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Cover

View of the Salina Canyon unconformity in the southern part of the Wasatch Plateau. The Jurassic Twist Gulch Formation forms the vertical to subvertical unit under the angular unconformity. Salina Canyon is an example of a progressive unconformity, with overlying strata including Paleogene sandstone beds of the Flagstaff and Colton Formations capped by the variegated cliffs of the Paleogene Green River Formation.

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# Utah Geosite—The Salina Canyon Unconformity, a Classic Example of Missing Time

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## ABSTRACT

Salina Canyon, Utah, reveals a spectacular angular unconformity along an east-west transect through the southern part of the Wasatch Plateau. This region of Utah is well known as the eastern extent of Sevier orogenesis, but it also includes subsequent extensional overprinting. Earliest descriptions of this unconformity were published by Dutton (1880) and Spieker (1946, 1949), and work continues today. Field relationships expose many classic stratigraphic and sedimentologic features of erosional surfaces. Due to the geometry of the progressive unconformity onto the topographic high of the Sanpete-Sevier Valley antiform, the angular discordance of strata results in a gap in time of greater than 107 million years in the west, decreasing toward the east to about 39 million years and finally to less than 17 million years. Paleosols and small-scale channels/scours with infilled basal conglomerates are also prominent along the unconformity, as are several mine adits. Because of its abundant geologic features, the Salina Canyon unconformity is a superb teaching and learning space for geoscientists and outdoor naturalists.

## INTRODUCTION

Unconformities are stratigraphic contacts between rock layers where nondeposition or extensive erosion of the underlying older rock unit occurred before deposition of the overlying younger rock, indicating a gap in time when sedimentation was not continuous. One type of unconformity—an angular unconformity—is easily identified in the field, because the rock layers above and below the unconformity are not parallel. As ancient surfaces of erosion, unconformities are important to geology because they signify a disruption in the typical, uninterrupted deposition of sedimentary layers. Unconformities help geoscientists understand geologic time by bracketing the age range of geologic events.

Salina Canyon, Utah (figure 1), is home to one of the most striking angular unconformities in the state. Many geoscientists travel to see this unconformity just east of the city of Salina and the Salina City Park. The Salina Canyon unconformity exhibits many of the classic features of unconformities. In addition, the erosional surface itself displays relief, and hence, ensuing depositional onlap. Geographically it marks the eastern extent in Utah of the Sevier orogeny, a mountain building event from about 170 to 40 million years ago.

Previous work has been instrumental in our understanding of this angular unconformity at Salina Canyon. Dutton (1880) published the earliest description of the Salina Canyon unconformity. The first detailed fieldwork at Salina Canyon was conducted by Spieker (1946, 1949), first with the U.S. Geological Survey and later as a faculty member at The Ohio State University. Spieker described the field relationships between rocks both below and above the unconformity. In 1947, Spieker

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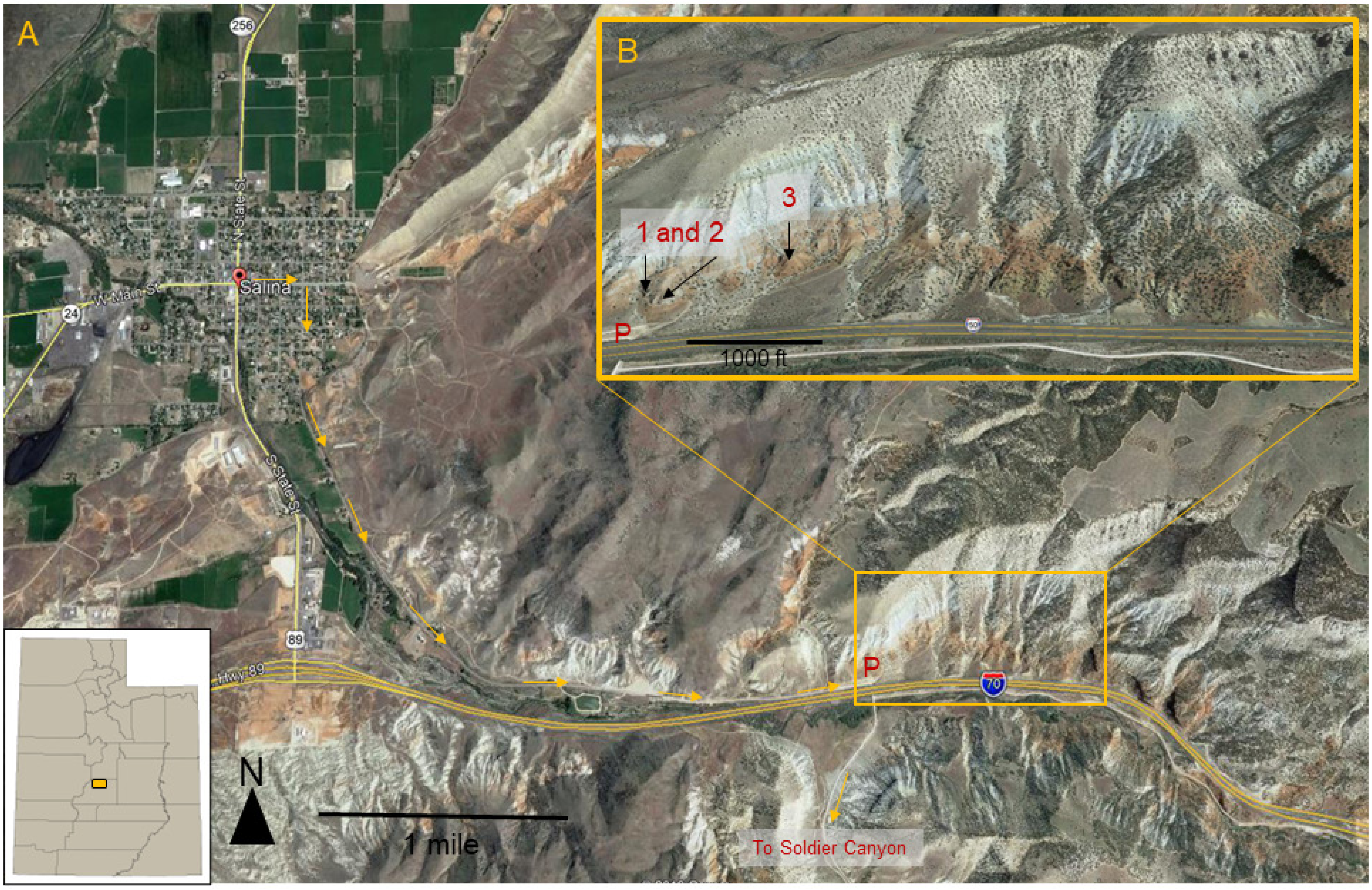


Figure 1. (A) Location of Salina Canyon in relation to the city of Salina, I-70, and major state highways. The area in the yellow box is the primary focus of this field guide. Yellow arrows indicate the driving route from downtown Salina to the unconformity. The red "P" denotes possible parking. (B) Inset map shows the transect where the Salina Canyon unconformity is well exposed. Stations 1, 2, and 3 are described in the text. Modified from Google Earth, Utah AGRC.

moved Ohio State's field camp program from Tennessee to Snow College in Ephraim in Sanpete Valley (Weiss, 1995). For decades, Ohio State's field camp (still based in Ephraim) has visited the Salina Canyon angular unconformity, colloquially known to these geoscientists as the "Spieker unconformity."

The Salina Canyon unconformity has been described by numerous additional workers. Gilliland (1963) attributed the large-scale folding in the Sanpete-Sevier Valley region to the Sevier orogeny, whereas Witkind (1982, 1983, 1994) considered diapiric action to be the cause of younger units pinching out against the regional large-scale fold. The unconformity has been described and interpreted in field guides (e.g., Lawton and Willis, 1987) and in geologic maps of the area (e.g., Willis, 1986). Additional research characterizing the unconformity and associated bedrock units (Judge and Krissek, 2003; Werthmann, 2018) has added to the story of the unconformity from a stratigraphic and sedimentologic perspective.

This paper aims to (1) provide the physical location and geologic setting for the Salina Canyon unconformity, (2) outline the geologic characteristics of this unconformity, which illustrates many classic stratigraphic and sedimentologic features of erosional surfaces, and (3) summarize recent research on the unconformity regarding paleosol (ancient soil) formation and the sedimentary characteristics along the boundary.

## LOCATION

The Salina Canyon unconformity is in northern Sevier County, central Utah (figure 1). Outcrops visited in this guide are within the Wasatch Plateau, which is immediately east of the Sanpete-Sevier Valley. The unconformity is exposed at the southern end of Cedar Mountain, which lies a few miles east of Salina, the northern segment of Fishlake National Forest. The unconformity is best exposed just north of Interstate 70 (I-70) at the entrance to Soldier Canyon. The dirt access road to the unconformity is 3.8 miles (6.1 km) east of State Street (U.S. Highway 89 [U.S. 89]) in Salina and just 2 miles (3.2 km) east of Salina City Park.

Beautiful exposures of the unconformity can be seen along an east-west transect for a minimum of 1 mile (1.6 km), although the surface continues farther to the east (figure 2A). Several of the most spectacular locations showing image-worthy angular discordance and other exceptional features are located within 0.25 mile (0.4 km) of each other. These stations are described in detail in the Stratigraphy section:

- Station 1 (well-developed paleosol): 38°56.049'N., 111°48.584'W. (figure 2B).
- Station 2 (mine adit): 38°56.033'N., 111°48.549'W. (figure 2C).
- Station 3 (stunning photo opportunity): 38°56.113'N., 111°48.404'W. (figure 2D).

## SUGGESTED DRIVING DIRECTIONS

The Salina Canyon unconformity is easily accessible from any cardinal direction because the nearby city of Salina is at the crossroads of several major state highways and I-70 (figure 1). Each of the directions below end on E. Main Street; from there, more detailed directions are provided in the last paragraph of this section.

- When driving from the north or south via U.S. 89 or when driving from the west via U.S. Route 50, proceed to the intersection of State Street and E. Main Street in downtown Salina. The famous Mom's Cafe (voted one of the best places to eat in America and featured in National Geographic Explorer magazine) sits on the southeast corner of this intersection. Proceed east on E. Main Street. (Follow directions below.)
- When driving from the west or east via I-70, take exit 56 (Salina). Proceed north on U.S. 50/U.S. 89 (State Street) to the intersection of State Street and E. Main Street in Salina. (Follow directions below.)

The pull-off for the Salina Canyon unconformity is 3.8 miles (6.1 km) from the intersection of State Street (U.S. 89) and E. Main Street. Drive east on E. Main Street and proceed three blocks to S. 300 E. Turn south on S. 300 E.; a small, wooden sign at this intersection marks this intersection as the turn-off for Salina City Park. S. 300 E. (old Highway 10) gently curves to the southeast and finally to the east. On the south side of the road, visitors will pass Salina City Park, which has two entrances/exits. The pull-off for the Salina Canyon unconformity is 2 miles (3.2 km) ahead. Proceed east to a "Y" junction at 38°55.964'N., 111°48.673'W. Vehicles with high clearance can proceed left at the "Y" junction and park along the dirt track once it flattens out. Vehicles lacking high clearance should park on S. 300 E. Do not park too close to the tunnel, which is just ahead, about 520 feet (160 m). Note: visitors have driven too far when the road curves to the south and turns into a one-lane tunnel as it passes under I-70.

Visitors who wish to observe a large segment of the Salina Canyon unconformity and Stations 1, 2, and 3 simultaneously can do so from the south side of I-70. When on S. 300 E., drive south under the I-70 tunnel toward the entrance to Soldier Canyon. Proceed immediately east on the frontal road before entering Soldier Canyon, and there will be opportunities for a large-scale perspective and transect photographs.

## STRUCTURAL GEOLOGY

### Physiographic Provinces

Salina Canyon is in a region that exposes the complex Mesozoic and Cenozoic geology of central Utah (Spieker, 1936, 1946, 1949; Villien and Kligfield, 1986; Anderson and others, 2001; Schelling and others, 2007). An older compressive phase (145 to 38 Ma) was followed by younger extension (post 38 Ma), creating exceptional structural overprinting (Mattox and Weiss, 1987; DeCelles and others, 1995; Constenius, 1996; DeCelles, 2004; Judge and others, 2005; DeCelles and Coo-

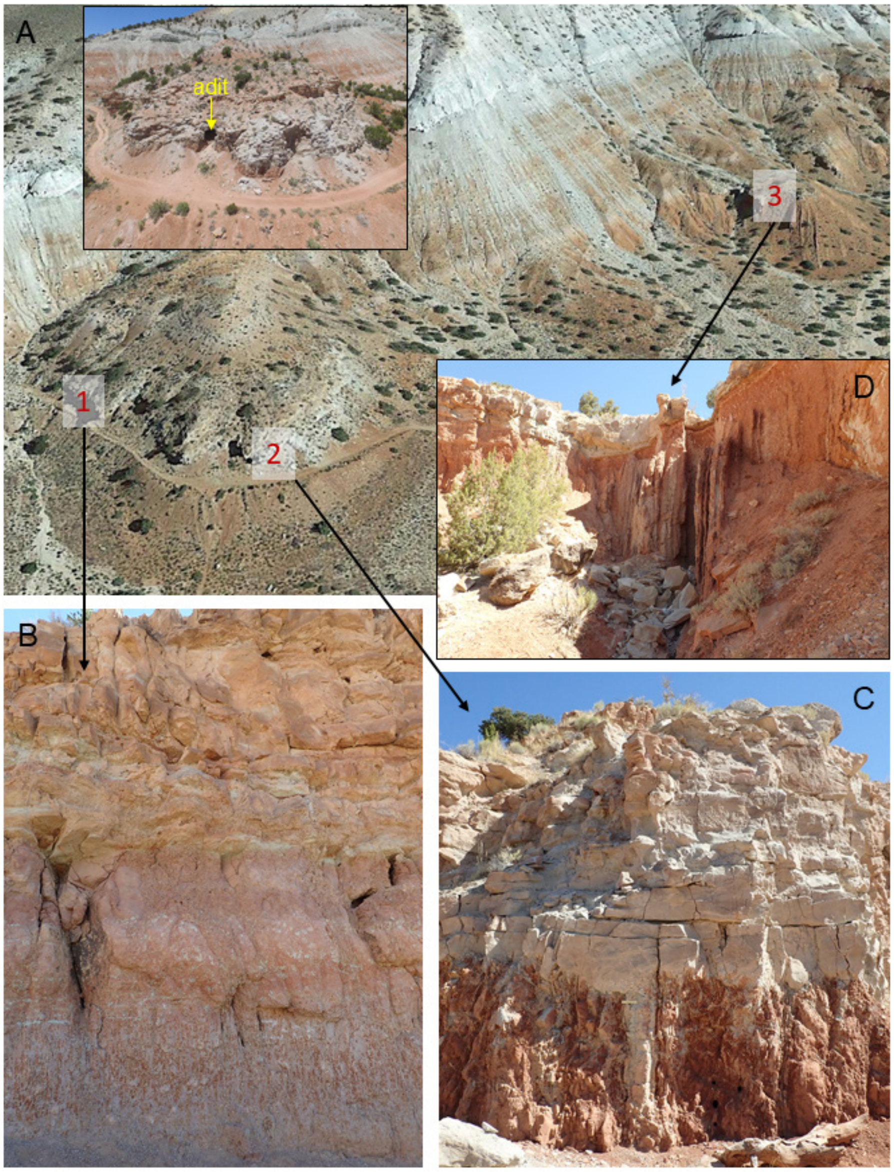


Figure 2. (A) Aerial photograph of the location of Stations 1, 2, and 3 in Salina Canyon. View to the northeast. Inset shows a clearer view of the outcrop for Stations 1 and 2. Note the adit in the center of the photograph. Modified from Google Earth. (B) Station 1, where a well-developed paleosol (purplish pink) is present below the unconformity. View to the east. (C) Station 2 depicts the vertical beds of the Jurassic Twist Gulch Formation (average attitude of 028°, 85° SE; N. 28° E., 85° SE) under the unconformity and the overlying Paleogene fluvial sandstones (average attitude of 320°, 12° SW; N. 40° W., 12° SW). View to the north. (D) Station 3, which is the best-known photogenic locality of the Salina unconformity. Strata here have similar attitudes to Station 2. View to the northeast.

gan, 2006). The Salina Canyon unconformity lies in the transition zone between the Basin and Range Province to the west and the Colorado Plateau to the east (figure 3; Stokes, 1977). The transition zone is within the Utah hingeline, a zone of structural weakness and repeated tectonic reactivation that runs generally north-south through the state and marks the eastern limit of the Sevier fold-thrust belt (Stokes, 1976; Ritzma, 1981; Schelling and others, 2007) as well as the boundary between thin and thick Paleozoic limestone successions.

## Contractional Tectonics

Deformation from the Sevier orogeny was a result of compressive stress established along the western margin of North America (DeCelles, 2004). In central Utah, the pulses of thrusting spanned about 80 million years (DeCelles and Coogan, 2006). Multiple research (i.e., structural geology and tectonics, stratigraphy, geochronology, and geophysics) guides our understanding of the timing of deformation in the region and of the regional paleostress orientations (DeCelles and Coogan, 2006; Schelling and others, 2007).

The Sanpete-Sevier Valley antiform (SSVA), also called the Salina anticline (Schelling and others, 2007), is one of the dominant geologic features of central Utah and is exposed in the Sanpete and Sevier Valleys (figure 3). A north-plunging, upward arching fold, the SSVA is

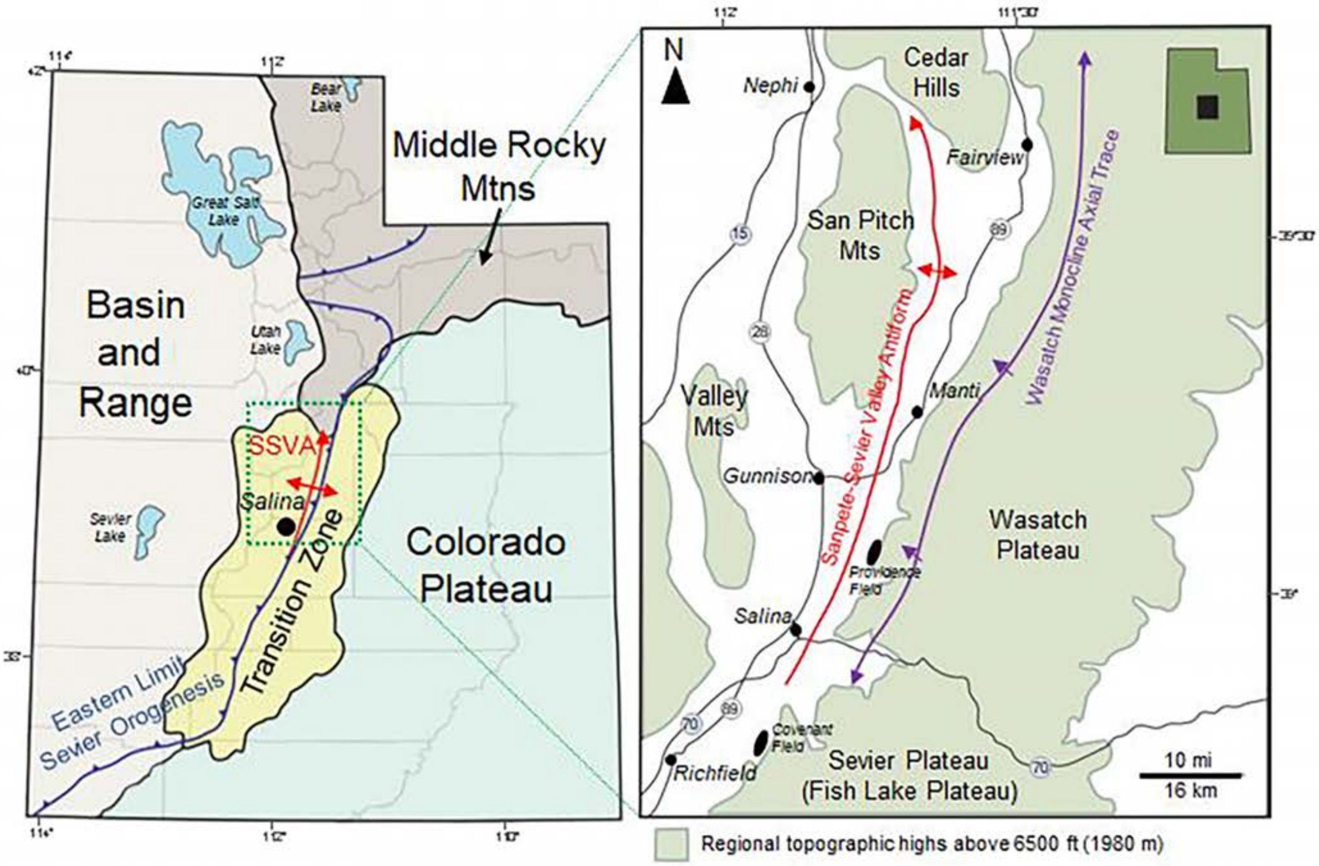


Figure 3. Simplified map on left shows the major physiographic provinces of Utah, including the relationship of the transition zone to the Basin and Range, Colorado Plateau, and Middle Rocky Mountains provinces. The blue line represents the eastern extent of Sevier orogenesis in Utah, whereas the red line is the axial trace of the SSVA. Modified after Utah Geological Survey (2018). Map on right illustrates the major geomorphic features of the Sanpete-Sevier Valley area. The red line shows the axial trace of the SSVA.

reported as 50 to 70 miles (80-113 km) long with vertical structural relief up to 20,000 feet (6100 m), varying from 2 to 4 miles (3-6 km) wide and opening toward the south (Gilliland, 1963; Anderson and others, 2001). Its location and sheer size play an important role in petroleum resources of central Utah. Covenant field in Sevier County is along the east limb of the SSVA (Chidsey and others, 2007), and a similar field, Providence, lies to the northeast of Covenant. In these regions, the subsurface geology includes a series of imbricate thrusts, fault-bend folds (with well-developed hanging-wall anticlines), and backthrusts that create a triangle zone within the core of the SSVA (Schelling and others, 2007). Here, the Jurassic Navajo Sandstone and Temple Cap Formation (White Throne Member) are the producing reservoirs, and the Jurassic Arapien Formation acts as the reservoir seal (Chidsey and others, 2007; Schelling and others, 2007; Sprinkel and others, 2011).

Several researchers hypothesized that buckling associated with Sevier thrusting was the primary cause of SSVA folding and related deformation. Lateral compression is likely the mechanism responsible for the deformation (Gilliland, 1963; Lawton, 1985; Willis, 1986; Weiss, 1994).

## Extensional Tectonics

The region also experienced a change in the stress regime from east-west crustal shortening to extension. Two distinct episodes of Cenozoic extension overprint previous compressive deformation (Constenius, 1996; Judge and others, 2005). Rowley and others (1998) correlated these extensional periods with two magmatic episodes: (1) an episode of pre-middle Miocene extension (also referred to as pre-Basin and Range extension), and (2) the more well-known and well-documented Basin and Range extension that began in late Miocene time and continues to this day. Regional structures on the Wasatch Plateau that demonstrate extensional tectonics include normal faults and extensional fractures (opening mode joints and calcite veins) that overprint the unconformity. In addition, the formation of the Wasatch monocline in Salina Canyon is interpreted as a roll-over fold from a half-graben caused by this regional extension (Judge and others, 2005, in press; Judge, 2007).

## GEOLOGIC HISTORY OF SALINA CANYON

The Salina Canyon uniformity captures millions of years of Earth history and tectonic deformation in the transition zone of central Utah. Below is a summary of the geologic history of the area, incorporating both sedimentation and age dating to create a timeline of events.

### Stratigraphy and Sedimentation

The Middle Jurassic and Cretaceous stratigraphy of central Utah was controlled by mountain building, creating a region of dynamic sedimentation. Depositional packages can be divided into four general time intervals: (1) Jurassic foreland basin development (Perkes and Morris, 2011; Sprinkel and others, 2011), (2) Cretaceous Sevier orogenesis (Villien and Kligfield, 1986; DeCelles and others, 1995; DeCelles and Coogan, 2006; Schelling and others, 2007), (3) Paleogene uplifts and basins (Dickinson and others, 1988), and (4) Miocene to recent regional extension (Mattox and Weiss, 1987; Constenius, 1996; Judge and others, 2005). In Salina Canyon, units representing each of these four intervals are exposed along an east-west transect through the area. Our focus is on the Jurassic, Cretaceous, and Paleogene units adjacent to the unconformity (figure 4).

Strata in the core of the SSVA were deposited during the Jurassic. The Arapien Formation is interpreted as an open marine, marginal marine, and restricted marine deposit, deposited in a developing foredeep basin as part of the Jurassic Carmel-Twin Creek Seaway (Sprinkel and others, 2011; Hintze and Kowallis, 2021; D.A. Sprinkel, Utah Geological Survey, written communication, 2023). The age range from palynomorphs for the uppermost member of the Arapien, which is exposed in Salina Canyon, is about 164 to 162 Ma (Sprinkel and others, 2011). Overlying the Arapien is the Jurassic Twist Gulch Formation, which is interpreted as primarily an alluvial to shallow marine unit in Salina Canyon, derived from highlands to the west and deposited into the Arapien basin (a subbasin within the regional foreland basin system; Perkes and Morris, 2011). Its age range from U-Pb geochronology of detrital zircons and supported by palynomorphs is about 165 to 155 Ma (Perkes and Morris, 2011).

Cretaceous units comprise the limbs of the SSVA (Spieker, 1946, 1949; Gilliland, 1963; Schelling and others, 2007). Cretaceous units are a thick sequence of clastic sediments, derived from the Sevier orogenic highlands to the west, that were deposited in a foredeep basin (Villien and Kligfield, 1986; DeCelles and others, 1995; DeCelles and Coogan, 2006; Schelling and others, 2007). These Cretaceous units are tied directly to multiple east-propagating thrusting events (DeCelles and Coogan, 2006). Sedimentation from the orogenic highlands to the west record a terrestrial to marine transition from west to east. In Salina Canyon, Cretaceous units include the Cedar Mountain Formation and the Indianola Group (San Pitch, Sanpete, Allen Valley, and Funk Valley Formations), which range in age from about 145 to 75 Ma (Spieker, 1949; Lawton and Willis, 1987; Sprinkel and others, 1999; DeCelles and Coogan, 2006). The North Horn Formation spans the Cretaceous/Paleogene boundary (figure 4).

### Sanpete-Sevier Valley Antiform and the Unconformity

The SSVA underwent several pulses of deformation and uplift during its evolution (Gilliland, 1963). Seismic interpretations, along with studies of exposed strata, indicated that the SSVA was initiated between about 80 to 70 Ma (Gilliland, 1963; Schelling and others, 2007) after deposition of the Funk Valley Formation (about 80 Ma; Lawton, 1985; Lawton and others, 1997). It may have been actively folding during deposition of the Sixmile Canyon Formation (Lawton and others, 1997), but it

**Salina Stratigraphic Column**

| Age | | Formation | | Max ft (m) | Lithologies |
|---|---|---|---|---|---|
| | | *column continues above* | | | |
| Paleogene | Oligocene | Fm of Aurora | | 1395 (425) | ss, mdst |
| Paleogene | Oligocene | Crazy Hollow | | 984 (300) | mdst, ss, cgl |
| Paleogene | Eocene | Green River | | 1165 (355) | mdst, sh, ls |
| Paleogene | Eocene | Colton | | 525 (160) | mdst, sh, ss |
| Paleogene | Paleocene | Flagstaff | | 98 (30) | ss, cgl, ls, mdst |
| Paleogene | Paleocene | North Horn | | 1198 (365) | slts, mdst |
| Cretaceous | | Indianola Group | Sixmile Canyon | *only part of the Indianola Group not observed along transect; equivalent rocks to the east* | |
| Cretaceous | | Indianola Group | Funk Valley | 853 (260) | ss, slts, sh |
| Cretaceous | | Indianola Group | Allen Valley | 820 (250) | slts, sh, ss |
| Cretaceous | | Indianola Group | Sanpete | 886 (270) | ss, slts, cgl |
| Cretaceous | | Indianola Group | San Pitch | 427 (130) | mdst, sh, ss, cgl |
| Cretaceous | | Cedar Mtn | | 427 (130) | cgl, ss, mdst, slts |
| Jurassic | | Twist Gulch | | 2001 (610) | slts, ss, mdst |
| Jurassic | | Arapien | | 5692 (1735) | sh, mdst, slts, ss |

Figure 4. Generalized stratigraphic column for Salina Canyon. Jurassic, Cretaceous, and Paleogene strata are exposed along the transect discussed in this manuscript and outlined in figures 1 and 2. Modified from Lawton and Willis (1987). cgl = conglomerate; ls = limestone; mdst = mudstone; sh = shale; slts = siltstone; ss = sandstone.

was uplifted prior to deposition of the basal beds of the North Horn Formation (Schelling and others, 2007). After SSVA formation and erosion, it was covered by a mile-thick (1.5 km) package of lacustrine, fluvial, and volcanic deposits that created unconformable relationships with the dipping strata of the SSVA (Spieker, 1946, 1949; Gilliland, 1963). In Salina Canyon, these younger Paleogene units include the Flagstaff, Colton, Green River, and Crazy Hollow Formations. Volcaniclastics and volcanic units overlie the Crazy Hollow. Due to the presence of unconformities between dipping SSVA strata and overlying strata in central Utah, researchers hypothesize that SSVA uplift was episodic, with each episode marked by an angular unconformity (Gilliland, 1963).

### Cenozoic Overprinting in Salina

For central Utah, Constenius (1996) proposed that south of 40° N. latitude, extensional tectonics (pre-Basin and Range extension due to the gravitational collapse of the Sevier orogenic belt) began between 40 and 35 Ma. Judge and others (2005) constrained the timing of Sanpete-Sevier extension to 38.0 ± 0.2 Ma from radiometric dates for an ash-flow tuff in the Aurora Formation, which onlaps the Wasatch monocline flexure adjacent to western Salina Canyon. Cline and Bartley (2007) noted evidence for extension in Sevier Valley, south of Salina Canyon. Overall, this extensional regime produced the normal faults that cross-cut the Salina Canyon unconformity, as mapped by Willis (1986).

## RECOGNITION OF THE UNCONFORMITY

Subaerial unconformities, like the one in Salina Canyon, can be recognized in the field by a suite of characteristics: angular discordance, a gap in the fossil record, karst features (in carbonate settings), paleosol formation, and basal conglomerates (Shanmugam, 1988). The Salina Canyon unconformity is an instructive teaching locality because it contains most of these classic features.

### Angular Discordance

The angular unconformity is easily observed at the outcrop. At several localities (especially Stations 2 and 3), the Jurassic Twist Gulch Formation beds are nearly vertical below the unconformity (figures 2C and 2D). At these photogenic stations, the Twist Gulch is a red, gray, tan/white, and sometimes mottled sequence of interbedded sandstones, mudstones, and siltstones. Sandstones vary from fine to coarse grained, subrounded to subangular, and are well sorted. They contain quartz/rose quartz, feldspar, biotite, red jasper, opaque/black lithics, and calcareous cement. The unit contains graded beds and parting lineation. Although determining facing (i.e., younging to the east) is sometimes a challenge for the beginning geology student at Station 2, students recognize the wonderfully preserved ripples, climbing ripples, cross-laminations, and cross-bedding at Station 3.

To the east of Station 3, progressively younger units are exposed below the unconformity, beginning with the Cretaceous Cedar Mountain Formation and ending with the Funk Valley Formation (figures 5A and 5B). There is an obvious change in the bedding dip of these units from west to east as they progressively pass from nearly vertical to subhorizontal, eventually becoming subparallel to those units that overlie the unconformity. The cause of this gradual change in bedding dip is structural. The dipping Jurassic and Cretaceous units below the unconformity form the eastern limb of the SSVA (Gilliland, 1963; Schelling and others, 2007), and this eastern limb gradually is less steep as you transect west to east through Salina Canyon.

Above the unconformity, beds pinch out to the west against the erosional surface, demonstrating onlap. Salina Canyon is an example of a progressive unconformity since overlying strata onlap onto the regional paleotopographic high of the SSVA. These strata have a shallow dip, observed from a distance. We interpret the small ledges of sandstone above the unconformity from Station 1 to Station 3 as Colton Formation beds because of their petrographic similarities to known Colton localities north of Salina (north of Stone Quarry and near Willow Creek). The unconformity exhibits slight relief; therefore, in this interpretation the Flagstaff Formation is missing where beds assigned to the Colton rest directly on the unconformity.

These basal Colton sandstones are gray to tan, but younger Colton strata include interbedded mudstone, shale, and limestone. Sandstones vary from fine to medium grained, subrounded to subangular, and moderately to well sorted. They contain quartz/rose quartz, feldspar (plagioclase and microcline), biotite, muscovite, amphibole, red jasper, malachite, chert, opaque/black lithics (in thin section, igneous, sedimentary, and metamorphic grains), and calcareous cement with minor iron oxides. The unit has planar cross-bedding, various sizes of trough cross-bedding, loading, pinch-and-swell geometries, and lenticular channel scours.

## Age Relationships

The Salina Canyon unconformity does not represent an equal gap in geologic time along its west to east transect. In the west, this gap in geologic time is greater than 107 million years, decreasing toward the east to about 39 million years and finally to less than 17 million years.

The age range for the unconformity can be constrained by using the ages of the units both below and above the surface. Below the unconformity, the Middle Jurassic Arapien Formation is exposed to the west of Station 1 in Salina Canyon, where they have an age range of about 164 to 162 Ma based on regional palynology (Sprinkel and others, 2011). The Arapien shows extreme diapiric deformation (Witkind, 1982, 1983, 1994), thus making for challenging field relationships and interpretations. Beds of the Upper Jurassic Twist Gulch near Station 3 have an age range of 159.5±5.1 Ma (Perkes and Morris, 2011). Above the unconformity near these stations, Colton sandstones are exposed but have not been radiometrically dated. The Colton in Salina Canyon has been assigned a late Paleocene to early Eocene age based on fossil evidence (Fouch and others, 1982; Willis, 1986). Therefore, at Stations 1 and 2, the unconformity spans approximately 107 million years (from ca. 160 to 53 Ma).

To the east in Salina Canyon, the age range for the unconformity is less, because younger Cretaceous units are below the surface. The Cedar Mountain Formation and Indianola Group are exposed to the east of the Twist Gulch Formation (figure 5) and have not been radiometrically dated in Salina Canyon. Their approximate age is based on fossil evidence and relative age relationships. East of Station 3 the Flagstaff Formation rests unconformably on the Sanpete Formation. Here, the unconformity spans about 39 million years (from the Late Cretaceous to the early Eocene, about 92 to 53 Ma). Still farther to the east (beyond the geologic map limit of figure 5) where the angular unconformity becomes a disconformity, beds of the North Horn Formation rest on the Funk Valley Formation. This disconformity spans

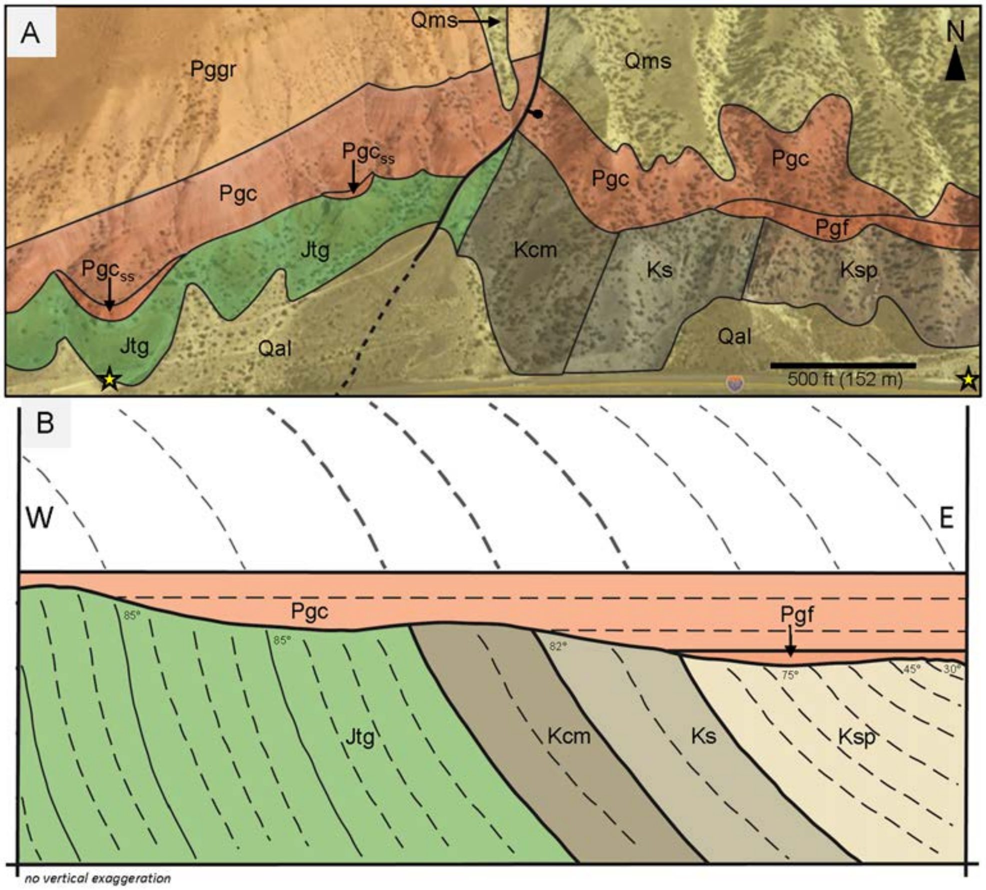


Figure 5. (A) Aerial photograph of Salina Canyon with superimposed geologic units. Modified from Google Earth; Willis (1986). Yellow stars denote the extent of the cross section in figure 5B. (B) Idealized cross section through Salina Canyon depicting the progressive unconformity, onlap of Paleogene strata onto paleotopography, and the folded SSVA. The cross section was constructed for the time of Flagstaff/Colton deposition and prior to deposition of the Green River Formation and subsequent extensional events. Jtg = Twist Gulch Fm; Kcm = Cedar Mountain Fm; Ks = San Pitch Fm; Ksp = Sanpete Fm; Pgf = Flagstaff Fm; Pgc = Colton Fm; Pggr = Green River Fm; Qms = landslide deposits; Qal = alluvial-fan deposits. Pg represepents Paleogene in the symbol Pgf, Pgc, and Pggr.

about 17 million years (within the Late Cretaceous; ca. 87 to about 70 Ma; Schelling and others, 2007).

## Paleosols

Paleosols are ancient soils that leave behind traces of past environments. These deposits can provide information on the climate, depositional environment, and flora/fauna present at the time the soils developed. They are commonly located at unconformities where little information can be inferred about the gap in the rock record (Kraus, 1999). A well-developed paleosol at Station 1 provides an opportunity to better understand the Salina Canyon area during formation of the unconformity.

At Station 1, the strata was divided into five distinct zones based on mottling (after Retallack, 1988), color, texture, burrow abundance, carbonate nodule abundance, and stage of paleosol development (figures 6A and 6B; after Retallack, 1997). Other characteristics, such as the presence or absence of drab-haloed root traces or hematite/goethite (after Kraus and Hasiotis, 2006), were also noted. Table 1 summarizes the characteristics of each zone.

Werthmann (2018) interpreted the paleosol at Salina Canyon to be two stacked paleosols that most closely resemble vertisols (figure 6B). The older Paleosol 1 comprises zones 1 through 3. It contains an abundance of burrows in zones 2 and 3, implying these portions of the soil were near the surface. Prominent mottling, commonly oriented in vertical streaks, is aligned with the bedding in the underlying Twist Gulch Formation and is attributed to organic matter within the vadose zone (Smith and others, 2008). There is gradual boundaries between each zones, suggesting high connectivity and internal deformation (Retallack, 1997). Paleosol 2, the younger paleosol, consists of zones 4 and 5. There are fewer burrows and root traces, as well as a decrease in mottling. There is a clear boundary between zones 3 and 4, which marks a change from red mottling to the bulbous structure characteristic of zone 4. Zone 5 is very weakly developed.

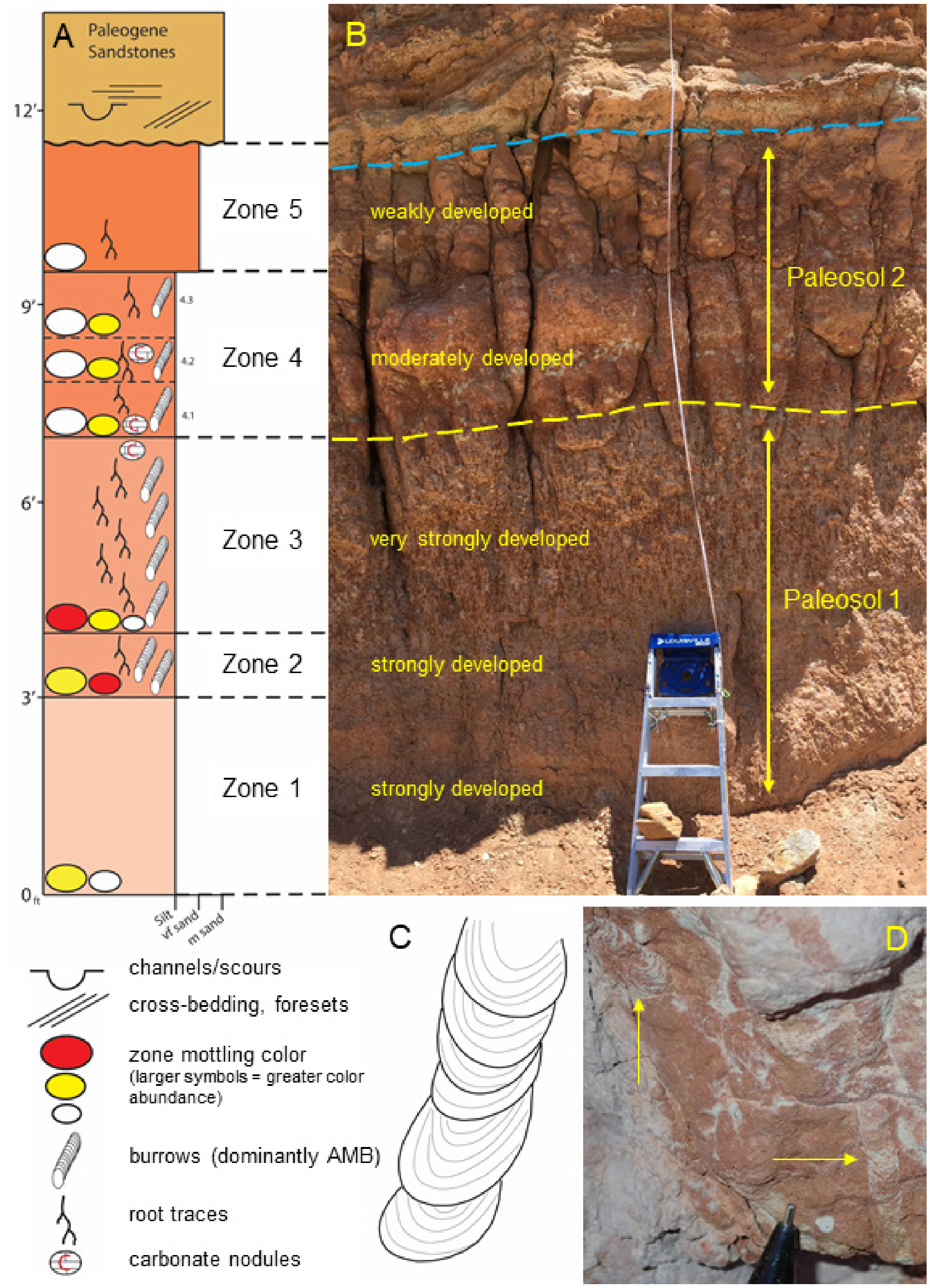


Figure 6. (A) Generalized stratigraphic column of the paleosol at Station 1. The internal features of the strata are depicted in the key: channels/scours, cross-bedding, mottling, burrows, root traces, and carbonate nodules. For mottling, the ellipses within each zone are organized by the abundance of color. The largest ellipse represents the most abundant mottling color, whereas the smallest ellipse represents the least abundant color. (B) Station 1 correlated to the stratigraphic column. Paleosol development for each zone is labeled (i.e., strongly developed, moderately developed, etc.). Two stacked paleosols are shown by respective yellow arrows, separated by the dashed yellow line. The blue dashed line near the top of the photograph marks the Salina Canyon unconformity, above which is subhorizontal Colton strata. View to the east. (C) Line drawing of adhesive meniscate burrow (AMB) showing the morphology of the burrow. Modified after Smith and others (2008). (D) AMB examples from within zone 3 at Station 1. A pencil tip at the bottom of the photograph provides scale. View to the east.

Perhaps the most interesting feature of these paleosols is the presence of *Naktodemasis bowni* (figures 6C and 6D), an adhesive meniscate burrow (AMB) defined as “burrows composed of distinct, ellipsoid packets that contain indistinct, meniscate backfill” (Smith and others, 2008). Defined by Smith and others (2008), *Naktodemasis* has since been noted as a junior synonym of *Taenidium* (Buatois and others, 2017). This is the first report of AMB at Salina Canyon, and these burrows are found without evidence of other organisms in the soil and in the presence of root traces. Smith and others (2008) concluded that AMB were formed by burrower bugs (Hemiptera: Cydnidae) and cicada nymphs (Hemiptera: Cicadae). We conclude that these insects probably produced the burrows in the Station 1 paleosol. Werthmann (2018) further classified these burrow-filled zones as A or upper B soil horizons using estimations of the soil depth where these insects typically live and the moisture content of the soil (Smith and others, 2008).

Table 1. Basic characteristics of each of the paleosol zones at Station 1, following the classification schemes of Retallack (1988, 1997).

| Zone | Level of Development | Burrows | Root Traces | Nodules | Ped Type |
|---|---|---|---|---|---|
| **5** | very weakly | none identified | none identified | absent | none |
| **4** | moderately | present | present | present | blocky |
| **3** | very strongly | present | present | present | granular |
| **2** | strongly | present | present | present | granular |
| **1** | strongly | none identified | none identified | present | granular |

## Basal Conglomerates

On a regional scale, paleotopography on the unconformity has been demonstrated by onlap of strata. At outcrop-scale, the erosional surface at the contact is undulatory. At Station 2, small-scale channels and scours are present along the unconformity (figure 7A) and are infilled with basal conglomerates. This reflects erosion and paleoflow on the boundary surface.

Twist Gulch beds contain small-scale paleoflow indicators (figure 7B), whereas the Colton fluvial sandstones above the unconformity contain large, planar to slightly festoon cross-bedding, as well as small-scale and broad trough cross-bedding (figure 7C). Paleocurrent analysis for the area near Station 2 shows a mean vector of 321° (N. 39° W.), indicating local paleoflow to the northwest along the regional paleoslope (figure 7D). This data agrees with all measured flow directions in the Colton Formation in the Sanpete-Sevier Valley region (Judge and Krissek, 2003; Judge, 2007). For decades, previous workers concluded that the Colton Formation was sourced primarily from the south-southeast as it onlapped onto the paleotopography of the unconformity (e.g., Stanley and Collinson, 1979; Chapman, 1982; Zawiskie and others, 1982; Dickinson and others, 1986; Judge and Krissek, 2003; Judge, 2007). More recent work concentrated on detrital zircons in the Colton Formation of the Uinta Basin and used U-Pb ages to interpret a source area to the south-southwest, suggesting that sediment was transported to central Utah from Arizona and California by a paleodrainage system named the California paleoriver (Davis and others, 2010; Dickinson and others, 2012).

## Additional Features

There are several small mine adits in the area easily viewed along the trace of the unconformity. The geographic area of Stations 1 through 3 is part of the Salina Creek mining district. The Lead Hill Mine is the adit immediately adjacent to Station 2 and was the only productive mine in the area (Perry and McCarthy, 1976). Historically, small amounts of lead ore was produced from 1908-1912 and in 1944. Perry and McCarthy (1976) identified both beds below the unconformity and the channel sandstones above the unconformity as the mining targets. Minerals identified include: galena, cerussite, sphalerite, pyrite, chalcocite, malachite, azurite, and celestite (Perry and McCarthy, 1976; Willis, 1986). Perry and McCarthy (1976) reported that the mineralized zone of the Lead Hill Mine was 0.5 to 6 feet (0.1-1.8 m) thick and was mined for nearly 600 feet (180 m) underground.

# GEOLOGIC UNIQUENESS

If you are driving through Salina, Utah, then the Salina Canyon unconformity is only a brief stop outside of town. It is well worth the visit for professional geoscientists, rockhound enthusiasts, and outdoor naturalists. Below are several reasons why the unconformity is special:

1. Outcrops provide spectacular views of classic features characteristic of unconformities. The outcrops near Stations 1, 2, and 3 are easily accessible and do not require much climbing, so most friends and family members can enjoy them.

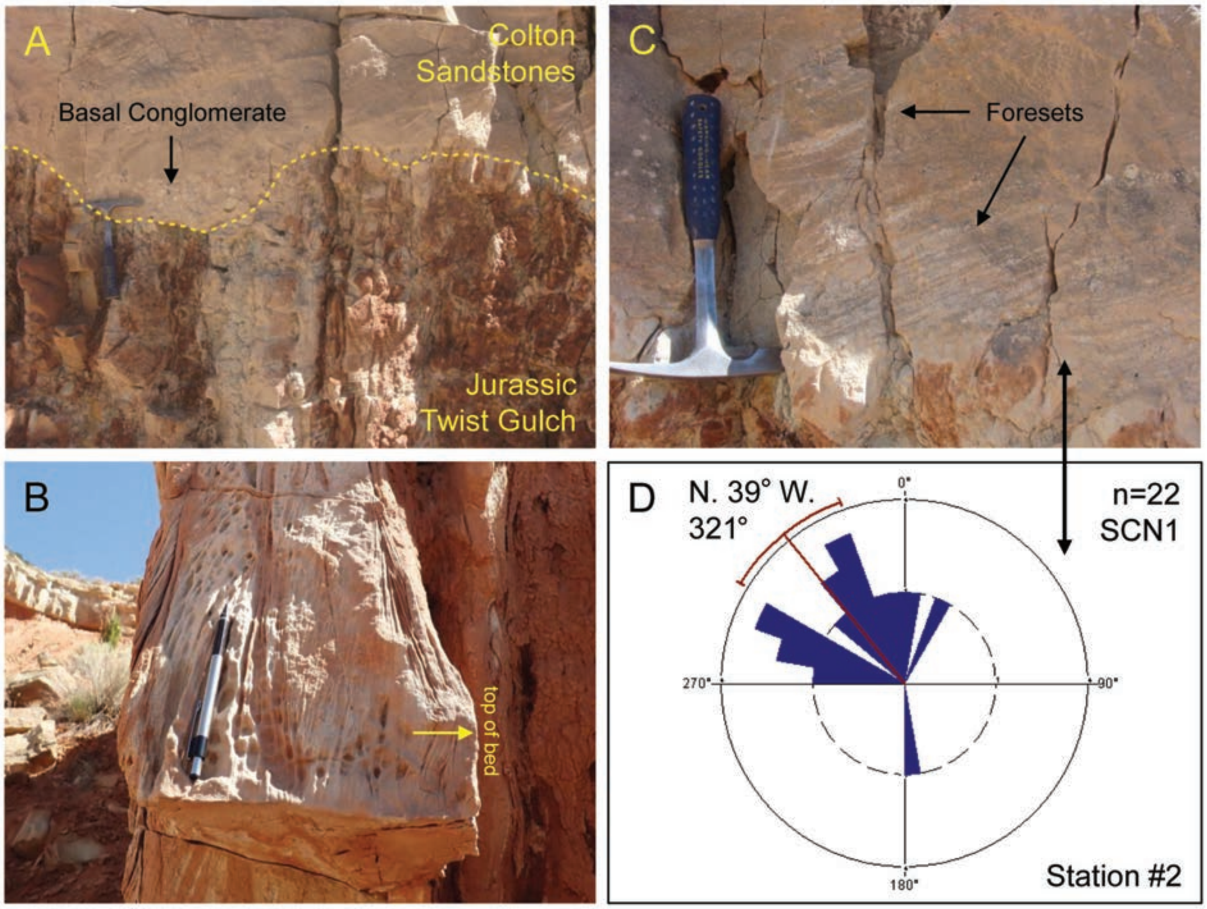


Figure 7. (A) Undulatory erosional surface at Station 2 showing small channel/scour with basal conglomerate. View to the north. (B) Paleoflow and facing indicators in the Twist Gulch Formation are best observed at Station 3. View to the north-northeast. (C) Colton fluvial sandstones above the unconformity at Station 2 show trough cross-bedding. (D) Rose diagram of paleocurrent analysis (mean vector = 321°) of Paleogene fluvial sandstones above the unconformity at Station 2.

2. Salina Canyon is an example of a progressive unconformity. Below the erosional surface, the bedding dips change from vertical in the west to horizontal toward the east. The overlying strata progressively onlap from the east onto the paleohigh of the SSVA. When you are at the outcrop on the north side of I-70, it can be difficult to view the "big picture." However, if you drive south under the I-70 tunnel toward Soldier Canyon and then proceed immediately east on the frontal road, you will have photo opportunities for the entire transect.
3. Salina Canyon geology represents the eastern extent of Sevier orogenesis in the region. Spieker (1949) wrote, "no less than 5,000 and possibly more than 7,000 feet of beds come in and flatten out beneath the unconformity, and the unconformity itself passes eastward into a disconformity that is not easy to discern." Spieker (1949) first noticed this relationship, but since his time, the geosciences have witnessed the advent of plate tectonics and our increased understanding of Sevier mountain-building. Salina Canyon can now be better placed in a comprehensive regional context. In a short transect, visitors can observe the near vertical deformed strata that were folded as part of the SSVA, flattening to the east. These near horizontal strata represent undeformed units not impacted by the lateral compression of Sevier mountain-building, marking the eastern limit of the Sevier orogeny in Utah.

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