GEOLOGIC MAP OF THE EPHRAIM QUADRANGLE, SANPETE COUNTY, UTAH

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

MAP 275DM
UTAH GEOLOGICAL SURVEY
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SCALE: 1:24,000

Cover photo: *Aerial view northward across Manti Canyon showing downthrown blocks and the Shoulder graben.*

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ABSTRACT

The Ephraim quadrangle is located about 140 miles (225 km) south-southeast of Salt Lake City in Sanpete County in central Utah. A diagonal line extending northeast-southwest across the quadrangle divides Sanpete Valley to the northwest from the Wasatch Plateau to the southeast. Sanpete Valley is a structural graben in which the San Pitch River flows southward 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 early Tertiary age. These include (ascending) the North Horn Formation (1100+ feet [340+ m] thick), Flagstaff Formation (500 to 1000 feet [150–300 m] thick), Colton Formation (1400+ feet [430 m] thick), Green River Formation (520 to 620 feet [160–190 m] exposed), and the Crazy Hollow Formation (less than 50 feet [15 m] exposed). 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 quadrangle is the faulted northeast-southwest trending Wasatch monocline. West of the axis, strata dip northwestward to more than 45° along the plateau front; southeast of the axis, beds dip gently westward. Dips increase westward due to folding of strata caused by sudden changes along associated subparallel normal faults. These faults form a graben termed Shoulder graben. Faults on the west and northwest side of the graben generally increase in displacement toward the graben, reaching a maximum of about 650 feet (200 m) of displacement. Faults on the east side of the graben have a maximum of about 750 feet (230 m) of displacement. The fault planes are normal and dip from nearly vertical to 75°.

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 large mass-wasting events. Such events have likely occurred throughout the Quaternary, and historically are most common during successive years of above-normal precipitation. Large rock slides, probably Pleistocene, consist of thick slabs of Flagstaff Formation that have slid off the plateau front, coming to rest more than a mile (1.6 km) away. Recent landslides are present on sides of canyons and in Shoulder graben. Geologic hazards in the Ephraim quadrangle include canyon-mouth floods, landslides, debris flows, and earthquakes.

Sand and gravel and building stone are the only known geologic resources of significance in the quadrangle. Several sand and gravel pits, dug in the alluvial fan at the foot of the plateau, have been in use intermittently for local construction and roads. Yellow-gray oolitic sandstone from the Green River Formation at Temple Hill is quarried intermittently and was used by the pioneers for the construction of homes, important buildings, and cemetery headstones. The area has potential oil, gas, and coal resources.

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, 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 (3115 m). The lowest elevation is in Sanpete Valley near the northwest corner of the quadrangle at about 5430 feet (1655 m). The valley-plateau boundary is at an elevation of roughly 6000 feet (1800 m).

Parts of the Ephraim quadrangle and adjacent quadrangles were geologically mapped prior to this study. Previous studies of note are those 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 modern U.S. Geological Survey topographic map series for the quadrangle. Baum and Fleming (1989) mapped landslides and debris flows in Ephraim Canyon after the 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 at 1:100,000 scale. Adjacent 1:24,000 scale quadrangles that were mapped prior to this study include Wales to the northwest (Lawton and Weiss, 1999), Manti to the west (Weiss and Sprinkel, 2002), and Sterling to the southwest (Weiss, 1994).

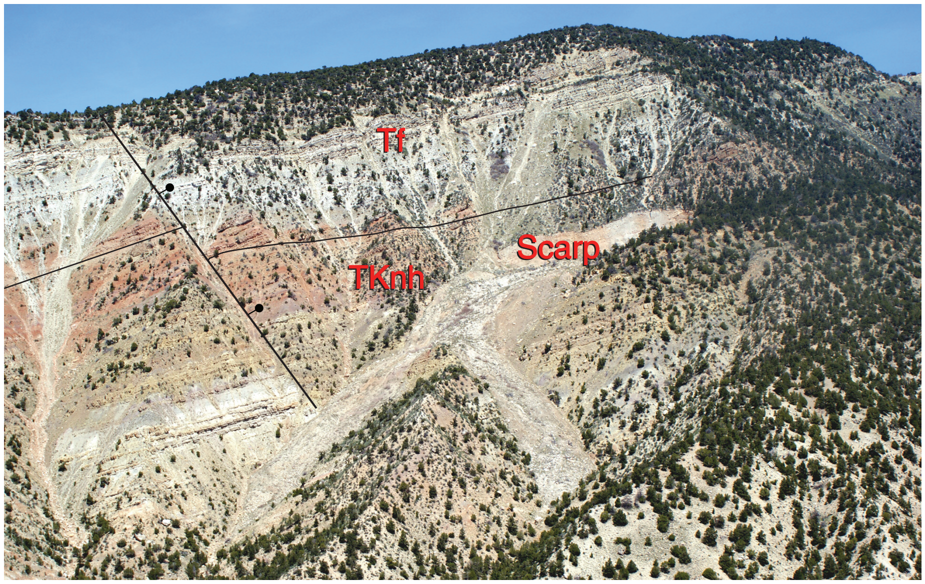

Figure 1. *View of the north wall of Manti Canyon. Unstable rock in the upper part of the North Horn Formation flowed as a large landslide down the upper canyon then split down two sides of a ridge. The headwall scarp of the slide is labeled.*

DESCRIPTION OF MAP UNITS

Quaternary Deposits

Alluvial Deposits

Qal **Floodplain alluvium** (Holocene to Pleistocene) – Moderately sorted, unconsolidated mud, silt, sand, and minor pebble- and cobble-gravel river and overbank deposits; brown and brownish gray; form gently sloping floor of Sanpete Valley; older underlying valley-fill alluvium may be as old as Pliocene (QTal of Weiss and Sprinkel, 2002); may exceed 300 feet (90 m) in thickness.

Qac **Alluvium and colluvium** (Holocene) – Poorly to moderately sorted, unconsolidated mud, silt, sand, and gravel deposited by ephemeral streams and washes and slope creep; mostly gray, brown, and yellowish brown; fills channels and smaller depressions in other Quaternary deposits or on bedrock units; derived from adjacent deposits; commonly grades into alluvial-fan deposits; 0 to 30 feet (0–9 m) thick.

Qafy, Qafc

Alluvial-fan deposits (Holocene to Pliocene?) – Unconsolidated mud, silt, sand, and poorly sorted gravel deposited at mouths of canyons and bases of slopes where gradients change; divisible into two units, younger alluvial fans (Qafy) and coalesced alluvial fans (Qafc); Qafc deposits are incised and eroded and probably grade downward into deeply buried Tertiary fan deposits; 0 to 500 feet (0–150 m) thick.

Mixed Alluvial and Mass-Movement Deposits

Qabc **Bouldery channel deposits** (Holocene) – Poorly to moderately sorted, unconsolidated, coarse alluvial gravel mixed with boulders and coarse debris derived from adjacent canyon walls and slopes that have rolled or slid into channels; mapped in Ephraim, Willow, and Manti Canyons; less than 10 feet (3 m) 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** (Historical) – Unconsolidated masses of poorly sorted mud, sand, and angular broken rock that have moved down steep slopes (figure 1); most have moved since 1980 as identified on aerial photographs; consist mostly of brown, reddish-brown, and gray, unsorted, boulder-, cobble-, and pebble-sized clasts of limestone and sandstone debris, supported by a matrix of sandy clay; surfaces of deposits hummocky, deformed, and have cracks and crevasses; heads of landslides are flat to gently sloped, main bodies slope parallel to neighboring slopes, and toes commonly have steep fronts; map unit locally includes debris-flow deposits developed below landslides; commonly form long narrow strips in and adjacent to gullies; as much as 90 feet (30 m) thick.

Qms **Landslides and slumps** (Holocene to Pleistocene) – Unconsolidated masses of poorly sorted mud, sand, and angular broken rock that have moved down steep slopes; similar to Qmsh and some may

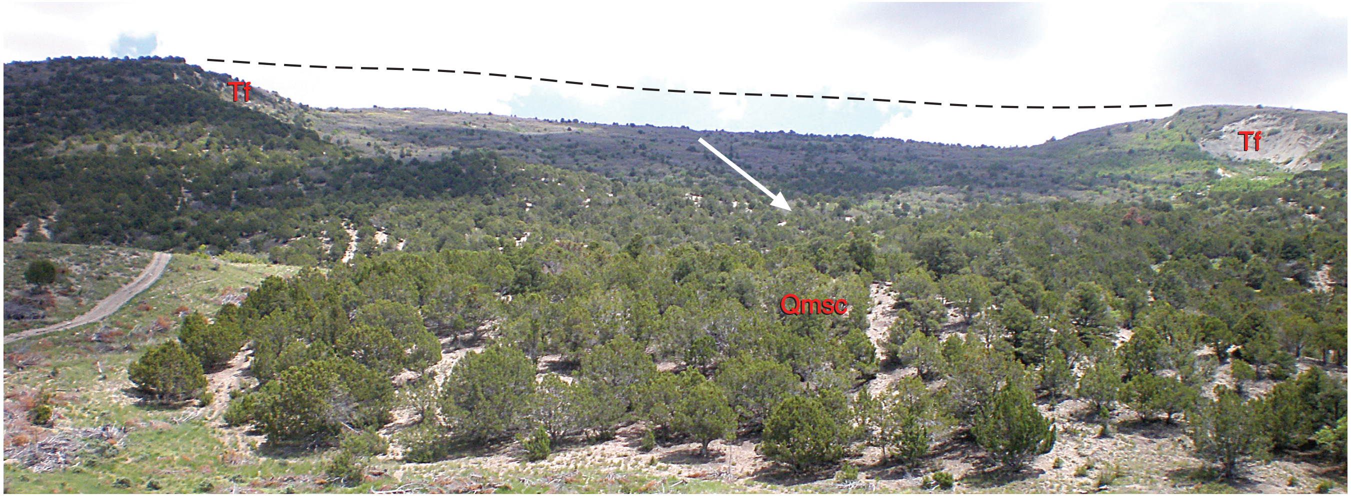

Figure 2. *Rock slide material (*Qmsc*) in foreground (white arrow) once resided between the two inward-facing slopes as part of the Flagstaff Limestone. Dashed line indicates approximate upper surface before sliding. Arrow points in direction of movement of the rock slide. View southeastward up slide from the valley near Cane Valley.*

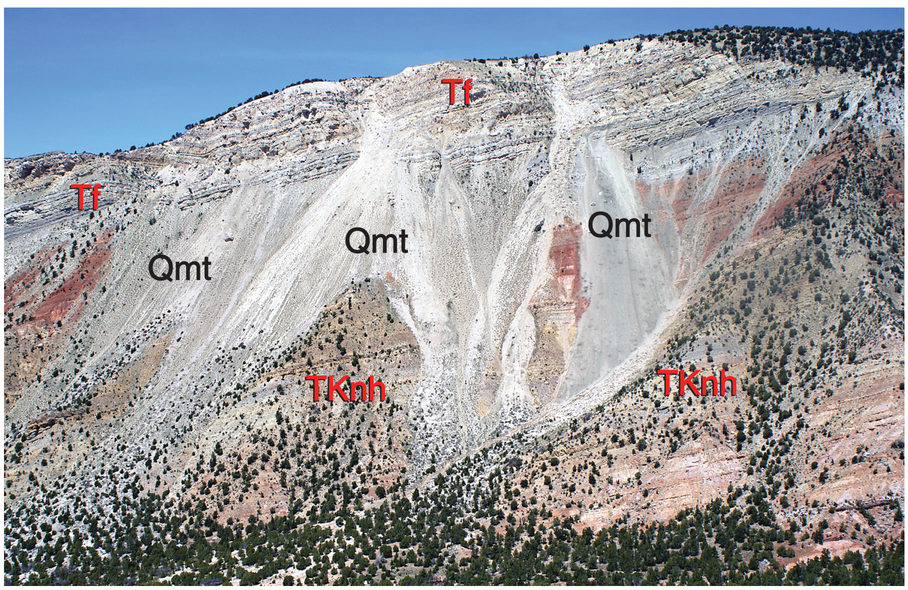

Figure 3. *View along the north wall of Manti Canyon showing extensive talus deposits (*Qmt*) and evidence of historical rock falls.*

be active; display typical hummocky landslide morphology, although somewhat subdued; as much as 90 feet (30 m) thick.

Qmsc **Landslides and colluvium** (Holocene to Pliocene?) – Mostly chaotic, angular, and broken limestone blocks derived from the Flagstaff Formation in a matrix of sand, mud, and clay deposited on moderate slopes; includes old landslides and slumps; commonly forms thick hummocky veneer on bedrock; masses suspected to be as much as 100 feet (30 m) thick (figure 2).

Qmt **Talus deposits** (Holocene) – Unconsolidated rock-fall debris on steep slopes and at the base of cliffs (figure 3); only larger deposits mapped; as much as 10 feet (3 m) thick.

Qms(g) **Landslide block of coherent Green River Formation** (Holocene to 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 quadrangle; variable thickness.

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

Qms(f) **Landslide blocks of coherent Flagstaff Formation** (Holocene to Pleistocene) – Displaced masses of Flagstaff Formation in the same general area as Qms(c) south of Willow Creek; variable thickness.

Qms(nh)

Landslides and slumps, mostly derived from the North Horn Formation (Holocene to Pleistocene) – Similar to Qms but composed primarily of North Horn Formation; landslides generally form veneers on other bedrock, but slumps include larger rotated blocks; located in eastern part of quadrangle in higher elevations; variable thickness.

Bedrock Units

Tertiary

Tch **Crazy Hollow Formation** (middle Eocene) – Yellow-gray, medium-brown and green-gray sandstone and pebble conglomerate; has a "salt and pepper" appearance with scattered black chert grains and clasts; mostly coarse-grained with subangular, poorly sorted grains; forms mostly thick ledges and cliffs; cliffs overlain locally by light-red brown, fine- to medium-grained, poorly sorted sandstone; 47.5+ feet (14.5+ m) thick with no top exposed; Tch is 70 feet (20 m) thick to the west in the Manti quadrangle (Weiss and Sprinkel, 2002).

Crazy Hollow Formation exposures are limited to the eastern part of Temple Hill in the southwestern part of the quadrangle. Outcrops are on both sides of a fault or slide plane (toreva slide block?) that is evident along the west edge of the quadrangle. Beds on the west side of the fault dip similar to nearby Green River cuestas. Beds on the east side are elevated above the west and warped into a syncline. Most of the upper slope-forming 15 to 20 feet (5–6 m) have been removed from the hill by erosion. The Crazy Hollow Formation unconformably overlies the Green River Formation and is late Eocene in age and was deposited about 42 to 45 million years ago (MacLachlan, 1982; Weiss, 1982; Weiss and Warner, 2001).

Tgu **Green River Formation, upper member** (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, and forms steep slope with a few ledges; shale is various shades of gray or green gray, marly or calcareous, and forms recesses or slopes; tuff is present in subordinate amounts, light brown to tan, somewhat resistant, and contains small biotite flakes; incompletely exposed; upper contact may be a slide plane; 120 to 220 feet (37–67 m) exposed; to the west in the Manti 7.5′ quadrangle the upper member is 220 to 400 feet (67–122 m) thick (Weiss and Sprinkel, 2002).

Tgl **Green River Formation, lower member** (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 (120+ m) thick; to the west in the Manti 7.5′ quadrangle, the lower member is 500 to 911 feet (152–278 m) thick (Weiss and Sprinkel, 2002).

The Green River Formation is exposed in shallow dipping cuestas along the east margin of Sanpete Valley. The formation is divided into two informal members. The lower member is dominated by calcareous shale and limestone and is mostly very light gray to green gray in color. The upper member contains thicker beds of limestone and is tan or light yellow gray in color.

The thickest beds are clustered near the base of the upper 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 brown to tan and contain small biotite flakes.

The top of the upper member is not exposed in the quadrangle except possibly 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. Weiss and Sprinkel (2002) also accepted this analysis in their mapping of the Manti quadrangle, which lies adjacent to the Ephraim quadrangle to the west. As such, the contact between the Green River and Crazy Hollow Formations is probably not exposed in the quadrangle.

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 and Wyoming portions. This paleolake has been termed Lake Green River by Hintze and Kowallis (2009) and Lake Uinta by early workers (Stokes, 1979; Franczyk and others, 1992). The Green River Formation is middle Eocene in age (Remy, 1992; Smith and others, 2008).

Figure 4. *Fossiliferous debris 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 likely from a lacustrine environment.*

Tc, Tcg **Colton Formation** (lower Eocene) – Interbedded mudstone (55–75%), sandstone (10–25%), and limestone (10–20%) (Tc); prominent discrete green-gray mudstone beds mapped separately as Tcg. Mudstone is gray, red, brown, olive green, gray, gray green, red brown, and light yellow; commonly variegated, banded, or mottled, generally weathers to lighter shades; commonly sandy or silty; finely laminated to thin bedded; fissile and breaks up into very small equidimensional fragments (granular); poorly to well cemented; calcareous and argillaceous; contains local biotite flakes, ostracodes, or small gastropods; generally forms steep slopes. Sandstone is mostly gray, yellow gray, brown, olive green, red brown, or tan, locally variegated, and mostly weathers lighter; fine to coarse grained; moderately to poorly sorted, subangular to subrounded grains; mostly poorly cemented; cross-bedded, irregularly bedded, or thin bedded; mostly ledge or cliff forming; largely calcareous; some argillaceous; friable and porous; beds grade upward from fine to coarse grained vertically. Limestone is gray to pink gray to yellow gray, and some is mottled; mostly very finely crystalline to micritic, calcarenite (limestone with sand sized grains) and calcisiltite (limestone with silt sized grains); locally sandy, silty, or argillaceous; generally forms thin rubbly ledges, but slope-forming beds are also present; mostly dense and hard; locally cross-bedded; laminated to medium bedded; locally brecciated probably from folding and faulting; commonly fractures conchoidally; locally nodular, rippled, platy weathering; fossiliferous, containing ostracode, gastropod, pelecypod, and bone fragments (figure 4). Entire unit is incompletely exposed and more than 1400 feet (430 m) thick.

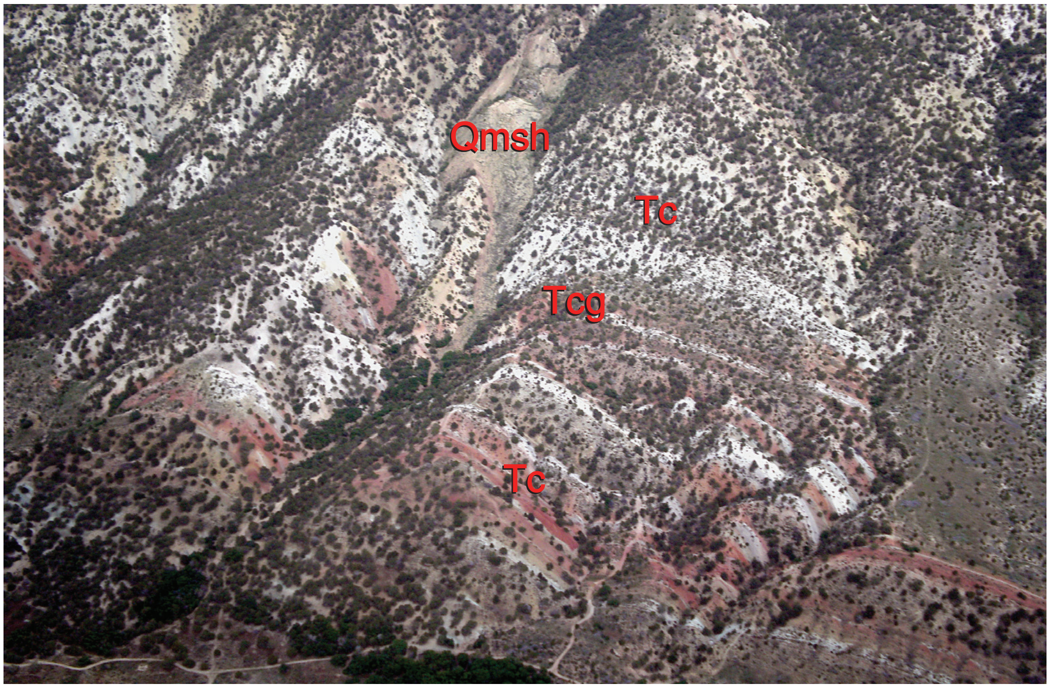

Figure 5. *Aerial view east of the Colton Formation (*Tc*) along the west side of the Wasatch Plateau between Ephraim and Willow Canyons. Colorful Colton beds dip an average of 45° valley- ward in the steepest part of the Wasatch monoclinal structure. Note the landslide (*Qmsh*) in the upper middle part of the photo.*

The Colton Formation overlies the Flagstaff Formation 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 5). The Colton Formation, like the North Horn Formation, was deposited in a fluvial environment consisting of flood plains, flood-plain lakes, and channels. Some landslides have also developed on the Colton. The upper contact is not exposed in the Ephraim quadrangle. Franczyk and others (1992) indicated that the Colton Formation in the Ephraim quadrangle is early Eocene in age, but Dickinson and others (2012) dated it to the east as extending into the late Paleocene, and show that the lowermost Colton Formation interfingers with the upper Flagstaff Formation.

Tf **Flagstaff Formation** (lower Eocene and upper Paleocene) – Interbedded limestone (55–65%), calcareous shale and mudstone (30–42%), and subordinate sandstone (2–8%). Limestone is 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; locally dolomitic or argillaceous; largely ledge- or cliff-forming; thin bedded to massive, dense and hard; many beds contain gastropods, pelecypods, ostracodes, and rare bone fragments; some beds weather nodular or platy, some are stylolitic; locally has cavities lined with calcite, and some beds are fetid. Calcareous shale is gray, green gray, olive green, green brown, and locally red; alternating resistant and nonresistant beds; evenly laminated to thin bedded; locally fissile; locally argillaceous; has gypsum stringers and fossil debris; some beds are granular or break into very small equidimensional fragments; generally slope forming and locally nodular weathering. Sandstone is light brown gray, gray, or light brown, generally weathers to light brown; mostly fine grained, but medium- to coarse-grained and pebbly beds 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 (150–300 m) thick.

The Flagstaff Formation makes up much of the upper surface of the Wasatch Plateau; the overlying Colton Formation is only preserved along the west margin of the plateau. The base of the Flagstaff generally caps the North Horn Formation in canyon walls. Some of the strata are clayey, like in the North Horn Formation, and are prone to landsliding in the Ephraim quadrangle. The Flagstaff was deposited in a large lake known as Lake Flagstaff that developed in late Paleocene time (Franczyk and others, 1992; Hintze and Kowallis, 2009, p. 81). Weiss and Sprinkel (2002) indicated (using other references [their p. 9 and lithologic column]) that the Flagstaff may be mostly early Eocene in age in the Manti and Ephraim area.

Tertiary-Cretaceous

TKnh **North Horn Formation** (lower Tertiary and Upper Cretaceous, Paleocene and Maastrichtian) – Interbedded, shaly mudstone, sandstone, limestone and/or calcarenite, and subordinate pebble conglomerate. Mudstone (about 60%) is variegated with shades of gray, green, yellow, orange, red brown, purple, brown, pinkish gray, and very dark gray, with many mottled horizons; commonly sandy, calcareous, or argillaceous; mostly indistinct bedding; forms steep hard, rubbly slopes, locally forms badland-type topography; breaks up into granular equidimensional fragments. Sandstone (about 33%) is mostly shades of light gray, yellow, brown, and pink, and weathers 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 and locally muddy; many pebbly streaks; usually resistant forming ledges and cliffs, but locally friable; commonly contains partings of mudstone or shale. Limestone and/or calcarenite beds (about 5%) are 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 contain broken gastropods and bivalves; have calcite-filled fractures. Pebble conglomerate (2–3%) forms light-brown-weathering ledges, commonly grades into sandstone; pebbles are mostly quartzite or sandstone that are locally up to small cobbles; beds are lenticular. Base is not exposed in quadrangle; more than 1100 feet (340 m) thick.

The North Horn Formation is exposed in canyons that have been cut into the Wasatch Plateau and is the oldest exposed unit in the quadrangle. The North Horn was deposited in a fluvial environment consisting of flood plains and channels (Bonar, 1948; Franczyk and others, 1992; Difley, 2007). Lakes commonly developed on the flood plains. Mud and clay in the weaker beds make the unit unstable and contribute to the ubiquitous presence of landslides and mudflows on 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, this boundary may be under a thick sequence of sandstone strata about 800 feet (240 m) below the top of the unit. The thickest exposed section of the North Horn in the quadrangle, in Manti Canyon, is more than 1100 feet (340 m) thick.

Subsurface Units

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. 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), Weiss (1994), and Weiss and Sprinkel (2002) to show units that are likely present. 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 of the Indianola Group. The Sixmile Canyon Formation correlates with the Castlegate Sandstone to upper Mancos Shale interval to the east; the Funk Valley Formation correlates with most of the Mancos Shale, and the Allen Valley Shale correlates with the Tununk Member of the Mancos Shale (Hintze and Kowallis, 2009). The transition to the Sanpete Valley units lies somewhere beneath the Ephraim quadrangle, but the exact location is unknown.

Thicknesses of these subsurface units as shown on the cross section are assumed using data derived from 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 and interfinger with the clastic units.

Cretaceous

Kp **Price River Formation** (Upper Cretaceous, Campanian) – Mostly tan and gray, medium- to coarse-grained sandstone, some gray shale and conglomeratic sandstone; forms ledges and slopes; 400 to 800 feet (120–240 m) thick.

Ksx **Sixmile Canyon Formation** (Upper Cretaceous, Turonian to 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 eastward 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 (see cross section); as much as 4000 feet (1220 m) thick.

Kc **Castlegate Sandstone** (Upper Cretaceous, Campanian) – Light-gray, yellowish-brown, and white, medium- to coarse-grained sandstone and conglomeratic sandstone; forms cliffs where exposed outside of quadrangle; 150 to 500 feet (45–150 m) thick.

Kb **Blackhawk Formation** (Upper Cretaceous, Campanian) – Light- to medium- gray sandstone; gray to black shale; gray siltstone; sandstone weathers tan, brown, yellowish brown; forms ledges and slopes where exposed outside of quadrangle; 400 to 1100 feet (120–340 m) thick.

Ksp **Starpoint Sandstone** (Upper Cretaceous, Santonian to Campanian) – Tan, light-gray, and white massive sandstone beds separated by one or more shale tongues; forms cliffs where exposed outside of quadrangle; 200 to 1000 feet (60–300 m) thick.

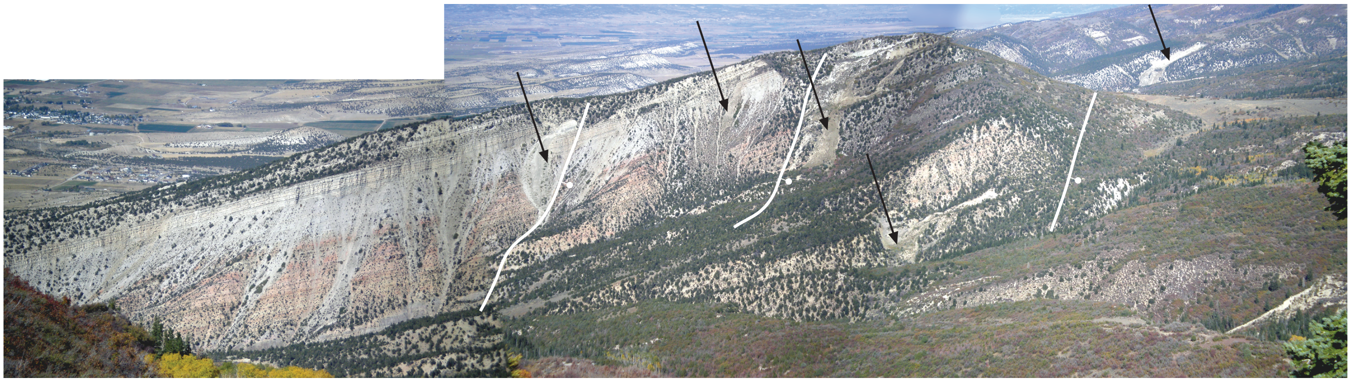

Figure 6. Aerial view north across Willow Creek Canyon. Pinkish rocks are North Horn Formation and capping white rocks are Flagstaff Limestone. White lines show the approximate position of normal faults with displacements down to the right (east). Note recent landslide scarps as indicated by black arrows.

Figure 7. Aerial view northward across Manti Canyon showing downthrown blocks and the Shoulder graben. White lines are the approximate fault traces. Bars and balls are 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 westward-steepening form of the Wasatch monocline.

Km **Upper Mancos Shale** (Upper Cretaceous, Turonian to Santonian) – Light-gray to blue-gray sandy marine shale; 300 to 1300 feet (90–400 m) thick.

STRUCTURAL GEOLOGY

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, but Weiss and Sprinkel (2002) provided subsurface information for the adjoining Manti quadrangle. This summary is also based on structural relationships seen in Sixmile Canyon, mapping and cross sections by Weiss (1994) in the Sterling quadrangle, and work done in central Utah by Schelling and others (2007).

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 Formation limestone, and seems to flex over the subsurface, high-angle, extensional Ephraim fault as defined by seismic lines (Schelling and others, 2007). In the subsurface, the Arapien Shale is offset by the Ephraim fault and significantly thickens west of the fault (Schelling and others, 2007). In the southeastern corner of the quadrangle, Flagstaff strata dip only a few degrees to the west. 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 (figures 6 and 7). Locally, dips in the Colton Formation are much steeper to overturned. The steepness of the monocline

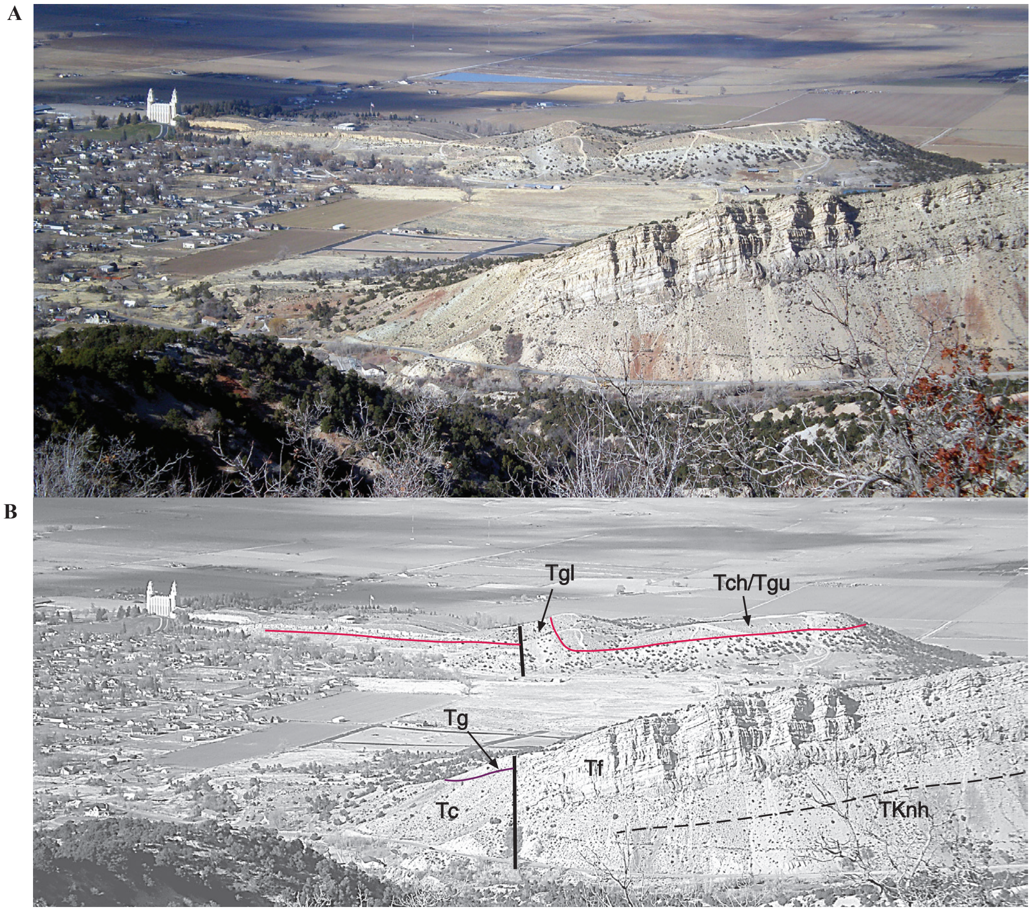

Figure 8. A. *View northwest of a Flagstaff Formation cliff on the north side of Manti Canyon in the foreground with Temple Hill in the background. The Manti LDS temple is on the left (southwest) end of Temple Hill.* ***B.*** *The red line is the contact between the upper and lower Green River Formation. The sharp bend in the line just right of the fault is the Temple Hill syncline. Cut oolitic limestone for the temple was quarried from the long linear outcrop just above the red line left of the fault (note fresh outcrop in A). The black line marks a reverse fault or landslide detachment surface that displaces and folds the strata. A different reverse fault displaces Colton and Green River strata downward in the north wall of Manti Canyon (not the same as the fault in Temple Hill, though they appear to align in the photograph). The purple line left of the fault separates nearly vertical Colton strata from gently west-dipping Green River strata.*

has precipitated bedding-plane rock slides that are intermittently exposed on the west side of the plateau.

Shoulder Graben

Shoulder graben is formed by several steeply dipping faults with offsets best observed in the Flagstaff Formation (figure 7). The faults trend approximately north-northeast and crudely parallel the trend of the monocline. They are especially obvious along the north walls of Manti and Willow Creek Canyons. Most faults on the west side of Shoulder graben are down to the east and generally increase in displacement from west to east; the greatest displacement is estimated to be about 650 feet (200 m) (fault on the east side of Manti Mountain). Eastern faults have displacements down to the west. The graben in the center was named Shoulder graben by Washburn (1948, p. 49). There are fewer faults on the east side of Shoulder graben; the largest is in the southeastern corner of the quadrangle and has a displacement of about 750 feet (230 m) down to the west. Dip of the fault planes ranges from nearly vertical to 75° with normal displacement. Dips of 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 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 unconformably overlies steeply dipping Cretaceous rock, 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. The fault plane (or slide plane if described as a landslide) dips steeply to the east, and rocks on the east side are displaced upward as much as 180 feet (55 m) 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 dip up 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 also forms a north-south fringe on the west side of the fault or slide plane and dips westward. Crazy Hollow strata were once continuous across the west part of Temple Hill as shown by the presence of a small outcrop just east of the Manti LDS Temple in the Manti quadrangle (Weiss and Sprinkel, 2002).

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.

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 in Manti Canyon 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

Gray, well-cemented, oolitic limestone quarried at Temple Hill 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 in Salt Lake City. The quarries at Temple Hill are intermittently used to provide replacement stone for the temple and local buildings, and 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 (2.4 m) thick have uniform texture. Small quarries were also opened at Little Hill and other Green River Formation outcrops north of Ephraim (Pratt and Callaghan, 1970). The fresh rock is light creamy gray in color, and the oolites have a uniform diameter of just under a millimeter, giving the rock a sandy appearance. The cut limestone weathers easily and needs to be sealed to prevent deterioration. The Manti Temple is 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.

A small amount of orange-red to red-brown dimension stone was also quarried in the Crazy Hollow Formation on Temple Hill. This stone was used by pioneers to build 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 Formation 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 and Green River Formations, but the quality of the rock is extremely variable. High calcium limestone is a highly desirable product but 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 magnesium.

Other Potential 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 North Horn Formation outcrops 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 a small amount of coal was produced from the partially equivalent Sixmile Canyon Formation near Sterling (Doelling, 1972). However, the Sterling Sixmile Canyon coal beds are relatively thin or split compared to mineable resources in other areas.

Petroleum exploration has been vigorous from time to time in 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 Corporation 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 (Chidsey and others, 2007; Schelling and others, 2007). The Covenant field near Sigurd is about 35 miles (56 km) southwest of the Ephraim

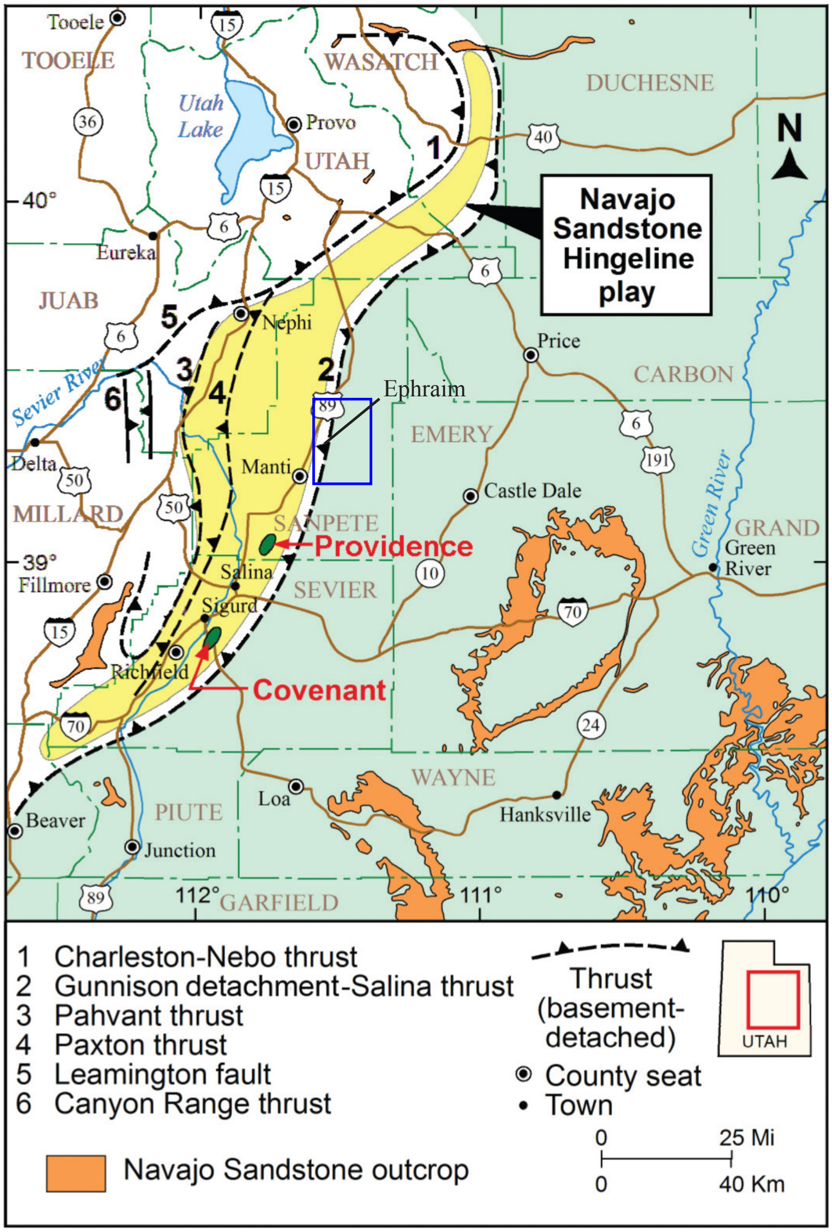

Figure 9. *Location of Covenant and Providence oil fields. Uplifts and selected thrust systems in the central Utah thrust belt are often referred to as the Utah "hingeline." Numbers and sawteeth are on the hanging wall of the corresponding thrust system. The yellow band is often called the Sanpete-Sevier valley anticline (SSVA) (after Chidsey and Sprinkel, 2014). The Ephraim quadrangle is indicated by the blue box.*

quadrangle. Oil production is mostly from the Jurassic Navajo Sandstone and Temple Cap Formation on a thrust structure that forms the core of the Sanpete-Sevier Valley antiform. The more recently discovered Providence field near Mayfield is about 15 miles (24 km) southwest of the Ephraim quadrangle. Chidsey and others (2011) and Chidsey and Sprinkel (2014) indicate oil and gas production is from the Navajo Sandstone and Temple Cap Formation located between the Gunnison detachment-Salina thrust and the Paxton thrust in the central Utah thrust belt, the same thrust plate as the Covenant field (figure 9). The Sanpete-Sevier Valley antiform trends northward into Sanpete Valley west of the Ephraim quadrangle. Potential thrust-structure reservoirs associated with the antiform are in the subsurface under the western part 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 (13 km) south in the adjacent Black Mountain quadrangle (Chidsey and others, 2007). 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 was drilled on a subtle structure on the upthrown block east of the Ephraim fault. Similar formations and structural geometries found in the Phillips well are under the Ephraim quadrangle.

WATER RESOURCES

While agriculture is the most important economic activity in the area, water resources are considered the most valuable commodity. More economic activity is focused on water than on any other earth resource. The hydrologic characteristics of each geologic formation and water quality have been studied and reported on by Lowe and others (2003) and Wallace and others (2007).

Surface water resources are replenished by winter and spring snowfall, supplemented by rainfall. The top of the Wasatch Plateau receives about 40 inches (100 cm) of precipitation during the year, while only about 12 inches (30 cm) is received in the valley below. Springs in the high country have been acquired by local municipalities for drinking water, and large reservoirs on the plateau are common near the springs. The principal aquifer is the Flagstaff Formation, but smaller springs arise from the more porous beds of the North Horn and Colton Formations and emit from just above tight shaly beds. During years of excessive water, Colton, Flagstaff, and North Horn Formation aquifers become filled and saturated and "bleed" from fractures and pores.

Ditches, tunnels, and pipelines have been constructed to generate electricity and to fill reservoirs used to water hay, other crops, and livestock. Groundwater is also produced from the alluvial fans and river alluvium in Sanpete Valley. Some wells are artesian, mostly near the Qal and Qafo contact. Although some wells have been drilled into the alluvium, the more productive produce from the alluvial-bedrock contact zone, up to 400 feet (120 m) beneath the surface.

GEOLOGIC HAZARDS

Floods, landslides, and earthquakes are the three types of geologic hazards most likely to affect the inhabitants and property of the Ephraim quadrangle. 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 spring runoff and storm waters; however, during wet years flooding may occur. The cities of Manti and Ephraim are partially developed on alluvial fans of Manti Creek and Ephraim Creek, and debris flows and floods have impacted these towns in the past (figure 10). Flooding is commonly accompanied by debris flows in which bouldery channel deposits move downstream. Debris flows and floodwaters can also "jump" the old channel, cutting a new one somewhere else on the fan and on developed land. Frequently, snowmelt and summer storms cause significant damage to roads in the high country, which become impassable due to deep mud and gullying (Baum and Flemming, 1989).

Landslides, slumps, and debris flows are common during wet years, primarily along canyons near the Wasatch Plateau front, damaging roads, pipelines, and ditches. The North Horn, Flagstaff, and Colton Formations are commonly involved.

A few small tremors and historic earthquakes have rocked the Ephraim quadrangle area (UUSS, accessed 2014). Expected impacts, should a large earthquake occur, are surface ruptures, ground shaking, and liquefaction of the ground in areas underlain by saturated fine-grained materials. Ephraim and Manti have many older masonry buildings that may not be properly reinforced and have high risk of collapse in an earthquake. Tall pieces of furniture, water heaters, and other objects may require fastening to walls to prevent their toppling in case of a stronger event.

ACKNOWLEDGMENTS

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Figure 10. *Large debris flows, probably from Manti Canyon in the southern part of the Ephraim quadrangle, caused major damage in the city of Manti in 1902. Used by permission, Utah State Historical Society, all rights reserved.*

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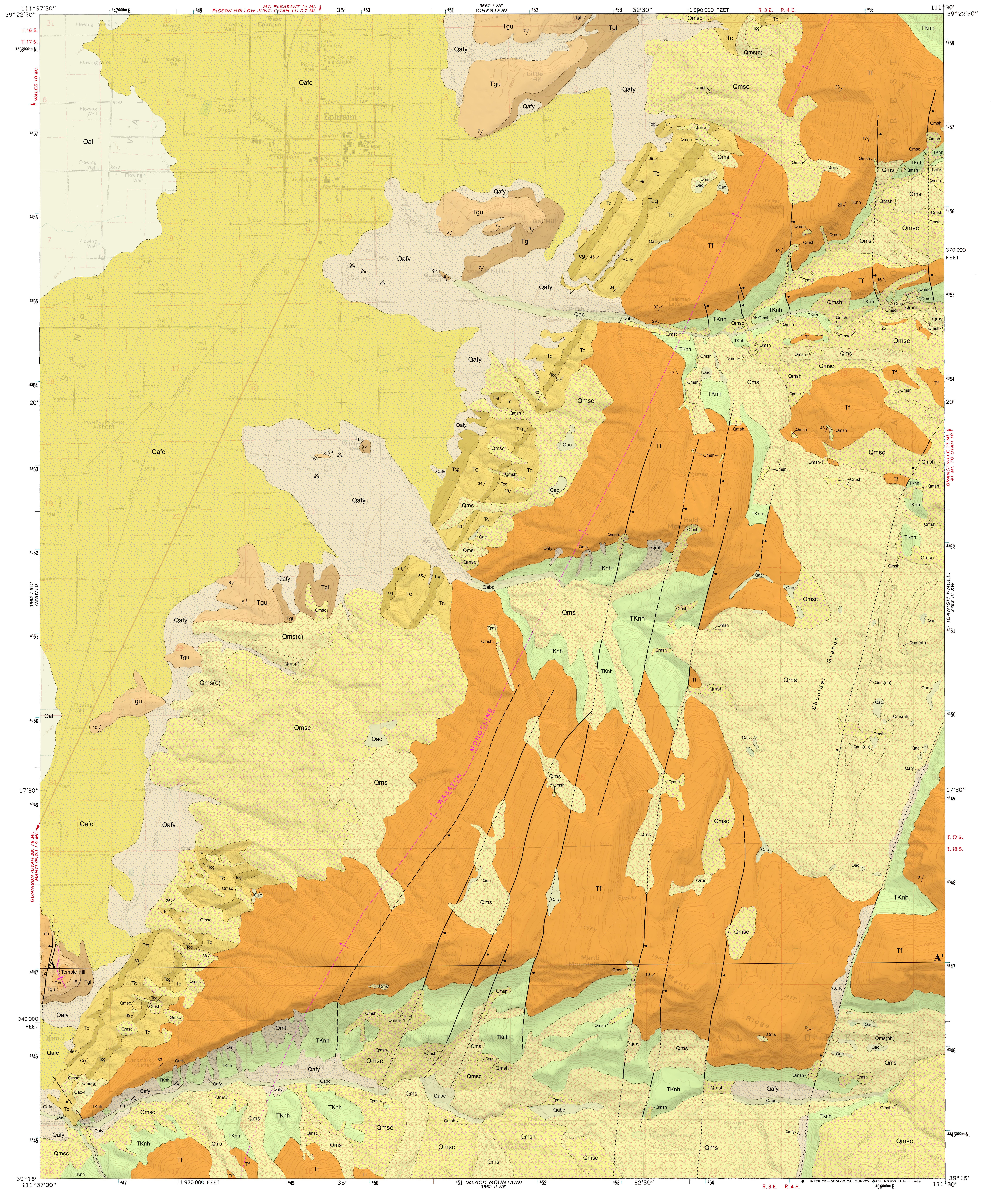

SCALE 1:24,000

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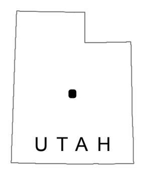
This geologic map was funded by the Utah Geological Survey and the U.S. Geological Survey, National Cooperative Geologic Mapping Program, through USGS STATEMAP award number 03HQAG0096.



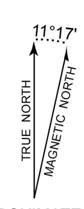
QUADRANGLE LOCATION

GEOLOGIC MAP OF THE EPHRAIM QUADRANGLE, SANPETE COUNTY, UTAH

by

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

2016



APPROXIMATE MEAN DECLINATION, 2016

Base from USGS Ephraim 7.5' Quadrangle (1966)
Projection: UTM Zone 12
Datum: NAD 1927
Spheroid: Clarke 1866

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

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(801) 537-3300
geology.utah.gov

This map was created from geographic information system (GIS) data.

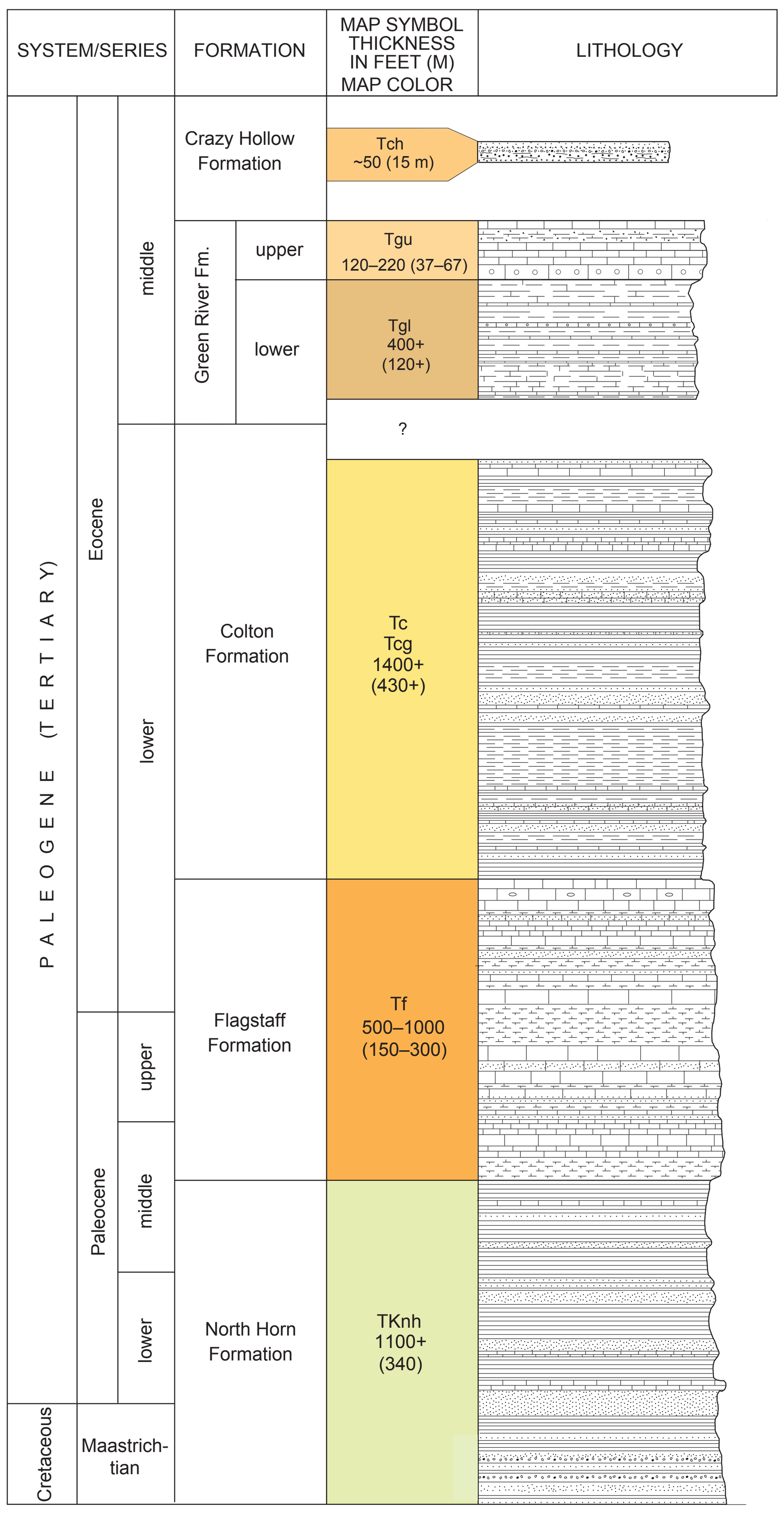
1	2	3
4		5
6	7	8

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

ISBN 978-1557919137

LITHOLOGIC COLUMN



GEOLOGIC SYMBOLS

Contact, dashed where approximate

Normal fault, dotted where concealed, dashed and queried where existence uncertain, ball and bar on downthrown side

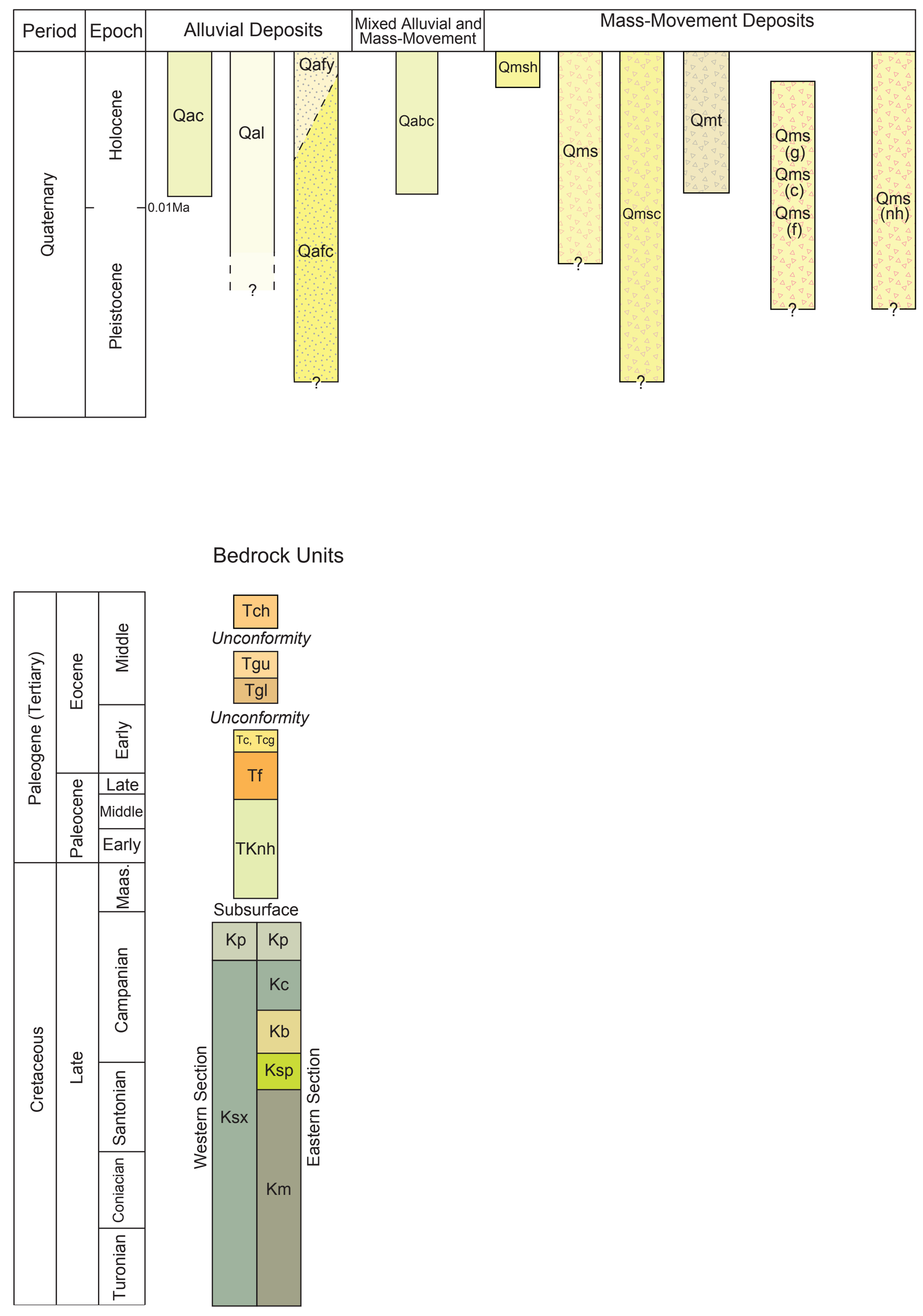
Axial trace of syncline

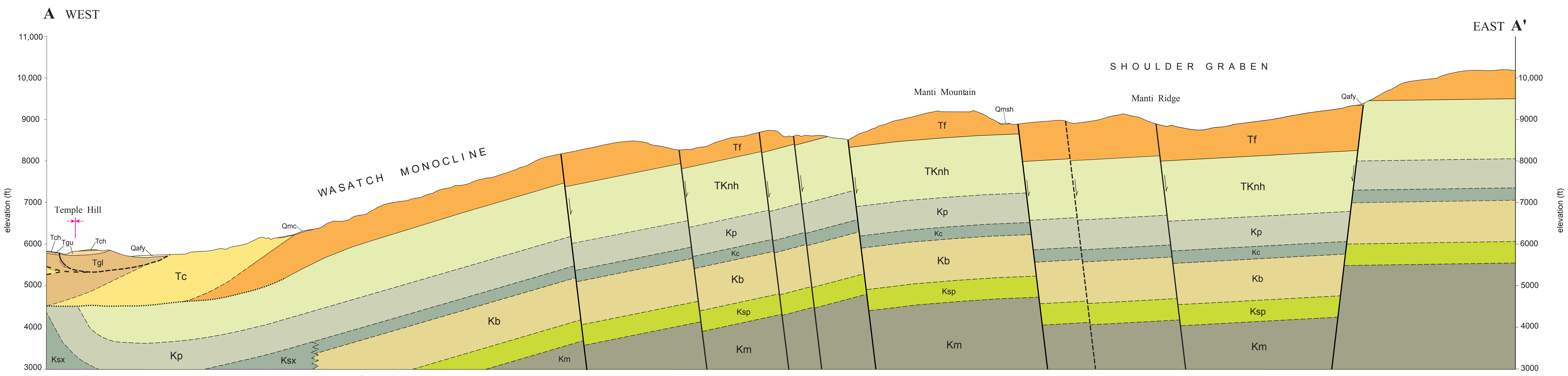
Approximate axial trace of monocline

50 Strike and dip of bedding

Gravel pit

CORRELATION OF UNITS





Location of transition between western and eastern sections has not been determined. See text for discussion.