INTERIM GEOLOGIC MAP OF THE EPHRAIM 7.5-MINUTE QUADRANGLE, SANPETE COUNTY, UTAH

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ABSTRACT

The Ephraim quadrangle is located about 140 miles south-southeast of Salt Lake City in Sanpete County in central Utah. A diagonal line, extending NE-SW across the quadrangle, divides Sanpete Valley to the northwest, from the Wasatch Plateau. Sanpete Valley is a structural feature in which the San Pitch River flows south along its west margin. Quaternary fans form a gently sloping surface from the plateau front to the floodplain of the river.

Bedrock units are mostly of early Tertiary age. These include the (ascending) North Horn Formation (1100+ feet thick), Flagstaff Limestone (500–1000 feet thick), Colton Formation (1400+ feet thick), Green River Formation (620+ feet exposed), and the Crazy Hollow Formation (less than 50 feet exposed). Of these, the North Horn Formation may also have some Late Cretaceous strata at the base. The older three units are exposed in the Wasatch Plateau, the other two along the plateau-valley margin.

The dominant structural feature of the Wasatch Plateau in the Ephraim quadrangle is the Wasatch monocline. Strata bend and are broken by subparallel normal faults along the west margin of the plateau. Strata dip northwestward and gently to the southeast, dips gradually increasing to more than 45° along the plateau front. The dips increase due to folding of strata rather than sudden changes along the subparallel faults. The faults form a graben, termed the Shoulder graben. Faults on the west or northwest side of the graben generally increase in displacement toward the graben, reaching a maximum of about 650 feet of displacement. Faults on the east side of the graben have a maximum of about 750 feet of displacement. The fault planes dip from nearly vertical to 75° in the direction of downward displacement.

The North Horn, Flagstaff, and Colton Formations all contain units prone to landsliding. The steep western boundary of the Wasatch Plateau and walls of the principal canyons promote mass-wasting events. Such events have occurred throughout the Quaternary Period and are most common during "wet" years, which are cumulative years of above-normal precipitation. Large rock slides have occurred, probably in the Pleistocene, in which thick slabs of Flagstaff Limestone have slid along the plateau front and have come to rest as colluvium more than a mile away. Recent landslides dot the sides of canyons and the Shoulder graben.

Sand and gravel and building stone are the only known earth resources of significance in the Ephraim quadrangle. Several sand and gravel pits, dug in the alluvial fan at the foot of the plateau, have been in use for local construction or road building. These are used intermittently. Pioneers quarried a beautiful yellow-gray oolitic sandstone

from the Green River Formation at Temple Hill for the construction of homes, important buildings, and cemetery headstones. These quarries operate intermittently. Geologic hazards in the Ephraim quadrangle include canyon-mouth flooding, landsliding, debris flows, and earthquakes.

INTRODUCTION

The Ephraim quadrangle is along the west margin of the Wasatch Plateau in central Utah. The boundary between the Wasatch Plateau and Sanpete Valley runs diagonally from southwest to northeast across the quadrangle. Ephraim city is just west of the plateau at the north end of the quadrangle on the east side of Sanpete Valley. Manti Canyon is an important east-west feature in the southern part of the quadrangle. In addition to Manti Canyon, Ephraim and Willow Creek Canyons emerge from the Wasatch Plateau in the quadrangle. The highest elevation of the quadrangle is in the Wasatch Plateau near the southeast corner at about 10,220 feet. The lowest elevation is in Sanpete Valley near the northwest corner of the quadrangle at about 5430 feet. The valley-plateau boundary is at an elevation of roughly 6000 feet.

Parts of the Ephraim quadrangle were geologically mapped prior to this study. Notable are the works of Washburn (1948) in the southern part of the quadrangle and Bonar (1948) in the north half of the quadrangle. These studies provided maps at scales of 1:31,680, but were not tied to the latest U.S. Geological Survey topographic map series for the quadrangle. Baum and Fleming (1989) mapped landslides and debris flows in Ephraim Canyon after the disastrous floods of 1983-1984, and we also mapped these features throughout the quadrangle. Additionally, Witkind and others (1987) included the Ephraim quadrangle in their mapping of the Manti 30' x 60' quadrangle.

STRATIGRAPHY

Exposed on the Ephraim quadrangle are strata from the Cretaceous-Paleocene North Horn Formation, the Paleocene-Eocene Flagstaff Limestone, and the Eocene Colton, Green River, and Crazy Hollow Formations. The subsurface probably contains a normal suite of Cretaceous deposits, as shown by Weiss and Sprinkel (2002), that extends westward from the east side of the Wasatch Plateau (Davis and Doelling, 1977). Additionally, extensive unconsolidated surficial deposits cover parts of the quadrangle. This surficial material includes fluvial, mixed fluvial and colluvial, and mass-wastage deposits. Most surficial deposits are Quaternary age, but some were estimated by Weiss and Sprinkel (2002) to be Pliocene (Tertiary) age; however, a proposed adjustment to the age of the Pliocene-Pleistocene boundary may render them completely Quaternary (Ogg and others, 2008; Kerr, 2009).

Cretaceous Rocks

Subsurface formations

Since no drill-hole data are available for the Ephraim quadrangle, the subsurface information presented on the cross-section (plate 2) is conjectural. We extrapolated data from Davis and Doelling (1977), Sprinkel (1994), and Weiss and Sprinkel (2002) to show units that are likely present beneath the oldest units exposed on the quadrangle. Units projected in from the east and south include (in descending order) the Price River Formation, Castlegate Sandstone, Blackhawk Formation, Star Point Sandstone, and upper Mancos Shale. Those found under Sanpete Valley (as shown by Weiss and Sprinkel, 2002, on their cross-section of the adjoining Manti quadrangle) are (in descending order) the Sixmile Canyon Formation, Funk Valley Formation, and Allen Valley Shale. The Sixmile Canyon Formation correlates with the Castlegate Sandstone to upper Mancos Shale interval to the east; the Funk Valley Formation with most of the Mancos Shale, and the Allen Valley Shale with the Tununk Member of the Mancos Shale (Hintze and Kowallis, 2009).

Thicknesses of these subsurface units as shown on the cross-section are assumed using data provided by Davis and Doelling (1977), Sprinkel (1994), and Weiss and Sprinkel (2002). Generally, marine units such as the upper Mancos Shale are expected to thin westwardly as the clastic units thicken.

Cretaceous-Paleocene Rocks

North Horn Formation (TKnh)

The North Horn Formation is exposed in the canyons that have been cut into the Wasatch Plateau and is the oldest exposed unit in the quadrangle. More than 1100 feet of North Horn Formation is exposed in steep slopes on the sides of the canyons.

The North Horn consists of interbedded, variegated mudstone, gray to brown sandstone, sandy gray fresh-water limestone, and a small amount of pebble conglomerate. The very thinly bedded mudstone dominates (an average of 59 percent of the section), and consists mostly of silt-size particles. Shale beds are commonly sandy, calcareous, and/or argillaceous. Mudstone and claystone make up some of the shale. Bedding is indistinct and is commonly displayed by changes in coloration. The shale commonly breaks up into grit-sized (~0.1 inch) equidimensional fragments, and commonly forms steep, hard, rubbly slopes and badland topography. Sandstone (about 34 percent) is generally gray or brown in color and weathers into shades of brown. It is generally fine to coarse grained, and commonly poorly sorted with subangular clasts. Locally, pebbles and locally pebble conglomerates (2-3 percent) are associated with the sandstone. Most sandstone strata are calcareous, lenticular, and form ledges and cliffs. They are found in medium to massive beds, are commonly cross-bedded, and contain partings of mudstone and shale. Many have a "salt-and-pepper" appearance and some are muddy. Limestone and/or calcarenite strata (~5 percent of the formation) are gray to brown, finely crystalline or fine grained, and form ledges or very steep slopes. Locally they contain broken shells (fossils) and calcite in fractures.

Bonar (1948) concluded that the North Horn was deposited in a fluvial environment consisting of flood plains and channels. Lakes commonly developed on the flood plains. Mud and clay in the shale beds make the unit unstable and contribute much to the ubiquitous presence of landslides and mudflows on the outcrops of the formation.

The North Horn Formation is Late Cretaceous (Maastrichtian) to Paleocene in age (Franczyk and others, 1992; Difley, 2007). No direct evidence of the Cretaceous-Tertiary boundary is present in the quadrangle. In Manti Canyon, we think this boundary is under a thick sequence of sandstone strata about 800 feet below the top of the unit. The thickest section of the North Horn, more than 1100 feet, is probably exposed in Manti Canyon.

Tertiary Rocks

Flagstaff Limestone (Tf)

The Flagstaff makes up much of the upper surface of the Wasatch Plateau. The base of the unit generally caps the North Horn Formation in canyon walls. The overlying Colton Formation is only present along the west margin of the Wasatch Plateau. Where available for complete measurement (only along the west margin of the Wasatch Plateau), the Flagstaff reaches a maximum of 700 feet, yet topographic contours, where the formation is incompletely exposed higher up on the plateau, show as much as 1000 feet of strata.

The Flagstaff Limestone consists of varying amounts of limestone, calcareous shale, and sandstone. Several measured sections show limestone makes up 55 to 65 percent, limestone shale 30 to 42 percent, and sandstone 2 to 8 percent of the unit. Limestone is found in varying shades of gray, gray brown, or light pink that usually weather to lighter shades. The limestone is mostly aphanitic (micritic) to finely crystalline, but locally has coarse grained, clastic (calcarenite and calcisiltite), and cataclastic textures. The strata are generally ledge or cliff-forming, thin bedded to massive, dense and hard, and locally dolomitic or argillaceous. Many beds are fossiliferous, containing shell and bone fragments and locally containing good, high-spired gastropod specimens. Locally, beds are nodular, slaty, stylolitic, cherty, or fetid. Calcareous shale is found in shades of gray, green gray, olive green, green brown, and locally red. Strata are laminated to thin bedded, locally fissile, locally argillaceous and clayey, or contain gypsum stringers and fossil debris. The strata form steep slopes and locally weather to nodules. Sandstone is buff, gray, or light brown, and mostly fine grained with local coarse to pebbly beds. The grains are angular to subrounded, and moderately to poorly sorted. Sandstone is generally poorly to massively bedded and lenticular.

Most investigators working with the Flagstaff Limestone in the Wasatch Plateau indicate the unit was deposited in a large lake known as Lake Flagstaff that developed in latest Paleocene time (Franczyk and others, 1992; Hintze and Kowallis, 2009, p. 81). Some of the strata are clayey, like in the North Horn Formation, and are prone to landsliding in the Ephraim quadrangle.

The age of the Flagstaff Limestone is generally considered to be latest Paleocene (Franczyk and others, 1992). However, Weiss and Sprinkel (2002) indicate (using other references [their p. 9 and lithologic column]) that the Flagstaff may be mostly early Eocene in the Manti and Ephraim area.

Colton Formation (Tc, Tcg)

The Colton Formation overlies the Flagstaff Limestone along the west edge of the Wasatch Plateau in the Ephraim quadrangle. The strata are present as colorful, steeply dipping (~45°) beds on the Wasatch monocline (figure 1). We mapped two zones in the Colton Formation with a decidedly green appearance that are most likely of lacustrine origin (Tcg). These zones were useful in our mapping, but are probably not correlatable into other areas or quadrangles. Our measurements indicate the formation is more than 1400 feet thick.

The Colton Formation consists of shale (55-75 percent), sandstone (10-25 percent), and limestone (10-20 percent). Shale, made up of varieties of siltstone, mudstone, and claystone, are found in shades of gray, red, brown, olive green, gray, gray green and other colors and are commonly variegated, banded, or mottled, and weather to lighter shades. The strata are finely laminated to thin bedded, fissile or granular (break up into grit-size fragments), and locally contain biotite flakes, ostracodes, small gastropods, and pelecypods (figure 2). They form steep and both hard and soft slopes. Sandstone may be gray, yellow gray, brown, olive green, red, orange, or tan. The beds are generally fine to coarse grained, moderately to poorly sorted, with subrounded to subangular grains. Some beds are poorly cemented; others well cemented. Most sandstone beds are ledge or cliff forming; some are irregularly thin to thick bedded. Many beds display cross-bedding and have a "salt-and-pepper" appearance due to scattered lithic and chert fragments. Some beds are friable and porous, but others are argillaceous. Most beds are calcareous. Limestone is found in various shades of gray, and is mostly micritic or finely crystalline, but calcarenite or calcisiltite are present. Limestone generally forms hard and thin ledges. Commonly, the limestone beds contain ripples, platy weathering, fossil fragments, conchoidal fracturing, and nodular weathering.

The Colton Formation, like the North Horn, was deposited in a fluvial environment consisting of flood plains, flood-plain lakes, and channels. The upper contact is not present in the Ephraim quadrangle. Some landslides have also developed on the Colton.

The age of the Colton Formation in the Ephraim quadrangle is early Tertiary (Eocene) (Franczyk and others, 1992). We found no diagnostic fossils to date the formation, and the age determination is based on previous work.

Green River Formation (Tgu, Tgl)

The Green River Formation is exposed in valley-ward, shallow dipping cuestas along the east margin of Sanpete Valley. Two members (lower and upper) have been identified based on the amount of ledge or cliff-forming limestone and by color. The lower member is dominated by calcareous shale and limestone and is mostly very light gray in color. The upper member contains thicker beds of limestone and is tan or light yellow gray in color.

The lower member of the Green River Formation (Tgl) consists of interbedded calcareous shale (about 75 percent) and limestone (about 25 percent). Both calcareous shale and limestone are very light gray; some of the shale is light green gray. The entire unit forms a steep slope with poorly exposed strata. The limestone beds are mostly finely crystalline and locally oolitic and form weak ledges in the slope. The limestone is generally thin to medium bedded, and is irregularly interbedded in the shale. Shale is commonly argillaceous and weathers earthy. We measured approximately 400 feet in the Ephraim quadrangle. The base of the lower member is not exposed in the quadrangle.

The upper member of the Green River Formation (Tgu) in the Ephraim quadrangle consists of limestone, calcareous shale, and tuff. The limestone beds are shades of gray, pink gray, yellow orange, and yellow gray that weather yellow brown or brown. The limestone is mostly finely crystalline and oolitic and is mostly thin to medium bedded. The limestone beds weather slabby to blocky and are resistant. The thickest beds are clustered near the base of the member and have been quarried to provide building blocks for the Manti LDS temple and other pioneer buildings in the area. Higher up in the section the outcrops form a steep slope consisting of subdued ledges of limestone, interbedded calcareous shale, and tuff. The shale, in various shades of gray or gray green, is marly and calcareous. Thin tuff beds are light to tan, and contain small biotite flakes.

No top for the member is exposed in the quadrangle except on Temple Hill, where it is overlain by the Crazy Hollow Formation. Strikes and dips of outcrops on Temple Hill vary dramatically, and we believe the Crazy Hollow beds moved by gravity on top of the upper Green River member in latest Tertiary or early Quaternary time. This analysis was also accepted and reported on by Weiss and Sprinkel (2002) in their mapping of the Manti quadrangle, which lies adjacent to the Ephraim quadrangle to the west. As such, the natural sequence of deposition between the Green River and Crazy Hollow Formations is not exposed in the quadrangle. Our measurements of the upper member of the Green River Formation in the quadrangle ranged from 120 to 220 feet in thickness.

Both members of the Green River Formation were deposited in lacustrine to palustrine environments. The paleolake covered much of central and northeastern Utah and southwestern Wyoming, with the Uinta Mountains dividing the Utah from the Wyoming portion. This paleolake has been termed the Lake Green River by Hintze and Kowallis (2009) and Lake Uinta by early workers (see Franczyk and others, 1992).

The Green River Formation is early Tertiary (middle Eocene) in age (Remy, 1992). We found no diagnostic fossils to date the formation, and the age determination is based on previous work.

Crazy Hollow Formation (Tch)

The Crazy Hollow Formation exposures are limited to eastern part of Temple Hill in the southwestern part of the quadrangle. They are exposed on both sides of a fault or slide plane that is evident along the west edge of the quadrangle; the east side is elevated above the west. Beds on the west side dip normally, as would be expected for the Green River cuestas. Beds on the east side are warped into a syncline.

The Crazy Hollow Formation in the Ephraim quadrangle consists of sandstone and pebble conglomerate. The sandstone is yellow gray, medium brown, or green gray, mostly coarse grained, and contains subangular, poorly sorted grains. The lower part forms thick-bedded ledges and cliffs; the upper part (which is mostly missing on Temple Hill) is a reddish or light red-brown slope. Interbedded with the lower part are loose or friable, poorly cemented sandy beds.

Nearly 50 feet were measured on the east of the slide block or fault, with about 30 feet of cliff-forming beds. The upper slope-forming 15-20 feet have mostly been removed by erosion from the hill. The Crazy Hollow Formation is early Tertiary (Eocene) in age.

Quaternary Deposits

Alluvial deposits

In the Ephraim quadrangle we mapped four types of alluvial deposits, floodplain alluvium (Qal), mixed alluvium and colluvium (Qac), younger alluvial-fan deposits (Qafy), and older alluvial-fan deposits (Qafo). Qal deposits are mostly unconsolidated sediments mapped as the flood plain of the San Pitch River. Qac deposits are along stream channels in canyons and smaller depressions and grade to alluvial-fan deposits. The Qafy deposits are located adjacent to the plateau front, at the mouths of canyons, and alongside more prominent canyons, whereas Qafo covers most of the valley floor as exposed in the Ephraim quadrangle.

Mixed alluvial and mass-movement deposits

The mixed alluvial and mass-movement deposits are composed of bouldery channel deposits (Qabc). These are composed of both slide and slump, and alluvial material. Qabc is found mostly along the front of the range where debris that slumped or rolled down collected as the Flagstaff Limestone detached and slid down the dip slope of the Wasatch monocline over the tops of the Colton Formation and parts of the Green

River Formation.

Mass-movement deposits

These deposits are common along the Wasatch monocline, especially where the North Horn, Colton, or Flagstaff Formations are present at or below the surface. The units we mapped include historical landslides and slumps (Qmsh), landslides and slumps (Qms), colluvium (Qmsc), talus deposits (figure 5) (Qmt), and landslides of coherent blocks including Green River (Qms[g]), Colton (Qms[c]), Flagstaff (Qms[f]), and North Horn Formations (Qms(nh). Both Qms and Qmsh are landslides and slumps and have been moving since the Holocene or longer; however, Qmsh deposits show evidence of post 1980 movement (figure 3). Qmt is rock debris that is deposited on steep slopes along canyon walls and at the base of cliffs. The landslide block deposits Qms(g), Qms(c), Qms(nh), and Qms(f) are coherent blocks that have slid, but can still be recognized (figure 4).

STRUCTURAL GEOLOGY

General

The most important structures of the Ephraim quadrangle include the Wasatch monocline, the Shoulder graben with the attendant faults, and the Temple Hill toreva block. No deep holes have been drilled in the Ephraim quadrangle. However, Weiss and Sprinkel (2002) provide subsurface information for the adjoining Manti quadrangle, including structural relations seen in Sixmile Canyon, and mapping and cross sections by Weiss (1994) in the Sterling quadrangle and work done in central Utah by Schelling and others (2007) offer a glimpse into the subsurface of the Ephraim quadrangle.

Wasatch monocline

The most obvious structural feature in the Ephraim quadrangle is the Wasatch monocline. The monocline is defined by the outcrop of the hard Flagstaff Limestone, and by the subsurface high-angle extension Ephraim fault as defined by seismic lines (Schelling and others, 2007). In the southeastern corner of the quadrangle, Flagstaff strata dip only a few degrees to the west. The Ephraim fault offsets the Arapien Shale and significantly thickens it in the subsurface. Dips steepen towards the west, and along the west edge of the Wasatch Plateau the rocks dip at an average of 45° westward and are cut by steeply dipping faults that are down on the east (figure 6). Locally, dips in the Colton Formation are much steeper to overturned. The steepness of the monocline has precipitated bedding-plane rock slides that are intermittently exposed on the west side of the plateau.

Shoulder graben

The Shoulder graben is formed by several steeply dipping faults; offsets are best observed in the Flagstaff Limestone, which defines the Wasatch monocline (figure 7). The faults trend approximately NNE and crudely parallel the trend of the plateau or monocline. They are especially obvious along the north walls of Manti and Willow Creek Canyons. All are normal faults with varying displacements up to 750 feet. To the west faults have displacements down to the east. The eastern faults have displacements down to the west. The graben in the center was named the Shoulder graben by Washburn (1948, p. 49). Most faults on the west side of the Shoulder graben are down to the east and generally increase in displacement from west to east. The greatest displacement along the faults on the west side of the graben is estimated to be about 650 feet (fault on the east side of Manti Mountain). There are fewer faults on the east side of the Shoulder graben. The largest fault is in the southeastern corner of the quadrangle and has a displacement of about 750 feet down to the west. Dip of the fault planes ranges from nearly vertical to 75° with normal displacement. Dips in the strata increase somewhat across each fault in a westward direction.

Temple Hill toreva block

Temple Hill was described by Witkind (1994, p. 100) as a detachment block composed of the Green River and Crazy Hollow strata that slid valleyward (westward) off the Wasatch monocline. Weiss and Sprinkel (2002), in a cross section showing the west end of the hill, show that the Green River Formation overlies steeply dipping Cretaceous rock unconformably, but that only part of the hill has slid on a low-angle fault. This slide contact or low-angle fault cuts nearly north-south across the hill. If described as a fault, the fault plane (or slide plane) dips steeply to the east and rocks on the east side are displaced upward as much as 180 feet or about the thickness of the upper member of the Green River Formation (figure 8). Rocks on the west side dip gently valleyward about 4 or 5°. On the east side of the fault or slide plane the rocks are deformed to form a sharp, crudely north-south trending syncline. Dips on the west side of the syncline range to 25°, while those on the east range to 15° (Washburn, 1948, p. 58). The resistant part of the Crazy Hollow Formation is warped into this syncline and marks the synclinal surface. The Crazy Hollow Formation forms a north-south fringe on the west side of the fault or slide plane that dips westward. That the Crazy Hollow Formation strata were once continuous across the west part of Temple Hill is proven by the presence of a small outcrop just east of the Manti LDS Temple in the Manti quadrangle.

ECONOMIC GEOLOGY

The principal geologic resources produced or with a potential for development in the Ephraim quadrangle are ground-water, sand and gravel, and building stone. The potential for finding coal and limestone (other than for building stone) is limited, but the potential for oil and gas may be higher. The potential for finding precious or base metallic resources is low.

Water Resources

Inasmuch as agriculture is the most important economic activity in the area, water resources are considered the most valuable commodity. More economic activity is concentrated in this area than for any other earth resource, and for the local populace, water is frequently the most popular subject of discussion.

The discussion of water resources includes that of both surface and ground-water supplies. Surface water rights are entirely subscribed. Water resources are replenished by winter and spring snowfall, supplemented by rainfall in other seasons. The top of the Wasatch Plateau receives about 40 inches of precipitation during the year (only about 12 inches is received in the valley below); snow accumulates mostly above 9,000 feet from December to April when melting begins to fill the channels of the streams flowing down the principal canyons and to recharge ground-water aquifers. The melt continues into early July and sometimes into August during "wet" years. Springs in the high country have been acquired by local municipalities for drinking water. Most municipalities have large reservoirs on the plateau near springs. The principal aquifer is the Flagstaff Limestone. Smaller springs arise from the more porous beds of the North Horn and Colton Formations. The water emits from just above tight shaly beds.

During years of excessive water, the Colton, Flagstaff, and North Horn Formation aquifers become filled and saturated and "bleed" from fractures and pores. Clay and argillaceous units become slippery and the adjacent rocks slump and slide, damaging roads and pipelines, and debris flows clog perennial streams.

Ditches, tunnels, and pipelines have been constructed to carry the water down canyons to the valley to fill reservoirs used to water the hay, other crops, and livestock. Some of the water is used to generate electricity on the way down. Water is also produced from the alluvial fans and river alluvium in Sanpete Valley. Some of the wells are artesian and others must be pumped. Most of the artesian wells are west of Ephraim, near the Qal and Qafo contact. Although some wells have been drilled into the alluvium, the more productive ones produce from the alluvial-bedrock contact, up to 400 feet beneath the surface.

The hydrostratigraphic characteristics of each geologic formation and water quality information have been outlined and studied by Lowe and others (2003) and Wallace and others (2007), and the reader is directed to these works for more information about the water resources and the potential for their development in Sanpete County and the Ephraim quadrangle.

Sand and Gravel

Several gravel pits have been dug and are intermittently active in the Ephraim quadrangle. The commercial pits are mostly located in the alluvial fans (Qafy) that emerge from the mouths of Willow Creek Canyon and Ephraim Canyon. These pits contain gravel that is 80 percent limestone and 20 percent sandstone, with 35 percent occurring as boulders and cobbles, 50 percent as usable gravel, and 15 percent fine material (Pratt and Callaghan, 1970, p.43). Other pits are found in Manti Canyon, which are intermittently used by governmental agencies for repairing and maintaining mountain roads. Most of this material is limestone talus and consists of 50 percent angular pieces of limestone in a matrix of lime mud and other fine material. Some boulders are also present in these deposits.

Building Stone

Yellow-gray oolitic limestone has been quarried at Temple Hill and has been used to build the Manti LDS Temple and other pioneer buildings in Sanpete County, including the County Courthouse. It was also used to build the Park Building at the University of Utah. The quarries at Temple Hill are intermittently used to provide replacement stone for the temple and local buildings. A small amount is produced as decorative stone. In pioneer days the stone was used as cemetery headstones and markers. The source of the oolitic limestone is at the base of the upper member of the Green River Formation where some beds as much as 8 feet thick have uniform texture. The fresh rock is a light creamy gray in color, and the oolites have a uniform diameter of just under a millimeter, giving the rock a sandstone appearance. It is somewhat soft and can easily be chiseled and beveled into decorative blocks. This is evident in its use as headstones in the Manti cemetery.

The limestone weathers easily and needs to be sealed to prevent deterioration. The Manti Temple is only occasionally sandblasted and retrimmed where the stone has been damaged by pollution. The sealed limestone holds up well against pollution in the relatively sparsely populated Sanpete Country area. However, the Park building at the University of Utah has suffered pitting, spalling, and etching by modern pollution more dramatically; sealing only partly protects the rock. Small quarries were also opened at Little Hill and other Green River Formation outcrops north of Ephraim (Pratt and Callaghan, 1970).

A small amount of dimension stone was also quarried in the Crazy Hollow Formation on Temple Hill. This stone was used to build pioneer retaining walls at various locations throughout Sanpete Valley.

Limestone

Washburn (1948, p. 66) mentioned the presence of two small deserted limestone kilns at the mouth of Manti Canyon. He indicated that the Flagstaff Limestone was the feed used by pioneers to produce lime. Pratt and Callaghan (1970) indicated that the two principal limestone sources that might be interesting for the production of lime are the Flagstaff Limestone and Green River Formation.

The quality of these formations for producing lime is extremely variable. High calcium limestone is a highly desirable product and early analyses of the formations indicate that most is unsuitable for this use (Pratt and Callaghan (1970). Most samples show a high percentage of silica and magnesia.

Metals

Many people believe that the wealth of the earth lies in its metallic minerals. Although sand and gravel revenues far exceed metal revenues, interest in metals abounds.

As explained by Pratt and Callaghan (1970, p. 53), sedimentary rocks almost wholly make up the formations of Sanpete County, and those in the Ephraim quadrangle are mostly of Tertiary age, with no significant occurrences of igneous or metamorphic rocks.

Thus, with little favorable evidence for metallic mineralization, its potential is very low. None of the small occurrences described by Pratt and Callaghan (1970, p. 54) in Sanpete Valley is present in the Ephraim quadrangle. We found only one prospect in the quadrangle, located in sec. 8, T. 18 S., R. 3 E., on the north wall of Manti Canyon. An adit about 10 feet long was dug into the North Horn Formation because of a minor show of limonite, but no ore was found.

Other Potential Earth Resources

Other potential earth resources that may be of interest in the Ephraim quadrangle include coal and petroleum. Coal is present in the North Horn Formation in the vicinity of Wales and as lignite in the vicinity of Milburn. Measurements of the North Horn Formation in the Ephraim quadrangle show no coal-bearing units of any kind, though it may be present in the subsurface. The Blackhawk Formation of eastern Utah is an important source of coal, and small amount of coal was produced from the Sixmile Canyon Formation near Sterling. The Blackhawk Formation correlates with a part of the Sixmile Canyon Formation and shows that coal may be present at depth. However, the Sterling Sixmile Canyon coal beds are relatively thin or split compared to mineable resources in other areas (Doelling, 1972).

Petroleum exploration has been vigorous from time to time in the Sanpete Valley, but no commercial production has yet been achieved (Weiss and Sprinkel, 2002). Weiss and Sprinkel (2002) noted that gas was encountered in the Cretaceous Funk Valley Formation and oil in the Cretaceous Allen Valley Shale under Sanpete Valley in the adjoining Manti quadrangle. Both of these occurrences proved uneconomical. Two recent discoveries by Wolverine Gas & Oil near Sigurd, Utah, in 2004 and near Mayfield, Utah, in 2008, both along the Sanpete-Sevier antiform trend, have elevated the potential for petroleum reserves in Sanpete Valley. The Covenant field near Sigurd is about 35 miles southwest of the Ephraim quadrangle. Oil production is mostly from the Jurassic Navajo Sandstone on a thrust structure that forms the core of the Sanpete-Sevier Valley antiform (Chidsey and others, 2007). The more recent Providence field near Mayfield is about 15 miles southwest of the Ephraim quadrangle. Little information has been released about the Providence field, although Wolverine has indicated oil and gas production is apparently from the Navajo Sandstone on a separate but similar structure to the Covenant field. The Sanpete-Sevier Valley antiform trends northward into Sanpete Valley, west of the Ephraim quadrangle. The potential thrust structures associated with the antiform are also west of the quadrangle. The nearest well to the Ephraim quadrangle with oil and gas shows is the Phillips Petroleum Company, US E-1 well (NW¼NE¼ section 27, T. 19 S., R. 3 E., Sanpete County, Utah) located about 8 miles south in the adjacent quadrangle. That well had shows in multiple formations and recovered oil and gas on a production test from the Triassic Sinbad Member of the Moenkopi Formation. Phillips eventually abandoned the well because it could not establish commercial quantities of petroleum. The well drilled on a subtle structure on the upthrown block east of the Ephraim fault (Chidsey and others, 2007). Similar formations and structural geometries found in the Phillips well are under the Ephraim quadrangle.

GEOLOGIC HAZARDS

The three types of geologic hazards are most likely to affect the inhabitants and property of the Ephraim quadrangle are floods, landslides, and earthquakes.
Most years the snowmelt runoff fills creek channels to capacity. Normally, the creek channels on alluvial fans at the mouths of the larger canyons emerging from the Wasatch Plateau are incised deeply enough to contain the floodwaters. However, during wet years flooding may occur. The alluvial fans of Manti Creek and Ephraim Creek are at least partially developed in the cities of Manti and Ephraim, bouldery material and the width of fans attests to flooding events in these towns in the prehistoric past. Flooding is commonly accompanied by debris flows in which bouldery channel deposits move downstream during flooding events, commonly filling the channels. Floodwaters can "jump" the old channel and cut a new one somewhere else on the fan. Significant damage can occur when material flowing in the new channel is deposited on developed land. Frequently, snowmelt and summer storms cause significant damage to roads in the high country, which become impassable due to deep mud channeling.

Landslides, slumps, and debris flows occur commonly during "wet" years, primarily along canyon sides near the Wasatch Plateau front. However, such earth movement can occur anywhere in the Wasatch Plateau. The North Horn, Flagstaff, and Colton Formations are commonly affected. Roads, pipelines, and ditches in the canyons are occasionally partially destroyed during such events.

Few earthquakes have rocked the Ephraim quadrangle area. Historically, these are small to moderate events that have caused more excitement than damage to local residents. Expected impacts, should a large earthquake occur, are ground shaking and liquefaction of the ground in areas underlain by saturated fine-grained materials. Ephraim and Manti have several older masonry buildings that may not be properly reinforced. High pieces of furniture and water heaters may require fastening to walls to prevent their toppling in case of a stronger event.

ACKNOWLEDGMENTS

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EPHRAIM DESCRIPTION OF MAP UNITS

Quaternary Deposits

Alluvial Deposits

Qal Floodplain alluvium (Holocene) – Unconsolidated mud, silt, sand, and minor pebble and cobble gravel, brown, and brownish gray; forms gently sloping floor of Sanpete Valley; older underlying alluvium may be as old as Pliocene (QTal) of Weiss and Sprinkel (2002); may be as much as 300 feet thick.

Qac Alluvium and colluvium (Holocene) – Unconsolidated mud, silt, sand, and gravel, mostly gray, brown, and yellowish brown, that fills channels and smaller depressions in other Quaternary deposits or on bedrock units; derived from adjacent deposits; commonly grades into alluvial-fan deposits along margins; 0-30 feet thick.

Qafy, Qafo Alluvial-fan deposits (Holocene and Pliocene?) – Unconsolidated mud, silt, sand, and poorly sorted gravel; divisible into two units, younger alluvial fans (Qafy) and older alluvial fans (Qafo); Qafo deposits probably grade downward into Tertiary fan deposits; 0-500 feet thick.

Mixed alluvial and mass movement deposits

Qabc Bouldery channel deposits (Holocene) – Unconsolidated coarse alluvial gravel mixed with boulders and coarse debris that have rolled or slid into the channels by gravity; less than 10 feet thick.

Mass-movement Deposits

This quadrangle is replete with landslides and slumps that have developed mostly on the Colton, Flagstaff, and North Horn Formations.

Qmsh Historical landslides and slumps (Holocene) – Unconsolidated masses of poorly sorted mud, sand, and angular broken rock that have moved down steep slopes, most of which moved since 1980; brown, reddish-brown and gray unsorted debris of boulder-, cobble-, and pebble-sized clasts of limestone and sandstone, supported by a matrix of sandy clay; surfaces of deposits cracked and deformed; heads of landslides slope gently, bodies slope parallel to neighboring ground and toes slope more steeply than neighboring ground; mapping includes debris flow deposits developed below landslides; deposits commonly form long narrow strips in and adjacent to gullies; as much as 90 feet thick.

Qms Landslides and slumps (Holocene and Pleistocene) – Unconsolidated masses of poorly sorted mud, sand, and angular broken rock that have moved down steep slopes; some may be active; display typical landslide morphology, although somewhat subdued; as much as 90 feet thick.

Qmsc Colluvium (Holocene and Neogene?) – Includes very old landslides and slumps; mostly angular broken rock derived from the Flagstaff Limestone in a matrix of limestone sand; forms thick hummocky ground; commonly forms veneers on bedrock or consists of masses suspected to be up to several hundred feet thick.

Qmt Talus deposits (Holocene) – Unconsolidated rock debris in steep slopes at the base of cliffs; only larger deposits mapped; as much as 10 feet thick.

Qms(g) Landslide block of coherent Green River Formation (Pleistocene) – Isolated remnant of displaced Green River Formation that has moved down slope as a coherent block; slide plane and bedding deformation well exposed; located near mouth of Manti Canyon in southwest part of the quadrangle; varied thickness.

Qms(c) Landslide blocks of coherent Colton Formation (Holocene to Pleistocene) – Displaced mass of Colton Formation along the steeply dipping hogbacks east of US Highway 89 southeast of Willow Creek and east of Cane Valley; varied thickness.

Qms(f) Landslide blocks of coherent Flagstaff Formation (Holocene to Pleistocene) – Displaced mass of Flagstaff Formation in the same general area as Qm(Tc) south of Willow Creek; varied thickness.

Qms(nh) Landslides and slumps, mostly derived from the North Horn Formation (Holocene and Pleistocene) – Slumps usually form veneers on other bedrock, but landslides include larger rotated blocks; located in eastern part of the quadrangle in higher elevations; varied thickness.

Bedrock Units

Tch Crazy Hollow Formation (middle Eocene) – Sandstone and pebble conglomerate, yellow gray, medium brown and green gray; mostly coarse-grained with subangular poorly sorted grains, forming mostly thick-bedded ledges and cliffs; overlain locally by light-red brown fine- to medium-grained, poorly sorted sandstone; incompletely exposed on the quadrangle in a toreva slide block(?) on the upper Green River Formation at Temple Hill in the southwest part of the quadrangle; 47.5+ feet thick.

Tgu Upper Green River Formation (middle Eocene) – Limestone, calcareous shale, and tuff; limestone is shades of gray, pink gray, yellow orange, and yellow gray, weathers yellow brown to brown; mostly finely crystalline and oolitic; mostly thin to medium bedded; weathers slabby and blocky; contains a few siliceous layers with poorly outlined chert nodules; forms steep slope with a few ledges. Shale is various shades of gray or green gray, marly or calcareous, forms recesses or slopes. Tuff is present in subordinate amounts, light brown to tan, somewhat resistant, contains small biotite flakes; probably incompletely exposed, upper contact may be a slide plan; 120-220 feet thick.

Tgl Lower Green River Formation (middle Eocene) – Interbedded calcareous shale and limestone; calcareous shale (75%) is varying shades of gray and green gray, forms poorly-exposed slopes, and is commonly argillaceous; limestone (25%) is mostly light gray in thin to medium beds, finely crystalline, commonly oolitic, and ledge-forming; base is not exposed in the quadrangle; 400+ feet thick.

Tc, Tcg Colton Formation (lower Eocene) – Interbeds of shale (55-75%), sandstone (10-25%), and limestone (10-20%) (Tc), with discrete greenish beds (Tcg). Shale (siltstone, mudstone, and claystone) is shades of gray, red, brown, olive green, gray, gray green, rust, creamy yellow; commonly variegated, banded, or mottled, weathering generally to lighter shades; commonly sandy or silty; either finely laminated, fissile, to thin bedded or breaks up into very small equidimensional fragments (granular); poorly to well cemented; calcareous and argillaceous varieties; contain local biotite flakes, ostracodes, or small gastropods; generally form soft to hard steep slopes. Sandstone is mostly in shades of gray, yellow gray, brown, olive green, red, orange, or tan, locally variegated, mostly weathering lighter; fine to coarse grained varieties, generally moderately to poorly sorted, subangular to subrounded grains, well cemented to poorly cemented, cross-bedded, irregularly bedded, thin bedded; mostly ledge or cliff forming, but subordinate slope forming varieties are also present; largely calcareous, some argillaceous; friable and porous; grades from fine to coarse laterally and vertically; salt and pepper varieties. Limestone is mostly in shades of gray including pink gray, yellow gray, some is mottled, commonly weathers to shades both darker and lighter; mostly very finely crystalline to micritic, some in form of calcarenite or calcisiltite; locally sandy, silty, or argillaceous; generally forms thin rubbly ledges, but slope-forming varieties are also present; mostly dense and hard; calcarenite is locally cross-bedded; laminated to medium bedded; some cataclastic varieties; commonly fractures conchoidally, locally nodular, rippled, platy weathering, and fossiliferous, containing gastropod, pelecypod, and bone fragments; incompletely exposed. unit is more than 1400 feet thick.

Tf Flagstaff Limestone (lower Eocene and Paleocene) – Limestone (55-65%), calcareous shale (30-42%), and subordinate sandstone (2-8%). Limestone, shades of gray, gray brown, light pink, generally weathering to lighter shades, locally mottled; commonly aphanitic to finely crystalline, but locally has coarse grained, clastic (calcarenite and calcisiltite), and cataclastic textures, locally contains black or dark gray chert, largely ledge- or cliff-forming; thin bedded to massive, dense and hard, locally dolomitic or argillaceous; many beds contain shell or bone fragments, mostly gastropods, pelecypods, and ostracodes; some beds weather nodular, slaty, some are stylolitic; locally there are cavities lined with calcite, and some beds are fetid. Calcareous shale, shades of gray, green gray, olive green, green brown, and locally red; some hard, some weak, evenly bedded, laminated to thin bedded, locally fissile, locally argillaceous or clayey, gypsum stringers, and fossil debris; some are granular or break into very small equidimensional fragments, generally slope forming and locally nodular weathering. Sandstone, light brown-gray, gray, or light brown, generally weathering to light brown, mostly fine grained, but medium grained and coarse and pebbly varieties are locally present, grains are generally angular to subrounded, poorly to well cemented generally with calcite, generally porous and friable, poorly to massively bedded and lenticular; unit is 500 to 1000 feet thick.

TKn North Horn Formation (lower Tertiary and Upper Cretaceous, Paleocene and Maastrichtian) – Variegated shale, sandstone, fresh-water limestone and/or calcarenite, and subordinate pebble conglomerate. Shale (about 59%) is variegated with shades of gray, green, yellow, orange, red, purple, brown, blue, pink, and black with many mottled horizons; commonly sandy, calcareous, or argillaceous; locally including mudstone and claystone; mostly indistinct bedding; forms steep hard, rubbly slopes, locally forming badland-type topography; breaks up into granular equidimensional fragments. Sandstone (about 34%) mostly with shades of light gray, yellow, brown, and pink weathering largely to shades of brown; fine to coarse grained and pebbly, largely poorly sorted with subangular grains, some intraformational conglomerate lenses; mostly medium to massive beds, some low-angle cross-bedding, mostly calcareous with local calcite matrix and locally muddy; salt and pepper appearance; many pebbly streaks; usually resistant forming ledges and cliffs, but locally friable, lenticular; commonly contain partings of mudstone or shale. Limestone and/or calcarenite (about 5%), light to dark gray or light brown; finely crystalline and usually fine-grained sandy beds; dense and hard forming ledges or very steep slopes, commonly finely laminated; locally contains broken shells (fossil) and calcite in fractures. Pebble conglomerate (2-3%) light brown weathering ledges, commonly grades into sandstone; pebbles mostly quartzite or sandstone; locally up to small cobbles, very lenticular; base is not exposed in quadrangle; more than 1100 feet thick.

Formations below are not exposed in this quadrangle but are assumed to be present at depth. Descriptions and thicknesses are from exposures south and east of the quadrangle.

Kp Price River Formation (Upper Cretaceous, Campanian) – Mostly tan and gray, medium to coarse-grained sandstone, some gray shale and conglomeratic sandstone; ledge and slope forming; 400-800 feet thick.

Ksx Sixmile Canyon Formation (Upper Cretaceous, Campanian) – Sandstone (fine to coarse grained), conglomerate, carbonaceous shale and coal; Sixmile Canyon Formation of Sanpete Valley and San Pitch Mountains is equivalent to formations recognized on the east side of the Wasatch Plateau, including the part of the Mancos Shale above the Emery Sandstone, the Star Point Sandstone, the Blackhawk Formation, and the Castlegate Sandstone. Interpreted as steeply dipping (flattening eastward) in the subsurface under an unconformity under the adjacent Manti quadrangle to form the east flank of Sanpete-Sevier Valley antiform under Sanpete Valley; as much as 4000 feet thick.

Kc Castlegate Sandstone (Upper Cretaceous, Campanian) – Light-gray, yellowish-brown, and white, medium- to coarse-grained sandstone and conglomeratic sandstone; cliff forming where exposed outside of quadrangle; 150-500 feet thick.

Kb Blackhawk Formation (Upper Cretaceous, Campanian) – Light to medium gray sandstones; gray to black shale; gray siltstones; sandstones weather tan, brown, yellowish brown; ledge and slope forming where exposed outside of quadrangle; 400 to 1100 feet thick.

Ksp Starpoint Sandstone (Upper Cretaceous, Campanian) – Tan, light gray, and white massive sandstones separated by one or more shale tongues; cliff forming where exposed outside of quadrangle; 200-1000 feet thick.

Km Upper Mancos Shale (Upper Cretaceous, Campanian) – Light gray to blue gray sandy marine shale; 300-1300 feet thick.

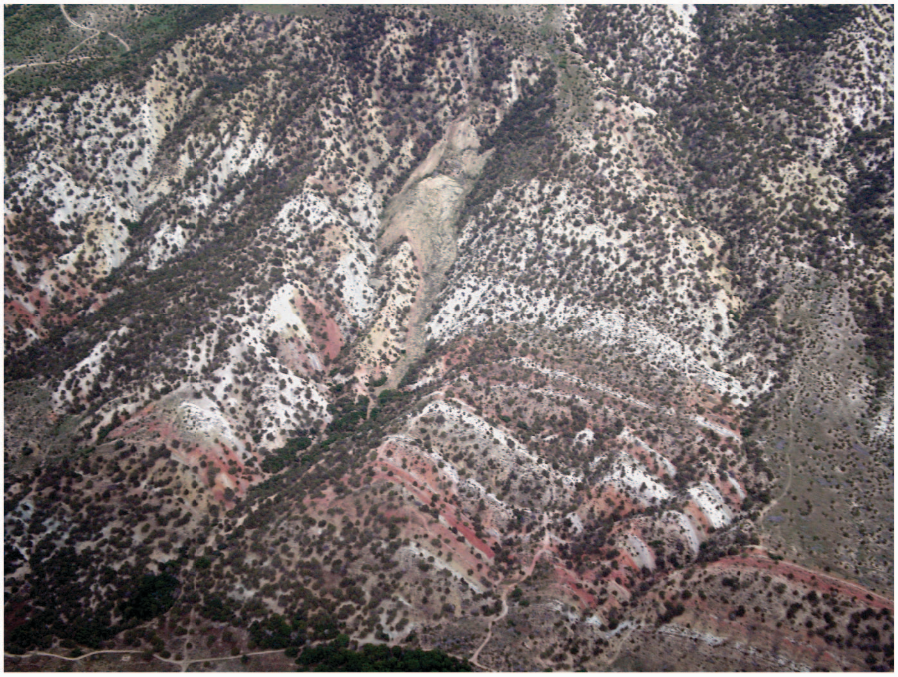


Figure 1. Aerial view of the Colton Formation along the west side of the Wasatch Plateau. The colorful formation dips an average of 45° valleyward in the steepest part of the Wasatch monoclinal structure. Note the landslide in the upper middle part of the photo.

Figure 2. Fossiliferous debris found in the lower part of the Colton Formation in the vicinity of Manti, Utah. The upper photo is of gastropod fossils and the lower is pelecypod fossils.

Figure 3. View to right is along the north wall of Manti Canyon. Unstable rock in the upper part of the North Horn Formation has moved and split, flowing down two sides of a ridge. The headwall scarp of the slide can be seen to the upper right of the slide deposit.

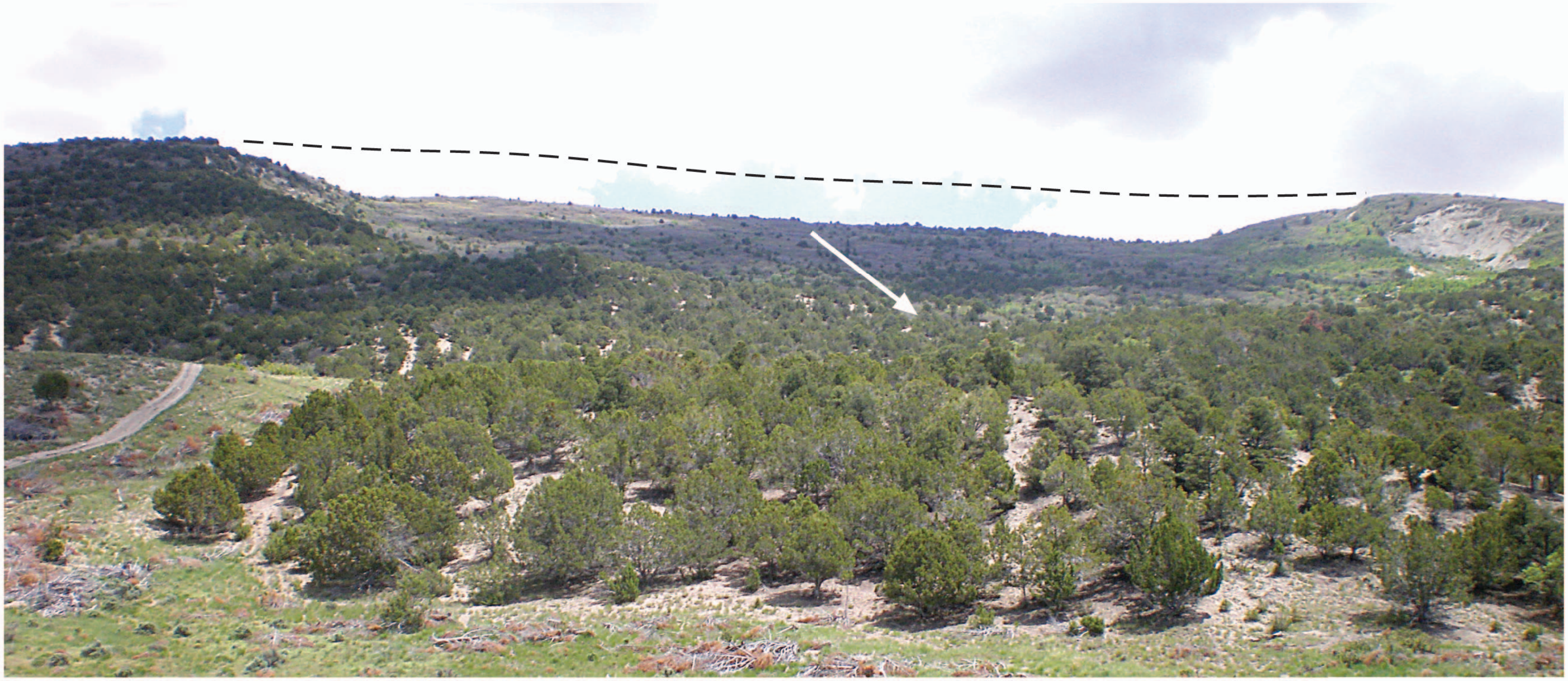


Figure 4. Rock slide material (Qmsc) in foreground once resided between the two inward-facing slopes as part of the Flagstaff Limestone. Dashed line indicates approximate upper surface before sliding. Arrow points in direction of movement of the rock slide.

Figure 5. View along the north wall of Manti Canyon showing extensive talus deposits, and evidence of historical rock falls.

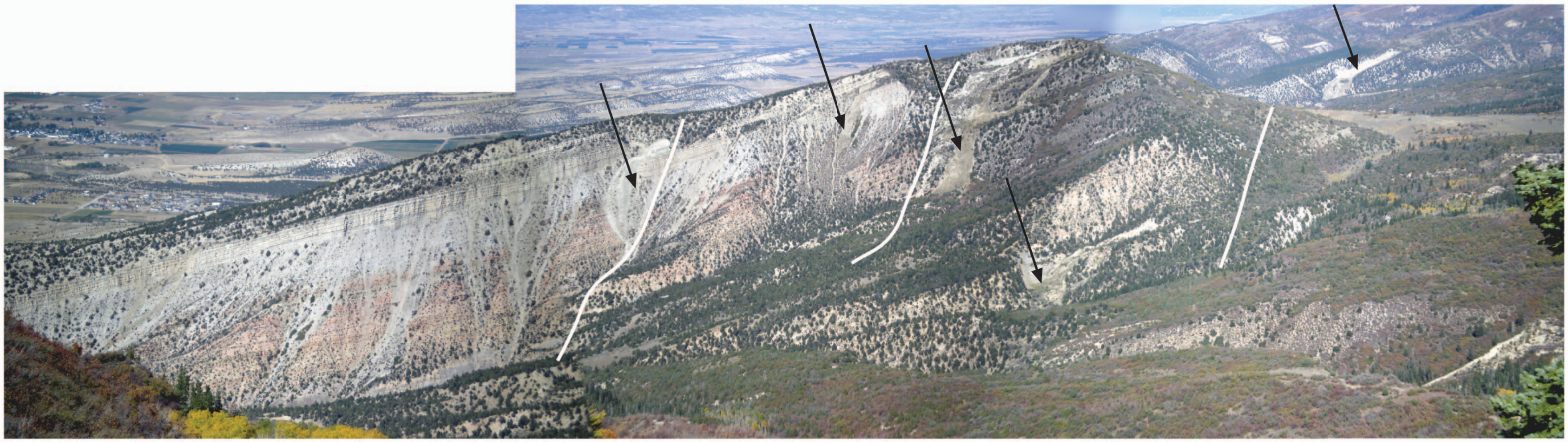


Figure 6. Aerial view north across Willow Creek Canyon. Pinkish rocks are North Horn Formation and capping white rocks are Flagstaff Limestone. White lines show the approximate position of normal faults with displacements down to the right (east). Note recent landslide scarps as indicated by the black arrows.

Figure 7. Aerial view northward across Manti Canyon showing downthrown blocks and the Shoulder graben. White lines are the approximate fault traces. White arrows are shown on the side of downward displacement. Black lines mark the approximate boundary between the Flagstaff Limestone (light outcrops) and the North Horn Formation (pink outcrops). Photo also shows the form of the Wasatch monocline.

(a)

(b)

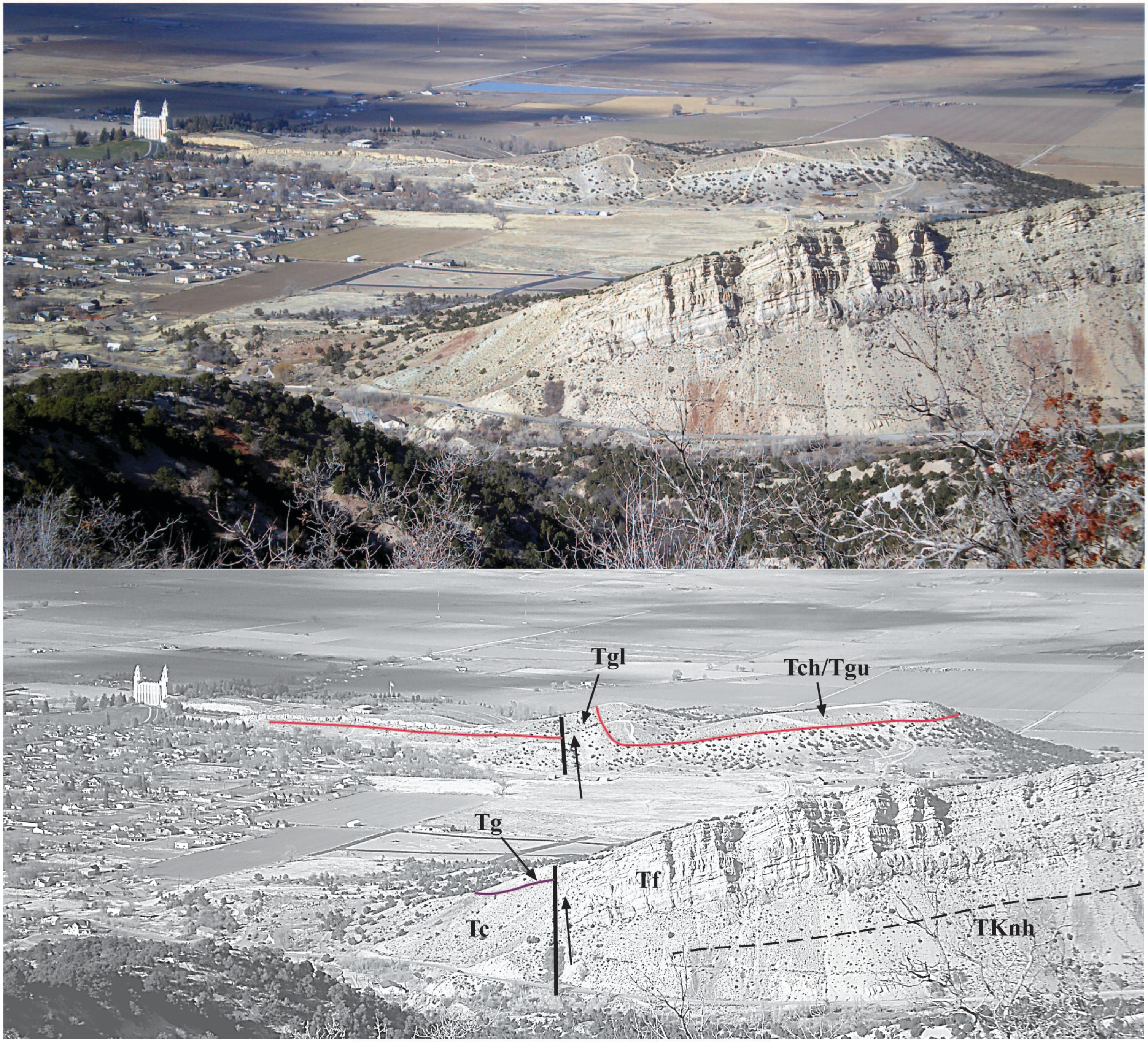
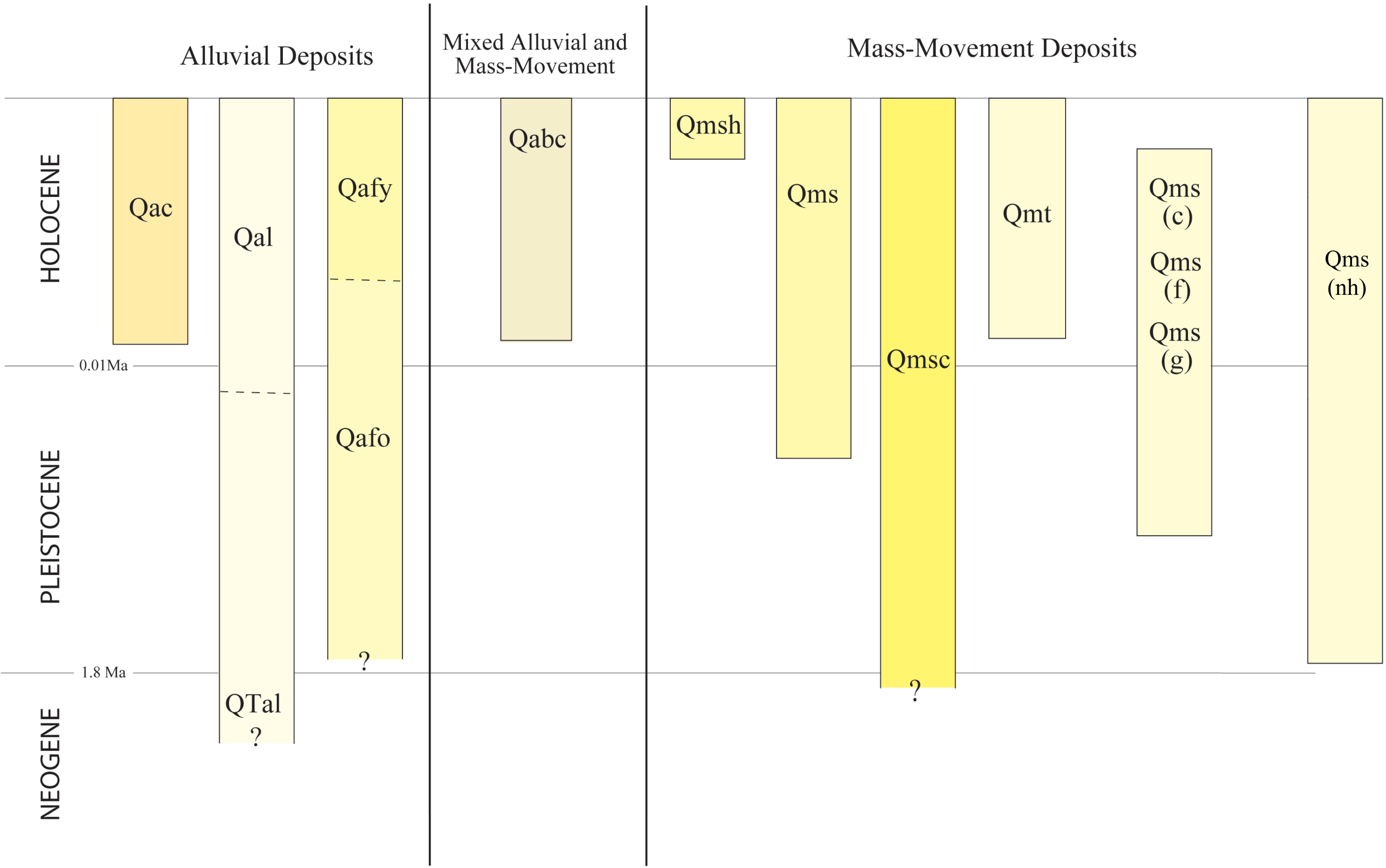


Figure 8. (a) View of north wall of Manti Canyon with Temple Hill in the background. The Manti LDS Temple is on the left part of Temple Hill.
(b) The red line is the contact between the upper and lower Green River members and marks the Temple Hill syncline. A reverse fault or slide plane (dark line) displaces the strata. The red line on the west or left side of the plane is at the same stratigraphic position as the red line on the right side.
The light band of rocks on the left side of the plane were quarried to construct the temple. In the foreground along the north wall of Manti Canyon is a reverse fault. On the left is a purple line separating nearly vertical Colton strata from gently west-dipping rocks of the Green River Formation.

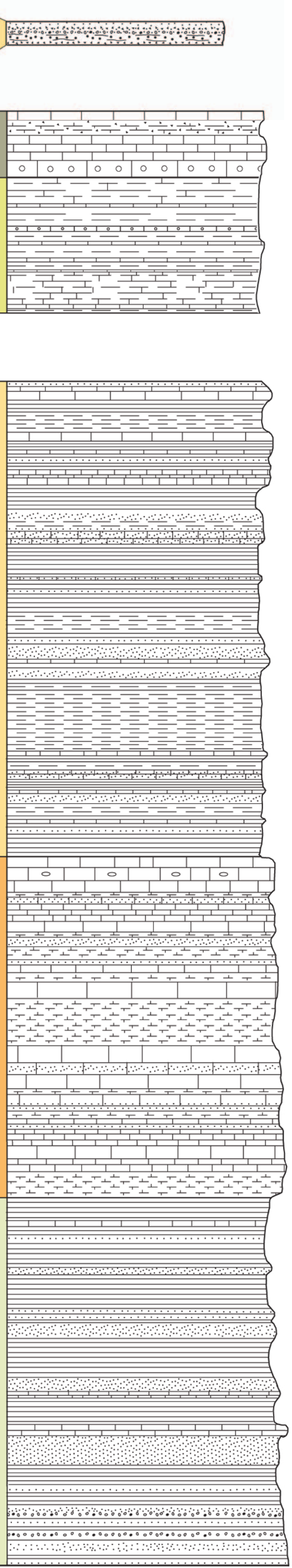


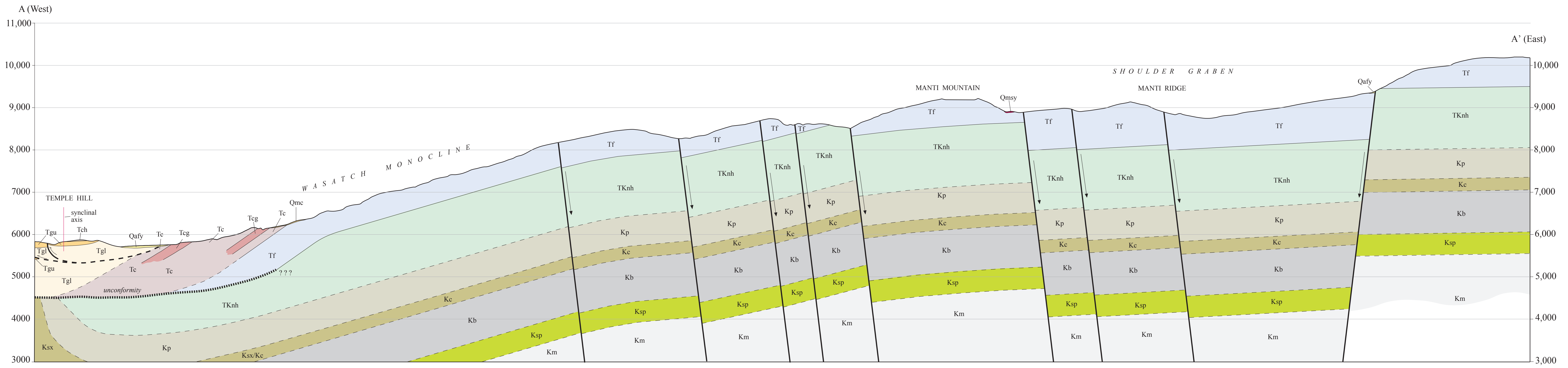
CORRELATION OF QUATERNARY UNITS, EPHRAIM QUADRANGLE

EPHRAIM QUADRANGLE

LITHOLOGIC COLUMN

SYSTEM/SERIES			FORMATION		MAP SYMBOL / THICKNESS IN FEET / MAP COLOR	LITHOLOGY
TERTIARY	Eocene	Middle	Crazy Hollow Formation		Tch ~50	
TERTIARY	Eocene	Middle	Green River Fm.	Upper	Tgu 120-220	
TERTIARY	Eocene	Middle	Green River Fm.	Lower	Tgl 400+	
TERTIARY	Eocene	Middle			?	
TERTIARY	Eocene	Lower	Colton Formation		Tc Tcg 1400+	
TERTIARY	Eocene / Paleocene	Lower	Flagstaff Limestone		Tf 500-1000	
TERTIARY	Paleocene		North Horn Formation		TKnh 1100+	
Cretaceous	Maastrichtian		North Horn Formation		TKnh 1100+	

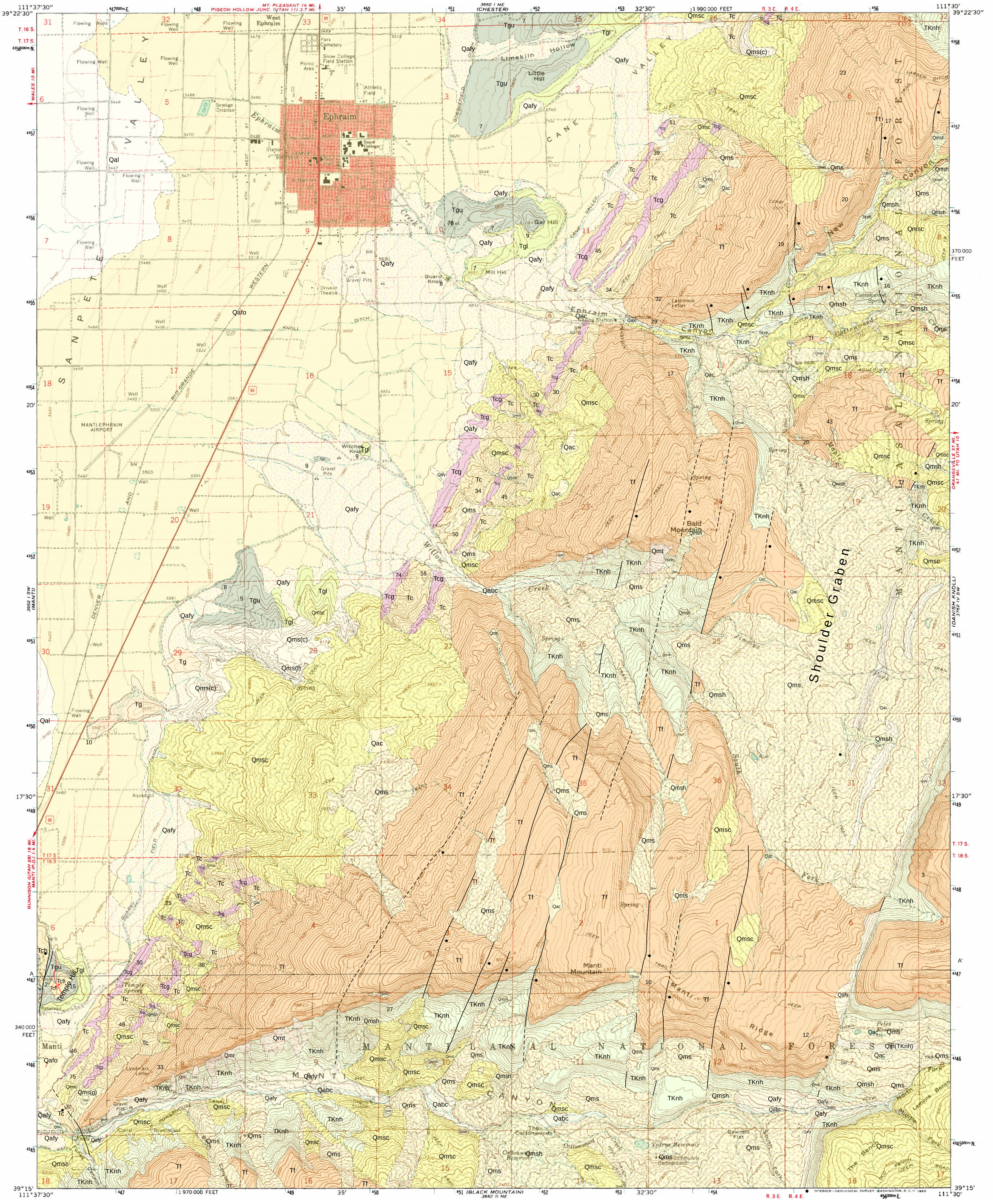




A (West)
A' (East)
11,000
10,000
9,000
8,000
7000
6000
5000
4000
3000
3,000
4,000
5,000
6,000
7,000
TEMPLE HILL
synclinal axis
WASATCH MONOCLINE
MANTI MOUNTAIN
SHOULDER GRABEN
MANTI RIDGE
Qafy
Qmsy
Qmc
Tgu
Tgl
Tch
Tc
Tcg
Tf
TKnh
Kp
Kc
Kb
Ksp
Km
Ksx
Ksx/Kc
unconformity
? ? ?

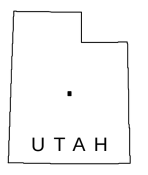
UTAH GEOLOGICAL SURVEY
a division of
Utah Department of Natural Resources

Plate 1
Utah Geological Survey Open-File Report 556
Geologic Map of the Ephraim Quadrangle



This geologic map was funded by the Utah Geological Survey and the U.S. Geological Survey, National Cooperative Geologic Mapping Program, through USGS STATEMAP award number 03HQAG0096.

The views and conclusions contained in this document are those of the authors and should not be interpreted as necessarily representing the official policies, either expressed or implied, of the U.S. Government.



QUADRANGLE LOCATION

SCALE

1 0.5 0 1 MILE

1000 0 1000 2000 3000 4000 5000 6000 7000 FEET

1 0.5 0 1 KILOMETER

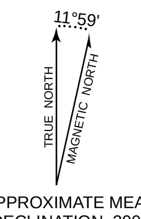
CONTOUR INTERVAL 40 FEET

INTERIM GEOLOGIC MAP OF THE EPHRAIM QUADRANGLE, SANPETE COUNTY, UTAH

by

Hellmut H. Doelling, Paul A. Kuehne, and Douglas A. Sprinkel

2009



APPROXIMATE MEAN DECLINATION, 2009

Base from USGS Ephraim 7.5' Quadrangle (1966)
Projection: UTM Zone 12
Datum: NAD 1927
Spheroid: Clarke 1886

Project Manager: Donald L. Clark
GIS and Cartography: Paul A. Kuehne

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geology.utah.gov

This map was created from Geographic Information System (GIS) data.

1	2	3
4		5
6	7	8

1. Wales
2. Chester
3. Spring City
4. Manti
5. Danish Knoll
6. Sterling
7. Black Mountain
8. Ferron Reservoir

ADJOINING 7.5' QUADRANGLE NAMES