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**GEOLOGY OF THE DESERET PEAK EAST 7.5' QUADRANGLE,  
TOOELE COUNTY, UTAH, AND IMPACTS FOR  
HYDROLOGY OF THE REGION**

by

**Torrey J. Copfer**

**A thesis submitted in partial fulfillment  
of the requirements for the degree**

of

**MASTER OF SCIENCE**

in

**Geology**

**Approved:**

**UTAH STATE UNIVERSITY  
Logan, Utah**

**2003**



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**ABSTRACT**

Geology of the Deseret Peak East 7.5' Quadrangle, Tooele County, Utah,  
and Impacts for Hydrology of the Region

by

Torrey J. Copfer, Master of Science

Utah State University, 2003

Major Professor: Dr. James P. Evans  
Department: Geology

Detailed geologic mapping of the Deseret Peak East 7.5' Quadrangle yields new interpretations regarding the stratigraphy of the Oquirrh Basin, fault and fold geometry, and structural evolution of the region. The Stansbury Range consists of the north-south-trending Deseret anticline. Basal Mississippian units rest unconformably on Cambrian beds in the central part of the range. Paleozoic uplift, Mesozoic contraction, and Cenozoic extension have created a series of broad folds, large thrust faults, and several normal faults.

The area is dominated by bedrock springs, with the presence of abundant and thick Quaternary deposits unrelated to Pleistocene glaciation, burying drainages, and mantling hillslopes. The influence of bedrock on groundwater flow paths and stream baseflow is suggested by local anecdotal reports that high snowfall in the Deseret Peak

region generates high discharge ten miles south in Clover Creek, though they are not in the same drainage basin.

(116 pages)

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I give special thanks to my family, friends, office partners, and colleagues at NRCE Inc., for their encouragement, moral support, and patience as I worked my way through. I could not have done it without all of you.

Torrey J. Copfer

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## CHAPTER I

### INTRODUCTION

The Deseret Peak East 7.5' quadrangle is located south of the Great Salt Lake and 15 miles (24 km) southwest of the town of Tooele, Utah (Figure 1). This study is part of a larger effort by the Clover Creek Coordinated Resource Management Planning Unit (CRMP). Interest by Utah state legislators, officials and the governor led to the formation of the CRMP and Utah State University's Clover Creek research station for long-term, watershed-scale studies. Federal, state, and local governments and landowners requested information about water fluxes, flow paths, and source areas following removal of juniper by fire. Geology plays a key role in controlling the groundwater in the study area, transferring water from one topographically defined drainage to another. The geologic mapping provided here contributes critical data needed to define the watershed and characteristics of the groundwater flow systems of the area.

Producing a detailed geologic map of the Deseret Peak East 7.5' quadrangle helps to determine the structural and tectonic history of this part of the Basin and Range system. Although other geologic maps exist for portions of the Deseret Peak East Quadrangle (Lambert, 1941; Teichert, 1958; Rigby, 1958; Bucknam, 1977; Moore and Sorenson, 1979) they are inconsistent, incomplete and/or inaccurate, and none separate individual members of the Pennsylvanian Oquirrh Formation. Studies in the southern Stansbury Mountains focus on sequence stratigraphy of the Cambrian through Pennsylvanian systems with little discussion of tectonic history and structure (Lambert, 1941; Rigby, 1958; Teichert, 1958; Armin, 1979).



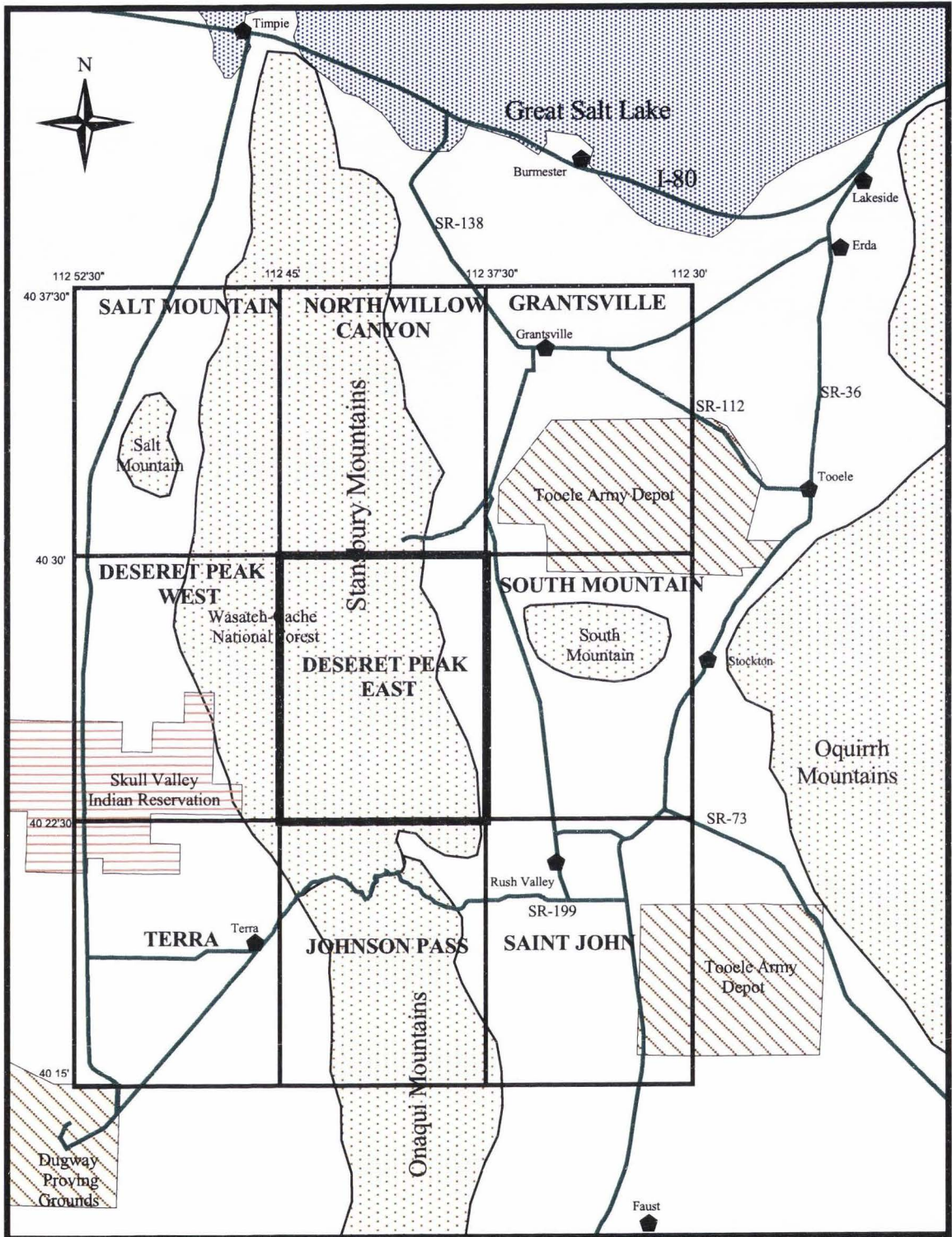


Figure 1: Index map of the Stansbury Mountains and surrounding area with quadrangle grid and names.

The only published geologic maps of the area that encompass the southern Stansbury Range are the 1:500,000 scale State Geologic Map of Utah (Hintze, 1980), the 1:250,000 geologic compilation of the Tooele 1° x 2° Quadrangle (Moore & Sorensen, 1979), and the 1:63,360 scale of the Deseret Peak 15' quadrangle (Rigby, 1958). These maps show little geologic detail, often lack a topographic base, made little use of aerial photography, ignore the stratigraphy and deformation of the Tertiary deposits and Oquirrh Formation, contain few strikes and dips, and show incomplete and inaccurate fault patterns. More broadly, producing a detailed geologic map of the Deseret Peak East 7.5' Quadrangle sheds light upon the structural and tectonic history of this part of the Basin and Range. Units exposed in the Deseret Peak East quadrangle consist of over 35,000 ft (11,000 m) of Cambrian through Triassic rocks.

Research for the project was conducted from November 1999 to December 2001 and field work from April 2000 to November 2001. Field mapping was done with aerial photographs, orthophotoquadrangles, and topographic base maps. Mapping was done to partially fulfill degree requirements for Master's of Science, Department of Geology, Utah State University.

Chapter II is being submitted to the Utah Geological Survey as the text booklet accompanying the Geologic Map of the Deseret Peak East 7.5' quadrangle, Tooele County, Utah (Plate 1) with all materials and information needed to facilitate the review and publication process (Plates 2-3). Chapter III provides a more detailed study of the structural geology encountered during mapping, the identification of new structures, clarification of existing structures, and interpretations on the tectonics of the area.

Recently, Tooele Valley has experienced a rapid increase in population. This increase has been accompanied by a commensurate increase in the demands being placed upon the valley's water resources, including groundwater. Water rights, which have previously been used largely for agriculture and mining are being transferred to municipal, domestic, commercial, and industrial uses. Chapter IV discusses in more detail the water resources in the area and the effects of bedrock control on groundwater movement.



**CHAPTER II**  
**GEOLOGIC MAP OF THE DESERET PEAK EAST 7.5'**  
**QUADRANGLE, TOOELE COUNTY, UTAH**

**ABSTRACT**

The Stansbury Range consists of Paleozoic rocks folded into the north-south trending Deseret anticline. Ordovician, Silurian, and Devonian rocks are absent in the central part of the range, where basal Mississippian units rest unconformably on Cambrian beds. Paleozoic uplift, Mesozoic contraction, and Cenozoic extension have created a series of broad folds, large thrust faults, and a variety of normal faults within the range and at range-basin margin.

Detailed mapping of the quadrangle yields new interpretations on stratigraphy of the Oquirrh Basin, fault and fold geometry, identification of additional structures, and clarification on existing structures. This study sheds light upon the structural and tectonic history of this part of the Basin and Range.

Studies show that the area is dominated by bedrock springs, with the presence of abundant and thick Quaternary deposits unrelated to Pleistocene glaciation, burying drainages and mantling hillslopes. The influence of bedrock on groundwater flow paths and stream baseflow is suggested by local anecdotal reports that high snowfall in the Deseret Peak region generates high discharge ten miles south in Clover Creek, though they are not in the same drainage basin.



## INTRODUCTION

The Deseret Peak East 7.5' quadrangle is located south of the Great Salt Lake and 15 miles (24 km) southwest of the town of Tooele, Utah (Figure 1). The southern boundary of the quadrangle is approximately 1.3 mile (2 km) north of State Road 199 (SR-199) between Rush Valley and Skull Valley. The western boundary runs along the high crest of the Stansbury Range with Deseret Peak (11,031 ft; 3,362 m) at the northwest corner. The eastern margin extends to the range front of Tooele Valley to the north, with Rush Valley to the south. The area has a minimum elevation of 5,303 ft (1,616 m).

The range rises south of the Great Salt Lake, trends southward for approximately 28 mi (45 km), has a maximum width of approximately 10 mi (16 km), and ends near Johnson Pass on SR-199 (Figure 1). The range is bordered on the north by Interstate Highway 80 (I-80) and on the northeast by SR-138. The principal access to the quadrangle is from a paved road (Mormon Trail) from Grantsville to SR-199 which parallels the east margin of the range and gives access to South Willow, Box Elder, and East Hickman Canyons. Several private dirt roads, used mainly for cattle and farming access, extend westward to the base of the eastern slopes of the range. East Hickman and Box Elder Canyons provide access to the central valley. South Willow Canyon provides access to the northern portion of the quadrangle, cutting perpendicular to Paleozoic stratigraphy, and ending at the trailhead for Deseret Peak and North and South Willow Lakes. State Highway 199 cuts across the south end of the range at Johnson Pass, providing access to Big Hollow. Four-wheeled drive is required along the Stansbury

Trail to reach the southern boundary of the quadrangle. The central Stansbury Trail runs the entire length of the quadrangle. The southern half of the trail is accessible to four-wheelers, with the northern half as a wide single-track trail for horses and bikes. A paved road between I-80 and SR-199 affords restricted access to the west side of the range. Only Deadmans Canyon and Barlow Hollow in the southwestern corner provide 4 wheeler access from Skull Valley. Other access is very limited through the Skull Valley Indian Reservation and requires several miles of hiking in very steep terrain.

The majority of the area lies within the Wasatch-Cache National Forest with only South Willow Canyon containing campground facilities, trailhead access, and a ranger station. Most of the western half of the quadrangle lies within the boundaries of the Deseret Peak Wilderness area, established in 1984. Many canyons and most of the range fronts are privately owned for cattle grazing. There is also a planned subdivision located in section 28 T.4S., R.6W., Salt Lake Base and Meridian.

The area lies within the eastern Basin and Range Province, about 35 miles (56 km) west of the Wasatch Front and the eastern transitional boundary of the Basin and Range Province into the Middle Rocky Mountains Province (Stokes, 1986). From east to west, the Oquirrh, Stansbury, and Cedar Mountains become narrower and lower in average elevation, and are in line with a westward projection of the Uinta Mountains axis and the high central part of the Wasatch Range. This same axis is marked by the Traverse Mountains connecting the Wasatch Range and Oquirrh Mountains, and also South Mountain between the Oquirrh and Stansbury Mountains (Stokes, 1986).

The Stansbury Mountains encompass formations of the Early and Late Paleozoic periods: Cambrian limestone, dolomite, and quartzite are exposed to the west, and are

unconformably overlain by Mississippian limestone and dolomite in the central area. Ordovician, Silurian, and Devonian units in the southwest are progressively pinched out by the Late Devonian unconformity. The Central Range Fault separates Permian-Pennsylvanian Oquirrh Formation to the east from the Mississippian limestones and dolomites. The Stansbury Mountains and Stansbury Island are part of a long, narrow fault block in which Paleozoic rocks, in addition to being faulted upward, comprise the Deseret Anticline.

### **PREVIOUS GEOLOGIC WORK**

Many workers have contributed to the understanding of the geology of the Stansbury Mountains. Lambert (1941) studied the structure and the stratigraphy of the southern Stansbury Range, providing a brief study of the location and extent of units and regional structural events, in the vicinity of Deseret Peak and Willow Creek. Teichert (1958) worked on biostratigraphy in the southern Stansbury Mountains giving stratigraphic correlation with surrounding areas and information on several unconformities and structural features of the area. Jordan and Allmendinger (1979) described in detail the upper Permian and lower Triassic stratigraphy within the Martin Fork syncline in the east-central part of the range. Studies of Armin and Moore (1981) focused on the stratigraphy and depositional environments of the Pennsylvanian/Permian Oquirrh Group and interpreted the structure of two areas in the Stansbury and southern Onaqui Mountains. Hintze (1988) compiled the above information into a typical stratigraphic column for the Stansbury Mountains.



Arnold (1956) and Helm (1994) conducted studies of the northern Stansbury Range in the vicinity of Flux and Dolomite (Figure 1). Helm (1994) provided a detailed quantitative report of the Stansbury Fault that bounds the Stansbury Mountains on the west, finding that most recent movement on the fault was post-Lake Bonneville. Helm (1994) also examined the effect of crustal structure on Cenozoic faulting patterns, showing times of rapid tectonic subsidence at several locations that correspond closely to late Neoproterozoic rifting (~540 Ma), early deformation in the Ancestral Rocky Mountains (360 Ma), and the development of the Oquirrh basin (320 Ma).

Rigby (1958) provides a thorough discussion of the late Devonian unconformity in the Stansbury Mountains and surrounding region and its tectonic implications. He documented early and mid-Paleozoic disturbances in the Stansbury Range. Rigby (1958) notes that the range also provides a relatively complete Cenozoic history of the area. He summarized the tectonic history of the Stansbury Mountains in terms of two main periods of uplift and folding. The "Stansbury uplift" occurred during the Late Devonian Antler orogeny (Burchfiel and Royden, 1991) and resulted in the formation of the Stansbury anticline and a regional unconformity. The second period of tectonism, according to Rigby (1959), was related to the Laramide orogeny which "broadly arched the range along the trend of the Devonian uplift" concurrent with reverse faulting and "overfolding of the range." This second deformation event is now termed the Sevier orogeny (Armstrong, 1968).

The conclusions of Tooker and Roberts (1971) contrast sharply with those of Rigby (1959) concerning the timing relationships of folding and faulting in the area and the number of reverse or thrust faults exposed in the range. Tooker and Roberts (1971)

and Tooker (1983) provided structural interpretations of the area and discussed the regional significance and correlation of multiple thrusts in the area and interpret four imbricate thrust faults within and bounding the range, including one along the Late Devonian unconformity. They also proposed that the lower Cambrian Tintic Quartzite is present due to folding and ramping up along the "Timpie thrust" during the Sevier orogeny, not during the Devonian Stansbury uplift or later Laramide tectonic events.

The nature of the contact between Early Devonian and older rocks and later Devonian and younger rocks is controversial. Rigby (1958) interprets this contact to be an unconformity, where as Tooker and Roberts (1971) suggest that it is a westward-dipping thrust fault. Both suggest that exposures in the study area are not sufficient to determine which of these hypotheses is correct.

## STRATIGRAPHY

Units exposed in the Deseret Peak East quadrangle consist of over 35,000 ft (11,000 m) of Cambrian through Triassic rocks. Bedrock, from the earliest Cambrian Tintic Quartzite to the Pennsylvanian-Permian Bingham Mine Formation of the Oquirrh Group are well exposed in the Stansbury Range. Early Cambrian rocks consist of the Tintic Quartzite. Middle Cambrian through Late Devonian strata is dominated by limestones and dolostones which were deposited in the Cordilleran miogeocline (Hintze, 1988). Devonian rocks consist of sandy limestones, thick dolostone formations, and quartzite beds of the Stansbury Formation. Mississippian rocks are primarily limestones and interbedded shales. The Pennsylvanian Oquirrh Group is a thick sequence of sediments deposited in the Oquirrh Basin during the Pennsylvanian and Permian time

(Bissell, 1962). Triassic rocks are only exposed in the northeast section of the quadrangle and are at times poorly exposed. A list of fossils found within the map boundaries can be found in the Appendix. Nomenclature for the Paleozoic rocks follows that of most previous workers in the area.

## **Cambrian**

Cambrian strata dominate the western slope and high crest of the Stansbury Range composed of cliff-forming quartzites and ledge-forming limestones and dolomites (Plate 1). Several small outcrops of unknown age of quartzite, limestone, and dolomite are present between the main range and the Tooele and Rush Valleys to the east and are thus labeled Cambrian through Mississippian undefined (€Mu).

### **Tintic Quartzite (€t)**

The Tintic Quartzite represents the oldest unit exposed in the quadrangle and is well exposed along the high crest of the range where it forms the hinge zone and back-limb of the Deseret anticline for nearly the entire length of the range. The lowermost part is a light-pink, brown and maroon quartzite-clast conglomerate. The majority of the unit is thin to thick-bedded, light gray to light tan quartzite, commonly weathered reddish-brown with hematite staining. The uppermost section is a reddish-brown, medium to thick-bedded, medium to coarse-grained pebbly quartzite.

The unit correlates with the Brigham, Tintic, and Prospect Mountain Quartzites of surrounding areas. The base of the unit is not exposed. Sorensen (1982a) provides an approximate thickness of 4,200 ft (1,280 m) of Tintic Quartzite for the Stansbury Range.



Within the boundaries of the map area, the thickness is estimated to be approximately 2,800 ft (853 m).

### **Ophir Group (€o)**

The Ophir Group is found in the northern, western and south-central parts of the Stansbury Mountains. The lower section consists of brown-tan weathering, calcareous sandstone and sandy blue limestone underlain by dark gray sandstone and shale. The upper section of the Ophir Group consists of dark gray to light green calcareous shale and siltstone with lenses and partings of black limestone. This overlies a thick sequence of interbedded limestone and shale. The Ophir Group correlates with the Ophir Formation in the Tintic District, Wasatch Range, and surrounding areas. The Group is correlated to the Ophir Group used by Cohenour (1957) within the Sheeprock Mountains, and to rocks of the Pioche and Condor Formations of Olsen (1956). Thickness of the Ophir Group in the study area varies from 800 ft (244 m) to 1,220 ft (372 m).

### **Teutonic Limestone (€te)**

The Teutonic Limestone is exposed at the northern and southern ends of the range. The lower part of the formation is exposed at the southern end of the mountains along both sides of Dry Canyon and parallels the upper portion of Indian Hickman Canyon. The Teutonic Limestone consists of thick- to medium-bedded argillaceous limestone with silty partings and blue gray limestone with thin silty partings interbedded with olive to brown green shale. The Teutonic Limestone conformably overlies the Ophir Group. Thickness of the formation in the study area varies from 0-410 ft (125 m).

### **Cole Canyon Dolomite and Opex Formation (Ec)**

These formations are exposed from the ridge between Indian Hickman and East Hickman Canyons in the southwestern part of T.4 S., R.7 W., and southeastward across Dry Canyon and Spring Canyon to Barlow Hollow in Section 22. These units are combined for mapping purposes.

The Cole Canyon Dolomite is an irregularly laminated dolomite. Alternating light and dark gray bands make it a distinctive unit. The Cole Canyon Dolomite is conformably overlain by the Opex Formation.

The Opex Formation includes the lower carbonates and clastic units of the Upper Cambrian rocks in the Stansbury Mountains. The lower member consists of dark gray to black, ledge-forming dolomite. The upper member has distinctively thin beds and is argillaceous. The Cole Canyon Dolomite and Opex Formation are approximately 0-460 ft (140 m) thick.

### **Ajax Dolomite (Ea)**

The Ajax Dolomite is the uppermost Cambrian unit and is composed entirely of dolomite. The unit is exposed at the southern end of the range from Indian Hickman southward to Deadman Canyon. The Ajax Dolomite is characterized by a dark gray, fine- to medium- grained, ledge-forming dolomite. Black and light gray chert nodules and stringers are common. Many beds are faintly mottled medium and dark medium-gray on weathered surfaces, and medium gray to black on fresh surfaces. The Ajax Dolomite conformably overlies the Opex Formation. Thickness of the Ajax Dolomite is approximately 0-1,000 ft (305 m).



## Ordovician

### **Garden City Formation (Ogc)**

The term Garden City Formation is used for the sequence of argillaceous limestones and dolomites that overlie the ledge-forming Ajax Limestone and are overlain by the Fish Haven and Kanosh formations. A complete section is exposed beneath the Kanosh Shale at the southern end of the range in a belt of outcrops extending from the head of Dry Canyon southward to near Rock Spring.

The Garden City Formation consists of four distinct units (Rigby, 1958): 1) a basal interbedded series of cherty limestone and dolomite; 2) a well-bedded, medium-gray argillaceous limestone which weathers distinctly blue-gray and is slightly more resistant than either the unit above or below; 3) an interbedded evenly bedded argillaceous limestone and shale or shaly siltstone. The formation is usually medium gray to light gray with argillaceous beds often dark green to dark-brown; and 4) the very cherty and sandy limestone which correlates with the Upper Cherty Member of the Garden City Formation as described by Ross (1951). Teichert (1958) found the thickness to be approximately 1,300 ft (400 m) along the ridge south of Dry Canyon. Thickness within the study area varies from 0 to 1,300 ft (400 m).

### **Kanosh Shale (Oks)**

The Kanosh Shale is exposed in the southern and western part of the Stansbury Mountains. The unit consists of dark blue and green to black, fissile, micaceous shales, interbedded with siltstone, sandstone, and quartzites that weather rusty orange-brown. Limestone and dolomite interbedded with the argillites are commonly black to very dark

gray, very argillaceous and thin-bedded. This unit thins north and northeastward beneath the overlying unconformity at the base of the Fish Haven Formation until it is removed by pre-Fish Haven erosion in the vicinity of Dry Canyon. In the southern part of the study area, the formation is approximately 0-260 ft (80 m).

### **Fish Haven Dolomite (Ofh)**

The Fish Haven Dolomite is exposed at the south part of the range at the head of Deadman and Dry Canyons where it is removed by Devonian erosion. The Fish Haven Dolomite is a thick- to thin-bedded, medium crystalline, dark and light gray dolomite, and is fossiliferous in the lower half. The base of the formation is easily established in the southern and western exposures at the top of the black graptolitic shales of the Kanosh Shale. The top of the formation is not easily placed, for the overlying Laketown dolomite does not differ noticeably or thoroughly in all outcrops from the Fish Haven. The upper contact of the Fish Haven Dolomite is placed between a predominantly dark gray dolomite and an overlying medium to light gray dolomite. This horizon was selected for ease in mapping and only approximates the Ordovician-Silurian boundary. The thickness of the unit is found to be approximately 0-260 ft (80 m).

### **Silurian**

The Laketown Dolomite (SlT) includes as much of the Silurian as identifiable and separable from the underlying Fish Haven Dolomite and the overlying Sevy Dolomite. The boundary between the Fish Haven and Laketown Dolomites is roughly approximated as described above. The unit consists of light to medium gray to dark blue-gray, thin-to-

medium bedded, coarse-to-medium crystalline dolomite, with common chert lenses. A complete section is exposed at the southern end of the range where the formation crops out from the head of Dry Canyon southward along the western face of Vickory Mountain to the Johnson Pass road. The thickness of the unit is approximately 0-590 ft (180 m).

### **Devonian**

The nature of the contact between Early Devonian and older rocks and later Devonian and younger rocks is controversial. Rigby (1958) interprets this contact to be an unconformity, whereas Tooker and Roberts (1971) suggest that it is a westward-dipping thrust fault. Both suggest that exposures in the study area are not sufficient to determine which of these hypotheses is correct.

### **Sevy and Simonson Dolomite (Dss)**

The Sevy and Simonson Dolomite extend northward along the west face of Vickory Mountain to the headwaters of Spring Creek where it is removed by an unconformity. The Sevy Dolomite gradationally overlies the Silurian Laketown Dolomite. The Sevy Dolomite is light gray on fresh surfaces, weathering to white, and consists of a microcrystalline, thin-to-medium bedded dolomite. Sevy Dolomite of the Stansbury Range correlates with the basal parts of the water Canyon Formation to the north and northeast. Sevy lithology has been recognized by several workers in the Tintic District within the Bluebell Dolomite and is correlated with part of that formation. The formation is missing in the Oquirrh and Wasatch Ranges to the east. The Sevy Dolomite is found to be approximately 0-75 ft (23 m) thick.



The Simonson Dolomite is mapped with the Sevy Dolomite because of the relative thickness of the two units. The Simonson Dolomite is interbedded dark gray, medium crystalline, and lighter gray, coarse crystalline, sandy dolomite. The Simonson Dolomite has not been preserved below the Late Devonian unconformity in other areas to the north and east. Rigby (1958) suggests that the Simonson Dolomite is not present in the range and that even those rocks provisionally termed Simonson should be included as a lower member of the Stansbury Formation. The top of the formation has been arbitrarily chosen to be the base of the lowest conglomerate unit of the Stansbury Formation. The Simonson Dolomite is approximately 240 ft (73 m) thick near Rock Springs at the southern end of the range.

#### **Stansbury Formation and Pinyon Peak Formation (Dps)**

The Stansbury Formation, as defined by Stokes and Arnold (1958), overlies the pronounced Late Devonian unconformity in the area and includes the clastic section that underlies the Pinyon Peak Formation. Teichert (1958) recognized the Upper Devonian strata in the southern end of the range and combined them on his map and in his discussion. The formations are exposed along the western face of Vickory Mountain at the southern end of the range from the head of Indian Hickman Canyon to Rock Springs. The Stansbury Formation contains poorly sorted conglomerates with subrounded clasts of dolomite and quartzite typically ranging from 1-20 cm in diameter.

The Pinyon Peak Formation consists of fine crystalline argillaceous dolomite. The unit also consists of a medium bedded, light tan-brown quartzite weathering rusty tan-brown; dark gray medium gray and tan microcrystalline limestone; and light tan-gray,

weathered rusty, commonly calcareous sandstone. The thickness of the unit ranges from 0-400 ft (122 m).

## **Mississippian**

### **Gardison Limestone (Mg)**

The Gardison Limestone is exposed in a continuous outcrop along the western side of the range. The Gardison Limestone consists of thin-to-medium bedded, blue-gray weathering, fossiliferous limestone underlain by thick bedded, dark gray-to-black dolomite, with brown weathering. Black chert nodules are common throughout the section. The lower contact of the Gardison Limestone is unconformable where it overlies Upper Devonian to Lower Cambrian rocks. The Gardison Limestone is overturned and is unconformable with the Lower Cambrian Ophir Group in the vicinity of South Willow Canyon. The Gardison Limestone is probably equivalent to the basal limestone of the Madison limestone in the Promontory, Lakeside, and adjacent ranges. Thickness of the Gardison Limestone ranges from 550-900 ft (168-274 m).

### **Pine Canyon Formation (Mpc)**

The Pine Canyon Formation rests unconformably on the upper fossiliferous limestones of the Gardison Dolomite. The Pine Canyon Formation is present along the eastern flank of the entire range to the head of White Pine Fork and along the western slope of Vickory Mountain near Devils Gate Narrows on the Johnson Pass Road. The lower part of the formation consists of dark gray limestone, interbedded in one to three-inch units with black chert. Clastic sediments with interbedded limestones characterize

the middle of the unit. A weathered reddish- yellow-brown color are characteristic of the siltstone and sandstone beds at the southern end of the range. The Pine Canyon Formation is conformable with the overlying Humbug Formation. The lower member correlates with the cherty limestone at the top of the Madison Group in the Tintic District and Oquirrh Range. The remainder of the formation is directly equivalent to the Deseret Limestone of the surrounding area. The thickness of the unit varies from 200-950 ft (50-290 m).

### **Humbug Formation (Mh)**

The Humbug Formation is located along the eastern side of the range in a nearly continuous outcrop exposed within the forelimb of the Deseret Anticline. Local outcrops of the formation might also occur in small isolated hills at the eastern edge of the map between South Willow and East Hickman Canyons. The unit consists of thin-bedded calcareous sandstone, containing detrital fossil fragments, interbedded with thin-bedded, light gray-blue weathering limestone and argillaceous limestone, and minor thin-bedded quartzite. The contacts of the Humbug Formation are gradational, and have been arbitrarily placed by Rigby (1958) at the base of the lowest sandstone bed, and at the top of the highest sandstone bed where sandstone is abundant in the Upper Mississippian section. The thickness of the Humbug Formation is found to be approximately 750 ft (229 m).

### **Great Blue Limestone (Mgb)**

The Great Blue Limestone forms the first steep escarpments west of the Central Range Fault, where the unit is typically overturned. The lower contact with the Humbug



Formation is conformable. The Great Blue Limestone is commonly medium-to-thick bedded, medium gray to dark blue-gray, weathering dark-to-light gray, fine-to-medium crystalline limestone, with intercalated sandstone. The limestone typically contains numerous corals, bryozoans and other fossils in a very fine-grained to microcrystalline matrix. Silty limestone weathers tan-brown. Dark brown-weathering chert occurs locally in networks and stringers within limestone beds. The unit grades upwards to thin-bedded shaly limestone near the gradational contact with the overlying Manning Canyon Shale. The Great Blue Limestone is approximately 1210 ft (370 m) thick.

The Long Trail Shale member of the Great Blue Limestone (Mgb-lt) can easily be traced in the field by prominent slope zones found in the upper third of the Great Blue Limestone. The unit is commonly dark green, calcareous, and contains a few thin interbedded arenites. This unit may also facilitate faulting of the Great Blue Limestone throughout the range. The Long Trail Shale has been correlated with that in the Oquirrh Mountains, even though here the shale is near the top of the formation and there it is near the base (Rigby, 1958). The shale and quartzite member of the Great Blue of the East Tintic Mountains is recognized near the southern end of the Oquirrh Range, but apparently pinches out before it reaches Ophir Canyon in the central part of the Oquirrh Range (Bissell, 1962). The thickness of the unit ranges from 0-80 ft (0-25 m).

### **Manning Canyon Shale (Mmc)**

The boundary between the Mississippian and Pennsylvanian rocks is not precisely known, but is believed to be near the top of the formation. The Manning Canyon Shale is not well exposed, but is easily distinguished in the field by its characteristic small black

shale chips and low topographic expression. The formation consists of black to olive-brown siltstone and shale, dark carbonaceous limestone, and hematite-stained quartzite and sandstone. The lower contact with the overturned Great Blue Limestone is conformable. The Manning Canyon Shale is in fault contact with the overlying Oquirrh Group throughout the map area. The unit ranges in thickness from 395-1315 ft (120-400 m) from north to south.

## **Pennsylvanian**

### **Oquirrh Group**

The Oquirrh Group is defined by an unusually thick accumulation of Upper Mississippian-Lower Permian marine sedimentary rocks in northwestern Utah and southwestern Idaho (Roberts et al., 1965). The depositional history and the paleoenvironmental framework of some of the rocks of the Oquirrh Basin have been interpreted by Chamberlain and Clark (1973), who used trace fossils to delineate water depths; and by Larson and Clark (1978), who interpreted Late Pennsylvanian and Early Permian paleoenvironments from a study of resedimented carbonate conglomerates. Jordan (1978) and Jordan and Douglas (1980) studied the paleogeography and structural development of the Oquirrh basin and regional distribution of paleoenvironments represented in upper Oquirrh rocks.

Three lithologic units have been recognized in the Bingham sequence (Upper Oquirrh) in the Oquirrh Mountains by Tooker and Roberts (1970): a lower clastic limestone (West Canyon Limestone), a middle unit consisting of interbedded limestone



and sandstone (Butterfield Peaks Formation), and an upper unit composed mainly of sandstone and quartzite (Bingham Mine Formation).

The Lower Oquirrh (Lower Pennsylvanian) is composed mainly of dark, dusky blue-weathering, medium-bedded, very fossiliferous limestone with brown- to dark brown weathering siltstone and sandstone. The limestone typically contains abundant crinoids, brachiopods, and corals in the bioclastic and micritic matrix. It was recognized in the Onaqui Mountains by Moore and Sorenson (1979) and may be correlative with the West Canyon Limestone in the southern Oquirrh Mountains (Tooker and Roberts, 1970).

### **Butterfield Peaks Formation (Pobp)**

The formation thins northward in the Stansbury Mountains and wedges out where the unit strikes into the fault separating it from the Manning Canyon shale. Lithology consists of monotonously interbedded, ledge-forming limestone and slope-forming sandstone. Massive biostromal limestone sequences are more prevalent near the contact with the Manning Canyon Shale, and interbedded quartzite and sandstone sequences are thicker toward the top of the unit. Quartzite and calcareous sandstone and siltstone are the most voluminous rock types, comprising an estimated 50 to 75% of the formation. These rocks are typically light grayish brown, and are composed of very well sorted, silt to medium sand-sized quartz and feldspar grains. Cross-stratification, horizontal lamination, and scouring at the bases of some beds have been observed in some thin- to medium-bedded sandstones. Bedding contacts are generally planar.

Similar Middle Pennsylvanian rocks in the Oquirrh Mountains, Cedar Mountains, and Grassy Mountains suggest that the topography was virtually flat. The great thickness

of the Butterfield Peaks Formation in the Stansbury and Onaqui Mountains apparently is due to pronounced subsidence at a rate roughly equal to that of sediment accumulation (Jordan and Douglas, 1980). The total thickness of the Butterfield Peaks Formation cannot be measured because of the discontinuity at its base. Thickness of the unit is estimated to be approximately 6,000 ft (1,830 m).

There is some disagreement as to the age of the lowest part of the Butterfield Peaks Formation in the Stansbury Mountains. Wright (1961) reported 835 ft (255 m) of Morrowan strata in his measured section at Chokecherry Spring and a thickness of about 160 ft (49 m) near Stradley Springs. Armin (1979) collected fusulinids and brachiopods of Desmoinesian and Atokan age very near the base of the Butterfield Peaks Formation in the vicinity of both Chokecherry and Stradley Springs. This implies that an interval of Morrowan strata, if present, is much thinner than suggested by Wright (1961). Fusulinids collected from the beds slightly below the upper contact of the Butterfield Peaks Formation are of probable early Missourian age (Armin, 1979). Desmoinesian-Missourian boundary presumably is located a few meters below the top of the Butterfield Peaks Formation, considered to be Atokan-Desmoinesian in age (Tooker and Roberts, 1970).

### **Bingham Mine Formation (PPobm)**

The contact between the Butterfield Peaks Formation and the overlying Bingham Mine Formation in the Stansbury Mountains apparently is conformable and is placed at the top of the highest interbedded limestone in the interbedded limestone and sandstone sequence of the Butterfield Peaks Formation. The Bingham Mine Formation is in fault

contact with the older Manning Canyon Shale near White Pine Canyon, covered by Tertiary volcanics north of Martin Fork and by Quaternary alluvium to the south.

The Bingham Mine Formation (Missourian-Wolfcampian) is a thick sequences of grayish yellow- and orangish brown-weathering, thin- to medium-bedded sandstone, siltstone, and quartzite, that contains intercalated medium gray- and bluish gray-weathering, fossiliferous limestone, and dark to light gray-weathering limestone conglomerates.

The lower member (Missourian-Virgilian) of the Bingham Mine Formation is a 4,920 ft (1,500 m) thick sequence of grayish yellow to orangish brown, calcareous sandstone and siltstone to vitreous quartzite with interbedded limestone becoming less common towards the top. Most quartzites, sandstones, and siltstones are texturally and mineralogically mature, consisting of subangular, well-sorted grains ranging from 0.02-0.20 mm in diameter, composed dominantly of quartz and subordinate microcline, orthoclase, plagioclase, and accessory minerals (Armin, 1979).

Sandstone, siltstone, and quartzite beds in the lower member commonly show internal lamination and cross-lamination with erosive contacts with underlying cross-bedded sets, but most beds are structureless at large scale. Intercalated limestones within the lower member of the Bingham Mine Formation contain abundant echinoderms, brachiopods, bryozoans, corals, and minor gastropods and phylloid algae. Communities of organisms that are known or inferred to require normal marine, shallow-shelf conditions, and also those that probably inhabited more restricted environments, are present in strata of the lower member, suggesting that sea level was fluctuating during this time, or that these are the result of the creation and destruction of restricting bars.



The upper part of the lower member was deposited in deeper marine water.

Much of it probably was deposited below wave base as indicated by the *Zoophycos* trace fossil assemblage (Seilacher, 1978) and the clastic rocks that generally are finer grained.

The upper member (Virgilian-Wolfcampian) is approximately 6,500 ft (1,980 m) thick. It is composed of quartzite, sandstone, and siltstone with subordinate limestone conglomerate and limestone. Presence of limestone conglomerate distinguishes the upper member from the lower.

Most of the post-Oquirrh Permian and Triassic rocks in the Stansbury Mountains are of shallow marine origin, indicating that shallow water conditions were restored to this area by late Wolfcampian time. The presence of algal oncolites in limestone at the base of this unit is suggestive of deposition in the low intertidal to subtidal environment (Heckel, 1972).

## **Permian**

### **Kirkman Limestone and Diamond Creek Sandstone (Pkdc)**

The Kirkman Limestone is in fault contact with the underlying Bingham Mine Formation. The Kirkman Limestone contains several lithologies which clearly distinguish it from the underlying rocks: chert stringers and nodules in quartz arenites and calcarenites; oncolitic limestone; thick bedded, relatively clean limestone; and conglomerates containing corals, brachiopods, and other shelled fauna.

The Diamond Creek Sandstone contact is not differentiated because the combination of gradational lithologies and structural complexities has made it difficult to map in the field at this location. The upper part is primarily quartz arenite, but lithology

is laterally variable and the interval is cut by high-angle faults. The principal rock types in the area are cherty, calcareous quartz arenite, which is massive to thinly, cross-bedded with tabular sets up to 8 in (20 cm) thick. The unit also contains thin interbedded chert and sandstone pebble breccia. No unfaulted section exists in the area. Combined thickness of the units is estimated to have a thickness of 490 ft (150 m).

### **Park City and Phosphoria Formations (Ppcp)**

The Park City and Phosphoria Formations are poorly exposed and covered by float from topographically higher units. These units are found in the northeast quarter of the quadrangle and are faulted in many locations (Plate 1). The unit is found to be conformable with the both underlying and overlying units. An outcrop of the formation is believed to occur on the southwest knob of bedrock in the valley. The Park City and Phosphoria Formations consist of interbedded cherty dolomite, dolomitic sandstone, quartz siltstone, bioclastic limestone, massive chert, and partially silicified oolitic phosphorite. The unit is commonly fossiliferous with bryozoans, conodonts, and brachiopods of *Thamnosia*, *Kuvelousia*, and *Peniculauris*. Combined thickness of the Park City and Phosphoria Formations is approximately 550 ft (168 m).

### **Triassic**

The Triassic units in northern Utah and southeastern Idaho were produced by interfingering marine and continental deposits (Jordan and Allmendinger, 1979). The terminology used in most of Utah was established by Boutwell (1907) in the Park City mining district in the central Wasatch Mountains. He divided the interval into a lower

unit of reddish siltstone and shale (Woodside Shale), a middle silty limestone and subordinate sandstone (Thaynes Limestone), and an upper red bed (Ankareh Formation). Corresponding units are also found in western Wyoming and easternmost southeastern Idaho. In the Stansbury Mountains, the Lower Triassic section is lithologically similar to the same part of the system found south of Salt Lake City (Jordan and Allmendinger, 1979). Triassic units are the main units in the Martin Fork syncline and anticline.

### **Woodside Shale (Tw)**

The Woodside Shale is a distinctive reddish unit that overlies the Park City/Phosphoria Formation. Calcareous siltstones, shales and very fine-grained sandstones rarely outcrop within the formation. However, the unit is easily mapped by its negative topographic expression and the occurrence of dark brownish-red talus in dark reddish soil. Thickness of the unit is approximately 100 ft (30 m).

### **Thaynes Limestone: Lower (Ttl), Upper (Ttu)**

The Thaynes Limestone is a resistant, medium-bedded, gastropod- and pelecypod-bearing limestone. The dominant lithologies are bioturbated, irregularly bedded calcareous siltstone and mudstone, pelecypod packstone, and very fine grained, locally cross-bedded quartz arenite. The unit weathers dull, medium gray, purple-brown, and brownish-yellow. The contact between upper and lower sections was placed below a single 2 ft (0.6 m) thick bed of ammonite-bearing, brownish gray weathering calcwackestone recognized by Jordan and Allmendinger (1979). The ammonites belong to the genus *Meekoceras*, a characteristic Lower Triassic fauna for the northern Utah and southern Idaho region (Mansfield, 1927; Kummel, 1954; Jordan, 1978). It is unknown if



a complete section exists within the quadrangle. The thickness of the lower member is approximately 500 ft (152 m) with the exposed thickness of the upper member is 600 ft (182 m).

## Tertiary

### Tertiary Conglomerate (Tc<sub>2</sub>)

This unit contains a pebble conglomerate with argillaceous and calcareous matrix stained reddish brown to light orange-red, with a general orientation of N5°E, 55°E measured at the Medina Flat Trailhead in South Willow Canyon (Figure 2). Clasts consist of lower Mississippian and upper Cambrian limestone and dolomite, and minor

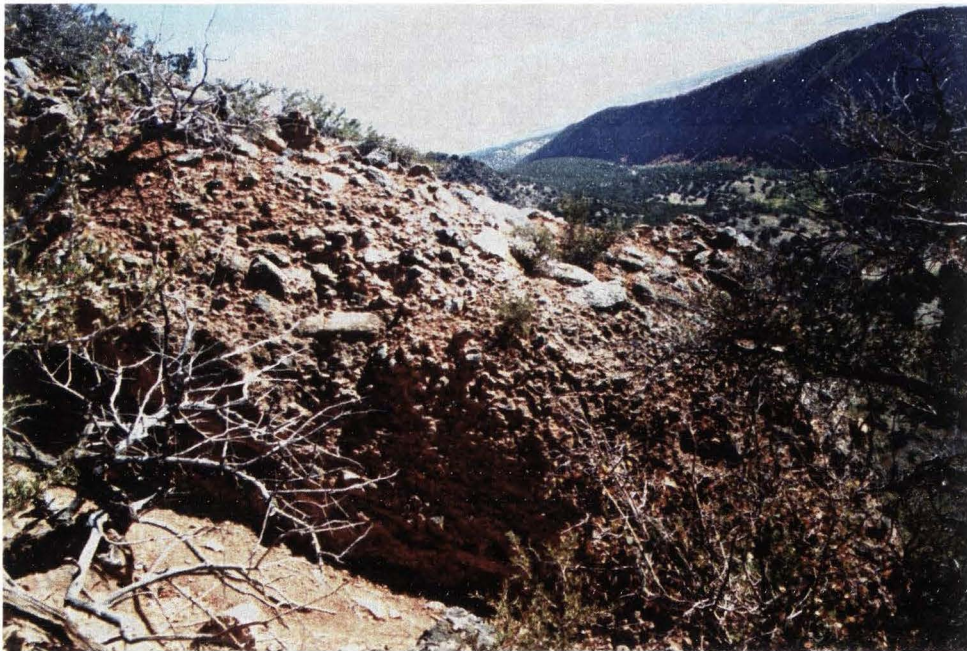


Figure 2. Tertiary Conglomerate-2 in South Willow Canyon. View is down canyon to the east. Unit is dipping away from view at ~60°.

clasts of Tintic Quartzite. Rigby (1958) applies the name North Horn(?) Formation to this unit. Although this unit might be considered time equivalent to the North Horn(?) Formation, the author has chosen not to designate it as such. The unit possibly correlates with similar red conglomerates noted by Cohenour (1957) in the Sheeprock Mountains and to a similar series of rocks in the Tintic District (Morris, 1957). The total thickness of the unit is unknown, with the exposed thickness in the study area being ~150 ft (46 m).

### **Tertiary Volcanic Rocks (Tv)**

A thick series of volcanic rocks occur in two main exposures in the quadrangle: at Mud Springs, and between White Pine Fork of Box Elder Canyon West Canyon to the

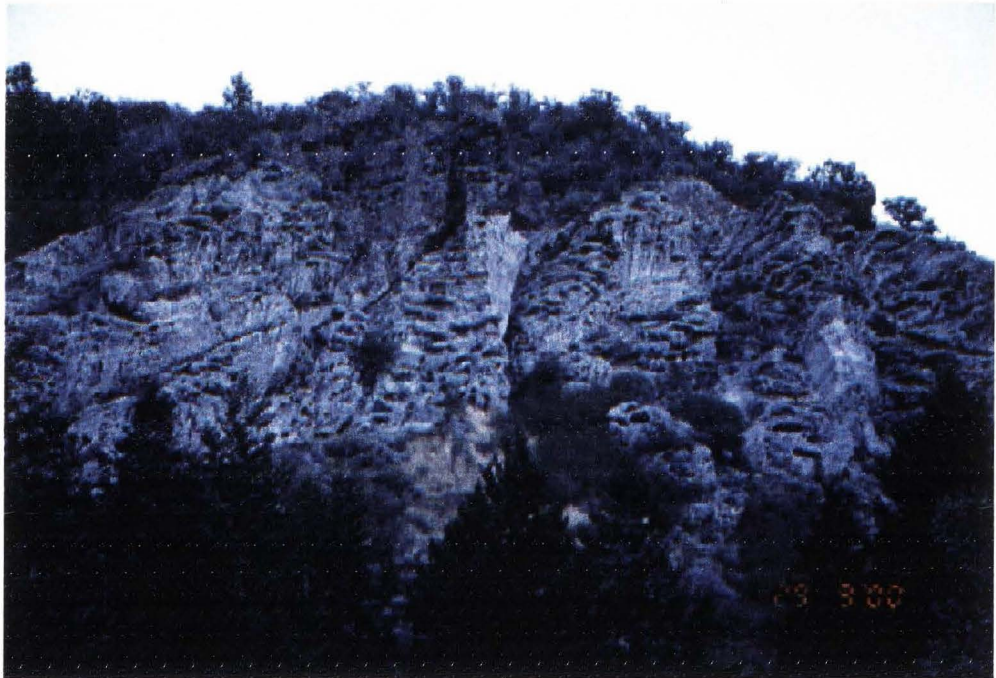


Figure 3. Tertiary volcanic cliffs in South Willow Canyon. View looking south. Down canyon to the left.



north. A well-exposed bedded series can be found in South Willow Canyon with dips ranging from 20°-30° east (Figure 3). Undifferentiated, bedded volcanic rocks consist of andesite, dacite, hornblende latite flows and breccias, and ash flow tuffs. Dark purplish brown hornblende latite comprises most of the flow rocks; white, tuffaceous beds are associated with them. K/Ar dating of biotites have yielded ages of  $39.4 \pm 0.5$  my and  $41.8 \pm 0.5$  my for volcanic rocks between North and South Willow Canyons (Moore and McKee, 1983). Volcanic flows of the Stansbury Mountains are similar to those described by Gilluly (1932) from the Oquirrh Range. They also appear similar to the latite series within the Tintic District dated at ~40 my (Morris, 1957). Thickness of the volcanic rocks varies from 0 to 1410 ft (430 m) within the study area.

Several small plugs, dikes, and sills of monzonite are found in the range. These intrusive bodies are concentrated in the central part of the mountains, from near Deseret Peak northward to the south side of Mining Canyon. Most have a finely crystalline porphyritic texture with phenocrysts of hornblende, biotite, and altered plagioclase feldspar.

The longest intrusion within the range is a sill of monzonite, which occurs near the anticlinal crest of the range from Dry Lake Fork of South Willow Canyon and extends approximately 4 miles (6.4 km) north to the head of North Willow Canyon. It locally contains minor quartz phenocrysts. The thickness of the sill varies from 50 to 75 ft (15-23 m).

### **Tertiary Conglomerate (Tc<sub>1</sub>)**

This unit is a series of volcanoclastic conglomerates located between South Willow and Box Elder Canyons. The unit is referred to by Rigby (1958) as the Salt Lake Formation, following the usage of Thomas (1946), who differentiated these rocks along the eastern margin of the Stansbury Range. This name is not used here because correlation with surrounding areas can only be made tentatively on the basis of stratigraphic and geomorphic position.

Deposits are poorly sorted, clast- to matrix-supported, angular quartzite pebbles with few cobbles and boulders, minor subangular-to-subrounded limestone and dolomite pebbles, and fine sandy lenses in a fine sandy matrix which weathers rusty-orange. For the Stansbury Range, Taylor (1992) interpreted it to be part of a middle alluvial fan complex composed primarily of sheet flood and debris-flow sieve deposits. The unit occurs in two small areas along the east-central part of the range. In South Willow Canyon, it dips approximately 30°E, and ranges in thickness from 0-1000 ft (305 m) (Figure 4). The age of the conglomerate is poorly constrained, but previous workers have suggested it is Paleocene to Eocene in the Stansbury Mountains (Sorensen, 1982a). However, Taylor (1992) suggested that it may be as old as Late Cretaceous. Clasts of surrounding volcanic lithologies incorporated in the conglomerates indicate an age of early to late Eocene or younger.

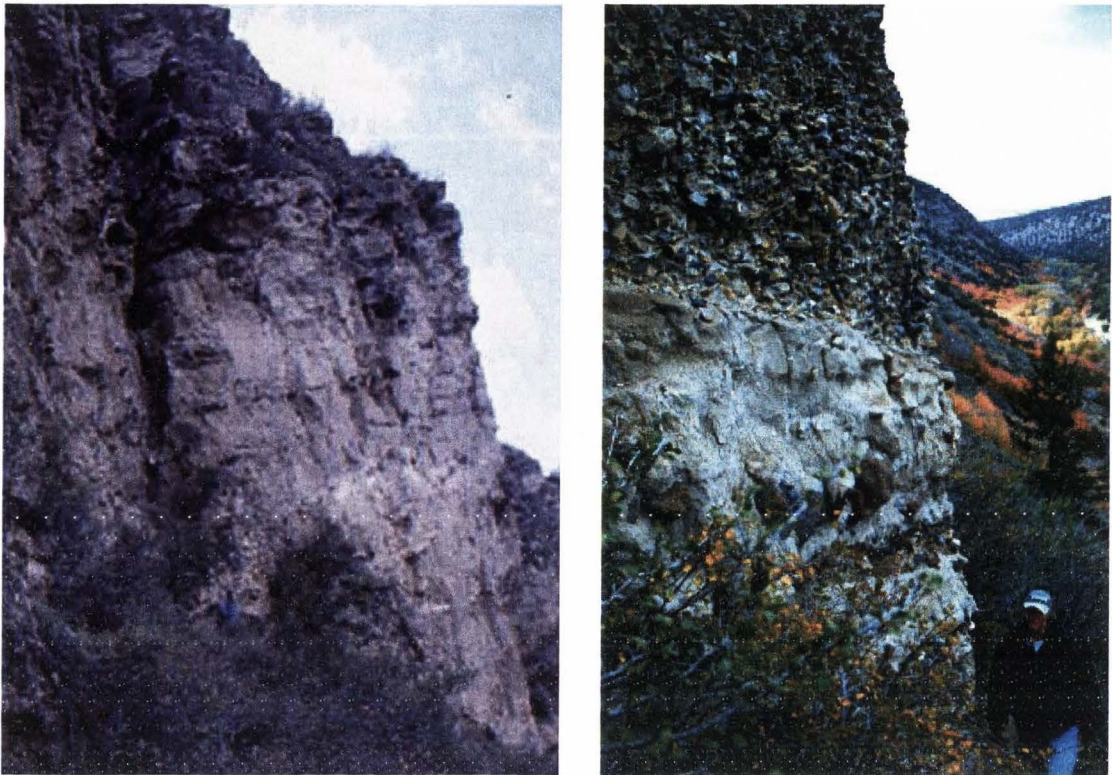


Figure 4. Tertiary Conglomerate-1 in South Willow Canyon. Left: Jim Evans in Blue as scale; view up canyon to the west. Right: Melissa Copfer as scale; view up canyon to the west.

### Quaternary

Quaternary deposits in the Deseret Peak East quadrangle consist of glacial, fluvial, and hillslope deposits. Pleistocene glacial deposits are confined to elevations above 7,800 ft in Hickman to North Willow Canyons and are in places overlain by younger colluvium. Lake Bonneville occupied much of Tooele, Rush, and Skull Valleys leaving depositional and erosional features on the mountain piedmont. With a maximum elevation of 5,300 ft, no deposits of Lake Bonneville are present within the map



boundaries, however, streams would have graded to the Bonneville and Provo shorelines potentially causing deposition of terrace and alluvial fan gravel.

### **Glacial Till (Qg)**

Pleistocene glacial till is located mainly in the headwaters of South Willow and Miners Fork Canyons. Till is matrix supported and composed of silt and sand with angular to rounded pebbles, cobbles, and boulders of Tintic Quartzite. Till of East Hickman Canyon contain clasts of lower Mississippian limestone and dolomite. The lowest set of end moraines tend to be preserved at ~7,800 ft. Bedrock outcrops in some locations acted as a buttress to the ice, trapping till and influencing moraine locations. In Dry Lake Fork of South Willow Canyon, two inset lateral moraines are present suggesting two glacial advances are preserved, or a recession and re-advance during a single glacial epoch. In addition to end moraines, a series of recessional moraines are preserved in Mining Fork and South Willow Canyons. Pronounced glacial U-shaped valleys are located in Hickman, Box Elder, South Willow, and Mining Fork Canyons. Cirques are found in South Willow and Mining Fork Canyons.

### **Terrace Gravels (Qt<sub>1,2</sub>)**

Stream terraces are prominent along Box Elder and East Hickman Canyons along the eastern side of the range. Two fill terraces occur with deposits consisting of sub-rounded to rounded sand and clast-supported gravel, bedded with thin- to thickly bedded silt, with minor cobbles.

Qt<sub>2</sub> (Pleistocene) is the oldest fill terrace and is located at the head of East Hickman Canyon, and at the junction of Abbot's Fork and White Pine Canyon in Box



Elder Canyon. It consists of areas of clast-supported pebble, cobble, and boulder gravel in a matrix of sand, silt, and minor clay, and is poorly sorted with angular clasts. The terrace grades upward to till in East Hickman Canyon. The terrace commonly has a slope of between 5-10° east, and project to the level of coalesced alluvial fans at the mouth of the canyons. The thickness of the gravel is approximately 5-50 ft (2-15 m).

Qt<sub>1</sub> (Lower Holocene to Middle Holocene) terraces are found at the junction of East Hickman Canyon and also extend up drainages in Bear Fork Canyon. Perennial and intermittent streams, debris flows and floods deposited these terraces. The terraces parallel the present drainages and are approximately 55 ft (17 m) above the modern floodplain (Qal).

#### **Alluvial Fan Deposits (Qaf<sub>2,3</sub>)**

Qaf<sub>3</sub> (Middle Pleistocene to Upper Pleistocene) is the oldest alluvium restricted to the area between Box Elder and South Willow Canyons. These deposits are poorly sorted with angular to subrounded pebble and cobble gravel, partially calcareous cemented with sands and silts. These older fans possess commonly exhibit a higher degree of drainage incision than younger alluvium. Total thickness of the unit is unknown, but thicknesses of approximately 100 ft (30 m) are observed.

Qaf<sub>2</sub> (Upper Pleistocene to Lower Holocene) is about 170 ft (52 m) above the present floodplains of the eastward drainages, and dominates the eastern piedmont of the range. This unit consists of pebble and cobble gravel, locally bouldery, in a matrix of sand, silt, and clay. Deposits are the result of intermittent streams, debris flows, and floods, and form a series of coalesced alluvial fans.

As the level of Lake Bonneville dropped, these deposits quickly became incised by streams. Rigby (1958) described the bajadas on the piedmont below South Willow and Box Elder Canyons, but interpreted the surface between Box Elder and East Hickman Canyons as a pediment, attributing its formation to erosion rather than deposition. This area appears, however, to have formed by depositional processes from older alluvial fans and varies in thickness from 20 to ~150 ft (6-45 m)

### **Terrace/Colluvial Deposits (Qt<sub>c</sub>)**

Mixed alluvial terrace and hillslope deposits are mapped at the Loop Campground in South Willow Canyon. Deposits consist of gravelly, rounded to angular silt- to cobble-sized colluvium, alluvium, and locally some talus. The deposit is mapped as mixed terrace and colluvium because of the variety of overlapping depositional processes.

### **Colluvium (Q<sub>c</sub>)**

Colluvium in the map area consists of sand to angular pebbles, cobbles, and boulders transported by hillslope processes in upper areas of drainages, with composition reflecting local bedrock from which it is derived. Unconsolidated talus and minor debris flow deposits are included. Large areas of poorly sorted sand to cobble sized sediment mantle upper portions of the Oquirrh Group, and bury the uppermost reaches of drainages. These areas facilitate infiltration and commonly produce seeps and areas of increased vegetation at the base of their slopes. Thickness of colluvium varies with location from approximately 10-100 ft (3-30 m).

### **Colluvial/Alluvial Deposits (Qac)**

Colluvial and alluvial deposits consist of poorly sorted clay, silt, sand, gravel, cobbles, and boulders, and includes reworked colluvium and till. Deposits are located in the upper areas of glaciated areas of South Willow and Miners Fork Canyons, and are coarser on steeper slopes and locally include some talus. The deposit is believed to be post glaciation (Pleistocene) with deposition continuing possibly through the Holocene. The thicknesses of these deposits are unknown.

### **Stream Alluvium (Qal)**

Undivided stream alluvium (Holocene) consists of recent stream channel sediment, terrace gravels below 20 ft (6 m), and minor alluvial fan deposits from contributing side canyons. The unit is mapped along numerous intermittent streams and consists of fine-grained to gravelly stratified sediment deposited in East Hickman, Big Hollow, Box Elder, South Willow, Welch, Deadman, Dry and Indian Hickman Canyons. Deposits include coarse- to fine-grained alluvium from smaller drainages in East Hickman and Box Elder Canyons. Thicknesses of these deposits are unknown.

## **STRUCTURAL GEOLOGY**

Paleozoic rocks in the Stansbury Mountains have been subjected to Mesozoic and early Cenozoic folding and thrust faulting, and the later Cenozoic normal faulting. The dominant structure is the north-south trending Deseret Anticline (Rigby, 1958). Bedding in these rocks dips about 45° to 60°-overturned east within the east limb of the Deseret Anticline, and 15° to 35° on the west limb of the anticline.

Due to pre-Mississippian uplift, Ordovician, Silurian, and Devonian rocks are absent in the central part of the range, where basal Mississippian rocks rest unconformably on Cambrian beds (Rigby, 1958; Wright, 1961). Paleozoic uplift, Mesozoic contraction, and Cenozoic extension have created a series of broad folds, several large thrust faults, a variety of normal faults both within the range and at the range-basin margin, and highly fractured rocks throughout the study area (Croft, 1956; Tooker, 1983; Taylor, 1992). Following folding, part of the southeast limb of the Deseret anticline was displaced by Sevier thrusting. Subsequent Basin and Range normal faults paralleled the Sevier faults and fold structures, tilting the range  $\sim 30^\circ\text{E}$ .

### **Late-Devonian Unconformity**

While most of the pre-Mississippian strata in the Stansbury Mountains were subject to of uplift during the Late Devonian, the principal area of uplift is delineated by areas where Devonian rocks are absent beneath an unconformity.

Rigby (1958) notes a regionally extensive unconformity in the Stansbury, Oquirrh, and Wasatch Mountains. In each of these ranges, upper Devonian and/or lower Mississippian strata unconformably overlie lower to upper Cambrian rocks, culminated in a broadly arching, north- northwest trending anticline. Similar stratigraphic relationships constraining the age of the Stansbury uplift are also reported to the east and the in Sheeprock Mountains (Morris and Lovering, 1961) to the south.

Map relationships (Sorenson, 1982a; Moore and Sorenson, 1979) indicate that the unconformity eliminates a maximum of 1.4 km of lower and middle Paleozoic strata in the northwestern part of the quadrangle, where lower Mississippian Gardison Limestone



overlies Cambrian Ophir Group. In the southern part of the Stansbury Mountains, the unconformity is overlain by a thin wedge of conglomerate of the Stansbury Formation, which in turn is overlain by the Upper Devonian Pinyon Peak Dolomite (Plate 4). In this vicinity, the Devonian Simonson Dolomite, underlain by the Stansbury Formation, are the youngest rocks truncated by the unconformity.

### **Deseret Peak Anticline**

The Deseret Peak Anticline is the most pronounced structural feature in the Stansbury Range. The core of the anticline is comprised of Cambrian Tintic Quartzite forming the crest of the range. The limbs in the northwestern portion of the Deseret Peak East quadrangle are nearly symmetrical and represent an exposure of over 25,000 ft (7,620 m) of strata. Stereonet analysis shows that in this location, the axis of the anticline trends N12°E. and plunges 3° to the north with an interlimb angle of 57°.

### **Tintic Valley Thrust**

The existence of the Tintic Valley thrust was initially proposed by Billingsley and Locke (1939) and Eardley (1944) to explain the structural discordance between the north-trending folds in the Stansbury Mountains and the west-northwest-trending folds at South Mountain (Figure 1). Roberts and others (1965) correlate the Tintic Valley thrust to a “comparable fault” in the Gilson Mountains and one they proposed to be concealed under Tintic Valley. The correlation of the Tintic Valley thrust which, near South Mountain with that of a “comparable fault” that remains unexposed for a distance of 60 miles (95 km) to the south, is not compelling. However, since the work of Roberts and others

(1965), several workers have included the Tintic Valley thrust in their regional structural correlations of the area, so the name Tintic Valley thrust is also adopted herein.

Between South Mountain (Oquirrh Formation) and the east slopes of Bald Mountain (Oquirrh Formation) numerous knobs of Paleozoic quartzite, dolomite and limestones are exposed (Plate 1). There is currently a question of ages of these formations. Rigby (1958) notes the occurrence of Devonian-age sandstone west of South Mountain, in close proximity to the Oquirrh Formation on South Mountain, and identified the formation as being Devonian Stansbury Formation (quartzite) and Mississippian carbonates. It is established through this work that fossils found in the westernmost outcrop indicates that it is probable Permian Park City/Phosphoria Formation, and the quartzite unit being Devonian Stansbury Formation based on sample comparison to other areas. It is necessary to place west-directed thrust fault between South Mountain and these knobs, and one between the knobs and the Pennsylvanian-Permian formations to the west (Plate 4, Section C-C'). This additional fault is interpreted to be a back thrust of the Tintic Valley Thrust.

The Oquirrh Formation in the Stansbury Mountains is located east of the Central Range Fault, and extends to the valley margin to the southeast and is fault bounded by the Martin Fork Fault to the northeast. Bedding dips in the unit range from  $30^{\circ}$  east to overturned  $30^{\circ}$  west. While it has been thought that this thick sequence of Oquirrh Formation is repeated by either folding or faulting (Teichert, 1958), extensive field studies has shown it to be continuous in section. The change in bedding orientations is due to the angle at which the sediments were transported and deposited within the basin (Section A-A'), with a single bed traceable for 1-2 miles.

### **Central Range Fault**

The Central Range fault is located in the center of the quadrangle, extending the entire length of the quadrangle. It separates Mississippian Manning Canyon Shale on the west from Pennsylvanian Butterfield Peak and Bingham Mine Formation to the east. This contact was formally termed the Broad Canyon thrust (Rigby, 1958; Moore and Sorenson, 1979; Armin and Moore 1981). The Broad Canyon thrust was first recognized in the northern Stansbury Mountains and is well exposed north of Davenport Canyon (Rigby, 1958). However, between Davenport and Box Elder Canyons, the fault has been covered with Tertiary volcanic rocks. In an attempt to continue this fault to the south, it was suggested that it run through the topographically negative central valley of Bear Fork and Big Hollow Canyons, thus explaining the angular discordance of the Manning Canyon Shale and Oquirrh Group.

Extensive field measurements and map relations indicate that the fault strikes N-S and dips between  $45^{\circ}$ - $55^{\circ}$  to the east. The name Central Range Fault is thus applied. In the vicinity of East Hickman Canyon, Quaternary terrace deposits conceal the fault. To the north, the fault is concealed under Tertiary volcanic rocks. Movement along the Central Range Fault is down to the east and was possibly the result of gravitational instability as the range was uplifted and subsequently tilted. It is uncertain if this instability was on a local scale, possibly caused by upwelling prior to Eocene volcanism, or is related to more regional Tertiary normal faulting.



### **Martin Fork Fault**

This fault is located in the northeastern quarter of the quadrangle and cuts the steeply overturned, west-dipping limb of the Martin Fork syncline and places Lower Triassic Woodside Formation against Upper Permian strata of the Bingham Mine Formation. Several young high-angle fault sets and a possible low-angle normal fault were recognized by Jordan and Allmendinger (1979) in the Martin Fork area. They also map a portion of the contact between Pennsylvania/Permian Oquirrh Formation and Permian Kirkman/Diamond Creek Formation as a west-dipping thrust fault. Fault plane measurements made during fieldwork along this portion of the fault indicate that the fault strike N5°W and dips 45° to the west. Tooker (1983) also describes this contact, and termed it the "Martin Fork Thrust."

Map analysis of the fault contact between the Oquirrh Formation and Permian and Triassic units indicate that the fault strikes N22°W and dips 30.1° to the east. This indicates an eastward dipping normal fault placing Pennsylvanian/Permian Oquirrh Formation in the footwall, and Permian and Triassic units in the hanging wall.

### **Martin Fork Syncline/Anticline**

The Martin Fork Syncline is an east-vergent, north-northwest-trending syncline termed "the Martin Fork syncline" by Tooker (1983). The syncline is also exposed in the northeastern portion of the range where it involves Ordovician to Permian age strata and trends north-northeastward (Taylor, 1992). The syncline folds Triassic Thaynes Formation with an interlimb angle of 139°. The syncline plunges 36° in the direction of 298°.



The Martin Fork syncline has an associated anticline parallel in the southern part. The Martin Fork anticline trends  $327^{\circ}$  and plunges  $20^{\circ}$  to the north. Another small syncline is also at the southern edge west of the anticline trends  $319^{\circ}$  and plunges  $27^{\circ}$  to the north and merges with the west limb of the Martin Fork Syncline.

### **Other Folds and Faults**

Minor folding and deformation events in the area include localized folding with deformation entirely within the unit and on the scale of several to tens of meters. A small anticline within the Oquirrh Group is located in Cow Canyon in the southeast corner of the quadrangle. Field measurements yield a trend of  $244^{\circ}$  plunging  $24^{\circ}$ W, and an interlimb angle of  $34^{\circ}$ . Another minor fold can be found in Abbots Fork of Box Elder Canyon. This syncline trends  $265^{\circ}$  and plunges  $40^{\circ}$  to the west with an interlimb angle of  $89^{\circ}$ .

Small faults recognized by offset of limestone beds show displacement on the order of a few meters to tens of meters. Most of these faults are oriented east-west high angle normal faults in Big Hollow, suggesting that they are small wrench faults related to the forces that folded and overturned the rocks in the Stansbury Mountains. They occur both in the Mississippian strata and Oquirrh Formation and do not appear to cut the Central Range fault.

In sec. 31, T.4.S., R.6.W., a nearly vertical fault striking  $N25^{\circ}$ W is traceable for about 1.5 km and locally forms the contact between the Butterfield Peaks Formation and the Bingham Mine Formation. The east block is downthrown relative to the west block

with unknown, but probably minor, displacement. Movement on this fault postdates overturning and folding.

Timing constraints on structural events in the Stansbury Mountains are poor. The Martin Fork syncline folds rocks as young as lower Triassic, which provides a lower age limit on thrusting. A more reliable upper age constraint for thrusting comes from K/Ar ages of biotites of  $39.4 \pm 0.5$  my and  $41.8 \pm 0.5$  my from volcanic flows and tuffaceous sedimentary rock (Moore and McKee, 1983) which unconformably overlie the Martin Fork syncline (Taylor, 1992).

Strong field evidence for a minimum of  $30^\circ$  of post-Eocene eastward tilting of the Stansbury Mountains exists in the east-central portion of the range (Taylor, 1992). Tertiary conglomerates exposed at the Medina Flat trailhead, in the lower part of South Willow Canyon, dip approximately  $55^\circ$ E. Just east of this locality, Tertiary volcanic rocks have a similar eastward dip of  $30$ - $35^\circ$ . With Tertiary deposits on a maximum  $10^\circ$ E dipping slope, a minimum of  $30^\circ$  of down to the east tilting would be required to restore the Tertiary units and the underlying Mesozoic structure to their pre-tilt orientation. This tilting is facilitated on the Stansbury Fault to the west and the East Oquirrh Fault to the east.

### **Quaternary History**

Episodes of glaciation occurred from the Pleistocene Epoch (1.8 million-10,000 years ago) to the Holocene Epoch (fewer than 10,000 years ago). Recent episodes elsewhere in the intermountain west include the Bull Lake glaciation, which began about 150,000 years ago, and the Pinedale glaciation that probably peaked 15,000-20,000 years

ago (Pierce, 1979). Pleistocene glaciation left its mark in the crest of the Stansbury Mountains. For example, Mill Fork, Dry Lake Fork, and Pockets Fork, head in well-defined cirques on the northern and eastern slopes of Deseret Peak and continue as U-shaped troughs. The ice is thought to have had a maximum depth of approximately 600 ft in the upper reaches of the valley, diminishing to only two or three hundred feet midway along the glacier. Ice reached down to 7,100 ft near the switch-backs on the road immediately below the Loop Campground in South Willow Canyon, where the terminal moraine is exposed in the road cut and along the valley wall near the Silver Drum Mine. Well-defined lateral moraines are preserved near the junction of Mill and Dry Lake Forks (Figure 5).

Lake Bonneville sediment dominates the basin floors, and was deposited between about 28,000 and 13,000 years ago. Although Lake Bonneville deposits are not located

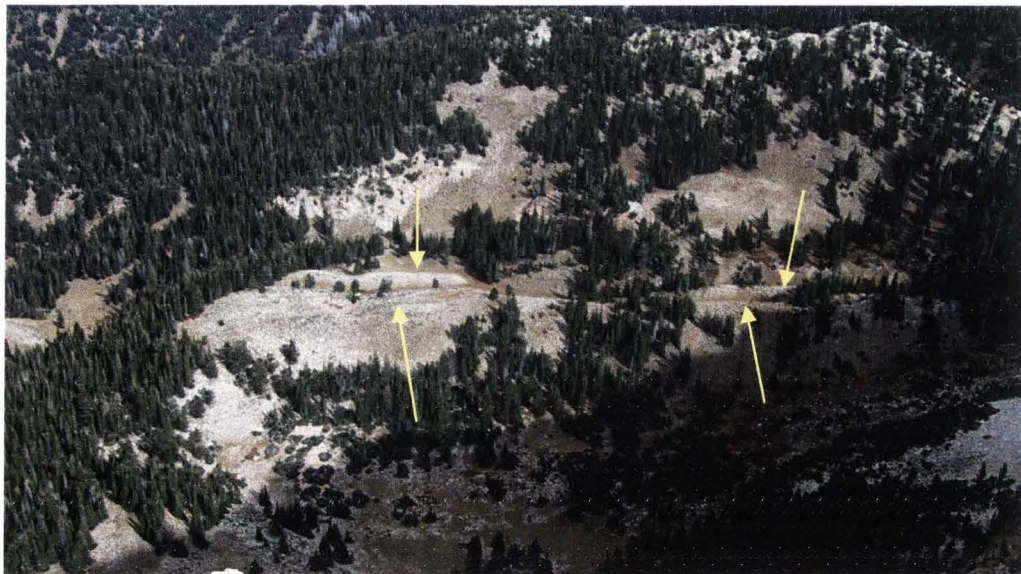


Figure 5. Two lateral moraines (indicated with arrows) in Dry Lake Fork of South Willow Canyon. Axis of the valley is down to the left.



within the quadrangle, the lake levels probably did affect streams upslope. At the same time as Lake Bonneville, glaciers were active in the crest of the range and the rivers draining into the lake adjusted to higher base level and greater sediment load develop the various terraces now seen in South Willow, Box Elder, and East Hickman Canyons. These eroded sediments formed broad pediments and large aprons of alluvium built from the mountain base into the valleys on both sides of the range.

### **ECONOMIC GEOLOGY**

Most of the mines and prospects in or near the Deseret Peak East quadrangle occur within a narrow north-trending zone bordered on the west by the Late Devonian unconformity and on the east by the Central Range Fault. All of the workings in or near the quadrangle are abandoned and caved in or covered, and all are inactive. The nearest active operations are approximately 10 miles (17 km) north near Flux, Utah, where limestone and dolomite are quarried as industrial minerals. The Kennecott Copper Mine located 20 miles (35 km) east in the Oquirrh Mountains. Several small test pits, adits, and shafts are located within the quadrangle (Plate 3).

The U.S. Bureau of Mines has examined the mines and prospects in and near the roadless area (Sorenson and Kness, 1982). Results of fire-assay and spectrographic analyses suggest that any near-surface deposits present are small and low grade (Table 1). Mines and prospects consist of small low-grade subeconomic deposits of copper, lead, and silver bearing minerals, and are identified as having a low to moderate potential for copper, lead, and silver mineralization.



TABLE 1. RESULTS OF FIRE-ASSAY AND SPECTROGRAPHIC ANALYSES FOR SAMPLES COLLECTED WITHIN THE STANSBURY ROADLESS AREA\*

Metal	No. samples	Grade	
		High	Average
Copper	73	1%	0.08%
Gold	3	0.04 oz/ton	0.018 oz/ton
Lead	70	13%	0.52%
Silver	69	7.4 oz/ton	0.6 oz/ton
Zinc	18	7.50%	0.93%

\*(Sorenson, 1982b)

Limestone and dolomite are the principal nonmetallic resources. These commodities have been quarried for a number of years at several sites near Flux on State Highway 138. The Great Blue and Deseret Limestones are the best sources for limestone and dolomite, respectively. An extensive program of sampling and testing is needed in order to evaluate this industrial mineral resource. There is no evidence of current or past quarrying operations within the area.

### **Mining Fork of South Willow Canyon**

The major workings in Mining Fork Canyon include the Metal Queen, Third Term, and Stansbury(?) mines and lie just north of the quadrangle boundary in the North Willow Canyon quadrangle. Lesser workings include eight adits ranging in length from 9 to 62 ft (3.3-18.8 m), three caved adits, and seven pits (Sorenson, 1982b).

### **South Willow Canyon**

The Silver Drum mine consists of a flooded lower adit and an upper 195-ft (59.5 m) adit. It is the only mine in South Willow Canyon. Within the mine, lenses and pods

of soft granular pyrite are concentrated in north-northeast-trending shear zones in fine-grained gray quartz sandstone. Assay results of five samples from the Silver Drum upper adit indicate one sample with 0.2 oz/ton silver. Spectrographic analyses of three samples indicate a range of 0.001 to 0.003% copper and a range of 0.01 to 0.02% lead (Sorenson, 1982b).

### **Bear Fork of East Hickman Canyon**

Workings consist of three caved adits, an 11-ft (3.3 m) adit, and a 24-ft (7.3 m) shaft within the Gardison Limestone near the Cambrian-Mississippian unconformity. Spectrographic analysis of four samples detected a maximum of 0.02% copper and 0.1% lead (Sorenson, 1982b).

There is little mineral potential in the bedrock units of the quadrangle. Most of the mines and prospects occur within a narrow north-trending zone, bordered on the west by the Late Devonian unconformity and on the east by the Central Range fault. All of the workings are abandoned and caved or covered, and all are inactive. Sorenson's (1982b) spectrographic analyses reports 31 elements (Table 2) have been made for heavy-mineral concentrates of stream-sediment samples collected mainly from streams that drain the Oquirrh Group, east of the fault. Gold is not reported in any of the analyses; silver is reported in one analysis at 0.7 ppm; copper has a high value of 300 ppm and a mean value of 28 ppm; and lead has a high value of 70 ppm and a mean value of 16 ppm. Examination of the analyses does not suggest the existence of any undiscovered mineral deposits (Sorenson, 1982b).

TABLE 2. GEOCHEMICAL ANALYSIS OF PANNED STREAM SEDIMENTS, DESERET PEAK EAST QUADRANGLE, TOOELE COUNTY, UTAH

Lower limits of determination are listed in parentheses. G, greater than value shown; L, detected but below limit of determination; N, not detected at level of determination. Analysts, D.F. Siems and B. Adrian (from Sorensen, 1982)

Sample	(0.05)	(0.2)	(0.05)	(0.002)	(10)	(0.5)	(200)	(10)	(10)	(20)	(1)	(10)	(20)	(5)	(10)	(5)	(20)	(5)	(20)	(5)	(10)	(100)	(5)	(10)	(100)	(100)	(10)	(50)	(10)	(200)	(10)
Number	Fe	Mg	Ca	Ti	Mn	Ag	As	Au	B	Ba	Be	Bi	Cd	Co	Cr	Cu	La	Mo	Nb	Ni	Pb	Sb	Sc	Sn	Sr	Th	V	W	Y	Zn	Zr
	%	%	%	%	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
22	10	1.5	2	1	1000	N	N	N	15	300	N	N	N	50	700	70	100	N	20	70	50	N	20	N	200	N	500	N	50	300	700
23	3	1.5	3	0.7	500	N	N	N	30	200	L	N	N	15	200	15	50	N	N	30	20	N	7	N	200	N	150	N	20	N	1000
24	3	1.5	5	0.7	500	N	N	N	100	300	L	N	N	15	300	20	50	N	N	30	20	N	7	N	150	N	200	N	30	N	1000
25	2	0.2	0.5	0.5	300	N	N	N	100	200	L	N	N	15	50	10	30	N	L	20	L	N	L	N	100	N	100	N	30	N	G1000
26	1.5	0.2	1	0.5	200	N	N	N	100	200	1	N	N	5	70	30	30	N	N	15	10	N	L	N	100	N	50	N	20	N	G1000
27	1.5	0.15	0.2	0.3	150	N	N	N	100	200	1	N	N	5	30	15	30	N	L	10	L	N	L	N	100	N	70	N	20	N	G1000
28	5	0.5	1	0.7	700	N	N	N	70	300	L	N	N	15	300	15	100	N	L	30	15	N	7	N	200	N	200	N	30	N	G1000
29	2	0.15	1	0.5	200	N	N	N	70	200	L	N	N	10	70	15	20	N	L	20	10	N	L	N	100	N	100	N	30	N	G1000
30	1.5	0.2	0.3	0.7	200	N	N	N	100	200	L	N	N	7	30	30	50	N	N	20	10	N	5	N	100	N	70	N	30	N	G1000
31	5	0.3	1	0.5	500	N	N	N	100	200	1	N	N	20	100	20	70	N	20	50	20	N	10	N	200	N	150	N	30	N	700
32	7	0.5	1	0.5	1000	0.7	N	N	150	200	2	N	N	50	200	50	50	7	20	100	70	N	15	N	150	N	150	N	50	L	500
33	2	0.2	7	0.5	200	N	N	N	70	100	L	N	N	7	30	10	30	5	L	20	15	N	L	N	150	N	70	N	20	N	G1000
34	5	1	3	1	700	N	N	N	150	150	L	N	N	20	200	30	70	N	L	50	20	N	7	15	100	N	200	N	100	N	G1000
35	1	0.15	0.2	0.5	200	N	N	N	50	200	L	N	N	7	20	15	50	N	L	15	L	N	L	N	100	N	70	N	20	N	G1000
36	2	0.2	0.7	0.7	500	N	N	N	70	200	L	N	N	15	100	15	50	N	20	20	15	N	5	N	100	N	150	N	50	N	G1000
37	1.5	0.15	0.2	0.5	200	N	N	N	70	200	L	N	N	7	50	15	30	N	L	10	L	N	L	N	100	N	100	N	20	N	G1000
38	2	0.2	0.2	0.7	300	N	N	N	100	200	N	N	N	15	70	300	100	N	L	20	10	N	5	N	100	N	150	N	30	N	G1000
39	2	1	2	0.5	300	N	N	N	50	100	L	N	N	10	70	15	50	N	N	20	20	N	5	N	150	N	100	N	30	N	1000
40	2	0.2	0.3	0.5	300	N	N	N	100	200	L	N	N	10	100	20	50	L	L	20	10	N	5	N	100	N	150	N	30	N	G1000
41	3	0.3	1.5	0.7	300	N	N	N	150	200	1	N	N	15	70	20	50	N	L	30	15	N	5	N	200	N	150	N	50	N	G1000



## WATER RESOURCES

The study area includes important headwaters for parts of Tooele, Rush, and Skull Valleys. Water resources in the region are generally limited. Only two small lakes are within the boundaries of the quadrangle: North and South Willow Lakes which contain little water during dry seasons. They are located in the northwest corner of the quadrangle, and are tarn lakes formed by Pleistocene glaciation.

South Willow Creek is the largest stream in the area, and its headwaters receive as much as 40 inches (102 cm) of precipitation annually (U.S. Weather Bureau). South Willow Creek has a drainage area of approximately 4 mi<sup>2</sup>, with an average discharge of 6.83 cfs (Table 3). East Hickman Canyon is the largest drainage in the study area, 12.8 mi<sup>2</sup>, with most of its water captured at the head of the canyon and transported by aqueduct to Rush Valley.

Sedimentary and igneous rocks and their relatively low permeability facilitate runoff. Most of the runoff is intermittent or ephemeral, occurring chiefly during spring and early summer in response to the melting snowpack. However, instantaneous peak discharges are commonly generated by summer thunderstorms.

Most of the flow of all the mountain streams that originate in the quadrangle is naturally depleted at or near those streams and canyon mouths, owing chiefly to seepage losses into permeable alluvial-fan deposits.

The principal use of streamflow that originates in the quadrangle is for irrigation in Tooele, Rush, and Skull Valleys. The irrigation is limited to small areas near the mouths of the perennial streams. Some streamflow is diverted for public supply in the



TABLE 3. SUMMARY OF DATA AT CREST-STAGE PARTIAL-RECORD GAGING STATIONS AND STREAMFLOW-GAGING STATION (SOUTH WILLOW CREEK)

<u>Site</u>	<u>Station</u>	<u>Name</u>	<u>Drainage Area (sq.mi)</u>	<u>Period of record</u>	<u>Average discharge</u>	<u>Maximum (cfs)</u>
P4	10172760	Clover Creek near Clover	6.71	1961-74	n/a	87 (8/13/1965)
P6	10172780	Hickman Creek near St. John	12.8	1961-68	n/a	18 (9/13/1963)
D5	10172800	South Willow Creek near Grantsville	4.19	1963-02	6.31-cfs (4,570 ac-ft/yr)	92 (6/8/1964)*

\* recorded by a crest gage operated from 1960-64

communities of Tooele, Grantsville, Stockton, and Rush Valley, and a small amount is used for watering of livestock. Runoff that reaches the lowermost parts of Tooele, Rush, and Skull Valley also help to support major migratory bird refuges in Tooele and Rush Valleys.

Steiger and Lowe (1997) mapped the valley's recharge and discharge areas along with water quality. Lambert and Stolp (1999) outlined the hydrology of the groundwater flow system and presented a numerical model simulating the system, using the USGS MODFLOW groundwater modeling package. Results of the model indicated that a key component of recharge to the basin-fill groundwater flow system is from subsurface inflow from consolidated-rock aquifers in the surrounding mountains and stream-channel deposits at the mouths of canyons. Chemical analyses of water from selected surface-water sources in the quadrangle are given in Table 4 (Price, 1981) and located on Plate 3. State of Utah water quality standards classify samples containing less than 500 mg/L

TABLE 4. SELECTED CHEMICAL ANALYSES OF WATER FROM MISCELLANEOUS SURFACE-WATER SOURCES

Site	C13	C14	C15	C16
Name	South Willow Creek	Hickman Creek Tributary	Morgan Canyon Tributary	Unnamed stream
Date of collection	9/21/64	9/21/64	9/21/64	9/21/64
Temperature (C)	8.5	-	-	-
Discharge est. (ft <sup>3</sup> /s)	-	0.02	0.02	0.02
Dissolved Silica (SiO <sub>2</sub> )*	7.4	11	7.8	8.9
Dissolved Calcium (Ca)	23	57	60	70
Dissolved Magnesium (Mg)	5.8	13	6.8	9
Dissolved Sodium (Na)	7.1	16	11	11
Dissolved Potassium (K)	0.6	1.3	0.8	0.7
Bicarbonate (HCO <sub>3</sub> )	89	199	202	239
Carbonate (CO <sub>3</sub> )	-	0	0	0
Dissolved Sulfate (SO <sub>4</sub> )	10	27	13	21
Dissolved Chloride (Cl)	11	27	14	15
Dissolved Flouride (F)	0.1	0.2	0.2	0.2
Dissolved Nitrate (NO <sub>3</sub> )	-	0.2	0.5	0.7
Dissolved Boron (B)	0.2	0.4	0.4	0.3
Dissolved solids (calc)	109	248	206	252
Calcium, Magnesium	81	196	178	212
Noncarbonate	8	33	12	16
Specific conductance (micromhos/cm@25°C)	192	426	376	435
Sodium-adsorption-ratio	0.3	0.5	0.4	0.3
pH*	7.7	8	7.9	7.9

\*pH: Determined during laboratory analysis (Price, 1981). Others in mg/l.

dissolved solids concentration with no water-quality standards exceeded to be of Class IA - Pristine quality. Groundwater in the surrounding valleys commonly exceeds water-quality standards and is very high in dissolved solids.

Bedrock geology plays a key role in controlling the groundwater in the study area. For example, springs in the area arise from the Manning Canyon shale in Big Hollow and East Hickman Canyon, and potentially transfer water from one topographically defined

drainage to another. Spring discharges within several of the canyons suggest that there is a strong north-to-south control, with springs on the north sides of the canyons discharging much more water than those across canyons to the south.

Within the Deseret Peak East quadrangle, 23 major springs (Plate 3) occur primarily in the Manning Canyon Shale and unconsolidated materials, indicating that the groundwater flow to the springs is through unconsolidated materials above the bedrock and that spring locations are controlled by bedrock outcrops. There are also numerous small, seasonal seeps around large areas of colluvium within the Oquirrh Formation.

### **GEOLOGIC HAZARDS**

The quadrangle is located within the Eastern Great Basin just west of the Intermountain Seismic Belt, a zone of pronounced earthquake activity extending from Montana to southwestern Utah and including the Wasatch Front (Smith and Arabasz, 1991). The two closest active faults are the East Oquirrh Fault and the Stansbury Fault.

The East Oquirrh Fault is a west-dipping normal fault located along the western side of the Oquirrh Mountains and bounds Tooele Valley on the east (Gilluly, 1932; Everitt and Kaliser, 1980; Black et al., 1999). The northern fault zone of the East Oquirrh Fault is marked by a discontinuous series of Holocene-age scarps located at the base of a steep mountain front (Olig et al., 1996). Late Pleistocene shoreline benches of Lake Bonneville are cut into the mountain front above younger Holocene fault scarps.

The Stansbury Fault bounds the western Stansbury Mountains with Skull Valley to the west (Helm, 1994). Recent large magnitude earthquakes ( $\sim M_L$  7.0) along this fault just outside of the quadrangle boundaries have occurred within historic times, the most



notable being that of 1915. A fault scarp is also located just east of the quadrangle boundary and south of the of East Hickman Canyon drainage. Solomon (1993) has interpreted it as a recently active east dipping normal fault.

Everitt and Kaliser (1980) assessed the seismic risk of the Tooele and Rush Valleys. Rock-fall deposits, landslides, and slumps may be triggered by earthquakes larger than  $M_L$  4.0. The steep, exposed cliffs of the canyons in most of the quadrangle, in addition to nearly vertical bedding planes, are susceptible to earthquake-induced mass movements. A few slumps or slides were mapped in the Deseret Peak East Quadrangle. They currently pose little threat, but may occasionally disrupt stream flows and affect downstream water supplies.

Flood hazards in the quadrangle are a result of the small, confined valleys in the Stansbury Range which act as catchment basins for snow melt and rainfall. Large runoff due to melting of snowpack in the spring, or the result of intense, short duration thunderstorms in the summer may result in flooding. Melt-induced floods and peak discharges for the Deseret Peak East quadrangle include June 1964 (~92 cfs) and May 1984 (~89 cfs).

With most of the range consisting of steep slopes and near vertical bedding, human activities such as irrigation, cutting steep slope angles into deposits susceptible to failure, and adding building loads to slopes will create future hazards for the area.



**CHAPTER III**  
**STRUCTURAL ANALYSIS OF THE DESERET PEAK EAST 7.5'**  
**QUADRANGLE, TOOELE COUNTY, UTAH**

**INTRODUCTION**

The Stansbury Range consists mainly of the north-south trending Deseret Anticline (Rigby, 1958). Due to pre-Mississippian uplift, Ordovician, Silurian, and Devonian rocks are absent in the central part of the range, where basal Mississippian rocks rest unconformably on Cambrian beds (Rigby, 1958; Wright, 1961). Paleozoic uplift, Mesozoic contraction, and Cenozoic extension have created a series of broad folds, several large thrust faults, a variety of normal faults both within the range and at the range-basin margin, and highly fractured rocks throughout the study area (Croft, 1956; Tooker, 1983; Taylor, 1992). Following folding, part of the southeast limb of the Deseret anticline was removed by Sevier thrusting. Subsequent Basin and Range normal faults paralleled the Sevier fault and fold structures, tilting the range  $\sim 30^\circ\text{E}$ .

Structural analysis of the Deseret Peak East quadrangle is important to the understanding of tectonics in the eastern Basin and Range. This chapter encompasses the structural geology encountered during mapping, the identification of new structures, clarification of existing structures, and interpretations on the tectonics of the area. The major structures and deformational events examined here include: 1) Deseret Peak Anticline; 2) Late Devonian Unconformity; 3) Central Range Fault; 4) Oquirrh Basin; 5) Martin Fork deformation; and 6) Minor Folding and Deformation Events.

## DESERET PEAK ANTICLINE

The Deseret Peak Anticline is the most pronounced structural feature in the Stansbury Range and is located in the northwestern corner of the Deseret Peak East quadrangle (Lambert, 1941; Teichert, 1958; Croft 1956; Arnold, 1956). The core of the anticline is comprised of Cambrian Tintic Quartzite forming the crest of the Stansbury Range and extends north through the center of Stansbury Island (Figure 6). The main fold axis of the range extends northward from the headwaters of Indian Hickman Canyon. The limbs, where both are present, are nearly symmetrical and represents an exposure of over 25,000 ft of strata. Analysis shows that in this location of the range, the axis of the anticline trends N12°E and plunges 3° to the north with an interlimb angle of 57° (Figure 7). Intersecting bedding patterns exhibited in the stereonet analysis are the result of

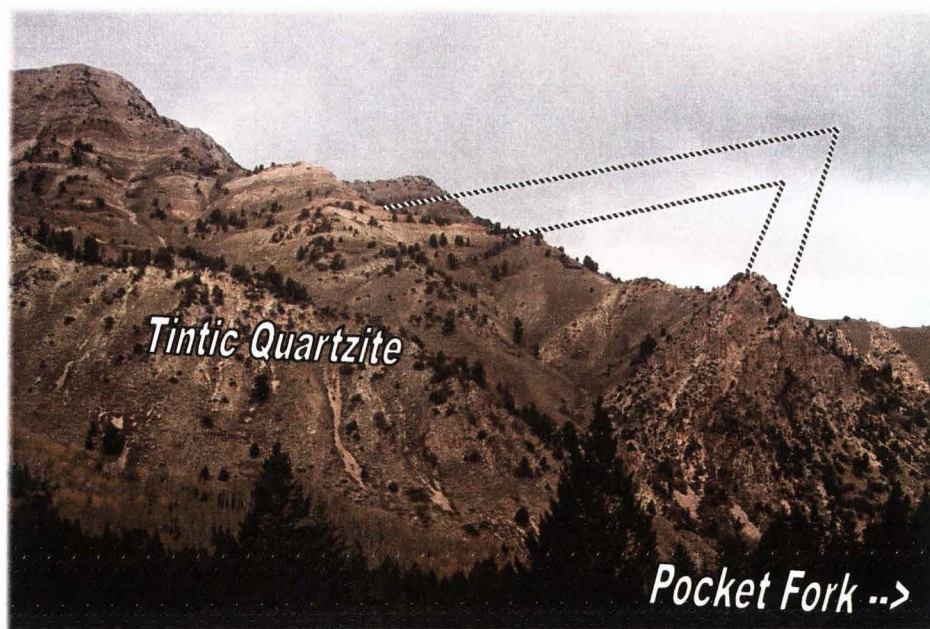


Figure 6. Deseret Peak Anticline; View to the north from South Willow Canyon.

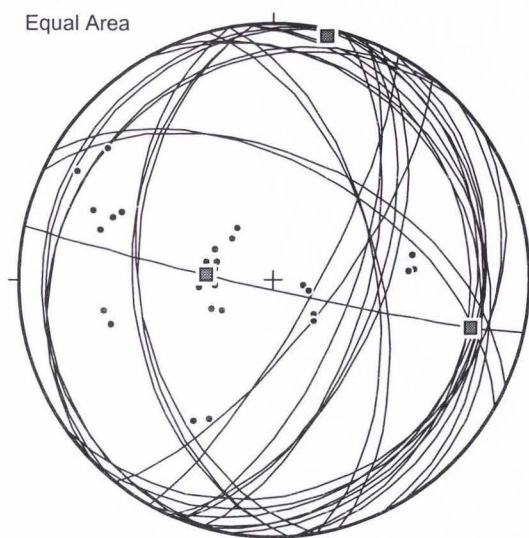


Figure 7: Stereonet analysis of the Deseret Peak Anticline: Trend and Plunge of Fold Axis:  $012^{\circ}$ ,  $03^{\circ}$ ; Best Fit Great Circle:  $102^{\circ}$ ,  $87^{\circ}$ S. Interlimb Angle:  $57.4^{\circ}$

outcrop limitations. Pre-Cenozoic orientation of the structure yields limbs dipping  $43^{\circ}$ W and  $25^{\circ}$ E.

### DEVONIAN UNCONFORMITY

Rigby (1958) provides a well documented history of early and mid-Paleozoic disturbances. Well-exposed stratigraphic section of these rocks is present with the Oquirrh, Tintic, and Stansbury Ranges. He notes a regionally extensive unconformity in the Stansbury, Oquirrh, and Wasatch Mountains. In each of these ranges, upper Devonian and/or lower Mississippian strata unconformably overlie lower to upper Cambrian rocks.

In the southern part of the Stansbury Mountains, a thin wedge of the Upper Devonian Stansbury and Pinyon Peak Formations overlies the unconformity. In the vicinity of Dry Canyon, the Devonian Simonson Dolomite unconformably underlies the



Stansbury Formation. To the north, at the mouth of Indian Hickman Canyon, the Stansbury Formation is truncated by another, more extensive unconformity. This unconformity also sequentially removes Cambrian Ajax, Cole Canyon, Teutonic, Cole Canyon and Opex Formations to the north.

Map relationships indicate that the unconformity omits a maximum of 1.4 km of lower and middle Paleozoic strata in the northwest section of the quadrangle, where Lower Mississippian Gardison Limestone overlies Lower Cambrian Ophir Group. This relationship occurs along the steeply dipping, eastern forelimb of the Deseret Anticline. To the south and west, middle Cambrian through middle Devonian units successively pinch out beneath the unconformity, towards Johnson Pass, and at Salt Mountain.

In the southern part of the Stansbury Mountains, the unconformity is overlain by a thin wedge of conglomerate of the Stansbury Formation, which in turn is overlain by the Upper Devonian Pinyon Peak Dolomite (Plate 4). In this vicinity, the Devonian Simonson Dolomite, underlain by the Stansbury Formation, are the youngest rocks truncated by the unconformity.

### **CENTRAL RANGE FAULT**

The Central Range Fault is located in the center of the quadrangle, and strikes the entire length from South Willow Canyon to Big Hollow. It separates Mississippian Manning Canyon Shales on the west from Pennsylvanian Butterfield Peak and Bingham Mine Formations to the east (Figure 8). This contact was formally termed the Broad Canyon Thrust by all previous authors. The Broad Canyon thrust is recognized in the northern Stansbury Mountains and is well exposed north of Davenport Canyon.



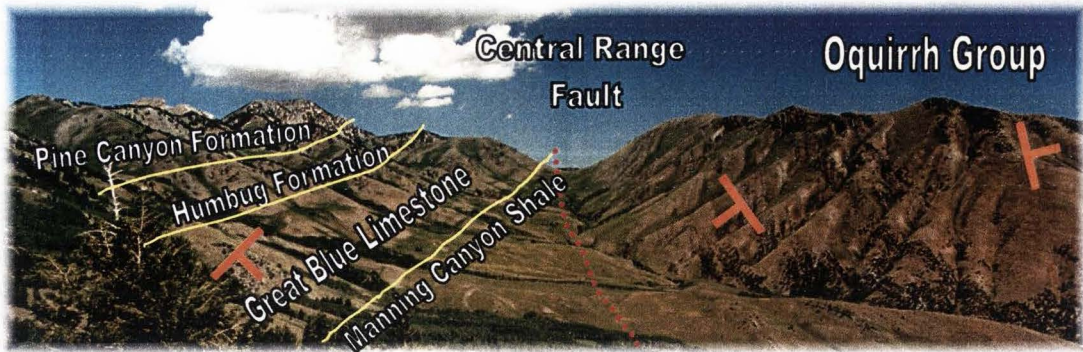


Figure 8. Central Range Fault. View to the north from Hickman Pass. East-dipping Mississippian units (yellow contact lines) to the west and overturned west-dipping Pennsylvanian units to the east are separated by the Central Range Fault (dashed red), concealed under colluvium and landslide debris.

However, between Davenport and Box Elder Canyons, the fault has been covered by Tertiary volcanic rocks.

In an attempt to continue this fault to the south, it was suggested that its trace run through the valleys of Bear Fork and Big Hollow Canyons, thus explaining the angular discordance of the Manning Canyon Shale and Oquirrh Group. Extensive field measurements and three-point problem analysis of map relations indicate that the fault strikes between  $355^{\circ}$ - $005^{\circ}$  and dips between  $45^{\circ}$ - $55^{\circ}$  to the east. Therefore, it is found to be a down-to-the east normal fault.

### MARTIN FORK FAULT

This fault is located in the northeastern quarter of the quadrangle and cuts the steeply overturned, west-dipping limb of the Martin Fork syncline and places Lower Triassic Woodside Formation against Upper Permian strata of the Bingham Mine Formation. Several young high-angle fault sets and a possible low-angle normal fault

were recognized by Jordan and Allmendinger (1979) in the Martin Fork area. They also map a portion of the contact between Pennsylvania/Permian Oquirrh Formation and Permian Kirkman/Diamond Creek Formation as a west-dipping thrust fault. Fault plane measurements made during fieldwork along this portion of the fault indicate that the fault strike  $N5^{\circ}W$  and dips  $45^{\circ}$  to the west (Figure 9). Tooker (1983) also describes this contact, and termed it the “Martin Fork Thrust.”

Map analysis of the fault contact between the Oquirrh Formation and Permian and Triassic units indicate that the fault strikes  $N22^{\circ}W$  and dips  $30.1^{\circ}$  to the east. This indicates an eastward dipping normal fault placing Pennsylvanian/Permian Oquirrh Formation in the footwall, and Permian and Triassic units in the hanging wall.

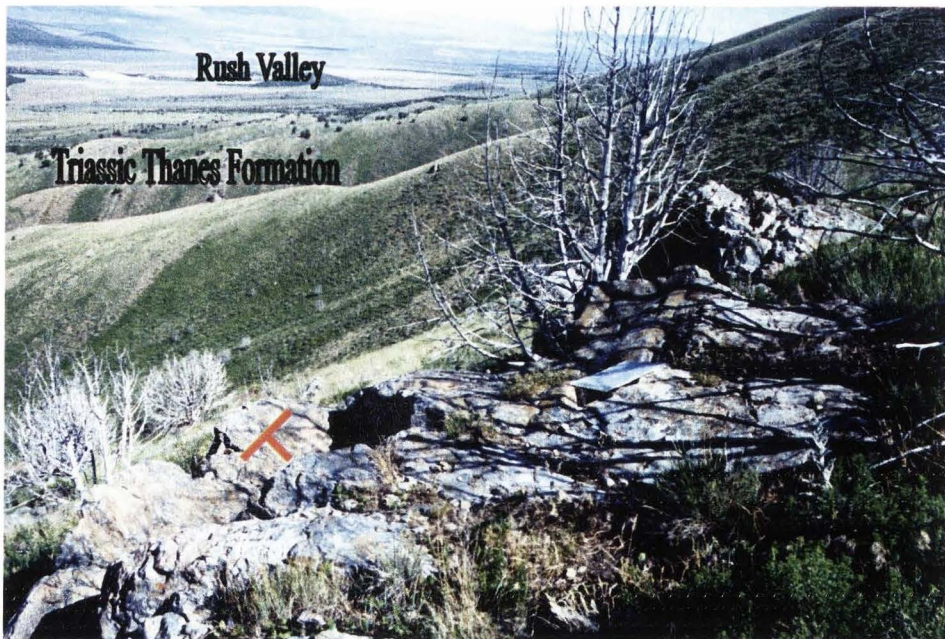


Figure 9. Martin Fork fault surfaces, Permian Diamond Creek quartzite. View to the south.



## MARTIN FORK SYNCLINE/ANTICLINE

The Martin Fork Syncline (Tooker, 1983) is an east-vergent, north-northwest-trending syncline (Figure 10) located in the northeast quarter of the quadrangle between Box Elder and East Hickman Canyons. The syncline folds Triassic Thaynes Formations and plunges  $36^{\circ}$  in the direction of  $298^{\circ}$  with an interlimb angle of  $41^{\circ}$  (Figure 11). Restoration of the structure to pre-Cenozoic faulting yields limbs dipping  $19^{\circ}$ E and  $67^{\circ}$ W.

The Martin Fork syncline has an associated anticline parallel in the southern part of the Triassic section (Figure 12). The Martin Fork anticline trends  $327^{\circ}$  and plunges

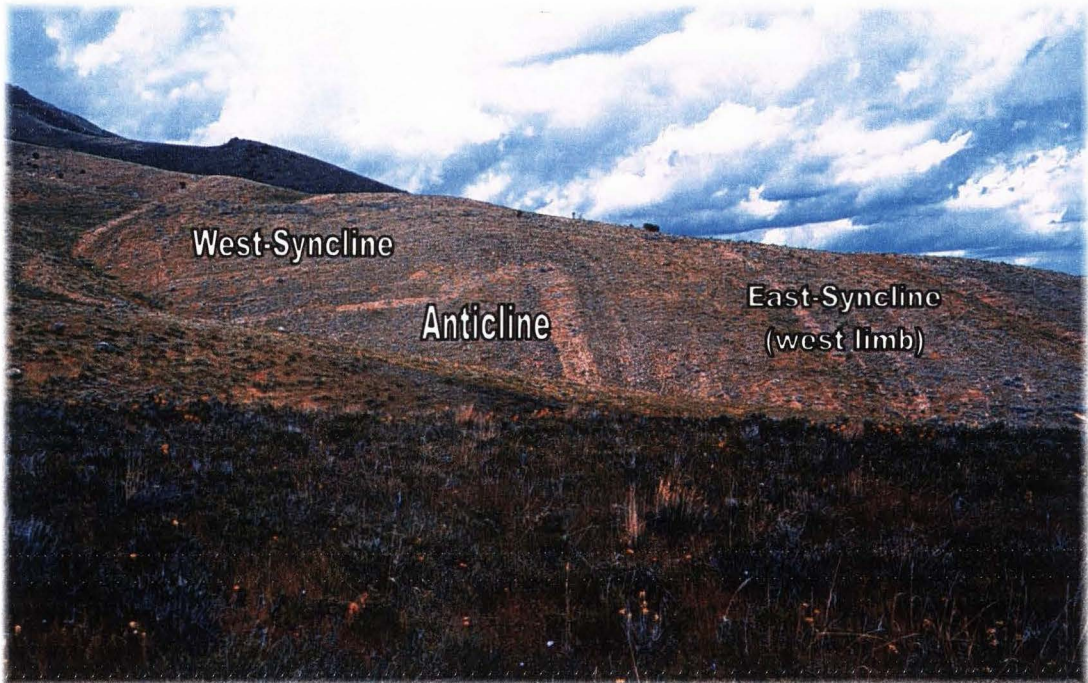


Figure 10. Martin Fork folds. Photo taken to the north-northwest.

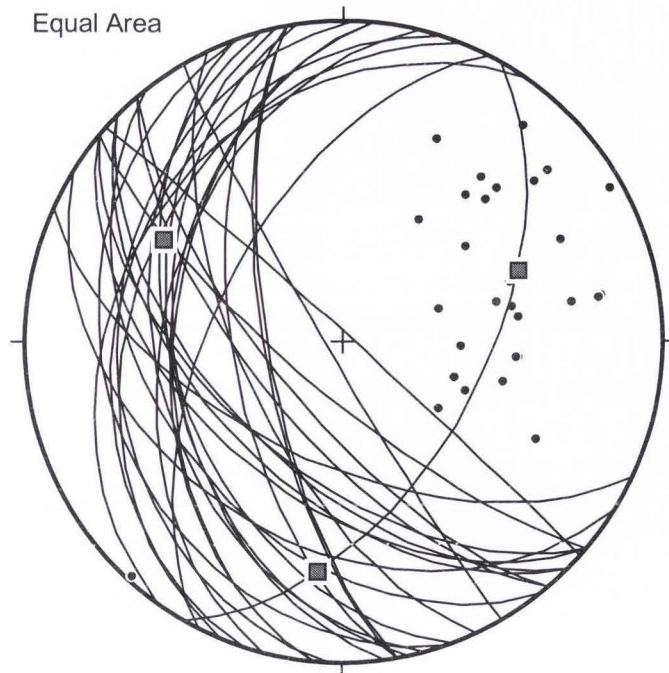


Figure 11. Stereonet analysis of the Martin Fork East Syncline. Trend and plunge of fold axis:  $298^{\circ}, 36^{\circ}$ ; Best fit great circle  $029^{\circ}, 54^{\circ}\text{E}$ ; Interlimb angle:  $41^{\circ}$

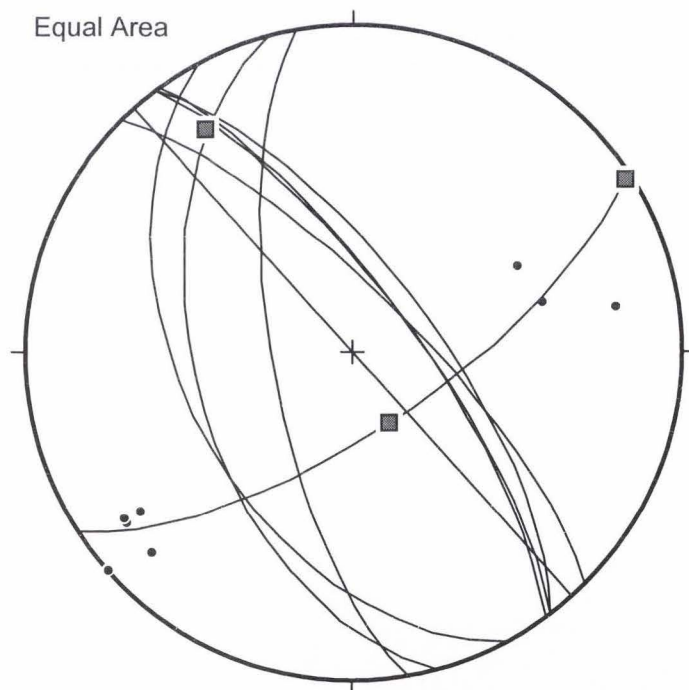


Figure 12. Stereonet analysis of the Martin Fork Anticline: Trend and Plunge of Fold Axis:  $327^{\circ}, 20^{\circ}$ ; Best Fit Great Circle:  $057^{\circ}, 70^{\circ}\text{S}$ ; Interlimb Angle:  $126^{\circ}$ .



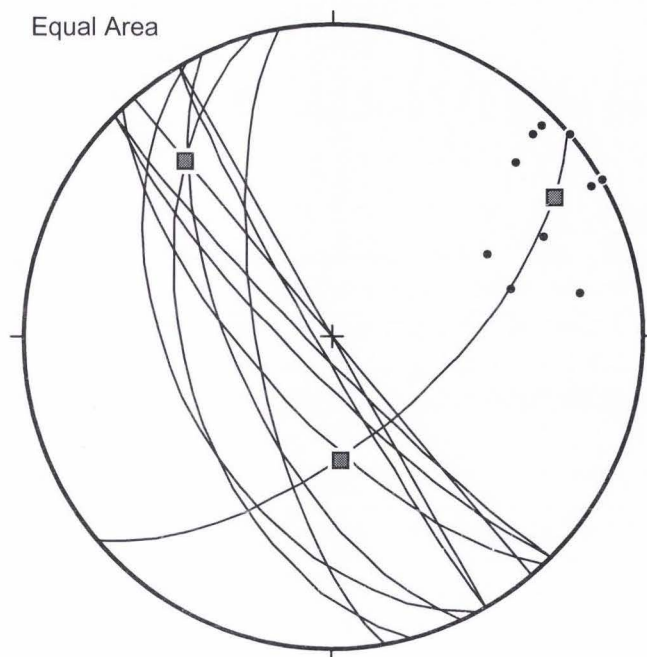


Figure 13. Stereonet analysis of the Martin Fork Syncline West: Trend and Plunge of Fold Axis:  $319^{\circ}$ ,  $27^{\circ}$ ; Best Fit Great Circle:  $049^{\circ}$ ,  $63^{\circ}\text{S}$  Interlimb Angle of  $35^{\circ}$  or  $145^{\circ}$ .

$20^{\circ}$  to the north. Restoration of the anticline to pre-Cenozoic orientation yields limbs dipping approximately  $19^{\circ}\text{E}$  and  $47^{\circ}\text{W}$ . At the southern edge there is another small syncline, west of the anticline, that trends  $319^{\circ}$  and plunges  $27^{\circ}$  to the north (Figure 13). It appears to merge with the west limb of the Martin Fork syncline.

### MINOR FOLDING AND DEFORMATION EVENTS

Minor folding and deformational events in the area include localized folding. Deformation is entirely within a unit and on the scale of a couple of meters to tens of meters. A small anticline within the Oquirrh Group is located about half way up Cow Canyon in the southeast corner of the quadrangle. Field measurements yield a trend of  $244^{\circ}$  plunging  $24^{\circ}$  west, and an interlimb angle of  $34^{\circ}$  (Figure 14).

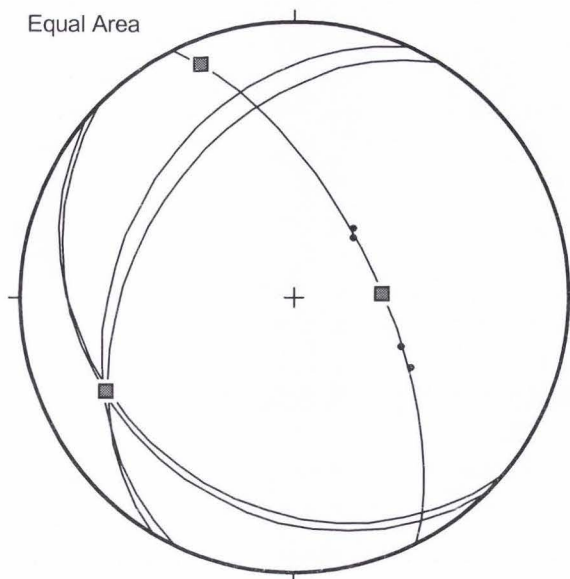


Figure 14. Stereonet analysis of the Cow Canyon Anticline: Trend and Plunge of Fold Axis:  $244^{\circ}$ ,  $24^{\circ}$ ; Best Fit Great Circle:  $334^{\circ}$ ,  $66^{\circ}\text{E}$ ; Interlimb Angle:  $145.6^{\circ}$

Another minor fold can be found in Abbots Fork of Box Elder Canyon. This syncline trends  $265^{\circ}$  and plunges  $40^{\circ}$  to the west with an interlimb angle of  $89^{\circ}$  (Figure 15).

Small faults recognized by offset of limestone beds show displacement on the order of a few meters to tens of meters. Most of these faults are east-west oriented high angle normal faults in Big Hollow (Figure 16), suggesting they are small wrench faults related to the forces that folded and overturned the rocks in the Stansbury Mountains. They occur both in the Mississippian strata and the Oquirrh Formation, and do not appear to cut the Central Range Fault.

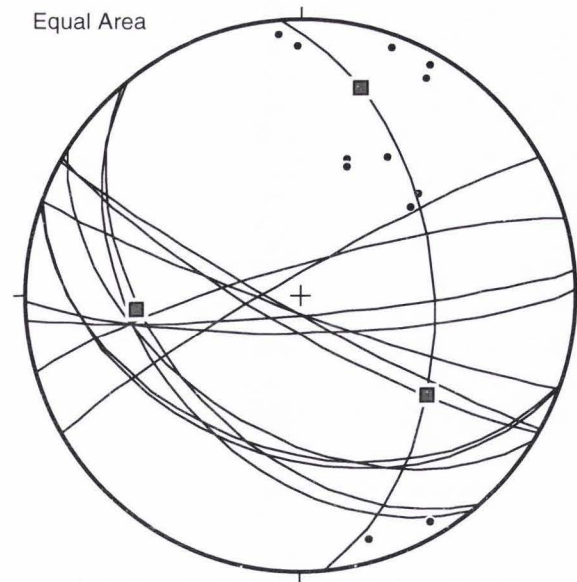


Figure 15. Stereonet analysis of the Abbot Fork Syncline: Trend and Plunge of Fold Axis:  $265^{\circ}, 40^{\circ}$ ; Best Fit Great Circle  $355^{\circ}, 50^{\circ}\text{E}$ ; Interlimb Angle:  $90.6^{\circ}$ .



Figure 16. Minor faults in Big Hollow Canyon, view to the west of small, high-angle normal faults in the Manning Canyon Shale.



In sec.31, T.4S., R.6.W., a nearly vertical fault striking N25°W is traceable for about 1.5 km and locally forms the contact between the Butterfield Peaks Formation and the Bingham Mine Formation. The east block is relatively downthrown with unknown, but probably minor, displacement. Movement on this fault postdates overturning and folding.

Another potential normal fault exists between South Willow and Box Elder Canyons, separating Tertiary volcanic rocks to the west and Tertiary conglomerates (Tc<sub>1</sub>) to the east (Figure 17).



Figure 17. Tertiary Conglomerate/Volcanic contact. View to the southeast across South Willow Canyon. Down stream to the left.





Figure 18. Fault breccia along Tertiary volcanic rock and conglomerate contact.

Breccias with calcite fill along the contact between these two units suggest the possibility of a fault (Figure 18). This potential fault might also extend and connect with faults in the Martin Fork region to the southeast.

No active normal faults were recognized within the boundaries of the quadrangle, though a fault scarp extends for approximately 1/4 mile through sec 29 & 36, T 4 S, R 6 W, just east of the quadrangle boundary at the mouth of East Hickman Canyon.

The Stansbury Fault (Figure 19) bounds the east side of Skull Valley, and lies west of the quadrangle boundary. Most notable activity along the fault occurred in 1915.



Figure 19. Stansbury Fault scarp, western slope of the Stansbury Mountains. View to the east up Indian Hickman Canyon. Deseret Peak in the upper left.

## CROSS-SECTIONS AND INTERPRETATIONS

### Devonian Unconformity

While most, if not all of the pre-Mississippian strata in the Stansbury Mountains were subject to some amount of uplift during the Late Devonian, the principal area of uplift is delineated by areas where Devonian rocks are absent beneath the unconformity.

In the northern part of the range only Cambrian and Ordovician strata are present below the unconformity (Section C-C'). Similar stratigraphic relationships constraining the age of the Stansbury uplift are reported in the Wasatch Mountains (Rigby, 1959) to the east and the Sheeprock Mountains (Morris and Lovering, 1961) to the south.

The unconformity is believed to be related to a broad, regional east-trending uplift, which occurred along the Uinta trend (Rigby, 1959). Tooker and Roberts (1970) suggest that the Uinta trend extended westward into northeastern Nevada during Late



Devonian time, based on the deflection in the strike of the Antler thrust belt at that latitude. The existence of upper Devonian coarse clastic sedimentary rock in the Newfoundland and Silver Island Mountains, in northwestern Utah, are sediments thought to have been derived from the Uinta uplift, also support this interpretation (Taylor, 1992).

The Late Devonian Stansbury uplift appears to be a broadly arching, north-northwest trending, anticlinal structure. A  $15^\circ$  angular discordance along the unconformity is exposed on the west side of Stansbury Range, and suggests that the orientation of the eastern limb of the Stansbury anticline dipped approximately  $15^\circ\text{E}$  during Devonian time (Taylor, 1992), indicating a broad, open fold geometry for the Stansbury anticline in the Middle Paleozoic.

The axis of the Stansbury uplift can be traced from Deseret Peak to the northern end of the range. A thick sequence of Late Devonian clastic rocks correlative with the Stansbury Formation exposed on Stansbury Island suggests that the axis of uplift may have extended north to the modern southern end of Great Salt Lake (Taylor, 1992). This interpretation is in general agreement with the pre-Mississippian paleogeographic map by Rigby (1959).

Other workers have alternatively interpreted the angular discordance along this contact in the Stansbury Mountains as a thrust fault (Tooker and Roberts, 1971). Field evidence that strongly supports the unconformity interpretation includes: 1) the typical clastic nature and uniform age of the rocks directly overlying the angular disconformity; 2) karst structure observed in carbonate strata directly underlying the contact, which suggests possible subaerial weathering during pre-late Devonian time (Taylor, 1992); and 3) exposure of the contact reveal no evidence of shearing or faulting.



The timing of the Stansbury uplift (post-middle Devonian and pre-latest Devonian) roughly coincides with that of the Antler orogeny (Rigby, 1958), and it is thought that the Stansbury uplift could be a forebulge to the Antler. Regional uplift of the east-west Uinta trend may have occurred in response to eastward directed compression of the Antler thrust belt against the east-trending rigid block of the Uinta Basin (Bryant and Nichols, 1988).

### **Oquirrh Basin**

The Oquirrh-Wood River basin of southern Idaho and northern Utah represents the northernmost known extent of Pennsylvanian-Permian Ancestral Rocky Mountain deformation. Burchfield et al. (1992) proposed that generally east-directed thrusting of part of the Roberts Mountains allochthon loaded the lithosphere and created a north-northwest-trending trough, the Oquirrh-Wood River basin.

Thick sequences of sediments were deposited in the Oquirrh Basin during the Late Carboniferous and Permian time (Bissell, 1962). Predominantly shallow-water carbonate deposition on the Cordilleran miogeocline continued from the Early Paleozoic through Early Pennsylvanian time. This was followed by large volumes of siliceous clastics with interbedded limestone sequences were laid down. The Middle Pennsylvanian Butterfield Peaks Formation in the Stansbury and Onaqui Mountains was deposited in extremely shallow-shelf conditions; sands migrated along the oscillating margins of the transgressive and regressive seas, and shelf carbonates accumulated in the shallow marine environments. Similar Middle Pennsylvanian rocks in the Oquirrh Mountains, Cedar Mountains, and Grassy Mountains suggest that the topography was

virtually flat (Armin, 1979). The great thickness of the Butterfield Peaks Formation in the Stansbury and Onaqui Mountains apparently is due to pronounced subsidence at a rate roughly equal to that of sediment accumulation.

The dominance of siliceous, clastic sedimentation that commenced in the late Desmoinesian became even more pronounced in the Missourian. Thick sequences of mature siliceous, detrital material characterize the main body of the Upper Pennsylvanian Bingham Mine Formation (Jordan, 1978). Sand and intercalated carbonate continued to accumulate in fairly shallow waters throughout most of the Missourian, but Virgilian and early Wolfcampian time was typified by relatively rapid subsidence. A thick section of sandstone with intercalated resedimented limestone conglomerate and proximal turbidities was laid down during this last pulse of Oquirrh Basin downwarping (Armin, 1979). By late Wolfcampian time, the Oquirrh Basin had been filled so that shallow marine conditions prevailed. Relatively thin sequences of post-Wolfcampian-Permian and Triassic rocks also were deposited in shallow water (Armin, 1979).

The paleogeography of the Oquirrh Basin is not yet agreed upon due to differences in the magnitude of late Mesozoic thrusting, resulting in displaced facies of the basin. Roberts and others (1965) proposed that the Oquirrh Basin originally was elongate with an east-west orientation, extending from central and northeast Nevada to the Utah-Wyoming shelf, whereas Bissell (1962) showed it as extending north south.

No basin-bounding faults have been recognized for the basin and Pennsylvanian and Permian thrust faults in the Roberts Mountains allochthon have not been documented west of the area. This may be an artifact of the limited exposures on the western margin of the basin.

The Oquirrh Formation of the Stansbury Mountains is found east of the Central Range Fault. Dips ranging from  $30^{\circ}$  east to overturned  $30^{\circ}$  west are observed. While it has been thought that this thick sequence of Oquirrh Formation is repeated by either folding or faulting (Teichert, 1956), extensive field studies have shown it to be continuous in section. Due to the nature of deposition of basin sediments, a single bed is only traceable of up to 1-2 miles. The change in bedding orientations is due to the angle at which the sediments were transported and deposited within the basin (Section A-A').

### **Contractional Structures**

According to Bryant and Nichols (1988), general "in-sequence" thrust activity began in north-central Utah during Albian time (latest Early Cretaceous) and ended during the Early Paleocene. Earlier activity was limited to the westernmost thrusts, including the Canyon Range and Willard-Meade thrusts, considered by Bryant and Nichols (1988) to be correlative structures. A tectonic map of the eastern part of the Sevier orogenic belt published by Bryant and Nichols (1988) shows the Canyon Range thrust as a regional structure trending northward from the Canyon Range, passing through the Sheeprock Mountains and trending through the general vicinity of the Stansbury Mountains. While a correlation of the Canyon Range thrust into the vicinity of the Stansbury Mountains is uncertain, the Albian age for activity along the Canyon Range thrust may provide an approximate age of folding and thrusting in the Stansbury Mountains since these thrusts both lie in the same general position within the thrust belt.

Folding of Sevier-age frontal thrusts around the west-trending Uinta trend which exists at the latitude of the Stansbury Range (Tooker, 1983). His hypothesis was that the



Uinta trend served as a buttress in the allochthon that Sevier-age thrusts wrapped around, resulting in a convex to the west structural map pattern of the orogenic belt. A similar but broader convex to the west map pattern exists in the Stansbury Mountains, where the hinge surface trace of the Martin Fork syncline trends north- northwest and north-northeast, respectively, along its southern and northern parts. The southeast-trending structural grain of the Onaqui and Sheeprock Mountains to the south enhances this convex pattern.

The concept of the Tintic Valley thrust was initially proposed by Billingsley and Locke (1939) and Eardley (1944) to explain the structural discordance between the north-trending folds in the Stansbury Mountains and the west-northwest-trending folds at South Mountain. Roberts and others (1965) correlate the Tintic Valley thrust to a “comparable fault” in the Gilson Mountains and one they proposed to be concealed under Tintic Valley. The correlation of the Tintic Valley thrust, near South Mountain, with that of a “comparable fault” unexposed for 95 km to the south, is not compelling. However, since the work of Roberts and other (1965), several workers have included the Tintic Valley thrust in their regional structural correlations of the area, so the name Tintic Valley thrust is also adopted herein.

Between South Mountain (Oquirrh Formation) and the east slopes of Bald Mountain (Oquirrh Formation) there are numerous knobs of Paleozoic quartzite, dolomite and limestones outcrop. There is currently a question of ages of these formations. Rigby (1958) notes the occurrence of Devonian-age sandstone west of South Mountain, in close proximity to the Oquirrh Formation on South Mountain. He assigned Devonian Stansbury Formation (quartzite) and Mississippian carbonates to these knobs. Current

field studies indicates that the westernmost outcrop is possibly Permian Park City/Phosphoria, while the quartzite unit is possibly Cambrian Tintic Quartzite(?). It is believed that the area between the knobs and the Pennsylvanian-Permian formations to the west is a back-thrust of the Tintic Valley Thrust (Section B-B').

Some interpretations view the positions of Sevier thrust features as controlling the geometry and structure of Cenozoic faults, especially the Wasatch fault (Smith & Bruhn, 1984). Although this likely applies in some cases, the underlying crystalline basement is interpreted to be the primary influence on geometries of both Cretaceous thrust and Cenozoic normal fault structures (Helm, 1994).

### **Central Range Fault**

Previously mapped as the Broad Canyon Fault, the Central Range Fault extends from Big Hollow Canyon, north through Bear Fork Canyon, and is concealed by Tertiary volcanic rocks at the northern quadrangle boundary. Previous workers continued the Broad Canyon Fault from the north across the large field of volcanic rocks, and placed it in the Central Valley to the south. Through field investigations and map analysis, it is found that this fault is a normal fault and not a thrust as defined by all previous authors.

Restoring the Central Range Fault to a pre-Basin and Range orientation (tilting the range  $30^\circ$  back to the west) would indicate the fault dip of  $15^\circ$ - $25^\circ$  to the east. In contrast to previous thrust interpretations of a  $50^\circ$  west-dipping fault, the pre-tilt orientation of the thrust fault would then become nearly vertical. The possibility exists for more work north of the volcanic field in determining the orientation of the Broad Canyon fault.

### Minor Faults

Small faults recognized by offset of limestone beds show displacement on the order of a few meters to tens of meters. Most of these faults are east-west striking high-angle normal faults in Big Hollow, suggesting that they are small wrench faults related to the forces that folded and overturned the rocks in the Stansbury Mountains.

Timing constraints on structural events in the Stansbury Mountains are poor. The Martin Fork syncline folds rocks as young as lower Triassic which provides a lower age limit on thrusting. A more reliable upper age constraint for thrusting comes from K/Ar ages of biotites of  $39.4 \pm 0.5$  ma and  $41.8 \pm 0.5$  ma from volcanic flows and tuffaceous sedimentary rock (Moore and McKee, 1983) which unconformably overlie the Martin Fork syncline (Taylor, 1992).

Strong field evidence for a minimum of  $30^\circ$  of post-Eocene eastward tilting of the Stansbury Mountains exists in the east-central portion of the range (Taylor, 1992). If Tertiary deposits within the area were deposited on a maximum  $10^\circ$  E dipping slope, a minimum of  $30^\circ$  of westward tilting would be required to restore the Tertiary units and the underlying Mesozoic structure to their pre-tilt orientation. Younger Tertiary conglomerates extending east of the volcanic rocks also have a  $20^\circ$ - $30^\circ$  eastward dip.

Eastward tilting of the range was first proposed by Davis (1959), who noted that volcanic rocks in the east-central part of the range presently dip approximately  $30^\circ$ - $50^\circ$  E. Davis hypothesized that the present orientation of these extrusive rocks, and others he mapped on Salt Mountain on the west side of the Stansbury Mountains, are a result of a regional eastward tilting event which affected the entire range. Similar eastward tilting



has been proposed for the nearby Sheeprock Mountains to explain the near horizontal and gently east dipping orientations of the Sheeprock thrust (Christie-Blick, 1983).

Stewart (1980) defined large regions in which major, late Cenozoic, basin and range fault blocks are consistently tilted to the east or west, including an east-tilted region extending from north-central to southwest Utah, which encompasses the Cedar, Stansbury, Oquirrh, and Sheeprock Mountains.

Tilting of the Stansbury Range is believed to have been facilitated by the Basin and Range faults of the East Oquirrh and the Stansbury Faults. This places the Stansbury Range in the footwall of the Stansbury Fault and the hanging wall of the East Oquirrh fault.

## CHAPTER IV

### WATER RESOURCES AND THE BEDROCK CONTROL OF GROUNDWATER

At 2.2 million people, Utah is the fourth-fastest growing state in the U.S. Utah grew by almost one-third during the 1990s—and 224% in the last 50 years. Utah's population has historically increased at a faster rate than the U.S. as a whole. Current trends suggest that it will continue to do so for the foreseeable future.

This population growth is apparent throughout the state, but some communities are growing at particularly staggering rates. Tooele County increased by 53 percent, from 26,601 in 1990, to 40,735 in 2000 (Figure 20). The town of Erda, just north of Tooele had a 122 percent population increase in the 1990s (Miller, 1998).

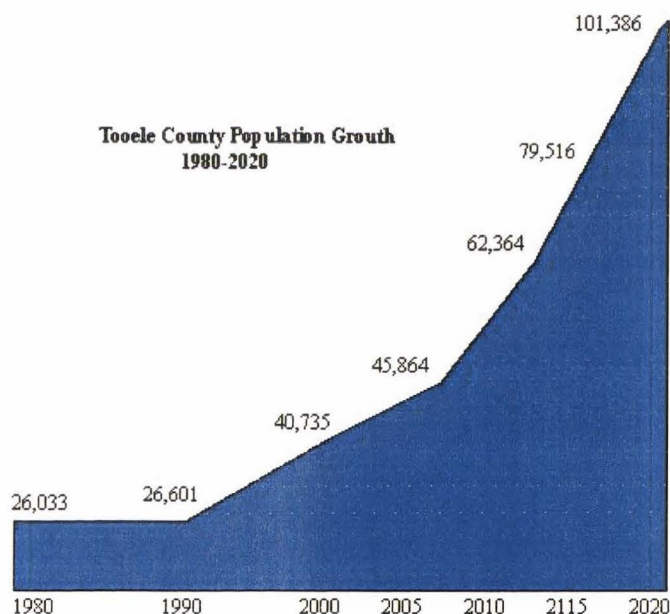


Figure 20. Utah population growth 1950 to 2010 (U.S. Census Bureau, 2000)

Water is already a scarce resource in this desert state, and even more so in this region. Increased demand for water generated by population growth only exacerbates the problem. This increase has been accompanied by a commensurate increase in the demands being placed upon the valley's water resources, including groundwater. Water rights, which have previously been used largely for agriculture and mining are being transferred to municipal, domestic, commercial, and industrial uses.

The state's water shortfalls due to frequent droughts can mean hardships for farmers, whose irrigation is cut when water is in short supply (Istraelsen, 2001). In 2001, some farmers faced yields 40% less than normal as a result of drought. Some farmers in Rush Valley are opting to sell their water rights and claims, to be used for irrigation and municipal water in Tooele County. Faced with a growing crisis, Utah's governor has asked residents to reduce their water use by 25% in the next several decades (Arave, 2001).

## **PRECIPITATION**

The climate of Tooele, Rush, and Skull Valley is typical of a semi-arid region, whereas the Stansbury Mountains sub-alpine. Minimum and maximum temperature data and precipitation data for Grantsville, Rush Valley and Dugway stations is obtained from TWC Weather.com Monthly Averages and Records and summarized in Table 5. Desert Peak temperature data and precipitation records were obtained through SNOTEL (Table 5). A standard SNOTEL (SNOWpack TELemetry) site consists of a snow pillow, a storage-type precipitation gauge, air temperature sensor, and a small shelter for housing the electronics. SNOTEL sites report on a daily or more frequent basis.



Precipitation records on Deseret Peak are located at the SNOTEL site and are reported in Table 6. The Deseret Peak site was discontinued in 1999 and replaced with the Mining Fork Station, Site #631, UT12J07S, at an elevation of 8,000 ft.

Long-term precipitation in Skull Valley generally ranges from 7-12 inches per year, whereas in the Stansbury Mountains, large areas receive 16-30 inches of precipitation, and Deseret Peak has averaged about 45 inches over the past decade.

Surface runoff is high on account of high rainfall intensities over a surface with sparse vegetation cover and limited soil development.

Mountainous regions play a critical role in the hydrology of semiarid drainage basins.

Due to orographic forcing of precipitation, they receive much more moisture than surrounding areas, especially from snow. Locally this varies from an average of less than five inches annually over the Great Salt Lake Desert, to more than 40 inches in parts of the greater Wasatch Mountains, including Deseret Peak. The mountains form the chief reservoirs of water for the valleys during the winter. It is estimated that 60-70% of the surrounding valleys recharge is due to the inflow from bedrock aquifers and stream-channel deposits at the mouths of canyons.

Upper catchments consist largely of carbonates and quartzites. Runoff from precipitation and snowmelt on these slopes was characterized by Hood and Waddell (1968) as the "Tin Roof Effect," which is indicative of rapid runoff response. They attribute loss of water after the creeks leave the mountains is due to the fact that channels traverses alluvial fans as they flow towards the center of the valley.





## STREAMS

South Willow Creek is one of the largest streams in the area, with an average discharge of 6.83 cfs (Figure 21). Sedimentary and igneous rocks of relatively low permeability underlie the drainage basin of South Willow Creek and lead to high runoff. Most of the runoff is ephemeral, occurring chiefly during spring and early summer in response to the melting snowpack. However, instantaneous peak discharges are commonly generated by summer thunderstorms.

Skull Valley contains only four perennial streams: Barlow, Indian Hickman, Antelope, and Lost Creeks. These streams head in the Stansbury Mountains and supply water to ranches in Townships 3-6 S., R.8W., and to the Skull Valley Indian Reservation. Diversions are made where the canyons open onto the heads of the alluvial fans, and the water is carried by ditch and pipeline to areas of use in the lower parts of the valley (Hood & Waddell, 1968).

Adequate hydrologic records are not available to calculate discharge of streams for western slope drainages. An estimate of the potential long-term average runoff for Indian Hickman Creek in Skull Valley was calculated based on the relation of precipitation to altitude. It is estimated that near the mouth of the drainage, it discharges approximately 2.0 cfs. Three miles below the mouth of the canyon, the flow is reduced to approximately 1.0 cfs (Hood & Waddell, 1968).

These estimates from Indian Hickman Creek suggest water in streams leaving the mountains is lost by infiltration on the piedmont. Also approximately 35-40% is lost to



**LOCATION:**Latitude 40°29'47", Longitude 112°34'25" NAD27,  
Tooele County, Utah , Hydrologic Unit 16020304  
**DRAINAGE AREA:** 4.19 square miles  
**GAGE:** Datum of gage is 6,360.00 ft above sea level NGVD29.

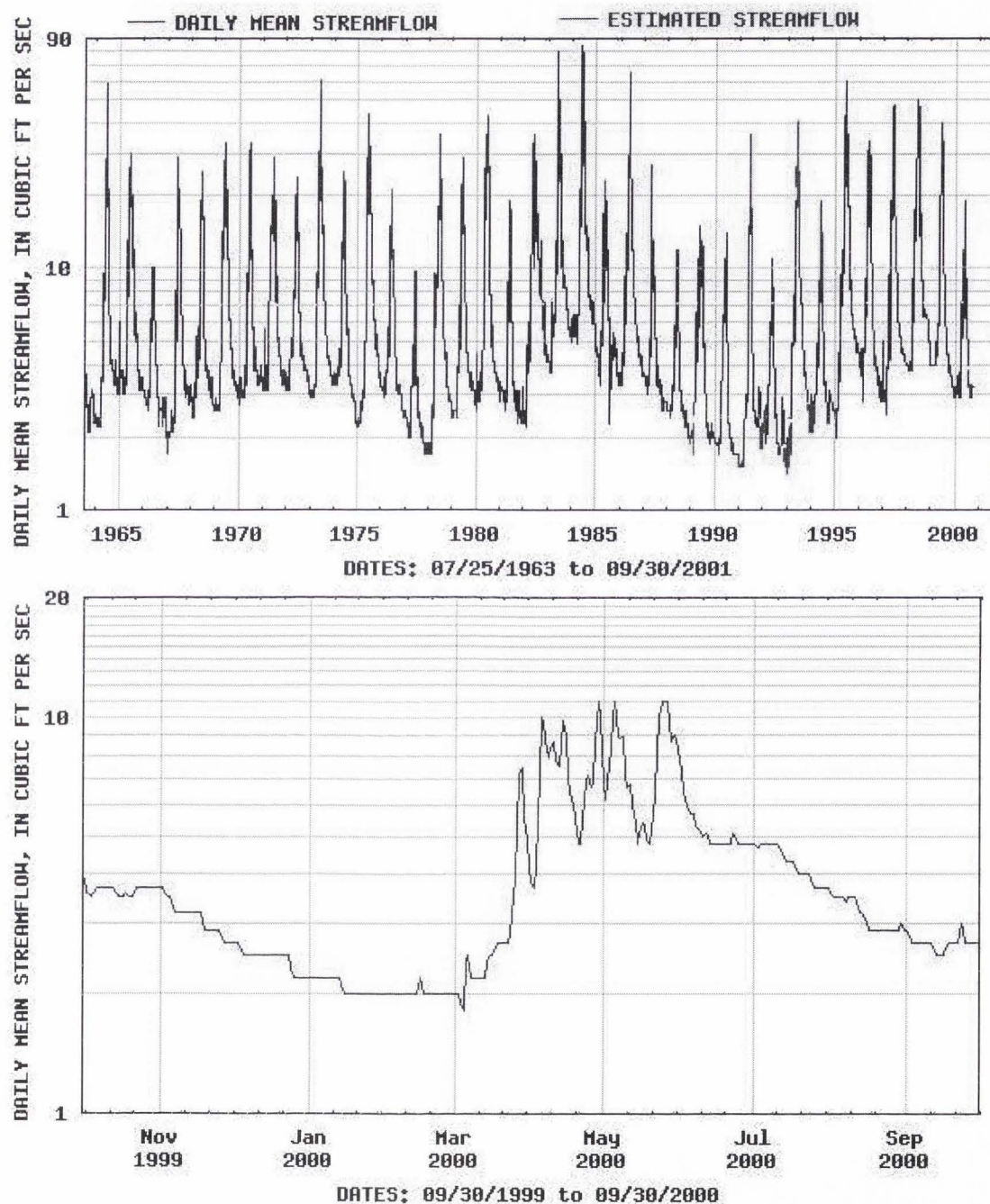


Figure 21. Hydrographs of South Willow Creek gaging station. Average flow of 6.83 cfs.

evapotranspiration due to the semi-arid climate (Lambert and Stolp, 1999).

Streamflow that reaches the valley floor is lost to evaporation or is infiltrated in stream channels and saltflats. Large flows in the streams are derived during the spring from snowmelt on the highest parts of the mountains, and during the summer from intense rainstorms. In late summer and fall, low flow in the few perennial streams is sustained by water discharging from springs in the mountains.

### **WATER QUALITY**

The hydrographs for South Willow Creek and Clover Creek Spring (Figures 21-22) show that flows are very much seasonal, with higher flows occurring April through June, coinciding with peak snowmelt. They are two major sources of water for Tooele and Rush Valleys, respectively. Dissolved-solids concentrations of runoff range from less than 100 mg/L in the principal runoff-producing areas, to more than 35,000 mg/L adjacent to Great Salt Lake (Price, 1981).

The dissolved-solids content of the water from the springs and streams in the Stansbury Mountains ranges from 98-395 ppm, and the principal chemical constituents are generally calcium and bicarbonate. The water discharged by the streams originating at high altitudes contains the lowest concentrations of dissolved solids, while springs at lower altitudes toward the northern and southern ends of the Stansbury Mountains contain slightly higher concentrations (Hood & Waddell, 1968). These levels are all within the EPA's levels for safe drinking water.

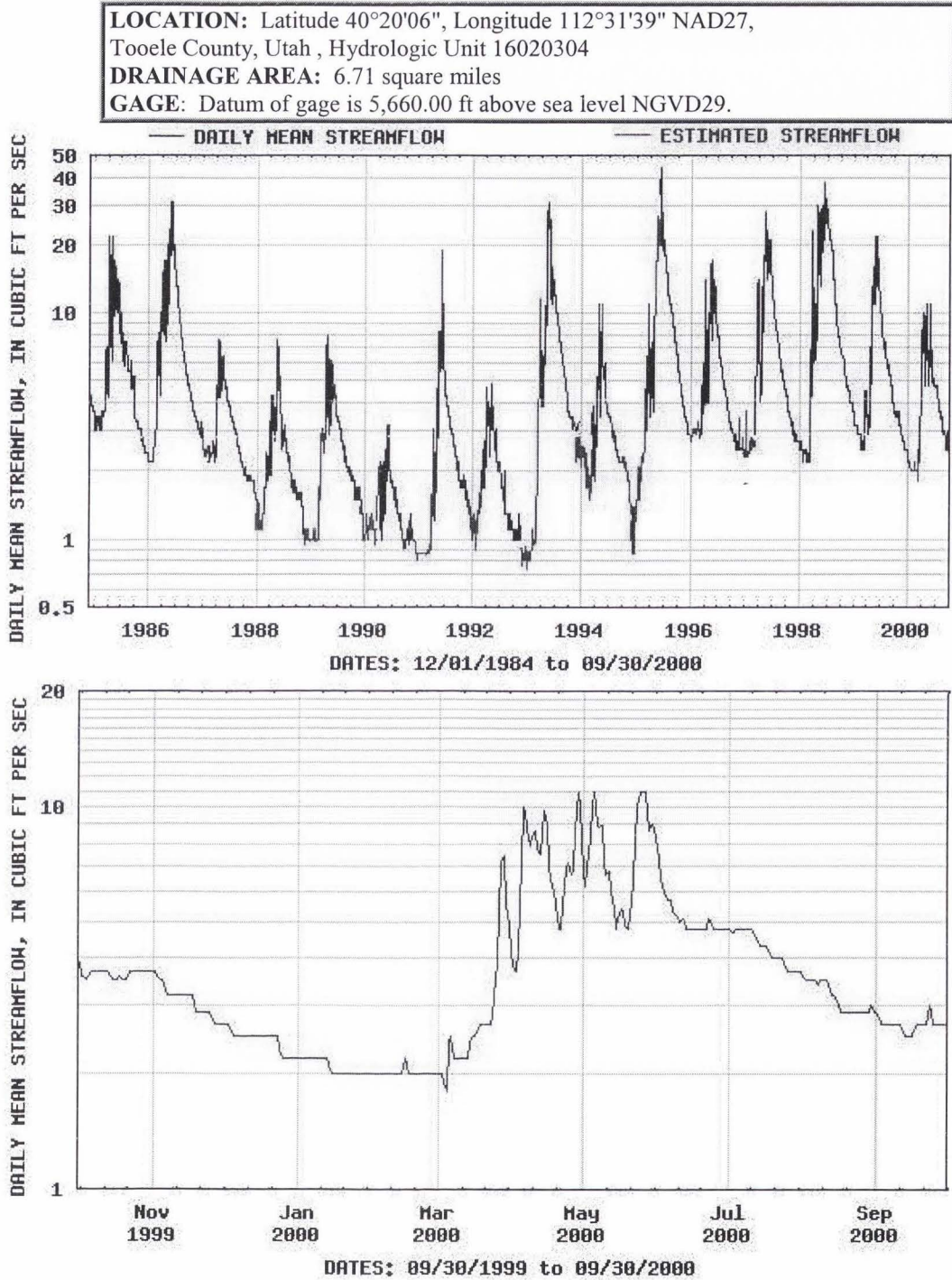


Figure 22. Hydrographs of Clover Creek gaging station. Average flow of 4.95 cfs.



## SPRINGS

Within the Deseret Peak East quadrangle, 23 major springs (Plate 3) occur primarily in the Manning Canyon Shale and unconsolidated materials, indicating that the groundwater flow to the springs is through unconsolidated materials above the bedrock and that spring locations are controlled by bedrock outcrops. There are also numerous small, seasonal seeps around large areas of colluvium within the Oquirrh Formation. Spring discharges within several of the canyons suggest that there is a strong north-south control, with springs on the north side of the canyon discharging much more water than those across the canyon to the south.

The largest of the springs in the area is the Clover Creek Spring at an elevation of 6,000 ft, located just south of the quadrangle boundary on the highway east of Johnson Pass. Clover Creek Spring is the main source of flow for Clover Creek. The drainage area of Clover Creek is 6.71 square miles (approximately 91,000 acres), and extends into the southern portion of the Deseret Peak East quadrangle and includes key recharge areas of Vickory Canyon, and Big Hollow. Clover Creek has an average discharge of 4.95 cfs, and is influenced mainly by seasonal snowpack (USGS, 2001).

## GEOLOGIC CONTROLS OF GROUNDWATER

Mountainous regions play a critical role in the hydrology of semiarid drainage basins. Due to orographic forcing of precipitation, they receive much more water than surrounding areas and, as a result, provide most of the runoff and groundwater recharge. It seems likely that a significant proportion of groundwater recharge for the entire basin

originates as infiltration through fractured bedrock high in the mountains and reaches the alluvial aquifer systems by permeating range-bounding faults, though it is difficult to quantify. Recent studies in humid climates in the northwest Continental US and in Japan indicate from 20% to close to 100% of the recharge can be via such subsurface pathways. There are few similar quantitative semi-arid climate studies.

Geology plays a key role in controlling the groundwater in the study area. For example, springs in the southern Stansbury Mountains arise from the Manning Canyon shale in Big Hollow and in East Hickman Canyon transfer water from one topographically defined drainage to another.

McCarthy and Dobrowolski (1999) studied the Onaqui Mountains to the south, and determined that springs are controlled by the Manning Canyon Shale Formation. This formation is highly fractured, producing shallow slopes which collect unconsolidated sediment. Springs not occurring within the unit still occur very near its contacts. They also found that the water is isotopically lighter than rainwater, suggesting that the spring water is derived from snowmelt. This indicated that the geology is conducive to subsurface flow.

Maxey and Mifflin's (1966) study of Paleozoic and Mesozoic carbonate rocks in southern Nevada concludes that in the Great Basin, ground water flow may transfer water from one topographically defined basin to another. They found that broad geologic and major tectonic features act as hydrologic boundaries. They also find that the distribution of the springs clearly indicate that the major hydrologic systems associated with limestone and dolomite occur only in the area of principal outcrops of carbonate rocks.

Fractures commonly provide the only significant effective porosity and permeability of carbonate rocks, igneous rocks, and shale. Groundwater flow direction is determined as much by fracture-related anisotropy as by the hydraulic gradient (Mayer and Sharp, 1998). High-permeability trends caused by preferential fracturing can determine if and where interbasin flow will occur and thus the extent of regional groundwater flow patterns.

The overall orientation of structures and bedrock units in the Stansbury Mountains is north-south. Many units dip in excess of  $45^\circ$  and alternate in composition from limestone, sandstones, and shale. The deformation of these units provides areas of high secondary-permeability, locally bounded by less permeable units. Springs generally issue from Great Blue Limestone, Manning Canyon Shale, and other carbonate units.

A comparison of three drainage basins in the area, Clover Creek, Hickman Canyon, and South Willow Canyon, show areas where infiltration seems to be greatest (Table 6). South Willow basin receives the highest average annual precipitation,



TABLE 6. COMPARISON OF DRAINAGE BASIN AREA, PRECIPITATION, AND STREAM FLOW

<u>Drainage Basin</u>	<u>Area (mi<sup>2</sup>)</u>	<u>Ave. Basin precipitation</u>	<u>Average flow</u>	<u>Peak flow (cfs)</u>
Clover Creek near Clover	6.71	20.03 in/yr (7,168 ac-ft)	4.95-cfs (3,586 ac-ft)	87
Hickman Creek near St. John	12.8	23.59 in/yr (16,104 ac-ft)	n/a	18
South Willow Creek near Grantsville	4.19	31.99 in/yr (7,149 ac-ft)	6.83-cfs (4,948 ac-ft)	92

with elevations greater than 11,000 ft. Clover Creek is the lowest in elevation and receives approximately the same amount of precipitation to the basin as a whole compared to South Willow. Hickman Creek drainage basin, however, receives more than twice the amount of precipitation than the other two basins, and yet has substantially less flow in the creek. The Hickman Creek basin is comprised of Mississippian limestones, dolomites, and shale. It also incorporates approximately 3.5 miles of the Central Range Fault, providing additional fracturing to the units. A substantial portion of the precipitation in the Hickman Creek basin is accounted for with infiltration rather than surface runoff. This water is then discharged to springs, such as Clover Spring, and also provides inflow to from the consolidated rock to the valley basin-fill aquifer systems.

## CHAPTER V

### CONCLUSIONS

Detailed mapping of the Deseret Peak East 7.5' Quadrangle has revealed that previous interpretations and mapping have been lacking. The Central Range Fault is found to be a normal fault rather than a continuation of the Broad Canyon Thrust from the north. Previously unrecognized or undivided Permian and Triassic units help link the Stansbury Range to regional structural and tectonic events including the deformation of the Oquirrh Basin and the Sevier Fold and Thrust Belt.

Paleozoic rocks exposed in the Stansbury Mountains have been subjected to Paleozoic, Mesozoic and early Cenozoic folding and thrust faulting, and later Cenozoic normal faulting. Compressional deformation during the Sevier orogeny (about 150 to 100 Ma) produced regional thrusts, folds, and (probable) wrench faults that fundamentally rearranged the positions of Paleozoic and older sedimentary rocks.

Quaternary colluvial deposits unrelated to Pleistocene glaciation contained in high regions of the Stansbury and Onaqui Mountains, burying drainages and mantling hillslopes, facilitate infiltration of precipitation and contribute to the flow of surrounding springs. Geology plays a key role in controlling the groundwater in the Stansbury Range. Springs in the area arise from the Manning Canyon Shale in Big Hollow and in East Hickman Canyon, transferring water from one topographically defined drainage to another. A well defined north to south transfer of water is prominent, with large springs occurring at the southern end of the range.

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APPENDIX



**Fossils that have been identified within the boundaries of the Deseret Peak East  
7.5" Quadrangle, Tooele County, Utah**

Ophir Group (Cambrian)

- Ehmaniella quadrans* (Teichert)
- Glossopleura* sp. (Teichert)
- Iphidella pannula* (Teichert)
- Westonia ella* (Teichert)
- Ehmaniella* cf. *waptaensis* Rasetti (Teichert)
- Ptychoparia kingii* (Lambert)
- Olenellus* sp. (Rigby)
- Ehmania* (Rigby)

Teutonic Limestone (Cambrian)

- Elrathia* (Rigby)
- Peronopsis* (Rigby)

Opex Formation (Cambrian)

- Housia varro* Walcott (Rigby)

Ajax Dolomite (Cambrian)

- Prosaugia misa* sp. (Arnold)
- Idahoia* sp. (Arnold)
- Billingsella* sp. (Teichert)

Garden City Formation (Ordovician)

- Symphysurina* sp. (Teichert)
- Nevadocoelia* (Teichert)
- Dictyonema* c.f. *flabelliforme* (Teichert)
- Philograptus ilicifolius* (Teichert)
- P. angustifolius* (Teichert)
- Hystricurus genalatus* (Rigby)
- Bellifontia chamberlaini* (Rigby)
- Clelandia utahensis* (Rigby)
- Remopleuridiella* sp. (Rigby)
- Lingulella* sp. (Rigby)

Fragments of trilobites

- Psalikilus* sp. (Rigby)
- Protopliomerops* sp. (Rigby)
- Didymograptus nanus* (Rigby)
- Phyllograptus ilicifolius* n. var. (Rigby)
- P. angustifolius* n. var. (Rigby)
- P. anna* (Rigby)
- Nevadocoelia* sp. (Rigby)
- Receptaculites elongatus* (Rigby)

From the upper cherty member, Arnold (1956)

- Lachnostoma latucelsum* (Ross)
- Kirkella declevita* (Ross)
- Hespernomia dinothides* (Ulrich and Cooper)
- Finkelburgia* sp. (Arnold)

Kanosh Shale (Ordovician)

- Eleutherocentrus petersoni* (Teichert)
- Didymograptus nitidus* (Teichert)
- D. patulus* (Teichert)
- D. murchisnoi* (Teichert)
- Lingulid brachiopods* (Teichert)
- Westonia* sp. (Rigby)
- Orthis michaelis* (Rigby)
- Eleutherocentrus williamsi*(?) (Rigby)

Fish Haven Dolomite (Ordovician)

- Halysites catenularia* (Teichert)
- Streptelasma trilobatum* (Teichert)
- S. corniculum* (Rigby)
- Favosites* sp. (Rigby)
- phaceloid corals (Rigby)
- Syringopora* sp. (Rigby)

Laketown Dolomite (Silurian)

- Favosites* sp. (Teichert)
- Halvsites* sp. (Teichert)
- Eridophyllum* sp. (Teichert)
- Pentamerus (?) sp. (Rigby)

Sevy Dolomite (Devonian)

- Spirifer kobehana* (Teichert)

Gardison Limestone (Mississippian)

- Paurorhyncha endlichii* (Rigby)
- Syringopora* sp. (Teichert)
- Lithostrotionella* sp. (Teichert)
- Euomphalus* sp. (Teichert)
- Caninia* sp. (Teichert)
- Fossil hash and crinoid stems (Teichert)

Most common in upper formation:

- Syringopora aculeata* (Girty)
- S. surcularia* (Girty)
- Amplexus expansus* (Easton)
- A. geniculatus* (Worthen)

- Amplexizaphrentis ellipticus* (White),  
*A. reversus* (Worthen),  
*A. compressus* (Milne-Edwards)  
*Turbophyllum* sp. (Hall)  
*Lithostrotion proliferum* (Hall)  
*Caninia* spp. (Hall and Whitfield)  
 Fennestellid bryozoans (Hall and Whitfield)  
*Spirifer* sp. (Hall and Whitfield)  
*Straparollus (Euomphalus) ophirensis* (?) (Hall and Whitfield)
- Arnold reports the following forms from the lower member:
- Syringopora* sp. (Teichert)  
 cup corals (Teichert)  
*Composita cf. Humulis* (Teichert)  
*Brachythyris* sp. (Teichert)  
*Straparollus (Euomphalus) utahensis* (Hall and Whitfield)
- Fossils collect from the upper unit (Rigby):
- Amplexus expansus* (Easton)  
*Aulopora* sp. (Teichert)  
*Caninia* sp. (Teichert)  
*Multithecopora* sp. (Teichert)  
*Rotophyllum densum* (Carruthers)  
*Lithostrotion whitneyi* (Meek)  
*L. proliferum* (Hall)  
*Turbophyllum* sp. (Teichert)  
*Syringopora verticillata* (Goldfuss)  
*S. perelegans* (Billings)  
*S. surcurlaria* (Girty)  
*Amplexizaphrentis ellipticus* (White)  
*A. paucicinctus* (Easton and Gutschick)  
*A. subcrassus* (Easton and Gutschick)  
*A. compressus* (Milne-Edwards)  
*A. compressus* var. *lanceolatus* (Worthen)  
*Fenestella* spp. (Teichert)  
*Polypora* spp. (Teichert)  
*Spirifer centronatus* (Winchell)  
*Composita* spp. (Teichert)  
*Linoproductus gallantinesis* (Teichert)  
 chonetid brachiopod (Teichert)  
*Straparollus (Euomphalus) ophirensis* (Hall and Whitfield)  
*S. (Euomphalus) utahensis* (Hall and Whitfield)  
*Loxonema* sp. (Teichert)  
*Proetus loganensis*(?) (Hall and Whitfield)



*Lithostrotionella* sp. (Teichert)  
 fenestellid bryozoans (Teichert)  
 crinoid columnals (Teichert)  
 productid brachiopods (Teichert)  
*Diphyphyllum inconstans* (Easton and Gutschick)  
*Ekvasophyllum turbineum* (Parks)  
*Amplexizaphrentis paucicinctus* (Easton and Gutschick)  
*Lithostrotion whitneyi* (Meek)  
*Fenestella* spp. (Teichert)  
*Polypora* sp. (Teichert)  
*Penniretepora* sp. (Teichert)  
 fistuliporid bryozoans hemispherical form (Teichert)  
*Leptaena*(?) sp. (Teichert)  
*Rhipidomella* sp. (Teichert)  
 spiriferid brachiopods (Teichert)  
*Straparollus (Euomphalus)* sp. (Teichert)

#### Humbug Formation (Mississippian)

*Ekvasophyllum* sp. (Teichert)  
*Lithostrotion whitneyi* (Teichert)  
*Diphyphyllum* (?) sp. (Teichert)  
 Brachiopods and corals (Teichert)

Corals from the formation were collected and identified by Davis (1956):

*Syringopora surcularia* (Girty)  
*Ekvasophyllum turbineum* (Parks)  
*Turbophyllum multiconum* (Parks)  
*Diphyphyllum inconstans* (Easton and Gutschick)  
*Lithostrotion proliferum* (Hall)  
*L. whitneyi* (Meek)

Spiriferid and productid brachiopods are locally common.

#### Great Blue Limestone (Mississippian)

Bryozoans  
 Corals  
*Faberophyllum* sp. (Teichert)  
*Ekvasophyllum* sp. (Teichert)  
*Faberophyllum araneosum* (Parks)  
*F. occultum* (Parks)  
*F. pisgahense* (Parks)  
*Ekvasophyllum inclinatum* (Parks)  
*E. turbineum* (Parks)  
*Ekvasophyllum* sp. A (Teichert)  
*Turbophyllum multiconum* (Parks)

#### Manning Canyon Shale (Mississippian)

*Dictyoclostus* sp. (Teichert)  
*Spirifer occidentalis* (?) (Teichert)  
*Diaphragmus* sp. (Teichert)  
*Myalina* sp. (Teichert)  
*Derbya* (?) (Teichert)  
*Cleiothyradina* (Teichert)  
*Composita subtilita* (?) (Teichert)

Oquirrh Group – Prolific fauna of Echinoids, Pelmatozoans, foraminifers, brachiopods, bryozoans, ostracods, pelmatozoans, sponges and sponge spicules, dasycladacean algae, phylloid algae, Rugose corals, gastropods, crinoids, and small coiled foraminifers (Stevens).

Permian System - Wolfcampian Series

*Beedelina?* sp. (Arnold)  
*Dunbarinella hugesensis* (Thompson)  
*Fusulinelia* sp. (Arnold)  
*Mesolobus* cf. (Arnold)  
*M. euampygus* (Girty)  
*Oketaella cheneyi* (Wright)  
*Pseudofusulinella utahensis* (Thompson, Verville & Bissell)  
*Schwagerina andresensis* (Thompson)  
*Triticites cellamagnus* (Thompson & Bissell)

Pennsylvanian System - Virgilian Series

*Triticites cullomensis* (Dunbar & Condra)  
*T. kellyensis* (Needham)  
*T. milleri* (Thompson)  
*Waeringella bailkeyi* (Thompson, Verville & Bissell)

Pennsylvanian System - Missourian Series

*Caninia* sp. (Wright)  
*Kansanella grangerensis* (Thompson, Verville & Bissell)  
*Oketaella lensensis* (Wright)  
*Triticites provoensis* (Thompson, Verville & Bissell)  
*T. hobblensis* (Wright)  
*T. springvillensis* (Thompson, Verville & Bissell)  
*Schubertella mulleriedi* (Wright)  
*Wedekindellina ultimata* (Newell & Keroher)

Pennsylvanian System - Desmoinesian Series

*Eoschubertella* sp. (Thompson)  
*E. mexicana* (Thompson)  
*E. gallowayi* (Wright)  
*Fusulina rockymontana* (Roth & Skinner)  
*F. lonsdalensis* (Wright)  
*Pseudostraffella needhami* (Wright)  
*Wedekindellina matura* (Thompson)  
*Syringopora* sp. (Wright)

Pennsylvanian System - Late Derryan Series

*Fusulinella acuminata* (Thompson)

Pennsylvanian System - Early Derryan Serie

*Profusulinella copiosa* (Thompson)

*P. regia* (Thompson)

*Komia* sp. (Wright)

*Osagia* sp. (Wright)

*Pseudostaffela* sp. (Wright)

Pennsylvanian system - Morrowan Series

*Millerella inflecta* (Thompson)

*M. marblensis* (Thompson)

*Nankinella* sp. (Wright)

*Archimedes* sp. (Wright)

Thaynes Limestone (Triassic)

*Meekoceras* sp.

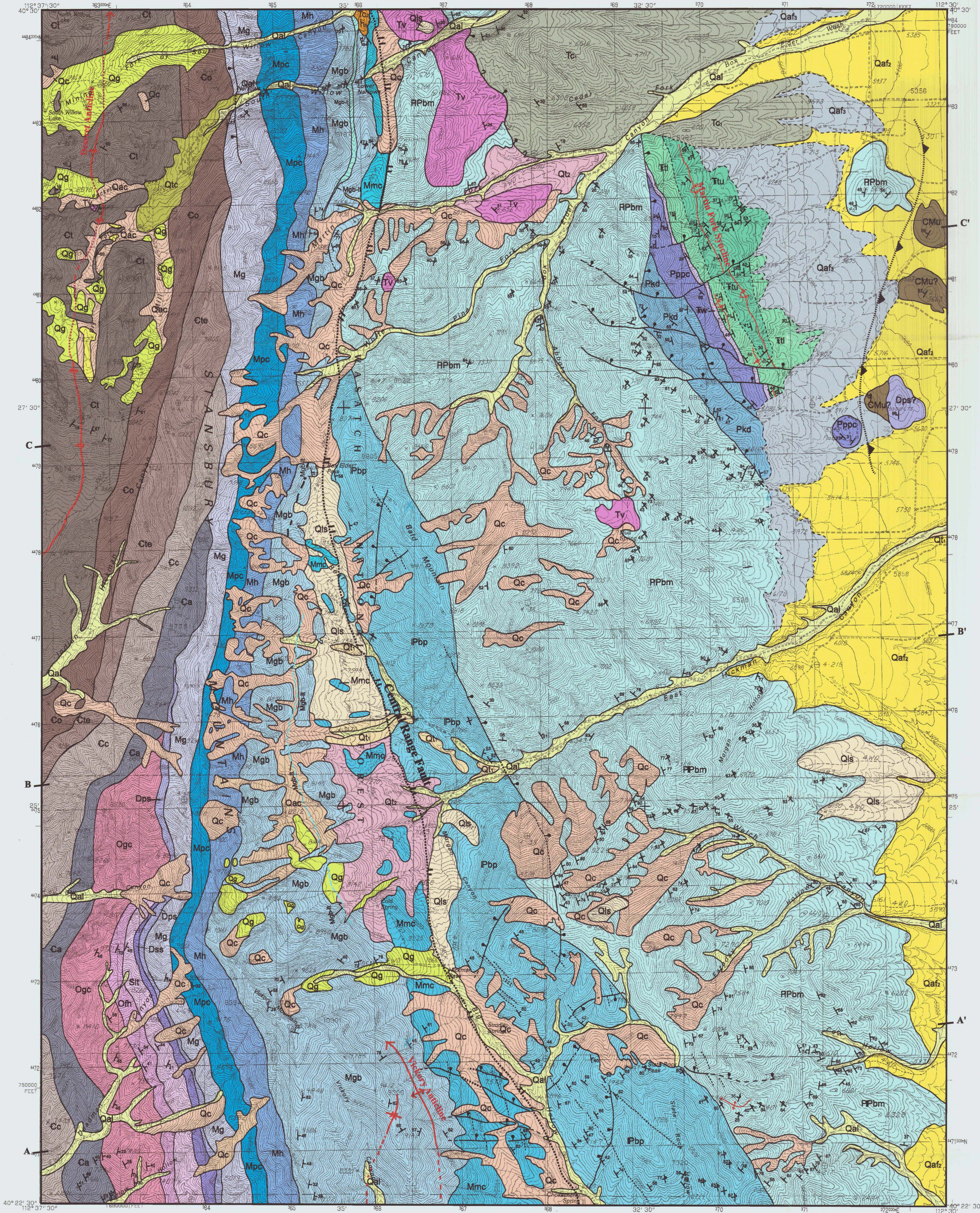
Park City/Phosphoria Formation (Triassic)

*Thamnosia*

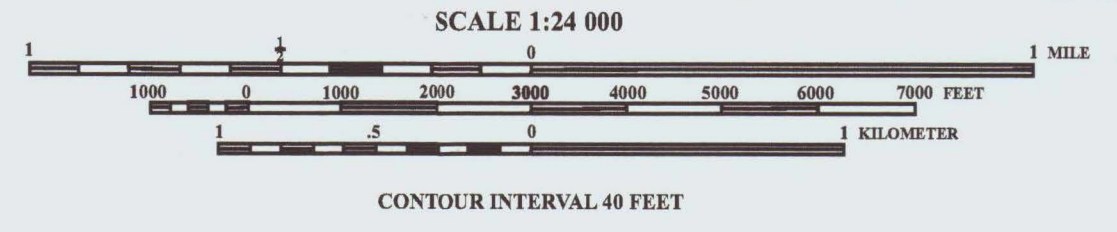
*Kuvelousia*

*Peniculauris*





Base map from U.S. Geological Survey  
Deseret Peak East 7.5' Quadrangle, 1983



1	2	3	1 Salt Mountain
2	3	4	2 North Willow Canyon
3	4	5	3 Granville
4	5	6	4 Deseret Peak West
5	6	7	5 Salt Lake
6	7	8	6 Terra
7	8		7 Johnson Pass
8			8 Salt Lake

Field mapping by T.J. Copfer 1999-2001  
Assistants: S. Carney, M. Swenson,  
M. Copfer, J. Pederson  
Thesis Advisor: J.P. Evans  
Utah State University

**GEOLOGIC MAP OF THE DESERET PEAK EAST QUADRANGLE,  
TOOELE CO., UTAH**  
by  
**Torrey J. Copfer, James P. Evans**  
2003



# Description of Map

## Quaternary

Qal

**Alluvium** - Fine-grained to gravelly stratified sediment, primarily deposited in most recent and active stream channels of East Hickman, Big Hollow, Box Elder, South Willow, Welch, Deadman, Dry and Indian Hickman Canyons. Includes coarse- to fine-grained alluvium and debris-flow deposits from smaller drainages in East Hickman and Box Elder Canyons. Includes terraces less than 20 feet (<6m) above the present floodplain.

Qaf

**Alluvial fan deposits (Upper Pleistocene to Lower Holocene)** - Coalesced alluvial fans consisting of pebble and cobble gravel, locally bouldery, in matrix of sand, silt, and clay. Approximately 170 ft above present floodplain.

Qaf

**Alluvial fan deposits (Middle Pleistocene to Upper Pleistocene)** - Poorly sorted boulders, cobbles, pebbles, and sand overlying Tertiary conglomerates between South Willow and Martin Fork and extending west from the range. Total thickness is approximately 100 ft (30 m)

Qt

**Terrace gravels (Lower Holocene to Middle Holocene)** - Thin to thick alluvial silt, very fine- to coarse-grained, sub-rounded to rounded sand, and gravel extending west from the range approximately 55 ft (17 m) above the floodplain of stream channels.

Qt

**Terrace gravels (Upper Pleistocene to Lower Holocene)** - Clast-supported pebble, cobble, and boulder gravel in a matrix of sand, silt, and minor clay. Poorly sorted with angular clasts. The deposits also contain large boulders from surrounding Paleozoic formation. Thickness is approximately 5-150 ft (2-46 m).

Qg

**Glacial deposits (Pleistocene)** - Till deposits associated with moraines. Silt and sand containing many angular to rounded pebbles, cobbles, and boulders.

Qac

**Colluvium/Alluvium (Upper Pleistocene to Upper Holocene)**- Poorly sorted clay, silt, sand, gravel, cobbles, and boulders. Includes alluvially reworked colluvium. Deposits are coarser on steeper slopes and locally includes some talus. The deposits are located in the upper areas of glaciated areas of South Willow and Miners Fork Canyons. Latest Pleistocene to latest Holocene in age.

Qc

**Colluvium** - Very coarse to fine, angular rock debris and fine-grained sediments. Located in upper areas of drainages in topographically high locations. Sand to angular pebbles, cobbles, and boulders transported by hillslope processes. Thickness varies between 10-100 feet (3-30 m).

Qtc

**Terrace/Colluvium deposits** - Mixed alluvial terrace and hillslope material. Contains gravelly, rounded to angular silt- to cobble-sized colluvium and alluvium, and locally some talus. It has been mapped as mixed terrace and colluvium because they were probably deposited by both processes.

Qls

**Landslide deposits** - Composition varies with parent material. Contain slides, slumps, and larger debris flows.

## Tertiary

Tc1

**Tertiary conglomerate (Early Eocene to Late Eocene) Salt Lake Formation (??)** - Poorly sorted, clast supported, angular quartzite pebbles with few cobbles and boulders, minor subangular-to-subrounded limestone and dolomite pebbles, and fine sandy lenses, in a fine sandy matrix which weathers rusty-orange. Highly cemented alluvial fan complex composed primarily of sheet flood and sieve deposits. Contains clasts of Eocene volcanics. The unit ranges in thickness from 0-1000 ft (305 m).

Tv

**Volcanic Rocks (Eocene)** - Undifferentiated. Consists of andesite, dacite, and hornblende latite flows and breccias, and ash flow tuffs. Dark purplish brown hornblende latite comprises most of the flow rocks associated with white, tuffaceous beds. Small plugs, dikes, and sills of monzonite occur as well. They range in thickness from 0-1410 ft (430 m). K/Ar dating of biotites have yielded ages of 39.4±0.5 my and 41.8±0.5 my for the unit

Tc2

**Tertiary conglomerate (North Horn Formation?) (Paleocene to Eocene)** - Reddish pebble conglomerate with argillaceous and calcareous matrix stained reddish brown to light orange-red composed primarily of Paleozoic carbonate clasts. Bedding is ill defined in most outcrops. There is an angular unconformity between this unit and the underlying Thaynes Limestone. Thickness is approximately 150 ft (46 m).

## Triassic

Tt

**Thaynes Limestone Upper/Lower** - Resistant, medium-bedded, gastropod- and pelecypod-bearing limestones. Dominant lithologies are bioturbated, irregularly bedded calcareous siltstone and mudstone, pelecypod packstone, and very-fine-grained, locally cross-bedded quartz arenite. The unit weathers medium gray, purple-brown, and brownish-yellow. The contact between the upper and lower units was placed below a single 2 ft (0.6 m) thick bed of ammonite (*Medioceras gn*) bearing, brownish-gray-weathering calcwackestone. Thickness of the lower member is 400 ft (152 m). The exposed thickness of the upper member is 500 ft (182 m).

Tw

**Woodside Shale** - Distinctive red-bed unit of calcareous siltstones, shales and very-fine-grained sandstones is poorly exposed. The unit forms valleys of dark brownish-red talus and soil. This unit conformable overlies the Park City and Phosphoria Formation. Thickness is about 100 ft (30 m).

## Permian

Pppc

**Park City and Phosphoria Formations** - Cherty dolomite, dolomitic sandstone, quartz siltstone, bioclastic limestone, massive chert, and partially silicified oolitic phosphorite. Commonly fossiliferous with bryozoans, condonts, and brachiopods of the *Thamnosia*, *Kanvelousia*, and *Peniculauris*. Exposures are poor and covered by float from topographically higher units. This unit conformably overlies the Kirkman Limestone. Minimum thickness of 550 ft (168 m).

Pkd

**Kirkman Limestone and Diamond Creek Sandstone** - Thick-bedded, massive limestone and conglomerates. Limestones contain corals, brachiopods, and other shelled fauna, contain chert stringers and oncolites. Conglomerates contain clasts of quartz arenites and calcarenites; Gradational contact with the Diamond Creek Sandstone. The upper part is primarily quartz arenite, but lithology is laterally variable and the interval is cut by high-angle faults. Cherty, calcareous quartz arenites are massive to thinly bedded, cross-beds with tabular sets up to 8 in (20 cm) thick. Also contains thin interbedded chert and sandstone pebble breccia. The Martin Fork Fault separates this unit with the underlying Bingham Mine Formation. Minimum thickness of 490 ft (150 m).

## Permian-Pennsylvanian Oquirrh Group

PPbm

**Bingham Mine Formation (Missourian-Wolfcampian)** - Thick intervals of grayish-yellow and orangish-brown weathering, thin- to medium-bedded sandstone, siltstone, and quartzite. Contains intercalated medium-gray and bluish-gray weathered, fossiliferous limestone and dark-to-light-gray weathered limestone conglomerate. The undivided lower member (Missourian-Virgilian) is a 4,920 ft (1,500 m) thick interval of grayish-yellow to orangish-brown calcareous sandstone and siltstone to vitreous quartzite with interbedded limestone becoming less common towards the top. The upper member (Virgilian-Wolfcampian) is approximately 6,500 ft (1,980 m), composed of quartzite, sandstone, and siltstone with subordinate limestone conglomerate and limestone. Presence of limestone conglomerate distinguishes the upper member from the lower. This unit is in conformable contact with the underlying Butterfield Peaks Formation.

IPbp

**Butterfield Peaks Formation (Middle Pennsylvanian)** - Interbedded, ledge-forming limestone and slope-forming sandstone. Massive biosheral limestone intervals are more prevalent near the lower contact, and interbedded quartzite and sandstone intervals are thicker toward the top of the unit. Rocks typically are light-grayish-brown, and are composed of very well sorted silt to medium-sand sized quartz and feldspar grains. Cross stratification, horizontal lamination, and scouring at the bases of some beds have been observed in some thin- to medium-bedded sandstones. Bedding contacts generally are planar. The Central Range Fault separates this unit from the underlying Manning Canyon Shale. Estimated thickness is approximately 6,000 ft (1,850 m).

## Mississippian

Mmc

**Manning Canyon Shale** - Consists of black to olive-brown siltstone and shale, dark carbonaceous limestone, and hematite-stained quartzite and sandstone. Not well exposed, but is easily discerned in the field by characteristic small black shale chips observed in float and low topographic expression, forming valleys. There is a gradational contact between this unit and the underlying Great Blue Limestone. The unit ranges in thickness from 395-1,315 ft (120-400 m).

Mgb

**Great Blue Limestone** - Medium- to thick-bedded, medium-gray to dark-blue-gray, weathering dark- to light-gray, fine- to medium-crystalline limestone with intercalated sandstone. Contains profuse corals, bryozoans and other fossils in a fine-grained to microcrystalline matrix. Silty limestone weathers tan-brown. Dark-brown weathered chert in present locally in networks and stringers within limestone beds. The unit grades upwards to thin-bedded shaly limestone near the gradational contact with the overlying Manning Canyon Shale. This unit has a gradational contact with the underlying Humbug Formation. The unit is approximately 1,210 ft (370 m) thick.

Mgb-It

**Long Train Shale Member** - Dark-green, calcareous shale contains few thin interbeds of quartzitic sandstone. Poorly exposed, but can easily be traced in the field by prominent slopes. Thickness ranges from 30-80 ft (10-25 m).

Mh

**Humbug Formation** - Thin-bedded calcareous sandstone, containing fossil fragments interbedded with thin-bedded, light-gray-blue weathered fossiliferous limestone and argillaceous limestone, and minor thin-bedded quartzite. This unit is in conformable contact with the underlying Pine Canyon Formation. Thickness is 750 ft (229 m).

Mpc

**Pine Canyon Formation** - Lower formation consists of dark gray limestone interbedded in one to three-inch units with black chert. The middle of the unit is characterized by terrigenous clastic sediments with some limestone beds. Reddish brown, yellow-brown, and related grays are characteristic of the siltstone and minor beds of sandstone found to the south. This unit unconformably overlies the Gardison Limestone. Thickness varies from 200-950 ft (50-290 m).

Mg

**Gardison Limestone** - Thick-bedded, dark-gray to black dolomite overlain by thin- to medium-bedded, blue-gray weathered, fossiliferous limestone. Brown weathering black chert nodules are common throughout the section. This unit unconformably overlies the Pinyon Peak Formation. Thickness ranges from 550-900 ft (168-274 m).

## Devonian

Dps

**Pinyon Peak Formation and Stansbury Formation undivided** - Poorly sorted dolomite and quartzite conglomerate with subrounded clasts typically ranging from 1-20 cm in diameter. Medium bedded, light tan-brown quartzite weathering rusty tan-brown; dark gray weathering light gray and tan, fine crystalline argillaceous dolomite; dark gray medium gray and tan microcrystalline limestone; and light tan-gray, weathered rusty, commonly calcareous sandstone. This unit unconformably overlies the Simonson Dolomite. Thickness ranges from 0-400 ft (122 m).

Dss

**Simonson and Sevy Dolomites** - The Sevy Dolomite is light gray, weathers white, microcrystalline, thin- to medium-bedded dolomite. Thickness is approximately 0-75 ft (23 m). The Simonson Dolomite is an interbedded dark-gray, medium-crystalline, and lighter-gray, coarse-crystalline, sandy dolomite. There is a gradational contact with the underlying Laketown Dolomite. Thickness is approximately 0-240 ft (73 m).

## Silurian

Slt

**Laketown Dolomite** - Massive light gray to dark-blue-gray, thin- to medium-bedded, coarse- to medium-crystalline dolomite, with common chert lenses. Thickness is approximately 0-590 ft (180 m).

## Ordovician

Ofh

**Fish Haven Dolomite** - Thick- to thin-bedded, medium-crystalline, dark- and light-gray dolomite, which is fossiliferous in the lower half. The base of the formation is easily established in the southern and western exposures at the top of the black graptolitic shales of the Kanosh Shale. The unit unconformably overlies the Kanosh Shale. Thickness is found to be 0-260 ft (80 m).

Oks

**Kanosh Shale** - Dark-blue and green to black, fissile, micaceous shale, interbedded with siltstone, sandstone, and quartzite; weathers rusty-orange-brown. Limestone and dolomite interbedded with the argillites are commonly black to very dark gray, very argillaceous and thin-bedded. The formation is approximately 0-260 (80 m) thick.

Ogc

**Garden City Formation** - Dark-blue-gray, thin- to medium-bedded limestone with abundant interbeds of silty limestone weathering reddish-tan. Lower section consists of a basal interbedded interval of cherty limestone and dolomites overlain by a well-bedded, medium-gray argillaceous limestone which weathers distinctly blue-gray and is slightly more resistant than either the unit above or below. Top is cherty sandy limestone above an interbedded argillaceous limestone and shale. The thickness of the unit is 0-1,300 ft (400 m).

## Cambrian

Ca

**Ajax Dolomite** - Thick-bedded, dark-gray, ledge-forming dolomite is. Abundant black and light-gray chert nodules and stringers are common. Many beds are faintly mottled medium-gray on weathered surfaces. The unit is conformable with the underlying formation. Thickness is 0-1,000 ft (305 m).

Cc

**Cole Canyon Dolomite and Opex Formation** - Cole Canyon Dolomite has distinctive alternating light- and dark-gray banded dolomite. Oolites are common. Light-colored dolomite is irregularly laminated. The Opex Formation consists of dark-gray to black, ledge-forming dolomite overlain by distinctively thin-bedded and common argillaceous limestone beds. The unit unconformably overlies the Teutonic Limestone. Total thicknesses are found to be 0-460 ft (140 m).

Ctc

**Teutonic Limestone** - Thick to medium bedded argillaceous limestone with silty partings and blue gray limestone with thin silty partings interbedded with olive to brown green shale. The unit is conformable with the underlying Ophir Group. Thickness varies from 0-410 ft (125 m).

Co

**Ophir Group** - Lower section consists of brown-tan weathering, calcareous sandstone and blue sandy limestone underlain by dark gray sandstone and shale. The upper section consists of dark gray to light green calcareous shale and siltstone with lenses and partings of black limestone, overlying a thick sequence of interbedded limestone and shale. Thickness is approximately 800-1,220 ft (244-372 m).

Ct

**Tintic Quartzite** - Medium-bedded, medium- to coarse-grained quartzite. The lowermost part is a light-pink, brown and maroon quartzite conglomerate. The uppermost section is a reddish-brown, medium- to thick-bedded, pebbly quartzite. The majority of the unit is thin- to thick-bedded, light-gray to light-tan quartzite, commonly weathered reddish-brown with hematite staining. Exposed thickness of the unit is approximately 2,800 ft (853 m).

CMu

**Cambrian-Mississippian undivided.** - Limestone, dolomites, and quartzites located east of the range between East Hickman and Box Elder canyons. Formation ages unknown. Faulting in the area places quartzite near Permian units.

## Map symbols

### FAULTS

Dashed where approximately located; dotted where concealed

High- to moderate-angle normal fault, primarily dip-slip; bar and ball on downthrown side; arrow shows amount of dip

Lineament visible on aerial photographs

Low-angle normal fault. Double bar on downthrown side.

Thrust fault. Teeth on upper plate. Dotted where inferred

### FOLDS (shown in red on map)

Dashed where approximately located; dotted where concealed

Anticline; arrow at tip showing direction of plunge

Syncline; arrow at tip showing direction of plunge

Overturned folds; arrows at tips showing direction of plunge

### CONTACTS

Dashed where approximately located; dotted where concealed

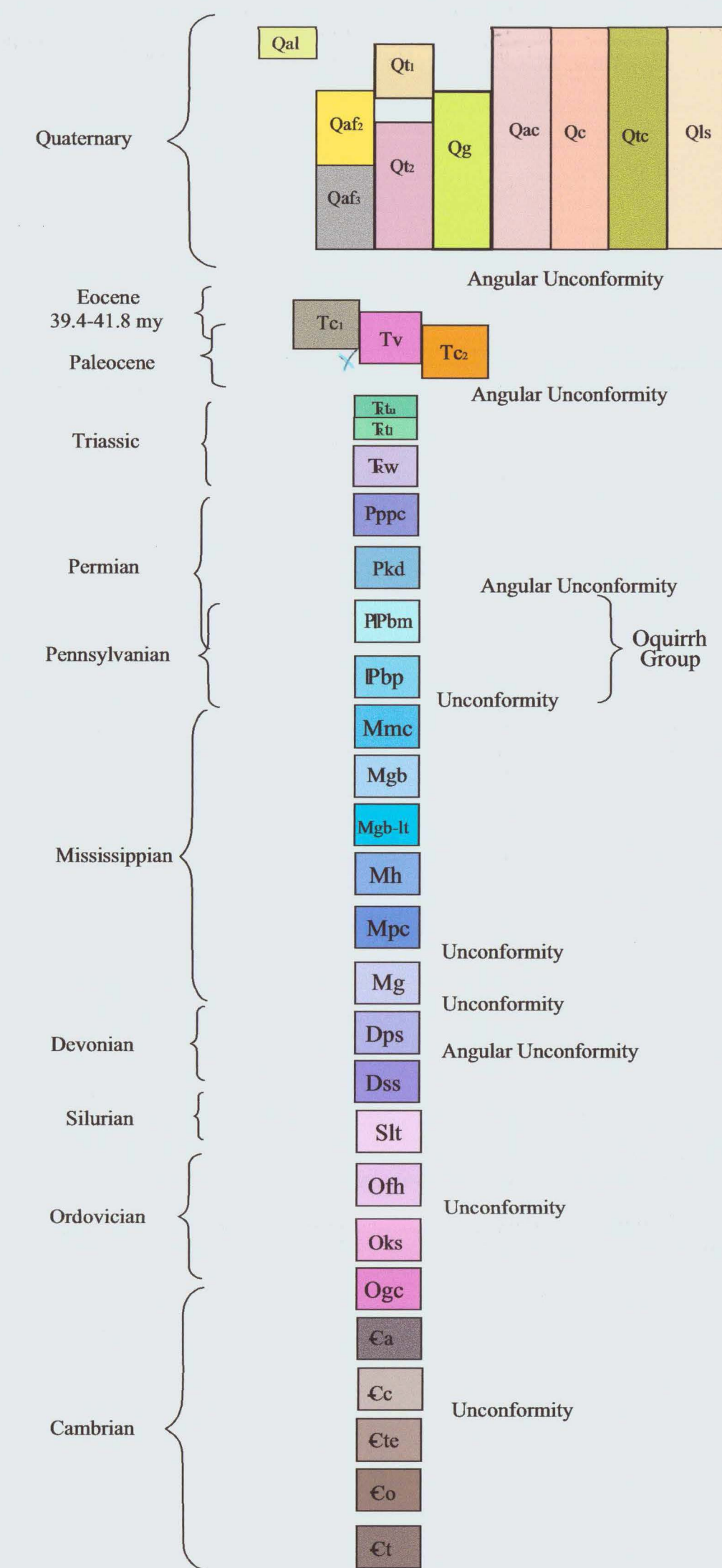
Strike and dip of bedding

Overturned

Approximate strike and dip direction of bedding

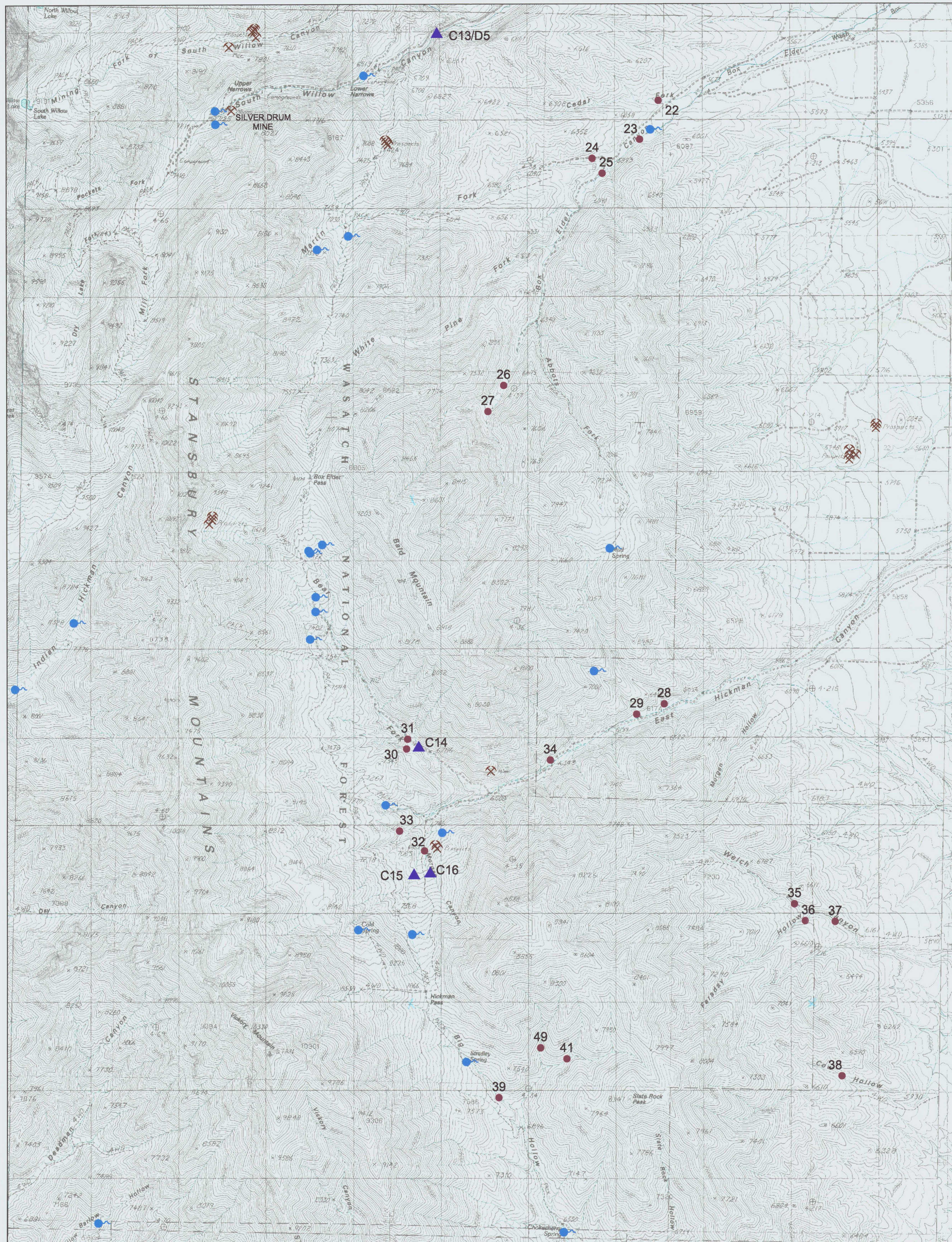
Bedding trace from aerial photographs

## Correlation of Map Units

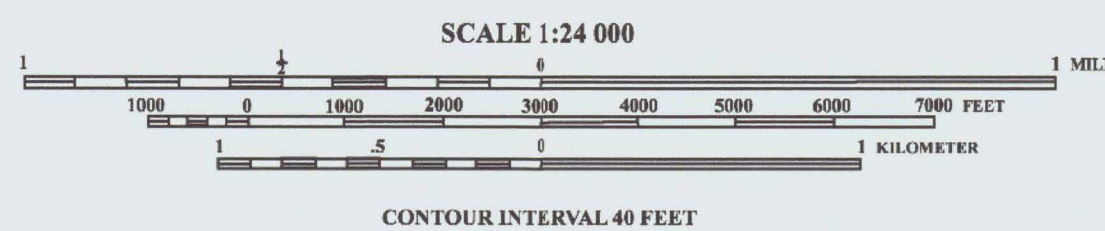
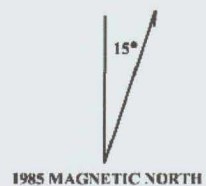


Period	Formation	Unit	Feet	
Cenozoic	Tertiary	Conglomerates	Tc1 0-1000	
		Layered Volcanics	Tv 0-1400	
	Triassic	Thaynes Limestone Upper	Tt 600	
		Thaynes Limestone Lower	Tt 500	
Mesozoic	Permian	Woodside Shale	Tw 100	
		Park City/Phosphoria	Pppc 550	
		Kirkman Limestone Diamond Creek Ss.	Pkd 490	
	Pennsylvanian	Oquirrh Group	Bingham Mine Formation	PPbm 6,560
			Butterfield Peaks Formation	IPbp 4,920
		Oquirrh Group	Butterfield Peaks Formation	IPbm 6,070
	Paleozoic	Mississippian	Manning Canyon Shale	Mmc 395-1,315
			Great Blue Limestone	Mgb 1,210
			Long-Trail Shale	Mgb-It 0-80
Humbug Formation			Mh 750	
Pine Canyon Fm.			Mpc 200-950	
Gardison Limestone			Mg 550-900	
Stansbury Formation - Pinyon Peak Limestone			Dps 0-400	
Sery-Simonson Dolomite			Dss 0-240	
Laketown Dolomite			Slt 0-590	
Fish Haven Dolomite			Ofh 0-260	
Kanosh Shale			Oks 0-260	
Garden City Formation			Ogc 0-1,300	
Ajax Dolomite			Ca 0-1,000	
Cole Canyon Dolomite and Opex Formation			Cc 0-460	
Teutonic Limestone	Ctc 0-410			
Ophir Group	Co 800-1,200			
Tintic Quartzite	Ct -4,200			





Base map from U.S. Geological Survey  
Deseret Peak East 7.5' Quadrangle, 1983



1	2	3	1 Salt Mountain
			2 North Willow Canyon
			3 Graniteville
			4 Deseret Peak West
			5 Salt Lake
			6 Terra
			7 Johnson Pass
			8 Salt Lake

- ▲ Water Sample locations
- Sample locations
- ✕ Mines, prospects
- Springs

**ECONOMIC, WATER, AND SAMPLE LOCATIONS MAP OF THE  
DESERET PEAK EAST QUADRANGLE, TOOELE CO., UTAH**

by  
**Torrey J. Copfer**  
2002



