willis (1986, 1988) mapped and described the Salina quadrangle to the southeast and the Aurora quadrangle to the south. Peterson (in preparation) mapped the Hayes Canyon quadrangle to the north. Witkind and others (1987) compiled the Manti 30' x 60' quadrangle that includes the Redmond Canyon quadrangle and Steven and others (1990) mapped the Richfield 1° x 2° quadrangle that borders the quadrangle on the south. Standlee (1982), Witkind and Page (1984),

Lawton (1985), Villien and Kligfield (1986) and Willis (1986, 1988), among others, discussed the structure of the area. Young and Carpenter (1965) discussed the ground water of the Sevier Valley area.

## STRATIGRAPHY

Most consolidated rocks exposed in the quadrangle are Tertiary and Quaternary in age, though the Jurassic Arapien Shale crops out in a small area in the Redmond Hills (figure 2). The Tertiary rocks can be divided into three groups: (1) Paleocene to Eocene fluvial-lacustrine deposits that are conformable where exposed in the Valley Mountains (figure 3), (2) middle and late Tertiary volcanic and volcanoclastic deposits exposed in the Redmond Hills, and (3) the late Tertiary Sevier River Formation, exposed in the southern part of the Valley Mountains. Some of the unconsolidated and surficial deposits may also be Tertiary in age.

Unconsolidated deposits cover most of the eastern half of the quadrangle and fill some of the valleys and washes in the western part. Those in the eastern part are mostly alluvial-fan and pediment-mantle deposits shed eastward off the Valley Mountains, and valley-fill deposits of the modern and ancestral Sevier River.

## JURASSIC

One Jurassic unit, unit E of the Arapien Shale (Hardy, 1952), is exposed near the eastern quadrangle boundary and probably

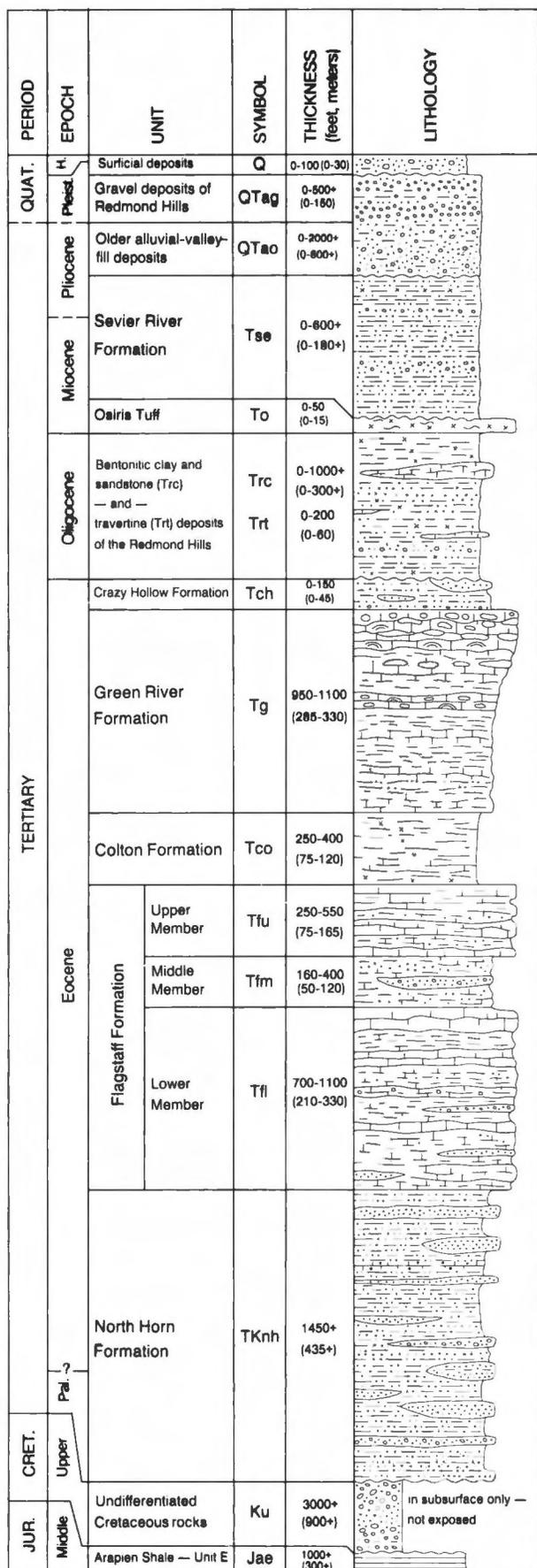


Figure 2. Lithologic column showing strata exposed in the Redmond Canyon quadrangle.

underlies Tertiary and Quaternary strata over a larger area (figure 2 and cross section A-A'). Jurassic rocks exposed elsewhere in central Utah, including the Arapien Shale, the Navajo Sandstone, the Twin Creek Limestone, and the Twist Gulch Formation, probably underlie the quadrangle several thousand feet below the surface.

Unit E of the Arapien Shale (Jae)

Unit E of the Arapien Shale is poorly exposed in small slopes in section 14, T. 20 S., R. 1 W. The name Arapien Shale, as used here, follows the nomenclature of Witkind and Hardy (1984) and is a separate formation from the Twist Gulch Formation, which directly overlies it to the east and southeast. The Arapien is Callovian in age and is probably equivalent to the Leeds Creek and Giraffe Creek members of the Twin Creek Limestone and possibly the lower part of the Preuss Sandstone (Imlay, 1980; Sprinkel, 1982). Hardy (1952) divided the Arapien Shale into five units, labeled A to E. Because of lithologic similarity with outcrops of unit E to the east and southeast, I believe the structurally complex, salt- and siltstone-bearing Arapien rocks exposed in the Redmond Hills are part of his unit E.

In the quadrangle, at the surface, unit E consists of weathered, crumbly, dark reddish-brown, silty mudstone. Better exposures in salt mines in the Redmond quadrangle and near Salina (Willis, 1986) show that beneath the weathered zone the unit consists primarily of salt with intermixed siltstone and mudstone. The mudstone found at the surface is residual caprock formed from salt dissolution. The contorted nature of the salt and associated rock, which were emplaced diapirically, make it impossible to determine the true thickness of the exposed section of unit E. Drilling and nearby salt mines reveal that the hills are cored by dark-reddish-brown salt with minor mudstone and siltstone. Pratt and others, (1966) reported one well that penetrated more than 1,000 feet (300 m) of salt, undoubtedly in the core of the diapir. Other units of the Arapien (units A to D of Hardy, 1952) are probably not involved in the diapirism and are not present at the surface.

Gilliland (1951) and Witkind (1981) mapped large outcrops of Arapien Shale in, and extending into, the Redmond Canyon quadrangle. However, my mapping and potassium-argon dating (table 1) have shown that most of these are Tertiary bentonitic clay deposits that are locally stained by material eroded from the dark-reddish-brown Arapien Shale. The Arapien is only locally exposed at the surface in the Redmond Canyon quadrangle.

TABLE 1. Analytical Data on Potassium-Argon Age Determination

Sample: RCVC-0102  
 Unit: Bentonitic clay deposits of the Redmond Hills  
 Location: 39° 00' 36" N., 111° 53' 13" W.  
 Material Analyzed: Biotite concentrate, -80/+200 mesh  
 Age: 25.8 ± 1.0 Ma (Late Oligocene)  
<sup>40</sup>\*Ar/<sup>40</sup>K = 0.001511  
<sup>40</sup>\*Ar (ppm) = 0.01374; 0.01267 Average = 0.01320  
<sup>40</sup>\*Ar/Total <sup>40</sup>Ar = 0.230; 0.342  
 %K = 7.383; 7.265 Average = 7.324  
<sup>40</sup>K (ppm) = 8.738  
 Constants Used:

$$\lambda\gamma = 4.962 \times 10^{-10}/\text{year}$$

$$(\lambda_e + \lambda_e) = 0.581 \times 10^{-10}/\text{year}$$

$$^{40}\text{K} / \text{K} = 1.193 \times 10^{-4}\text{g/g}$$

Laboratory: Krueger Enterprises, Inc., Geochron Laboratories Division, Cambridge, MA

## CRETACEOUS (?) — TERTIARY

Rocks of known Cretaceous age are not exposed in, but underlie, the Redmond Canyon quadrangle (figure 2; cross section A-A'). The North Horn Formation, which is exposed, has been recognized as partly Cretaceous in the Wasatch Plateau about 30 miles (48 km) to the east but it is possibly entirely Tertiary in age in the Valley Mountains (Spieker, 1949; Griesbach and MacAlpine, 1973; Fouch and others, 1982). I have used the "TK" (Tertiary-Cretaceous) designation in the map symbol to follow convention established by earlier maps and to leave open the possible Cretaceous age of its lower part. The Cretaceous Cedar Mountain Formation, Indianola Group and Price River Formation are exposed in surrounding areas (Gilliland, 1951; Tucker, 1954; Willis, 1986, 1988; Witkind and others, 1987), and undoubtedly underlie the Redmond Canyon quadrangle at depth.

### North Horn Formation (TKnh)

The North Horn Formation crops out near the western border of the quadrangle in a few fault-bounded blocks. Maximum exposed thickness in the quadrangle is about 1,450 feet (435 m); however, the formation probably exceeds 2,000 feet (600 m) in thickness based on exposures west of the quadrangle. The North Horn Formation is composed of yellowish-brown, thick- to massive-bedded, ledge- and cliff-forming sandstone interbedded with gray, yellowish-brown, lavender or reddish-brown, non-bedded to thin-bedded, slope-forming sandstone and mudstone. A few beds of muddy- to sandy-limestone, sparse beds of conglomerate, a few oncolite beds, and rare carbonaceous shale to coal zones are also present.

The cliff- and ledge-forming sandstone beds are generally medium grained; however, they range from the fine to coarse grained and locally contain grit and pebble-sized clasts. The sandstone is moderately to moderately well sorted, with subangular to subrounded grains. Grains are primarily quartz, though weathered lithic fragments are commonly present, making up 10 to about 40 percent of the rock. Mudstone rip-up clasts are widespread. Individual beds are generally 5 to 20 feet (1.5-6 m) thick, but locally range up to 50 feet (15 m) in thickness. The sandstone beds are lenticular; few are continuous for more than a mile. Bedding in the sandstone varies from convolute to cross-bedded, although bedding is not commonly apparent.

One or two conglomerate beds are normally present in the formation. In one type the outcrop is dark reddish brown, with poorly sorted clasts ranging from ½ to 6 inches (1-15 cm) in average dimension contained in a weakly cemented, sandy mudstone matrix. In the other type, the clasts are moderately well to well sorted, ranging from ½ to 1 inch (1-3 cm) in average diameter and are contained in a clean, moderately sorted, sandy matrix. Clast composition ranges from 50 to 90 percent quartzite, 5 to 20 percent chert, 0 to 40 percent limestone, locally containing Paleozoic fossils, and as much as 10 percent other types such as dense sandstone and mudstone.

The intervening slopes range from 20 to 100 feet (6-30 m) thick and are commonly poorly exposed (figure 3). They are underlain by thin-bedded, fine-grained, calcareous sandstone, and knobby to chippy, structureless, mottled mudstone.

The limestone content increases upward in the unit, and a few pale-gray, yellowish-gray, or reddish-gray micritic limestone beds occur in the upper part. The North Horn is gradational with the overlying Flagstaff Formation, which is mostly limestone. I select the contact at the point where limestone becomes dominant over

sandstone. A few beds with abundant oncolites up to about 8 inches (20 cm) in diameter occur in the gradational zone and are included in the North Horn Formation (figure 4).

## TERTIARY

Early Tertiary rocks, which include Eocene fluvial-lacustrine deposits that make up the Flagstaff, Colton, Green River, and Crazy Hollow Formations (and most or all of the North Horn Formation, described previously), are exposed in a series of faulted, eastward-dipping beds (figure 2; cross section A-A'). The fluvial-lacustrine Sevier River Formation of Miocene and Pliocene age crops out along the east flank of the Valley Mountains. Oligocene and Miocene volcanic and volcanoclastic deposits are exposed in the Redmond Hills. They include the formation of Black Cap Mountain, the Osiris Tuff, and bentonitic clay and sandstone deposits.

### Flagstaff Formation

The Flagstaff Formation, which makes up the largest part of the bedrock exposure in the quadrangle, is the most resistant unit in the Valley Mountains and forms most of the higher ridges and peaks (figure 3). It ranges from 1,300 to 1,800 feet (400-550 m) thick in the quadrangle and locally may be thicker. Map relationships suggest thicknesses of as much as 2,500 feet (762 m); however, this excessive thickness may be caused by unrecognized faults and the lack of good bedding surfaces for measuring attitudes needed for accurate calculations. The Flagstaff Formation consists of interbedded limestone, calcareous mudstone, and sandstone with minor conglomerate and shale. I divide the formation into three informal members.

**Lower member of the Flagstaff Formation (Tfl) —** The lower member of the Flagstaff consists of 700 to 1,100 feet (210-330 m) of sandy limestone and mottled, calcareous mudstone, with lesser conglomerate and oncolite zones. The unit generally forms a steep, ragged slope with numerous limestone ledges separated by poorly exposed, slope-forming, calcareous mudstone. The limestone is generally yellowish gray, pale reddish gray, or pale gray while the calcareous mudstone beds are mottled gray, purplish gray, and reddish gray. In some places, limestone float imparts a yellowish color. Fossils, which are rare, consist of a few poorly preserved gastropods and macerated plant impressions.

The lower, gradational part of the member contains a few sandstone beds similar to those common in the North Horn Formation. A thick, resistant, laterally continuous limestone bed that can be traced through most of the quadrangle marks the upper contact. It consists of light- to medium-gray to pinkish-gray, dense, micritic limestone in which internal bedding is poorly defined or absent. It is commonly 5 to 20 feet (2-6 m) thick and caps many of the ridges, forming a broad dip slope where the less resistant middle member has been stripped off by erosion. A change to medium- to dark-reddish-gray calcareous mudstone and silty to muddy limestone of the middle member further defines the upper contact. In some places, a thin slope-forming zone that is lithologically similar to, and included with, the lower member separates the resistant limestone from the middle member.

**Middle member of the Flagstaff Formation (Tfm) —** The middle member consists of interbedded muddy limestone, calcareous mudstone, and sandy, calcareous mudstone (figure 5). It contains more clastic material than either the upper or lower members and is best recognized by its brick-red to purplish-red color; however, the



**Figure 3.** Looking south into west-central part of quadrangle. The peak, which consists of the lower member of the Flagstaff Formation, is the highest point in the Redmond Canyon quadrangle. The Flagstaff and North Horn Formations form the low hills in the middle distance. The North Horn Formation makes up the low hills to the right of the high peak. The hills and valleys are cut by several faults, including one that passes through the saddle in the upper left of the photograph.



**Figure 4.** Oncolites ranging up to 8 inches (20 cm) in diameter are in several beds in the upper part of the North Horn and lower part of the Flagstaff Formation. The oncolites are commonly cored by a gastropod fragment. Pen 6 inches (15 cm) long for scale.

lower and upper members locally are similarly colored. Generally the middle member is nonresistant, forming shallow slopes and saddles, though it has resistant ledges of limestone. Well-defined bedding is rarely observed, but the unit is layered mudstone, limestone, sandstone, and siltstone. Mottled zones and root traces give evidence of bioturbation. Float consists of irregular knobby blocks and crumbly chips.

The middle member is about 400 feet (120 m) thick in the southern part of the quadrangle and thins northward to about 160 feet (50 m) near the north quadrangle boundary. In its thicker, southern part, it contains several ledges of fine- to coarse-grained sandstone and pebble conglomerate and one distinctive zone of conglomerate with clasts up to 6 inches (15 cm) in diameter. The clasts are mostly quartzite, though chert and limestone are also present. The sandstone and conglomerate decrease in abundance toward the north; the northernmost outcrop of conglomerate in the quadrangle is near Redmond Canyon and only a few sandstone beds crop out near the northern border.

The contact between the middle and upper members is marked by a change from dominantly reddish-gray, calcareous mudstone and muddy limestone of the middle member, to pale- to medium-gray, pale-reddish-gray or yellowish-gray micritic limestone beds that make up the more resistant upper member.

**Upper member of the Flagstaff Formation (T<sub>fu</sub>)** — The upper member of the Flagstaff Formation is composed of yellowish-gray, pale-reddish-gray, or pale-gray, interbedded muddy limestone, mudstone, micritic limestone, and calcareous sandstone, and is similar in composition and appearance to the lower member (figure 5). The upper member ranges from about 250 to 550 feet (75-165 m) thick, though some of the variation may be due to structural deformation. It forms steep, ledgy slopes and many of the higher ridges in the quadrangle. Locally, it contains medium-brownish-red layers similar in color to the middle member. The upper part of

the upper member contains a laterally continuous, micritic limestone ledge similar to the ledge that crops out near the top of the lower member. Strata above the resistant ledge are gradational with the Colton Formation and consist of chippy to blocky limestone interbedded with bentonitic mudstone.

#### Colton Formation (T<sub>c</sub>)

The Colton Formation is a nonresistant, poorly exposed unit that forms gentle slopes and strike valleys. It is composed of variegated, bentonitic mudstone and thin-bedded shale, sandstone, and limestone. Drab to vivid, pale-gray, olive-gray, white, green, dark-brown, red and purple colors are the most prevalent. It weathers to form plastic "popcorn" soil when wet. The sandstone is generally fine to very fine grained and well sorted. The Colton Formation ranges from 250 to 400 feet (75-120 m) thick in the quadrangle, thinning toward the south. It is about 50 feet (15 m) thick about 8 miles (13 km) south of the quadrangle and is missing farther south (Willis, 1988). Though the Colton is gradational with both the underlying and overlying units, it is normally distinctive and easily recognized.

#### Green River Formation (T<sub>g</sub>)

The Green River Formation forms a resistant northward-trending ridge that makes up the east flank of the Valley Mountains (figure 5). It also crops out in faulted areas to the west. The Green River Formation is 950 to 1,100 feet (285-330 m) thick in the Redmond Canyon quadrangle and consists of a lower, slope-



*Figure 5. View looking east in Lone Cedar Canyon. The middle unit of the Flagstaff Formation forms a reddish slope in the lower left; it is capped by the upper unit. The Green River Formation forms the juniper-covered hill in the right half of the photograph. An eastward-trending, down-to-the-south fault separates the two formations.*

forming part that is gradational with an upper, ledge-forming part.

The lower part is composed of pale-greenish-gray, calcareous mudstone and thin beds of yellowish-gray to brownish-white, platy, siliceous limestone that form a slope marked by a few small ledges. A few beds consist of very fine- to fine-grained sand. Bioturbation and soft-sediment deformation are locally present. The upper part, which represents a gradual change from mudstone to siliceous limestone, is composed mostly of yellow, yellowish-gray, or pinkish-gray siliceous limestone that commonly contains silicified algal stromatolites. Some beds a few inches thick are composed of more than 90 percent white, pale- to dark-brown, or yellowish-brown chert. The chert generally contains remnants of breccia and possible rip-up clasts that have also been silicified. Bedding is commonly poorly developed and discontinuous within the ledgy beds, but many ledges can be traced for more than a mile. One to three beds of resistant, dense, dark-orangish-brown, silicified, oolitic limestone as much as 2 feet (60 cm) thick are found near the top of the formation.

The Green River is easily recognized in large exposures. However, small or poorly exposed outcrops of the lower part can be mistaken for the Colton Formation and some beds of the lower and upper parts can be mistaken for the Flagstaff Formation. White or dark-brown to tan chert, extensive siliceous limestone, and silicified oolites are diagnostic of the upper part of the Green River.

The Green River is overlain by the Crazy Hollow Formation in the south-central part of the quadrangle. The contact is probably conformable; however, limited exposures prevent precise determination. Elsewhere in the central Sevier Valley area Willis (1986, 1988) and Norton (1986) have noted both conformable and unconformable contacts. In those locations where an unconformity exists the hiatus is minor. In the remaining areas of the quadrangle the Green River Formation is overlain unconformably by the Sevier River Formation or by Quaternary alluvial deposits.

#### **Crazy Hollow Formation (Tch)**

The late Eocene Crazy Hollow Formation is primarily composed of brownish-red and orangish-red, and to a lesser extent, medium-gray and light-yellowish-gray sandstone, mudstone, siltstone and minor pebble conglomerate. The sandstone, which occurs in lenticular fluvial-channel deposits and as more continuous, thin-bedded layers, has an immature "salt and pepper" appearance imparted by light and dark chert and lithic grains. It is commonly medium to coarse grained and has angular to subrounded grains. The sandstone lenses are locally bleached pale yellow or white. The mudstone is generally silty to sandy, bentonitic, and forms low slopes. It is commonly brownish red, but locally it is variegated gray, greenish gray, yellowish gray, or purple. In most places the unit has a distinctive basal conglomeratic sandstone with distinctive black chert grains and pebbles  $\frac{1}{2}$  to 2 inches (1-5 cm) in diameter.

The Crazy Hollow is only present in the southern part of the quadrangle where it is 0 to about 150 feet (0-45 m) thick. The formation is truncated by an angular unconformity that cuts it out toward the north. To the south, in the Aurora quadrangle, the Crazy Hollow is about 1,000 feet (300 m) thick (Willis, 1988). Probably more than 2,000 feet (600 m) of Crazy Hollow and overlying rock were eroded in the Redmond Canyon quadrangle before deposition of the Sevier River Formation on the unconformity.

#### **Interbedded bentonitic clay and sandstone (Tre) and travertine deposits (Trt) of the Redmond Hills**

Interbedded bentonitic clay, sandstone, and travertine deposits are exposed in the Redmond Hills in the southeastern part of the quadrangle (figure 6). A few of the travertine bodies are large enough to map separately, but many of the smaller outcrops are not differentiated from the clay deposits. The sandstone is interbedded with the clay.

The clay deposits are composed of poorly to well-bedded, mottled green, greenish-gray, yellowish-gray, purple and red, sandy, bentonitic clay and mudstone, locally interbedded with sandstone and lenticular beds of conglomeratic-sandstone. The sand in the clay and the sandstone are composed primarily of medium- to very coarse-grained, subangular to rounded, lithic grains, most of which were probably derived from welded tuffs. Clasts in the conglomeratic-sandstone range up to 1 foot (0.3 m) in diameter, though most are pebble-sized (figure 7). Most clasts are composed of welded tuff and resemble tuff units exposed in the Marysvale volcanic field to the south (Steven and others, 1990).

The travertine deposits are composed of orange, yellowish-orange, and reddish-orange, well-bedded travertine, interlayered with very thin to thick layers of bentonitic clay. The travertine is finely laminated, with laminae ranging from planar to highly contorted and lobate. It is highly fractured and jointed such that it breaks into small, angular blocks generally less than 6 inches (15 cm) in average dimension.

The clay, sandstone, and travertine deposits were pushed to the surface by diapirism and thus outcrops are structurally complex (figure 6). A precise thickness cannot be determined, but the clay and sandstone probably exceed 1,000 feet (300 m) in places, while the thickest travertine mounds may be 200 feet (60 m) thick. More typically, the travertine beds are 5 to 20 feet (1.5-6 m) thick and pinch out within a few tens to hundreds of feet. The bentonitic clay and travertine deposits are unconformably overlain by gravel deposits of Redmond Hills (QTag) and younger alluvial deposits.

These clay, sandstone, and travertine deposits were mapped as Jurassic Arapien Shale by earlier workers (Gilliland, 1951; Witkind, 1981; Witkind and others, 1987); however, I believe they are Oligocene in age and correlate with the formation of Black Cap Mountain, exposed to the southeast, in the Salina area (Willis, 1986). A potassium-argon age determined on biotite from a sample collected from the clay yielded an age of  $25.8 \pm 1.0$  million years (table 1). Because the clay deposit is reworked, the number reflects the age of the volcanic source rather than the age of deposition, but it does support a Tertiary, rather than Jurassic, designation. Near the center of the eastern border of the quadrangle, the clay unit appears to be conformably overlain by the Osiris Tuff of Miocene age (described below). The coarser sandstone and conglomerate parts of the bentonitic clay unit are also lithologically similar to the formation of Black Cap Mountain, both consisting primarily of volcanic-derived lithic fragments. The clay content varies dramatically between the two units, but I believe the clay is a diagenetic alteration product, possibly related to the springs that deposited the travertine. The association with the Tertiary rocks, the volcanoclastic content, depositional patterns that existed during the Oligocene, and the potassium-argon age suggest that the clay was eroded from the Marysvale volcanic field (which extends southward from the Redmond Hills area), between 26 and 23 million years ago (Steven and others, 1984). I have chosen not to apply the term "Black Cap Mountain" until such correlation can be confirmed, and because there are distinct lithologic differences (the clay and travertine content). The clay, sandstone, and travertine



**Figure 6.** Tertiary bentonitic clay and travertine in the Redmond Hills. Travertine forms the jagged ledges and the cap of the hill in the upper left. The clay is commonly white, gray, or yellowish gray. Locally, it is stained dark red, probably by siltstone from nearby salt-bearing, diapiric, Jurassic Arapien Shale that pushed up the hills. The hills support little vegetation, probably due to high salt content.



**Figure 7.** Conglomeratic sandstone interbedded with bentonitic clay deposits in the Redmond Hills. The clasts in the conglomerate range up to 1 foot (0.3 m) in diameter, though most are pebble sized. Most are welded tuff derived from the Marysvale volcanic field south of the quadrangle.

were deposited by fluvial, lacustrine, and spring processes.

### Osiris Tuff (To)

The Osiris Tuff is exposed in a small hill near the center of the east quadrangle boundary where it stratigraphically overlies bentonitic clay and sandstone deposits. It is composed of densely welded, porphyritic, latitic tuff. It is commonly purplish gray, but also reddish brown, reddish purple, or brownish gray and it has a dark-gray to black basal vitrophyre about 5 feet (1.5 m) thick. It contains 10-20 percent plagioclase, 1-3 percent biotite, 2-5 percent sanidine, 0.5-2 percent pyroxene, minor Fe-Ti oxides, and 70-80 percent matrix. The biotite, which weathers copper brown, and the plagioclase are particularly conspicuous in hand samples. The Osiris typically weathers into large rounded blocks that break down into granular fragments. It is about 50 feet (15 m) thick in the one exposure but is considerably thicker to the southeast in the Salina quadrangle (Willis, 1986). The Osiris erupted from the Monroe Peak caldera, located 30 miles (48 km) to the south, about 23 million years ago (Fleck and others, 1975; Steven and others, 1984). Gilliland (1951) identified the Redmond Hills outcrop as a dike, but comparison to outcrops of Osiris Tuff exposed to the southeast confirms the Osiris identification.

### Sevier River Formation (Tse)

The Sevier River Formation is exposed along the east flank of the Valley Mountains in the central and southern parts of the quadrangle where an incomplete section exceeds 600 feet (180 m) in thickness (figure 8). It is composed of pale-gray, pinkish-gray, orangish-gray, and greenish-gray, mudstone, sandstone, and conglomerate. It is locally bentonitic and has a few thin, reworked

volcanic-ash deposits. Bedding is poor and discontinuous; conglomerate beds are lenticular. Clasts in the conglomerate beds, which are generally 1 to 3 inches (3-8 cm) in diameter, are lithologically similar to rocks of the North Horn, Flagstaff, or Green River Formations. The unit is poorly consolidated but contains a few resistant beds, mostly of conglomerate, that form knolls. It contains angular blocks up to 6 feet (2 m) in diameter in the lower part of the unit in the western exposures and becomes finer eastward and up-section where clasts are seldom larger than 2 inches (5 cm). Weathered surfaces develop a thick, soft, crumbly residue that obscures sedimentary features.

A partially reworked ash bed in the upper part of the formation about a mile south of the quadrangle was dated by fission track methods at  $5.2 \pm 0.4$  million years (Willis, 1988). Steven and Morris (1983) reported an age range of 7 to 15 million years for the Sevier River Formation to the south. The formation consists of basin-fill deposits, but the basin configuration was not the same as the modern topography; the southern part of the Valley Mountains was not present when the unit was deposited. The formation lies on an angular unconformity of which the hiatus increases in duration to the northwest.

### Abandoned Bald Knoll Formation

The outcrops of Sevier River Formation in the Redmond Canyon and northern part of the Aurora quadrangles were previously incorrectly defined and mapped as the Bald Knoll Formation and considered late Eocene or Oligocene in age (Gilliland, 1951; Witkind and others, 1987; Steven and others, 1990). In fact, Gilliland designated the exposure in section 6, T. 21 S., R. 1 W., in the southwestern part of the Redmond Canyon quadrangle near Bald Knoll, as the type section of his Bald Knoll Formation. He



**Figure 8.** View looking north in the south-central part of the quadrangle (SW¼, section 5, T. 21 S., R. 1 W.). The Sevier River Formation forms the low hills in the center and left of the photograph. Older alluvial valley-fill deposits (QTao) comprise most of the slope beneath older pediments deposits (Qap) that form the gently-sloping surface in the upper right.

defined the Bald Knoll as consisting "chiefly of light-green, light-tan, gray, and white calcareous clays with interbedded siltstone, sandstone, and minor amounts of soft limestone of the same colors" that are Eocene or Oligocene in age, that overlie the Crazy Hollow Formation, and that preceded Oligocene volcanism. My mapping, a comparison of lithologies, correlation of bounding units, and fission-track dating has shown that the rocks in his type section are not Eocene nor Oligocene in age, nor do they precede Oligocene volcanism, and thus they do not correlate with rocks to the south and southeast that fit that definition. The strata are much younger than his definition, postdating the volcanic rocks instead of predating them. I found that the miscorrelation resulted because a large, poorly exposed, previously unrecognized fault in the Aurora quadrangle, to the south, juxtaposed similar-appearing, but unrelated strata. South of the fault, the strata do fit the definition of Gilliland's Bald Knoll Formation, but north of the fault, including at the types section of the Bald Knoll, the similar-appearing strata actually correlate with the Sevier River Formation (Willis, 1987, 1988). The North American Code of Stratigraphic Nomenclature dictates that under such circumstances the inappropriate name may be abandoned (North American Commission on Stratigraphic Nomenclature, 1983). Since the name "Sevier River Formation," proposed by Callaghan (1938), predates the name "Bald Knoll Formation" applied by Gilliland in 1949 (1951), and is more widely used, I abandoned the name "Bald Knoll Formation" and its type section. I renamed Eocene to Oligocene strata exposed south of Aurora that do fit the description of the original Bald Knoll Formation, the "formation of Aurora" (pending formalization to "Aurora Formation") (Willis, 1987, 1988). The formation of Aurora is not present in the Redmond Canyon quadrangle, having been cut out by a major unconformity beneath the Sevier River Formation.

## QUATERNARY TERTIARY

### Older alluvial valley-fill deposits (QTao)

Thick, partially consolidated gravel deposits that represent a late Tertiary or early Quaternary period of valley fill are exposed beneath dissected pediment deposits along the east flank of the Valley Mountains (figure 8). The gravel deposits are well exposed, and mappable, only where ephemeral streams have dissected the pediments. Generally the gravels are obscured by colluvium, and are lumped with the pediment deposits (Qap<sub>4</sub>), that overlie them. The gravel deposits are composed primarily of poorly consolidated, interbedded conglomerate, sandstone, and mudstone. The clasts are mostly pebble-sized, but range up to boulders 1 to 2 feet (0.3-6 m) in diameter in the westernmost exposures and are moderately well sorted, moderately rounded, and poorly cemented or noncemented. Rare volcanic clasts occur in the unit south of the quadrangle but, in the Redmond Canyon quadrangle, all clasts are of sedimentary lithologies (Willis, 1988). The deposits coarsen toward, and are lithologically similar to, early Tertiary formations exposed west of the outcrops. Exposures are not complete enough to determine the thickness of the unit in the Redmond Canyon quadrangle, however, the unit probably ranges from a pinchout near the mountains to more than 2,000 feet (600 m) in the valley. To the south, in the Aurora quadrangle, exposed deposits are more than 1,000 feet (300 m) thick (Willis, 1988). At least part of the partly consolidated gravel deposits are probably younger than nearby faults that cut the Sevier River Formation, but they have been tilted in some places (cross section A-A<sup>7</sup>). An eastward dip of 22 degrees was measured in Lone Cedar Canyon, and the beds have been

beveled by the pediment surface. These older gravel deposits are probably Pliocene or Pleistocene in age. Though I consider the deposits to be younger than the Sevier River Formation, the strata may be partly correlative with Sevier River deposits as they are mapped in some areas in central Utah.

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, the clast size and composition is reflective of the present basin configuration; i.e., highlands present during the deposition of this unit seem to have been similar to those present today. Gilliland (1951) mapped this unit (and the overlying pediment veneer) as Axtell Formation, a name established on the east side of Sevier Valley to the northeast (Spieker, 1949). I have chosen not to use that term for this unit until more precise correlation is documented, though ages may be similar.

### Gravel deposits of Redmond Hills (QTag)

Poorly cemented or noncemented, moderately well-sorted, mostly volcanic cobbles, pebbles, and sand with minor interbedded mud and clay are widespread in the Redmond Hills in the southeast corner of the quadrangle (figure 9). Most of the gravel is clean and moderately well sorted, but some poorly sorted beds contain clay, mud, and subangular clasts. The outcrops are generally cross-bedded with individual cross sets ranging from 2 to 5 feet (1-2 m) thick. Most cross beds indicate current flow toward the north, though precise directions are difficult to determine. Cobbles in the gravels are primarily of volcanic origin, but locally they are as much as 50 percent sedimentary derived. The dominance of volcanic clasts suggests that the primary source was to the south where volcanic outcrops are common.

Exposed, incomplete sections of the deposits are locally over 500 feet (150 m) thick, although no complete section exists. Where exposed near the margins of the Redmond Hills, the beds dip away from the hills at 30 to 60 degrees, while beds closer to the center are commonly subhorizontal (figure 9). The age of these deposits is probably Pleistocene but may be late Tertiary.

## QUATERNARY

Surficial deposits of Quaternary age are widespread throughout the quadrangle. Most are alluvial and form stream or debris and mudflow deposits on older pediment and active fan surfaces. Colluvium is ubiquitous throughout the quadrangle on most slopes and the flanks of most washes, obscuring underlying bedrock. However, the colluvium commonly occurs as unmappable thin cover rather than as thick, mappable deposits. Ancient Lake Bonneville, which reached an altitude about 5,105 feet (1,556 m) in this area, probably extended into the northeast corner of the quadrangle about 14,000 years ago (Currey, 1982). That area is now under cultivation and no lacustrine deposits are now recognizable.

### Pediment deposits (Qap<sub>2-4</sub>)

Alluvial, mudflow, and debris-flow deposits that mantle two major levels of pediment surfaces cover much of the eastern half of the quadrangle (figure 8). The pediment deposits are composed of poorly sorted, angular boulders, cobbles, pebbles, and fine-grained



**Figure 9.** Tilted, late Tertiary or Quaternary gravel deposits in the Redmond Hills (QTag) (section 11, T. 21 S., R. 1 W.). The beds of gravel generally dip away from the center of the hills. In this outcrop, the gravel is composed of mudstone and moderately sorted gravel with a muddy matrix. Some outcrops are composed of clean, well-sorted gravel with a sandy matrix.

material reworked from immediately underlying units or from units exposed upslope, to the west.

The deposits are differentiated based on geomorphic form and relative altitude above present drainage systems. Though intermediate levels occur, all pediment deposits are divided into two groups in which surfaces with minor altitude differences are lumped together. The deposits of the higher, older, and most deeply dissected pediments are labeled Qap<sub>4</sub>, while the younger, lower level pediment deposits are labeled Qap<sub>2</sub>. The symbols reflect mapping begun in the adjacent Aurora quadrangle (Willis, 1988); in the Redmond Canyon quadrangle, pediment deposits Qap<sub>1</sub> and Qap<sub>3</sub> are not well defined, and hence, were not mapped separately. The oldest pediments (Qap<sub>4</sub>) are the most prominent, rising more than 200 feet (60 m) above adjacent drainages in some places. Relief gradually decreases toward the east, and in some places near the eastern border the pediments merge with active alluvial-fan surfaces. In other places, mostly east of the quadrangle, the pediments are cut off abruptly by a steep erosional scarp along the margin of the Sevier River flood plain. The younger pediments (Qap<sub>2</sub>) occur only in the southern part of the quadrangle where they form a well-defined intermediate surface about 40 to 70 feet (12-21 m) above present drainages.

Generally, the pediment deposits unconformably overlie the Sevier River Formation and the older alluvial valley-fill deposits (QTao) (figure 8). In a few places along their western exposures they lap onto the Green River Formation. Near their eastern margin they unconformably overlie the gravel deposits of Redmond Hills (QTag), in which case the reworked deposits are mapped as Qapv. The contact between the pediment deposits and the underlying unit commonly is poorly exposed and difficult to define. Thus, locally they are lumped together. The pediment deposits are generally less than 40 feet (12 m) thick.

#### **Pediment deposits containing volcanic clasts (Qapv)**

In some places in the east-central part of the quadrangle, deposits mantling pediment surfaces contain volcanic clasts reworked from the gravel deposits of Redmond Hills (QTag). In other aspects they are similar to, and continuous with, other pediment deposits (Qap<sub>2</sub> and Qap<sub>4</sub>). Though the morphology of the pediment surface does not change between the two types of deposits, the change in lithology is distinctive. They are generally less than 30 feet (9 m) thick.

#### **Landslide deposits (Qms)**

Three small landslides were mapped in the quadrangle. Each consists of hummocky, rotated blocks of colluvium and shallow, weathered bedrock, and is generally less than 50 feet (15 m) thick. Two of the landslides contained open fractures and disturbed vegetation indicating that the latest movement was in historical time, probably during the 1983-1985 wet cycle. All the landslides involve the Colton Formation, a bentonitic unit that becomes slippery when wet. In many other places, deposits composed of, or deposited on, the Colton Formation show evidence of slope creep or other signs of instability.

#### **Older alluvial-fan deposits (Qaf<sub>2</sub>)**

Older alluvial-fan deposits, mapped in several places around the Redmond Hills, are similar in composition to younger alluvial-fan deposits, but they have been uplifted relative to surrounding areas and tilted by diapiric forces beneath the Redmond Hills. These deposits are not consolidated and are not erosional remnants of older surfaces. Thickness of the deposits is unknown.

### Younger alluvial-fan deposits (Qaf<sub>1</sub>)

Large parts of the lowlands in the eastern part of the quadrangle are mapped as alluvial fans. The fans are composed mostly of clay- to pebble-sized material but include cobbles and boulders, especially closer to the stream mouths. Windblown material and humus make up a small portion of the fans. The deposits are poorly to well sorted. Most are under cultivation. Thickness of the deposits is unknown.

### Older alluvial deposits (Qa<sub>2</sub>)

Older alluvial deposits, consisting of poorly sorted sand, silt, clay, gravel, and boulders, occur in several areas in and near the Valley Mountains. These deposits have been dissected or isolated by downcutting of modern drainage systems and are being eroded, but they are younger than nearby pediment surfaces. Locally, they grade into colluvium and other alluvial deposits. They are generally less than 100 feet (30 m) thick, except in some of the faulted valley areas where the thickness is unknown.

### Younger alluvial deposits (Qa<sub>1</sub>)

Younger alluvial deposits are extensive in washes and basins in the quadrangle. They consist of locally derived boulders, gravel, sand, silt, and clay and range from poorly to well sorted. They tend to grade into, and locally include, colluvium and other alluvial deposits. They are generally less than 100 feet (30 m) thick except in some of the faulted areas where the thickness is unknown.

## STRUCTURE

The Redmond Canyon quadrangle contains three structural elements: eastward-dipping, faulted strata of the Valley Mountains, diapirically deformed strata of the Redmond Hills and, in between, faulted and folded bedrock concealed by alluvial-fan and pediment deposits.

### VALLEY MOUNTAINS

The Valley Mountains are a northward-trending range about 30 miles (48 km) long and 4 to 8 miles (6-12 km) wide. All rocks exposed in the range are Tertiary, except for a small exposure of steeply dipping Cretaceous rocks about 10 miles (16 km) north of the Redmond Canyon quadrangle (Witkind and others, 1987). With only minor exceptions, the Tertiary strata in the range dip approximately east 15 to 40 degrees and are cut by generally northward- and eastward-trending fault sets (figure 3). In parts of the range, a flexural steepening of strata occurs along the east side that Witkind and Page (1984) describe as the Valley Mountains monocline. The center of the range contains a series of northward-trending grabens bounded by high-angle normal faults. The largest of these, which extends into the northern part of the Redmond Canyon quadrangle, is called Japanese Valley. The range is bounded on the west by a high-angle, down-to-the-west, normal fault that forms the east side of Round Valley. On the east side of the range the strata plunge beneath alluvial-fan and pediment deposits with no apparent range-front fault, though farther east faults may exist beneath the surficial cover.

In general, the structure of the Valley Mountains within the quadrangle is similar to the rest of the range except that the monoclinical flexure is minor and, if present, is mostly masked by faulting.

Strata generally strike from N. 15° E. to N. 15° W. and have a homoclinal dip of from 15 to 35 degrees east, averaging 20 to 25 degrees. I attribute the wide range of attitudes to different degrees of tilting of fault-bounded blocks. A few spurious steeper or westward-dipping attitudes were also measured that were caused by localized deformation near faults. Though only a few attitudes are available, the Sevier River Formation strikes similarly, but dips more gently, suggesting either a shallow angular unconformity between it and the older strata or an eastward decrease in dip of all strata. I was only able to measure the attitude of bedding in the older alluvial strata (QTao) in one place (15 degrees), thus I am unsure if it has been tilted throughout most of the quadrangle. It definitely is tilted in the Aurora quadrangle to the south (Willis, 1988).

### Faults

Two prominent fault sets cut strata of the Valley Mountains, a northward-trending set and an eastward- to southeastward-trending set (figure 5). Where different formations are offset, the faults are easily recognized, but the actual fault surfaces are seldom exposed. Faults that do not offset formations or that are covered by slope-wash and colluvial deposits are difficult to recognize and it is likely that additional faults, unrecognized during this mapping, occur in the quadrangle.

Offset on most of the faults ranges from a few feet to about 2,000 feet (600 m). All the faults are at high angles; some may be vertical. Most of the northward-trending faults are down to the west, while the offset on the other set is about evenly split. The largest fault, a splayed, down-to-the-south fault in the southwest corner of the quadrangle, juxtaposes the Green River Formation against the North Horn Formation, indicating an offset exceeding 2,500 feet (760 m). Faults of the northward-trending set are generally longer and more continuous; one such fault can be traced for about 7 miles (11 km) in the quadrangle and it continues for an undetermined distance to the north along fault-bounded Japanese Valley (Witkind and others, 1987). Neither fault set is obviously younger than the other; in places, faults of each set appear to cut faults of the other, suggesting simultaneous development. Gilliland (1951, p. 61) reached a similar conclusion.

Two small, parallel, northeastward-trending faults create a small graben in the older pediment deposits in section 29, T. 20 S., R. 1 W., and are of Quaternary age. These faults are not on trend with any other faults and may be the result of differential compaction or some other sedimentary process, rather than of tectonic origin.

### Age and Cause of Faulting

The youngest unit cut by the faults in the quadrangle is the Sevier River Formation, from which I obtained a fission-track age of  $5.2 \pm 0.4$  million years from a sample collected in the Aurora quadrangle (Willis, 1987, 1988). Faulting may cut the poorly exposed, older alluvial deposits (QTao) but I found no outcrops with visible offset (cross section A-A').

Geomorphic and circumstantial evidence suggest that some fault movement may be as young as Quaternary although, within the Redmond Canyon quadrangle, no scarps of certain Quaternary age are known. In some places along the major northward-trending fault in the western part of the quadrangle, several slopes that form a linear trend appear to be faceted and colluvium on the slopes is at a steeper angle than elsewhere, suggesting fault-scarp morphology.

Several small, closed basins, or basins that appear to have been closed recently, are perched on the downthrown block along the fault, forming a stairstep-type drainage suggesting Quaternary fault movement. Also supporting Quaternary movement, the fault bounding the west side of the Valley Mountains (west of the quadrangle) which I believe is closely related to faults in the quadrangle, has offset Quaternary alluvial and colluvial deposits. In one place, trees that are still living may have been disturbed by a recently developed fault-scarp, although the evidence is uncertain. North of the quadrangle, in Japanese Valley, Quaternary sediments are also offset by faulting (Witkind and others, 1987; Hecker, in preparation; Peterson, in preparation). Together, the evidences suggest that at least some of the faults in the quadrangle may have had Quaternary movement.

I attribute both the range-bounding fault west of the quadrangle and the faulting within the quadrangle to late Tertiary and Quaternary, basin-and-range-type, extensional faulting that is prevalent in much of the surrounding region. Faults similar to those in the Valley Mountains occur in most other areas of the transition zone, such as the San Pitch Mountains to the north and the Wasatch and Sevier Plateaus to the east and southeast (Standlee, 1982; Witkind and others, 1987). The eastward tilt of the range mimics the pattern of many mountain blocks in the Basin and Range Province and may be due to rotation on a listric normal fault concealed beneath Sevier Valley that passes beneath the range; perhaps the same fault that controls the linear trend of the Redmond Hills.

Structure of older rocks underlying the quadrangle is unknown but is believed to be complex. The Valley Mountains and Sevier Valley are probably underlain by at least two thrust faults that offset Cretaceous and older strata, referred to as the Gunnison and Wasatch thrusts by Villien and Kligfield (1986). In many places, deformation on these thrust plates may be primarily folding, with duplication of strata generally limited to the Arapien Shale (Willis, 1986, 1988). Cretaceous rocks exposed through a window in the Tertiary strata in the northern part of the range are complexly folded, which I attribute to the thrusting. Witkind and Page (1984) explain the same features as related to salt diapirism and dissolution. Two wells drilled west and northwest of the western border of the quadrangle penetrate distinct sections of strata, another possible indication of thrust deformation (figure 1) (D.A. Sprinkel, personal communication, 1990). Thrust faults have not cut the Tertiary rocks exposed in the quadrangle, but they may influence the position of Tertiary and Quaternary faults.

### SEVIER VALLEY

The structure and identity of bedrock underlying the alluvial fans and pediments deposits in the eastern part of, and east of, the quadrangle are largely unknown due to the lack of exposures and sparse subsurface control. However, I believe that Mesozoic and Tertiary strata underlie the surficial sediments and form the east-dipping, west flank of a large, faulted syncline (see cross section A-A') similar to the syncline that folds much of the strata of the San Pitch Mountains (Gunnison Plateau) to the north (Willis, 1986, 1988). This syncline underlies most of Sevier Valley and may be one of the reasons for the development of the valley. The east flank of the syncline forms the west side of the Sanpete-Sevier Valley anticline, exposed in the White Hills along the east side of Sevier Valley (figure 1). Strata froming the syncline may be cut by many high-angle faults, as in surrounding areas, creating poor seismic reflectors. One of the largest of these faults may be a major down-to-the-west fault that also controlled the linear emplacement of the diapirs that formed the Redmond Hills. Supporting this idea, the

Redmond Hills are on trend with a large down-to-the-west fault that cuts Quaternary sediments, exposed about 15 miles (24 km) to the north, near Fayette (Witkind and others, 1987). Alternatively, Witkind (1981) showed most of Sevier Valley to be underlain by diapiric Arapien Shale, with all younger Mesozoic and Tertiary strata having been displaced by diapirism and removed by erosion. In addition, he attributes the faulting and folding of the rocks in the Valley Mountains to withdrawal of salt, but doesn't rule out extensional normal faulting as a factor (Witkind and Page, 1984; Witkind and others, 1987).

### REDMOND HILLS

Stratified units in the Redmond Hills are complexly folded and faulted; however, most of these folds and faults are not differentiated on the map because their complexities are too small for this map scale and because of the lack of marker beds (figure 6). Slickensides and sheared rock are common in float and in excavated clay deposits. Bedding attitudes range from horizontal to steeply overturned. Most strata strike roughly northward, although other trends are common. The beds generally dip away from the center of the hills and younger deposits occur along the flanks. Near the Red Knolls area at the southern end of the hills, gravel beds of possible Quaternary age curve around the end of the hills, forming a semicircle, and dip away from the hills at 30 to 60 degrees (figure 9).

The Redmond Hills were formed when salt within the Arapien Shale diapirically uplifted the overlying strata; mining east of the quadrangle has revealed that the hills are cored by salt. The linear northward trend of the hills suggests that the diapirism is concentrated along a major subsurface fault. The fact that the hills parallel and are on trend with major structures in the area, such as the Quaternary fault near Fayette, supports this theory. Brown and Cook (1982) show a northward-trending gravity low centered in the western part of Sevier Valley that may be caused by this fault and an associated sediment-filled depression west of the hills (cross section A-A').

Subsurface strata must be penetrated and are probably bowed up and structurally thinned, by the drag and upward pressure of the diapiric mass (cross section A-A'), similar to outcrops near Aurora and Salina (Willis, 1986, 1988). Some thinning of units near the hills may also be due to deposition over a positive area formed by the diapirism.

Geomorphic evidence suggests that the diapirism is still active, though there is little evidence to suggest when it began. It seems to be younger and more active than diapirism in the Sanpete-Sevier Valley anticline to the south and east (Willis 1986, 1988). Also, the Arapien Shale in the Redmond Hills consists primarily of salt, while in those areas it is primarily mudstone. The Redmond Hills are near the middle of the Sevier River flood plain and deflect the river around their flank. As the hills are composed mostly of unconsolidated, easily eroded material, normally they would be rapidly eroded rather than stand as topographic highs, unless they are presently being actively raised, presumably by the salt diapirism.

### ECONOMIC DEPOSITS

Several kinds of geologic resources occur in the Redmond Canyon quadrangle. Clay and gravel are currently being produced and other materials show potential for future production.

## SALT

Salt was the first mineral resource produced in Sevier Valley. None is known to have been produced from the Redmond Canyon quadrangle but salt cores the Redmond Hills and may be mined in the future. Currently, it is being mined a few hundred feet east of the quadrangle.

Salt deposits in the mines commonly occur as large structureless masses with secondary crystals more than 6 inches (15 cm) in length. Residual bedding, commonly near-vertical, is sometimes present. Unevenly dispersed, dark-red clay gives the salt a mottled appearance. A typical analysis of salt from the Redmond Hills area yields: 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% (Gilliland, 1951). Redmond Clay and Salt Co., Inc. (company literature, 1987) reports an average composition of: sodium chloride 95%, calcium 0.55%, potassium 0.12%, magnesium 0.09%, sulfur 0.13%, zinc 0.0006%, silicon 0.001%, copper 0.0007%, iodine 0.002%, iron 0.07%, phosphorus 0.05%, and manganese 0.0007%. Smaller, less pure deposits typically have higher quantities of clay-forming elements.

It is difficult to estimate the size of the salt bodies or reserves because of their highly contorted and discontinuous nature and unknown depth. Pratt and others (1966) estimated that the Redmond Hills deposit is about 1,000 feet (300 m) across and extends at least 1,000 feet (300 m) deep. It could be more than 5 miles (8 km) in length. Most salt deposits in the area are irregular in shape. The Chevron USA #1 Salina Unit well, about 5 miles (8 km) to the southeast, penetrated more than 1,000 feet (300 m) of salt in section 33, T. 22 S., R. 1 W., but wells drilled nearby in sections 31 and 32 penetrated much less salt (Standlee, 1982, p. 366). Other wells throughout Sevier Valley also penetrated highly variable thicknesses of salt.

## CLAY

Sizable deposits of sodium-bentonite-clay are exposed in the Redmond Hills (figure 6). They are mined for use as drilling mud additives, foundry sand molding, water proofing, pet waste absorbents, filtering materials, suspension agents, plugging materials, floor cleaners, and binders in animal and food products. Typical analysis is SiO<sub>2</sub> (silica) 65%, Al<sub>2</sub>O<sub>3</sub> (aluminum) 21%, Fe<sub>2</sub>O<sub>3</sub> (iron) 4%, Na<sub>2</sub>O (sodium) 3%, MgO (magnesium) 2%, CaO (calcium) 2%, and K<sub>2</sub>O (potassium) 1%, all as oxides. Cation exchange capacity is 76 meq./100 gr (milliequivalents per 100 grams), API viscosity is 12 cps (centipoise) at 600 RPM, and grit content is 5 percent (Redmond Clay and Salt Co., Inc., company literature, 1987). Van Sant (1964) described physical properties of the clay deposits.

The clay is altered, water-deposited, volcanic ash derived from the Marysvale volcanic center to the south, and contains variable amounts of clastic impurities in the form of fluvial-deposited sand and silt. It is interlayered with spring-deposited travertine and is probably diagenetically altered Oligocene deposits, though earlier workers thought it was part of the Jurassic Arapien Shale (Gilliland, 1951; Van Sant, 1964; Witkind and others, 1987).

## GRAVEL AND ROAD METAL

The Redmond Canyon quadrangle contains significant deposits of gravel and other alluvial and colluvial deposits suitable for highway construction, concrete production, riprap, and other uses.

Deposits are of two types: (1) clean, well-sorted gravel deposited by an ancestral Sevier River in the Redmond Hills area, and (2) poorly to moderately sorted gravel mixed with boulder- to clay-sized material contained in colluvial, pediment-mantle, and alluvial deposits along the flank of the Valley Mountains.

The best quality gravel is mapped as "gravel deposits of the Redmond Hills" (QTag). The deposits consist of moderate to well-sorted cobbles, pebbles, and sand with little or no silt- or clay-size material. Some may be suitable for concrete production without washing.

Thick, older pediment-mantle (Qap<sub>2-4</sub>) and related deposits east of the Valley Mountains are composed of unconsolidated or poorly consolidated boulder- to clay-sized chert, quartzite, limestone, and sandstone clasts in a muddy matrix. Closer to the mountains they are poorly sorted, while farther out into the valley they are moderately sorted and mostly finer grained, containing pebbles ranging from ½ to 2 inches (1-5 cm) in diameter. Deposits commonly contain thin interfingering beds of mudstone. Minor iron oxide gives the deposits a pale red or orange color. Unwashed and unscreened, the deposits are generally unsuitable for concrete or asphalt aggregate but have been used extensively for road fill and similar uses.

The Utah Department of Transportation tested three pits and potential fill sites in the quadrangle and found one suitable for cement aggregate and two suitable for surface gravel or borrow fill (Utah Department of Transportation, 1966).

## LIMESTONE, TRAVERTINE, 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 Redmond Canyon quadrangle but has not been quarried, although boulders have been used locally for decorative landscaping. Parts of the Green River are flaggy to thin bedded and could be used as flagstone or building stone. 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.

Travertine deposits in the Redmond Hills are a pleasing orangish-yellow color and have finely detailed laminae and bedding. However, the outcrops have been intensely shattered during structural deformation and as a result the rock is strongly jointed and generally occurs in blocks only a few inches across. Some attempts have been made to quarry the stone, however.

## HYDROCARBONS

Sanpete and Sevier Counties have been the scene of moderate hydrocarbon exploration in the past and they show good potential for the future (Stark and Gordon, 1982). Though no wells have been drilled in the quadrangle, several have been drilled in the area. No production has been achieved but shows of oil and gas were reported. Britt and Howard (1982) summarized potential source beds and reservoir rocks in the area. Source beds that underlie or are close to the quadrangle, along with a regional average of total organic carbon content, are: Mississippian Great Blue and Deseret Limestones (0.61%), Mississippian Chainman and Manning Canyon Shales (0.98%), Permian Park City and Phosphoria Formations (1.26%), Jurassic Twin Creek Limestone and Arapien Shale (0.27%), and the Cretaceous Mancos Shale and

Mesa Verde Group (1.52%). Possible reservoir rocks occur in several formations.

The North Horn Formation contains thin, discontinuous coal seams. In the Hayes Canyon quadrangle to the north a road cut reveals 6- to 12-inch (15-30 cm) seams. No coal from the area is known to have been utilized.

### GEOHERMAL POTENTIAL

The east part of the Redmond Canyon quadrangle lies in an area "favorable for discovery and development of local sources of low-temperature (less than 195°F (90°C)) water" (Gurgel, 1983). However, no discoveries have been made and no exploration is known to be in progress.

### 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, which passes just east of the quadrangle, has an average annual flow of 73,100 acre-feet. This is much less than upstream near Marysville (165,800 acre-feet) because of irrigation use. Two major canals that transport water from the Sevier River cross the quadrangle. The water table is within 10 feet (3 m) of the surface in most of the flood plain of Sevier Valley, including near the eastern border of the quadrangle, and artesian conditions are common (Young and Carpenter, 1965; Hecker and Harty, 1988). Agricultural and culinary wells have been successfully drilled in the eastern part of the quadrangle. No perennial streams occur in the quadrangle and most washes are dry except during unusually heavy rain storms. Small springs that have been developed for livestock occur in Redmond, Lone Cedar, and Dastrup Canyons.

### GEOLOGIC HAZARDS

#### EARTHQUAKE HAZARDS

The Redmond Canyon quadrangle, located in a seismically active part of the state, is in an area with several Quaternary faults (Anderson and Bucknam, 1979; Bucknam and Anderson, 1979; Anderson and Barnhard, 1987; Hecker, in preparation). The southern part of the Wasatch fault is about 20 miles (32 km) to the north. The Elsinore and Sevier faults bound Sevier Valley to the south near Richfield. Round Valley, just west of the Redmond Canyon quadrangle, is bounded on both sides by large, high-angle faults that have Quaternary fault scarps, and Japanese Valley, located north of the quadrangle, is bounded by Quaternary faults. Other faults with Quaternary movement are also in the area.

No large faults with documented Quaternary scarps were recognized in the quadrangle, even so, some of the large, northward-trending faults in the west part of the quadrangle do have geomorphic features suggesting latest Tertiary or Quaternary movement (see page 12). Such features include closed, fault-bounded depressions, drainages that are out of equilibrium, and steep fault-bounded slopes. A small graben with a few feet of Quaternary offset is in an older pediment in section 29, T. 20 S., R. 1 W., but it may not be tectonic in origin.

Several moderate earthquakes (more than 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; Richens and others, 1981). Several were 20 to 30 miles (32-48 km) to the south along the Elsinore fault. Shock waves from an earthquake generated on any of these faults could cause significant damage in the Redmond Canyon area.

The Redmond Canyon quadrangle is in Uniform Building Code zone 3 (International Conference of Building Officials, 1988). Primary risk is from ground motion. There is also some risk of liquefaction in the Sevier River flood plain. Communities in the area have many older habitations constructed of unreinforced masonry that present the greatest hazard to injury or property damage during a significant earthquake.

#### FLOODING, MUDFLOWS, DEBRIS FLOWS

Heavy runoff from melting snow or heavy rain has the potential to generate mud- or debris flows. Many of the steep, narrow canyons draining the Valley Mountains have abundant unconsolidated material that could be transported by a mudflow. Some are sparsely vegetated, and are especially vulnerable. The major threat is to roads since cultural improvements are sparse and in less vulnerable locations.

#### LANDSLIDES, SLUMP BLOCKS, AND ROCK FALLS

No large landslides were recognized in the quadrangle, but three small landslides involving material derived from the Colton Formation were mapped. The Green River Formation is susceptible to landslides in nearby areas but none were mapped in the Redmond Canyon quadrangle. The North Horn Formation, which is the source of many landslides in areas to the east, is widely exposed in the Valley Mountains; however, Valley Mountain exposures contain more resistant, coarse, clastic beds that are not as conducive to landsliding. Risk to property is low because possible landslide areas are free of man-made structures or cultural improvements. Numerous steep, boulder-strewn slopes could be a source of rock falls, especially during seismic events.

#### EXPANSIVE CLAY, SALT

The bentonitic clays in the Redmond Hills, the Colton Formation, and the Arapien Shale contain expansive clays which present potential problems for buildings, roads, and other structures in the quadrangle (figure 6). In a few nearby communities, older buildings have been damaged by expansive clays.

Salt deposits with thin overburden occur in the Redmond Hills area. Settling and collapse due to salt dissolution and mining occurred, both historically and prehistorically. The potential for catastrophic collapse is probably low but settling could damage foundations. Contamination of culinary and agricultural water supplies by dissolved salt is also possible.

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