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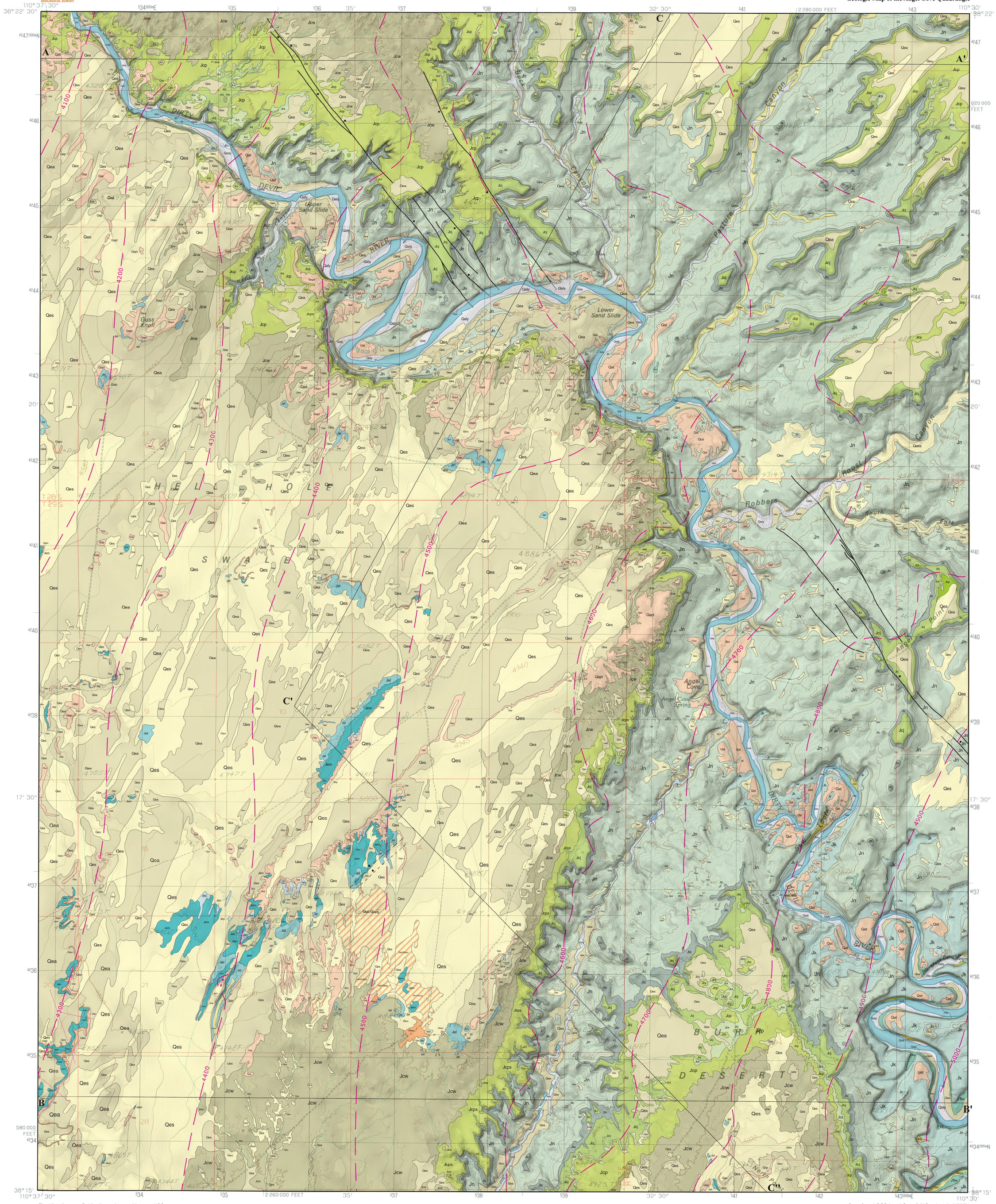
Plate 1
Utah Geological Survey Miscellaneous Publication 172
Geologic Map of the Angel Cove Quadrangle



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SCALE 1:24,000

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

APPROXIMATE MEAN DECLINATION, 2019

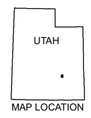
GEOLOGIC MAP OF THE ANGEL COVE QUADRANGLE, WAYNE COUNTY, UTAH

by

Hellmut H. Doelling[1], Paul A. Kuehne[2], and Martin R. Lindgren[3]

2019

[1]Utah Geological Survey, retired
[2]formerly Utah Geological Survey, Salt Lake City, Utah
[3]Salt Lake City, Utah



MAP LOCATION

1	2	3
4	·	5
6	7	8

1. The Notch
2. Point of Rocks West
3. Point of Rocks East
4. Hanksville
5. Angel Point
6. Bull Mountain
7. Baking Skillet Knoll
8. Burr Point

ADJOINING 7.5′ QUADRANGLE NAMES

Base from USGS Angel Cove 7.5′ Quadrangle (1986)
Shaded relief derived from USGS 10-meter NED
Projection: UTM Zone 12
Datum: NAD 1927

Project Manager: Grant C Willis
Cartography: Hellmut H. Doelling and Kent D. Brown

Utah Geological Survey
1594 West North Temple, Suite 3110
Salt Lake City, UT 84116
(801) 537-3300
geology.utah.gov

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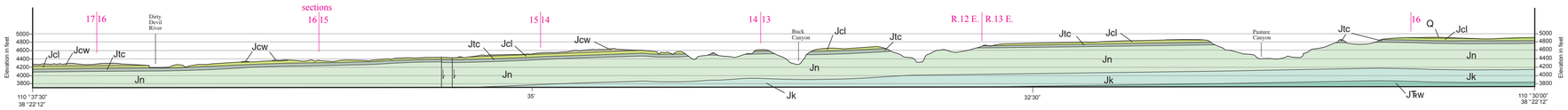
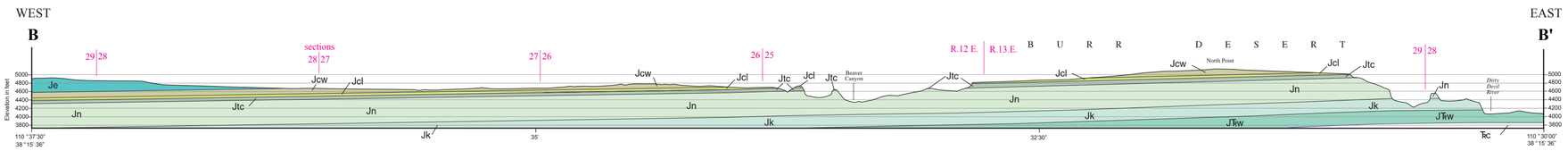
Plate 2
Utah Geological Survey Miscellaneous Publication 172
Geologic Map of the Angel Cove Quadrangle

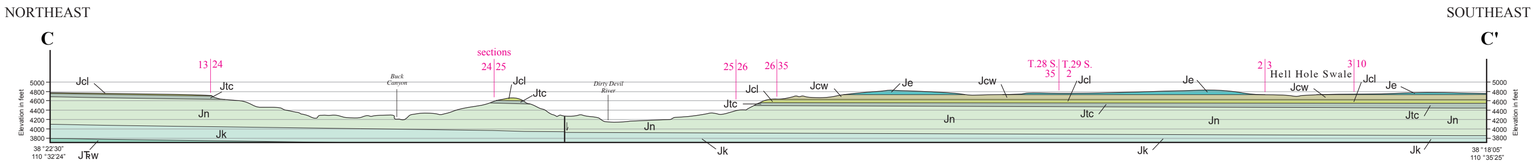
WEST — **A** — EAST **A'**



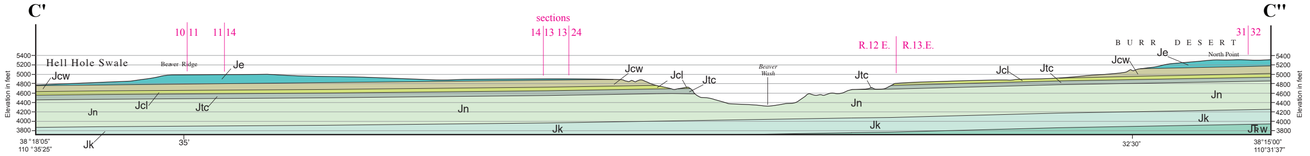
WEST — **B** — EAST **B'**



NORTHEAST — **C** — SOUTHEAST **C'**



NORTHWEST — **C'** — SOUTHEAST **C''**



View east across canyon of Dirty Devil River from the southeastern part of the quadrangle showing Lower Jurassic outcrops of JTrw (Wingate Sandstone), Jk (Kayenta Formation), and Jn (Navajo Sandstone). Capping the Navajo is the (Jtc) Temple Cap Formation, Middle Jurassic in age.

Canyon of Dirty Devil River looking westward. A meander has cut a vertical cliff into the Lower Jurassic Jn (Navajo Sandstone) and Middle Jurassic Jtc (Temple Cap Formation), which is overlain by the Middle Jurassic Jc (Carmel Formation). Pediment and terrace deposits cover the bench.

Tributary canyon of Dirty Devil River looking west. Jn (Navajo Sandstone) is overlain by the Jtc (Temple Cap Formation) with its two members (Jtcs-Sinawava and Jtcw-White Throne). They are followed by the members of the Carmel Formation (Jcj, Jcx, Jcp, and Jcw).

SYSTEM	SERIES	FORMATION - MEMBER		MAP SYMBOL	THICKNESS Feet	LITHOLOGY
QUATERNARY	Holocene / Pleistocene	Surficial deposits		Q	Thicknesses generalized (see unit descriptions)	
TERTIARY	Pliocene					
JURASSIC	Middle	Entrada Sandstone	upper	Jeu	70+	Subtle colored bands of sandstone
			middle	Jem	~160	
			lower	Jel	~180	Slickrim outcrops
		Carmel Formation		Jc	185–237	Bedded gypsum; Red ledge
		Temple Cap Fm.		Jtc	30–100	White Throne and Sinawava Members; unconformity
	Lower	Navajo Sandstone		Jn	550–615	Large-scale, high-angle cross-stratification; Thin limestone ledges; Bare-rock outcrops
		Kayenta Formation		Jk	275–364	Ledge- and bench-former
		Wingate Sandstone		JTrw	280–342	Prominent vertical cliff former; Desert-varnished surfaces
UPPER TRIASSIC		Chinle Formation		Trc	NM	unconformity?

Sketch profile of Carmel and Temple Cap Formations in the Angel Cove quadrangle, Wayne County, Utah.

CORRELATION OF QUATERNARY DEPOSITS IN THE ANGEL COVE QUADRANGLE

HOLOCENE	Qmt	Qaly	Qes	Qapg	Qapc	Qapt	Qat	Qap	Qaes	Qea	
PLEISTOCENE											
PLIOCENE											

MAP SYMBOLS

- Geologic contact
- Normal fault - Bar and ball on down thrown side. Dotted where concealed.
- Anticline - showing trace of axial plane.
- 4500 — Structure contour - drawn on top of Navajo Sandstone: 100-ft contour interval. Strikes and dips were not plotted because of local dominance of contorted strata. Dips rarely exceed 4° and average 2°.
- B——B' Line of cross section.
- Dirt roads or trails - Heavier line denotes better road.

EXPLANATORY INFORMATION ACCOMPANYING THE GEOLOGIC MAP OF ANGEL COVE QUADRANGLE, WAYNE COUNTY, UTAH

by

Hellmut H. Doelling, Paul A. Kuehne, and Martin R. Lindgren

2019

DESCRIPTION OF MAP UNITS

Qaly **Young alluvial channel deposits** – Unconsolidated deposits of poorly to moderately sorted silt, sand, and lenses of gravel in the beds of the Dirty Devil River and its major tributaries; much exotic (derived from outside quadrangle area); locally contains moderate amounts of windblown sand, small alluvial fans, and talus along its flanks; weak soil development in upper parts; Holocene; up to 35 feet thick.

Qaes **Mixed sandy alluvial channel and eolian deposits** – Unconsolidated deposits of moderately sorted silt and sand generally in smaller tributaries of the Dirty Devil River with limited provenance; commonly deposited or reworked by ephemeral streams; includes windblown sand deposits in protected areas; mostly Holocene; up to 25 feet thick.

Qat **Terrace deposits** – Unconsolidated deposits of poorly to moderately sorted silt, sand, and lenses of gravel on the sides of the Dirty Devil River canyon; gravels are commonly coarse, well-rounded quartzite cobbles; higher terraces probably Pleistocene; up to 25 feet thick.

Qap **Alluvial pediment-mantle deposits** – Mostly unconsolidated deposits of poorly sorted silt, sand, grit, and gravel; mostly developed on the Entrada Sandstone and Winsor Member of the Carmel Formation; gravel contains volcanic and intrusive igneous cobbles derived from the high plateaus and Henry Mountains to the west up to about 6 inches in diameter, but averaging 1–3 inches in diameter; agate, jasper, and petrified wood also abundant, probably derived from Upper Jurassic and Lower Cretaceous formations on flanks of Henry Mountains; usually more gravelly in upper 5 feet of deposits; along their flanks erosion has redistributed some of the deposits downslope as lag on older units; mostly Pleistocene; up to 50 feet thick.

Qapt **Mixed alluvial pediment-mantle and terrace deposits** – Terrace and pediment deposits as described above, with components of both; typically the pediment complement is dominant; common on benches high above the level of the river; mostly Pleistocene; up to 50 feet thick.

Qapg **Gypsiferous alluvial pediment-mantle deposits** – As described above but with gypsiferous zone; common on surfaces of Winsor Member of Carmel Formation; mostly Pleistocene; up to 25 feet thick.

Qapc **Alluvial pediment-mantle deposits with calcic soil** (caliche) – As described above but with prominent calcic soil developed mostly in upper 1–4 feet of gravelly part of deposit; frothy calcium carbonate loosely cements gravel making outcrop appear prominent white; some thicker deposits directly on eroded older formations commonly stained red-brown; only more continuous occurrences mapped; mostly Pleistocene.

Qes **Eolian sand deposits** – Sand and silt deposited or reworked by wind; mostly fine-grained but some coarser with minor grit; forms dunes, sheets, and coppice dunes (mounds partially anchored by vegetation); coppice dunes in this area are discontinuous but closely spaced, up to 10 feet high, partially stabilized by several species of shrubs, such as Mormon tea, rabbit brush, or blackbrush, and commonly rest on older pediment-mantle or mixed eolian and alluvial sand deposits; dunes are up to 30 feet high; have strong linear trend of N.65°E., indicating prevalent regional wind direction of the region; most sand derived from Entrada Sandstone, which it covers; overall deposit Holocene to Pleistocene, but much sand reworked and Holocene; up to 30 feet thick.

Qea **Mixed eolian and alluvial sand deposits** – Mostly fine to coarse sand with minor gravel composed of reworked pediment deposits and windblown sand; generally stable and hosts desert shrub population; boundaries with eolian sand deposits generally gradational; mostly poorly stratified but locally well stratified; Late Pleistocene and Holocene; up to 25 feet thick.

Qmt **Talus deposits** – Mostly angular rockfall blocks, boulders, and smaller fragments deposited on slopes below ledges and cliffs; some grade downslope into alluvial fans; only larger deposits mapped; mostly Holocene; variable thickness, mostly less than 10 feet.

unconformity

Je (Jeu, Jem, Jel) **Entrada Sandstone** (Je) – Undivided on cross sections; member usage local.

Upper member (Jeu) – Sandstone interbedded with siltstone, very fine grained, light orange-brown; forms steep earthy slope; exhibits faint color banding through poorly exposed surface; Middle Jurassic (Callovian); upper part eroded from quadrangle—up to 70 feet remain.

Middle member (Jem) – Sandstone, interbedded with minor siltstone; mostly fine grained with about 10% scattered medium grains; contains few very thin partings of purple volcanic ash; alternating laminar bedding and low- and high-angle (eolian) cross-bedding; mostly earthy and slope forming, some knobby and ledgy; uppermost part forms hard bench; Middle Jurassic (Callovian); about 160 feet thick.

Lower member (Jel) – Sandstone, orange-brown; contains few very thin partings of purple volcanic ash; mostly high-angle cross-bedded; bedding commonly contorted; typically massive and forms bare-rock slick-rim outcrop to steep rounded cliff; upper foot commonly bleached white; Middle Jurassic (Callovian); about 180 feet thick.

Carmel Formation (Jc) – See expanded (colored) lithologic column.

Jc (Jcw, Jcl, Jcpx, Jcp, Jcx, Jcj)

Winsor Member (Jcw) – Mostly red-brown, fine-grained sandstone and siltstone. Crudely separable into three parts. Upper beds are commonly contorted and contain local "blobs" (Entrada Sandstone-like bodies) over and under which sandstone and siltstone beds are deposited. Middle part contains impure white gypsum (alabaster) beds, flaky silty or sandy limestone beds, and some flaky weathering, green-gray, rippled shale; gypsum in discontinuous, frothy, ledge-forming beds up to 20 feet thick interbedded with red-brown siltstone and sandstone; some red-brown siltstone beds include thin crisscrossing satin-spar veins; gypsum beds commonly contorted, causing local differences in thickness of member. Lower part consists of red-brown sandstone and siltstone that forms steep slope. Middle Jurassic (upper part probably Callovian, gypsiferous and lower parts Bathonian); 115–185 feet thick.

Lower Member (Jcl) – On cross sections only; combined Paria River, Crystal Creek, and Judd Hollow Members of Carmel Formation.

Paria River Member (Jcp) – Limestone, pink-red-gray to white; generally in two ledges; platy weathering capped by a white frothy marl; locally contains poorly preserved fossils; Middle Jurassic (Bathonian); 16–36 feet thick.

Crystal Creek Member (Jcx) – Siltstone and very fine grained red-brown sandstone that form slope; green-gray siltstone a few feet thick generally found at base; Middle Jurassic (Bathonian); 2–20 feet thick.

Combined Paria River and Crystal Creek Members (Jcpx) – Combined where Crystal Creek outcrop width too narrow to map.

Judd Hollow Member (Jcj) – Sandstone, siltstone, calcarenite, and limestone beds that form mostly dark red-brown cliff capped by bench-forming limestone; upper bed is gray-brown, hackly weathering, hard, finely crystalline limestone with rare, poorly preserved brachiopod remains; main body of cliff consists of very thick, irregular beds of sandstone and calcarenite divided by deep red-brown recessed siltstone partings; base is 1-2-foot thick flat bed of reworked Temple Cap Formation; Middle Jurassic (Bajocian); 27–46 feet thick.

unconformity

Jtc **Temple Cap Formation** – Sandstone, fine to medium grained, well sorted; calcium carbonate or siliceous cement; tan to buff; local fluid-migration pipes; mostly high-angle cross-bedded—cross-beds generally steeper angled than those in the Navajo below; forms steep concave slope; commonly has two members (visible but not mapped separately here)—lower Sinawava and upper White Throne Members; Sinawava is generally darker hued than White Throne, contains some coarse grains throughout, and has some angular, white chert fragments (most less than 0.5 inches in average diameter) in lower foot; Middle Jurassic (Bajocian); 30–100 feet thick.

unconformity

Jn (Jnl) **Navajo Sandstone** – Tan to buff, eolian sandstone, mostly fine grained; calcium carbonate or siliceous cement; forms vertical cliffs in deep canyons and domes and rounded bare-rock knolls elsewhere; well displayed, high-angle cross-beds; contains local thin, resistant, gray to brown carbonate beds (Jnl); Lower Jurassic; 550–620 feet thick.

Jk **Kayenta Formation** – Sandstone, thin to very thick bedded (up to 25-foot-thick beds), orange-pink, red-brown, and lavender; commonly poorly sorted with subangular and angular grains; forms steep cliffs commonly stained with dark brown-black desert varnish; many sandstone beds contain 1 to 2-foot-thick partings of dark red-brown siltstone in beds that form recesses in the cliff; upper third has higher percentage of siltstone in thicker beds that erode back on top of better-cemented thick sandstone beds, forming series of steps and benches; Lower Jurassic; 275–364 feet thick.

JTrw **Wingate Sandstone** – Mostly orange-brown or red-orange eolian sandstone, well sorted, fine grained, medium to coarse grains common along some high-angle cross-bed laminae; forms massive smooth vertical cliff; Lower Jurassic–Upper Triassic; about 250 feet of upper Wingate exposed in quadrangle; 280–342 feet thick in completely exposed outcrops to south.

unconformity

Trc **Chinle Formation** – Subsurface; shown on cross section B-B' only; Upper Triassic.

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2019

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by Hellmut H. Doelling[1], Paul A. Kuehne[2], and Martin R. Lindgren[3]

[1]Utah Geological Survey, retired
[2]formerly Utah Geological Survey
[3]Salt Lake City, Utah

Cover photo: *Canyon of Dirty Devil River looking westward. A meander has cut a vertical cliff into the Lower Jurassic Navajo Sandstone and Middle Jurassic Temple Cap Formation, which is overlain by the Middle Jurassic Carmel Formation. Pediment and terrace deposits cover the bench.*

Suggested citation:

Doelling, H.H., Kuehne, P.A., and Lindgren, M.R., 2019, Geologic map of the Angel Cove quadrangle, Wayne County, Utah: Utah Geological Survey Miscellaneous Publication 172, 13 p., 2 plates, scale1:24,000, https://doi.org/10.34191/MP-172.

MISCELLANEOUS PUBLICATION 172
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2019

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contact
Natural Resources Map & Bookstore
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UTAH GEOLOGICAL SURVEY
contact
1594 W. North Temple, Suite 3110
Salt Lake City, UT 84116
telephone: 801-537-3300
website: geology.utah.gov

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by Hellmut H. Doelling, Paul A. Kuehne, and Martin R. Lindgren

INTRODUCTION

The 1:24,000-scale Angel Cove 7.5′ quadrangle lies in east-central Wayne County, its northwest corner less than 5 miles east of the junction of State Roads 24 and 95 at the east end of the town of Hanksville, Wayne County, Utah. The Dirty Devil River, formed from the union of the Fremont River and Muddy Creek, flows south-southeast through the quadrangle in route to the Colorado River. The river carves an entrenched meandering canyon, cutting ever deeper into the strata and crudely following a shallow syncline in the warped table land. It drops approximately 200 feet in its traverse across the quadrangle, but the table land increases in elevation toward the southeast such that the highest point is North Point at 5341 feet above sea level near the southeast quadrangle corner, whereas the lowest point is only about a mile east along the river at approximately 4080 feet. There, the canyon is about 1200 feet deep, approximately the thickness of all exposed strata. The deeply entrenched canyon of the Dirty Devil River, along with several of its tributaries, forms the basis of the Dirty Devil Wilderness Study Area, which includes most of the east half of this quadrangle and parts of neighboring quadrangles to the east and south. The Glen Canyon Group of sandstones (Wingate, Kayenta, and Navajo Formations) form majestic bare-rock outcrops in the deeper canyons. The Middle Jurassic Entrada Sandstone weathers to produce much of the eolian sand that blankets large benches and accumulates in the canyons. Broad pediment and terrace gravel benches containing pebbles and cobbles from the nearby Henry Mountains are partially buried by the sand veneer.

PREVIOUS WORK

The area is included on the Salina 1° x 2° quadrangle geologic map (Williams and Hackman, 1971) at 1:250,000 scale and the Dirty Devil Wilderness Study Area geologic map (Dubiel and others, 1985; 2019) at 1:50,000 scale. Small-scale maps of the area accompanied earlier workers' reports. Especially noteworthy are Gilbert (1877), Baker (1946), Hunt and others (1954), and Hintze and Stokes (1964). Other works of use to this mapping included Rich (1935), Graf (1980), Hintze and Kowallis (2009), Sprinkel and others (2011), Doelling and others (2013), and Sprinkel and others (in preparation).

SURFICIAL DEPOSITS

QUATERNARY

Much of the quadrangle consists of high broad mesas, benches, and plateaus between incised washes and canyons. Erosion rates are slower on these surfaces due to minimal desert precipitation, sparse but important vegetation, and because most precipitation quickly evaporates or soaks into the porous sand rather than flowing across the surfaces. As a result, many of these surfaces have accumulated extensive cover with common thick calcic soils that indicate relatively long periods of stability and soil accumulation. Pediment and terrace pebble to cobble gravel, much derived from igneous and Morrison Formation outcrops in and near the Henry Mountains, is locally abundant. Deep side canyons contain windblown sand (commonly redistributed by ephemeral or perennial streamflow), transported (commonly reworked) alluvial gravel, and talus, most derived from the adjacent benches. The Dirty Devil River canyon contains the above materials, plus significant materials transported downstream from its upper basins. Terrace deposits of quartzitic cobbles and silicified limestone parallel the river. Most surficial deposits in the quadrangle are gradational.

Young alluvial channel deposits (Qaly)

The water of the Dirty Devil River runs in anastomosing or braided channels along the entire length of the river in the quadrangle. Channel configurations change with the amount of water. Generally, the most water arrives with the spring runoff and then recedes throughout the remainder of the year. Occasional heavy rain produces flash floods. Channels shift, change shape, and new channels are scoured. Channels have two parts: (1) The active channel meanders in the canyon and locally touches canyon walls; channel paths frequently shift as the flow wanders from canyon wall to canyon wall; deposits are saturated with water but the river itself anastomoses across the active channel area. The width of the active channel locally reaches 400 feet. (2) A bench or series of benches 5 to 20 feet above the main channel are preserved in many areas; these are flooded during unusually high flood events that occur every few years to few decades for the largest events. Both levels are lumped together in map unit Qaly. Such channel deposits continue up large tributary canyons, which occasionally carry flash floods. The alluvium that makes up the channel consists of silt to boulder clasts, though silt and sand are primarily exposed at the surface. Underly-

ing layers of coarse gravel were apparently deposited during periods of very high energy stream flow, such as during flash floods. This gravel is similar to that described for the terrace deposits. Qaly channel deposits are Holocene in age. Graf (1980) discussed the fluvial processes in the Fremont River just above the confluence with Muddy Creek, which joined the Fremont to form the Dirty Devil River.

Alluvial terrace deposits (Qat)

Above the current river level are several levels of gravel terrace deposits. Clasts are angular to well rounded, and up to 1 foot in diameter, but mostly in the 1- to 4-inch range. The clasts are mostly Henry Mountains debris (fine-grained diorite, diorite with large hornblende crystals, jasper, agate, and brown petrified wood). About 15% to 20% are tan and purple quartzite, hard sandstone, hematitic sandstone, siltstone, and minor colorful metaconglomerate probably reworked from the high plateaus farther to the west. The matrix consists of red-brown to tan sand and silt, grit, and small pebbles. The ratio of clasts to matrix is about 60:40. Terraces cover bedrock benches and range in thickness from about 15 to 60 feet. The terraces are present at many different levels; their abundance appears to be influenced by the presence of protective bedrock benches. Terrace gravels are common to the top of the river canyon where they mix with the pediment deposits over 800 feet above the current river bed. In the mixed deposits, well-rounded spherical and disc-shaped quartzite river cobbles diminish in quantity and then disappear a short distance from the canyon edge. The terrace deposits are Pleistocene to Holocene in age.

Alluvial pediment-mantle deposits (Qap, Qapt, Qapg, Qapc)

A pediment is a broad, gently sloping, bedrock surface with low relief at the base of a steeper slope, such as a mountain range (here the Henry Mountains) that is generally covered with alluvial gravel and sand. The pediments that surround the Henry Mountains were first described by Gilbert (1877, p. 126–133), followed by Rich, (1935, p. 999–1024), Baker (1946, p. 92–94), and Hunt and others (1954, p. 189–191). Pediment deposits or fanglomerates are generally not related to a particular stream, but were laid down as extensive sheets that thin away from the mountains. Deposits in the quadrangle are now deeply dissected by incised stream channels. The present-day Dirty Devil River canyon begins approximately at the northwest corner of the quadrangle and increases in depth southeastward. Remnant pediment deposits east of the canyon indicate that pediments probably once extended across the position of the present canyon to near the east edge of the quadrangle, suggesting that the current position of the river and cutting of its canyon are relatively young. The deposits thin and clast size generally decreases eastward. The oldest pediment deposits in the quadrangle are being eroded and are limited today. Most remaining pediment deposits are covered by younger eolian or alluvial surficial deposits.

Most deposits have been eroded around their flanks and clasts are commonly reworked into younger deposits. A thick caliche (pedogenic soil) of white calcium carbonate that cements the upper 1 to 5 feet of gravel clasts is locally present at the top of some pediment mantle deposits (mapped as Qapc where more continuous). Most pediment mantles were originally deposited on the Entrada Sandstone and are sandy (Qap). Where deposited on the gypsiferous Winsor Member of the Carmel Formation, the deposits are gypsum rich, either by original mixing of weathered gypsum or later reworking of the gypsum into the gravel (locally mapped as Qapg). In the north half of the quadrangle and at the top of the Dirty Devil River canyon, some pediment gravels also contain rounded quartzite river terrace gravels. We labelled the largest of these mixed deposits Qapt. They are present at many levels between the top of the canyon and the river, but most have been reworked and lower deposits generally have more terrace gravel. They are Pleistocene and Holocene in age.

We measured less-disturbed pediment deposits in various parts of the quadrangle. The total thickness ranged from 40 to 65 feet. Following is one example:

3. Top of pediment: 50% gravel and 50% sand (appears that some sand has been eroded from the top of the unit). [5 feet]
2. Gravel in red-gray sand: cobble or lesser sized, poorly sorted; gravel contains weathered Henry Mountains diorite, black silicified limestone, quartzite, dark volcanic boulders (probably derived from the high plateaus to the west), dense sandstone and siltstone (a few clasts contain Cretaceous fossils), petrified wood, agate, and jasper (all derived from rocks that are younger [higher in the section] than those now exposed in the quadrangle). [43 feet]
1. Reworked sandstone: yellow-gray interbedded with red-pink sand, poorly sorted, cemented with calcium carbonate (caliche) indicating surface is very old. [0–3 feet] Total 51 feet

Mixed sandy alluvial channel and eolian deposits (Qaes)

Larger ephemeral tributaries of the Dirty Devil River commonly have flat-bottomed stream channels dominated by sand and silt blown into the canyons by winds and carried in from adjacent benches by occasional heavy rains. Most of the tributaries are dry most of the time, but some have small springs and seeps important to wildlife. The sand and silt are redistributed by occasional stream flow, mostly during spring melts and summer monsoonal rains.

Mixed eolian and alluvial deposits (Qea)

Sand sheet deposits containing small angular pebbles, probably derived from pediment deposits and eroding Entrada Sandstone, cover much of the upper surfaces of the plateau. The de-

posits contain silt, poorly sorted sand, and grit, most distributed to shallow areas on the plateau during flash floods. Between flash floods the wind redistributes much sand. At present this sand is more stable and compacted than Qes deposits, and partially anchored by calcic soil (caliche) and sparse vegetation, and forms the covering for much of the plateau area. The deposits range up to 40 or 50 feet thick. The thick calcic soils indicate a relatively old Pleistocene to Holocene age.

Eolian sand deposits (Qes)

Loose windblown (eolian) sand is present across the top of the older Qea and Qap deposits and bedrock surface of the plateau as long streaks that are aligned with the direction of the prevailing wind, about N. 30° E. The sand is present as dunes, coppice dunes (mounds or small hills partly stabilized by vegetation), sheets, and small discontinuous hummocks. Very thick accumulations of windblown sand are common on the lee sides of buried pediment benches. The sand is mostly fine grained, but some coarse grains are present. The area between coppice dunes is sometimes blown clear of sand, exposing the underlying Qea or bedrock surface. The small discontinuous hummocks are like miniature coppice dunes, but only rise to about 3 feet above the surface, and the intervening space is much less. The wind blows much in this area and dunes commonly migrate across roads and trails. If not maintained, in a few years trails almost disappear. Thicknesses range to 40 feet, but most deposits are less than 20 feet thick. Overall, the sand deposits are probably late Pleistocene to Holocene in age, but much sand is frequently reworked and thus many deposits are late Holocene in age.

Talus deposits (Qmt)

Talus, piles of broken bedrock (rockfall deposits), collect beneath cliffs where they form steep fans that commonly grade into alluvial fans. Talus is present below most cliffs but only larger deposits were mapped. Most deposits are probably Holocene in age.

BEDROCK STRATIGRAPHY

Rocks above the Glen Canyon Group form a warped plateau top that is mostly covered with eolian sand reworked from the uppermost stratigraphic unit exposed in the quadrangle, the Entrada Sandstone. Exposed strata include (descending) the lower 200 to 300 feet of the Entrada Sandstone; the Carmel Formation, about 240 feet thick; the Temple Cap Formation (here mostly sandstone), 60 to 90 feet thick; the Navajo Sandstone, 500 to 600 feet thick; the Kayenta Formation, 300 feet thick; and the Wingate Sandstone, about 300 feet thick.

Entrada Sandstone (Je)

The Entrada Sandstone overlies the Carmel Formation in the Angel Cove quadrangle. It is dominantly orange-brown to red-brown eolian sandstone. It is incompletely preserved in the quadrangle as an unknown amount has been removed by erosion. The Entrada is mostly poorly cemented, friable at exposures, and prone to quickly disintegrate. In most of the western part of the quadrangle, the Entrada Sandstone is buried under its own debris. The maximum preserved thickness is about 410 feet based on measurements of poorly exposed outcrops. The Entrada Sandstone is Callovian in age.

We have divided the formation into three informal members in our mapping—lower, middle, and upper—that are probably not correlative with divisions made by other investigators in other areas.

Upper member (Jeu)

We only identified our upper member in the Beaver Ridge area. The upper member may also be present along the western edge of the quadrangle, but we could not differentiate it from the middle member where present in small outcrops (we labelled all such outcrops as middle member). In the Beaver Ridge area it overlies the middle member as a single steep earthy slope. There it is largely siltstone interbedded with subordinate very fine grained sandstone and is very poorly exposed. It is mostly light orange brown and exhibits faint color banding. The maximum exposed thickness is about 70 feet.

Middle member (Jem)

The middle member is also mostly fine grained sandstone, but does not form slickrim surfaces. It contains thicker subordinate siltstone beds, and overall, the color is more variable. Sandstone beds have lighter hues, mostly tan and light brown, but locally white or light gray, and the siltstone beds are medium to dark brown, or maroon, red, and purple. The sandstones are commonly low-angle cross-bedded, but structureless beds are also present. They are generally more resistant than the siltstones, forming moderate slopes to medium cliffs, but less resistant than the slickrim below. The siltstones weather soft and flaky, whereas the entire unit forms earthy slopes to medium cliffs. The middle member is best exposed in and around Beaver Ridge, but underlies pediment gravels at many western locations. It is about 160 feet thick in the Beaver Ridge area.

Lower member (Jel)

The lower member is the most resistant and best exposed in scattered outcrops around Beaver Ridge where it forms mostly orange-brown sandstone "slickrim" outcrops. It is mostly fine grained, though beds commonly contain scattered medium and coarse grains and medium- and coarse-grained beds are locally present. Most of the grains are frosted and

a few dark minerals are present. It forms massive-appearing, bare-rock outcrops with eolian cross-beds in 20- to 25-foot sets. Partings of dark purple-brown to maroon, recess-forming siltstone, some probably containing volcanic ash, are common at cross-bed set boundaries. A few 1- to 2-foot-thick horizontal layers are locally present. The unit mostly forms smooth steep slopes and rounded cliffs. The rock is weakly cemented with calcareous or siliceous cement and is friable. About 1 to 2 feet of rock at the top of the unit is bleached. It is about 180 feet thick.

MIDDLE JURASSIC

Carmel Formation (Jc)

The Carmel Formation is represented by four members in the Angel Cove quadrangle, from older to younger, Judd Hollow (Jcj), Crystal Creek (Jcx), Paria River (Jcp), and Winsor Members (Jcw). The contacts are reasonably sharp and easily identifiable. On some parts of the map outcrops of the Crystal Creek Member are too thin to map separately and are combined with the Paria River Member (Jcpx).

Winsor Member (Jcw)

Whereas the lower three members are relatively thin, the Winsor is thick and represents about two-thirds of the total Carmel Formation in the quadrangle. Lithologically it is roughly divisible into three subunits. The lowermost subunit consists of 10 to 20 feet of red-brown siltstone and very fine grained sandstone that normally forms a steep slope. This subunit is overlain by a discontinuous gypsiferous subunit as much as 100 feet thick. Impure gypsum beds up to 20 feet thick, thickest near the bottom and thinning toward the top, are interbedded with red-brown siltstone and very fine grained sandstone, and commonly criss-crossed with satin-spar gypsum veinlets. Locally, these gypsum beds are contorted, and the total thickness of the member is correspondingly variable. In some places gypsum beds are missing, presumably replaced by thin beds of white or light-gray calcarenite. The upper Winsor subunit is dominated by redbrown, fine-grained sandstone and dark red-brown siltstone. It locally contains large, bulbous, orange-brown, fine-grained sandstone bodies (blobs) similar to the overlying lower part of the Entrada Sandstone. We include them in the Winsor because the sandstone and siltstone beds underlie and overlie the blobs. The total Winsor Member, where measured in the quadrangle, varies from 115 to 185 feet thick. The lower two subunits of the member are probably Bathonian in age; the upper is probably Callovian. The entire member forms steep to moderate slopes along the west side of the Dirty Devil River canyon, but form rolling hills to the south on the west side of Beaver Canyon and in the graben to the far north and around North Point.

Paria River Member (Jcp)

The Paria River Member consists of one or two ledges of light-brown, pink, light-gray, or near-white, thin- to medium-bedded limestone (calcarenite or calcisiltite). The limestone weathers flaky or platy. Interference and directional ripple marks commonly adorn the platy surfaces. It also commonly contains some interbedded red-brown siltstone or very fine grained sandstone. At the top is a white or light lavender, argillaceous or calcareous marl that forms a shallow slope. A poorly preserved brachiopod fauna is locally identifiable on the upper ledge of the Paria River Member (*Camptonectes*). The upper contact is placed at the top of this white marl, above which is the steep, redbrown siltstone and fine-grained sandstone slope of the first unit of the Winsor Member. The Paria River Member varies from 16 to 36 feet thick in the quadrangle and is Bathonian in age.

Crystal Creek Member (Jcx)

The Crystal Creek Member forms a prominent, relatively thin, red-brown, earthy slope between the limestones of the upper ledge of the Judd Hollow Member and the chippy weathering limestone of the Paria River Member. It is generally in two parts. The lower part is very light gray to light-pink, generally very calcareous siltstone that breaks up into small chips. The upper part is interbedded, very fine grained, red-brown, calcareous sandstone and siltstone. The Crystal Creek varies from 2 to 20 feet thick in the quadrangle and is considered lowermost Bathonian in age.

Judd Hollow Member (Jcj)

The Judd Hollow Member is thin- to thick-bedded sandstone, calcarenite, limestone, and siltstone that forms a nearly vertical cliff that is the rimrock of Dirty Devil River canyon and its tributaries. This cliff is stained medium to dark red brown and contrasts sharply with the Temple Cap Formation below. Rock varieties are well indurated, well cemented (calcareous), and medium to thick bedded, except dark red-brown siltstones that are thin bedded and form partings between the other rock types. The base is generally a 1- to 2-foot-thick layer of reworked Temple Cap Sandstone. The upper bed is mostly bench-forming, medium-brown-gray limestone. Locally this upper ledge is replaced by calcareous sandstone. Rare, poorly preserved brachiopods are locally present in the limestone. The interior medium to thick beds vary slightly in thickness and are

undulating, appearing like low-amplitude waves. The Judd Hollow varies from 27 to 46 feet thick in the quadrangle and is entirely Bajocian in age.

Temple Cap Formation (Jtc)

Earlier investigators did not recognize the Temple Cap Sandstone in the area as it is similar to, and though separated by an unconformity, appears continuous with the Navajo Sandstone. In a regional study, Sprinkel and others (2011; in preparation) revised stratigraphic names and correlations of rocks above the Navajo Sandstone. They recognized two members of the Temple Cap Formation in the Angel Cove quadrangle, an upper White Throne Member and a lower Sinawava Member. Near Zion National Park in southwestern Utah, a third member, the Esplin Point Member, overlies the White Throne Member, but it is not present in the Angel Cove area. The two members were not mapped separately in the quadrangle. The Temple Cap Formation overlies the Navajo Sandstone above the J-1 unconformity and is conformable with the overlying Judd Hollow Member of the Carmel Formation, and has been dated as Bajocian in age (Sprinkel and others, 2011; Doelling and others, 2013). Together with the upper Navajo Sandstone, the Temple Cap forms a steep concave slope. The two members combined are 30 to 100 feet thick.

The basal Sinawava Member is represented by a yellow-brown to red-brown, fine- to coarse-grained, moderately sorted sandstone that forms smooth, bare-rock outcrops or a noticeable recess. It serves as a continuous marker at the base of the Temple Cap Formation. Cementation is calcareous or siliceous. Cross-bedding is not as prominent as in the Navajo below or White Throne Member above. Locally, angular bits of white chert are scattered through the basal foot of the member. The lower contact is probably an unconformity, but angular discordance is not noticeable. The thickness of the Sinawava Member in the quadrangle ranges from 1.5 to 30 feet.

The White Throne Member is much like the Navajo Sandstone with sweeping high-angle cross-bedding composed of several thick sets. Locally the cross-beds are contorted, and pipes and other soft-sediment features are present. The unit appears massive and commonly forms a steep cliff. The color is much like the Navajo—light gray, yellow gray, or pink gray—but when compared to the Navajo from a distance the White Throne looks slightly darker. The sandstone is fine to medium grained and well sorted, with a few coarse grains in many cross-bed laminae. Cement is siliceous and calcareous. The member is 30 to 70 feet thick in the quadrangle, but mostly 40 to 65 feet.

LOWER JURASSIC

Navajo Sandstone (Jn, Jnl)

The Navajo Sandstone tends to form steep rounded slopes. In the Dirty Devil River canyon it has a nearly vertical lower part up to 100 feet thick that is surmounted by rounded domes. The uppermost part forms a steep concave slope matched to the overlying Temple Cap Formation. The Navajo is homogeneous, gray to tan, fine- to medium-grained sandstone consisting of subangular to rounded grains of quartz with a few grains of feldspar and ferromagnesian minerals poorly cemented by lime and silica. The sand grains range in size from about 0.02 to 0.5 mm with an average diameter of about 0.15 mm. The sandstone is largely eolian and consists mostly of high-angle cross-beds. Lenses of light-brown, unfossiliferous limestone as much as 6 feet thick are more resistant than the sandstone and form protective caps on a few small flat-topped mesas or buttes (Jnl). Lenses are common but only a few larger ones in the southern part of the quadrangle were mapped. They probably represent interdunal lakes and playas ("paleo-oases"). The Navajo thickens east to west and ranges from 550 to 615 feet thick in the area. Thicknesses reported in older publications generally include the Temple Cap Formation.

Kayenta Formation (Jk)

The Kayenta Formation consists principally of irregularly bedded sandstone with some interbedded mudstone and conglomerate. Some of the sandstone beds contain grit and clay pellets. Local beds of intraformational conglomerate containing angular fragments, 2 inches or more in diameter, of sandstone, mudstone, limestone, and thin lenses of red- to green-gray shale are interbedded with the sandstone. The lower part forms irregular ledges or ledgy cliffs above the massive Wingate cliff. The upper part is less resistant to erosion and commonly forms several low benches. The sandstone is fine to coarse grained, red brown, lavender, buff, and gray, and forms beds from a fraction of an inch to tens of feet thick. Individual beds are lenticular and are commonly cross-bedded. The lower cliff-forming part is commonly coated with blue-black desert varnish while fresh surfaces are red brown. The sandstone changes upward through lavender to gray to buff near the top. The formation is just under 300 feet thick where measured, but regional measurements range from 265 to 364 feet. The lower contact may be unconformable as suggested by bleaching on top of the Wingate.

LOWER JURASSIC—UPPER TRIASSIC

Wingate Sandstone (JTrw)

The Wingate Sandstone is exposed in the southeast corner of the quadrangle at the bottom of the Dirty Devil River canyon where outcrops form a near-vertical wall about 300 feet high. Only the upper part is exposed; its thickness is based on complete exposures south of the quadrangle. The unit is nearly homogeneous, fine- to medium-grained quartz sandstone poorly cemented with calcite and quartz. The grains are subangular to rounded and are coated with iron oxide that imparts its color. Angular pebbles of shale and sandstone and

discontinuous stringers of grit are locally present at the base. It is pale red tan to light orange brown, but weathers to brown red and is commonly coated with blue-black desert varnish. The Wingate appears to be a single massive bed, but where weathered it shows numerous bedding planes and large-scale cross-bedding. The thickness, as measured and estimated by earlier investigators, ranges from 280 to 342 feet in the area to the south (Baker, 1946; Hunt and others, 1954). The upper contact is sharp at some localities and marked by a thin bleached zone and a slightly irregular surface that may represent an unconformity. The lower contact is not exposed in the quadrangle.

STRUCTURE

Geologic structure in the quadrangle consists of warped bedrock surfaces that overall dip gently westward from the Monument uplift to the east into the Henry Mountains syncline to the west. Unit thicknesses vary across the quadrangle. The upper Carmel Formation and lower Entrada Sandstone are variably contorted and deformed, probably due to soft-sediment deformation shortly after deposition. Regionally the Navajo and younger units generally thicken westward, though these subtle changes are not apparent in the quadrangle. Dips up to 15° have been measured on local contorted outcrops; however, average dip across the quadrangle ranges from less than a degree to just over 2 degrees, roughly to the west. The 2° dips are more prevalent in the southeast part of the quadrangle. Strikes range from about 355° to 020°, with an average of about 012°. A few small-displacement (less than 20 feet), northwest-striking (320°–330°) faults are probably shallow. Two groups of faults are in the east-central and north-central parts of the quadrangle, and roughly align. The north-central group form a graben.

RESOURCES

No mines or prospects are known in the quadrangle. Small borrow pits have been dug to construct roads. Local petroleum drill holes were classified as dry. A few water wells have been drilled in the quadrangle to water grazing livestock and wildlife. Small springs issue from several sandstone formations in the Dirty Devil River canyon, which are regarded as good aquifers. Gypsum from the Winsor Member of the Carmel Formation is present but has not been exploited, probably because of its distance to market and because much of it is impure. The area is a scenic resource and a few tourists traverse it each year. Deep, narrow tributary canyons of the Dirty Devil River are popular slot canyons for adventurers. The quadrangle contains much of the Dirty Devil Wilderness Study Area. Views from the edges of the Dirty Devil River canyon are spectacular and a few hiking trails cross the canyon.

HAZARDS

Hikers and adventurers in the Dirty Devil River canyon and its tributaries should carry plenty of water, especially since temperatures are commonly significantly higher than on the plateau tops. In contrast, narrow slot canyons may never see sunlight and air and water temperatures may be cold, even on hot days. Dangerous flash floods are common in the river and tributary canyons, and many canyons do not have places where someone can climb to safety for long distances. Even small rainfalls can create dangerous flash floods in the very narrow (commonly shoulder-width) slot canyons. The sloping bare rock surfaces of the sandstones can be slick and dangerous without proper equipment. Rockfalls are common in the canyons. Road conditions on the plateau top vary. Loose, windblown sand is common. Fourwheel-drive vehicles are necessary on many roads, especially in loose dry sand, which is most common in summer.

ACKNOWLEDGMENTS

I (lead author) appreciate the reviews of Grant Willis, Stephanie Carney, and Mike Hylland of the Utah Geological Survey. The Utah Geological Survey appreciates the volunteered time, effort, and resources of Doelling and Lindgren, who offered to do this project through their love of Utah's geology and great outdoors, and of Kuehne, who was a temporary employee of the UGS.

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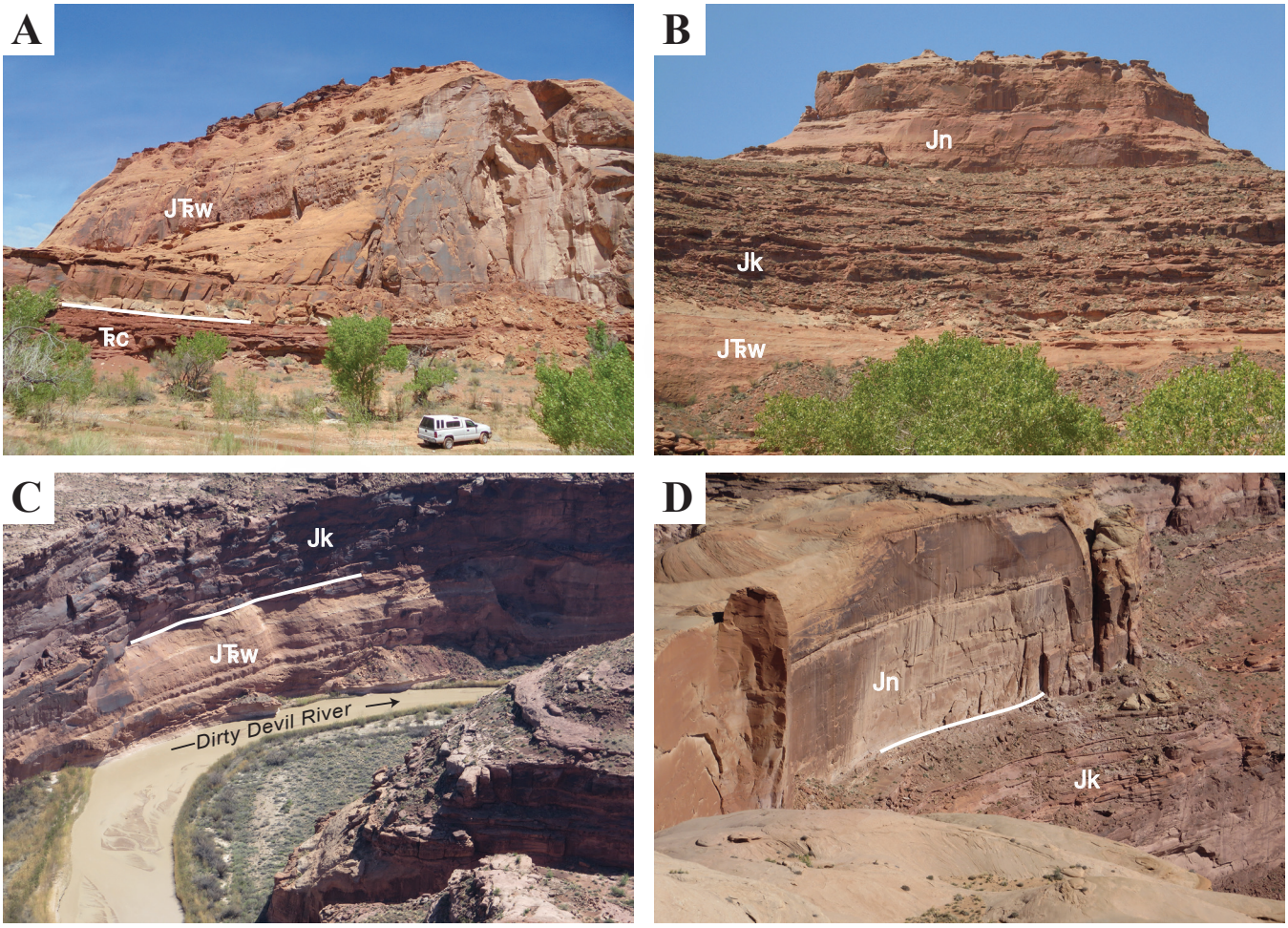
APPENDIX

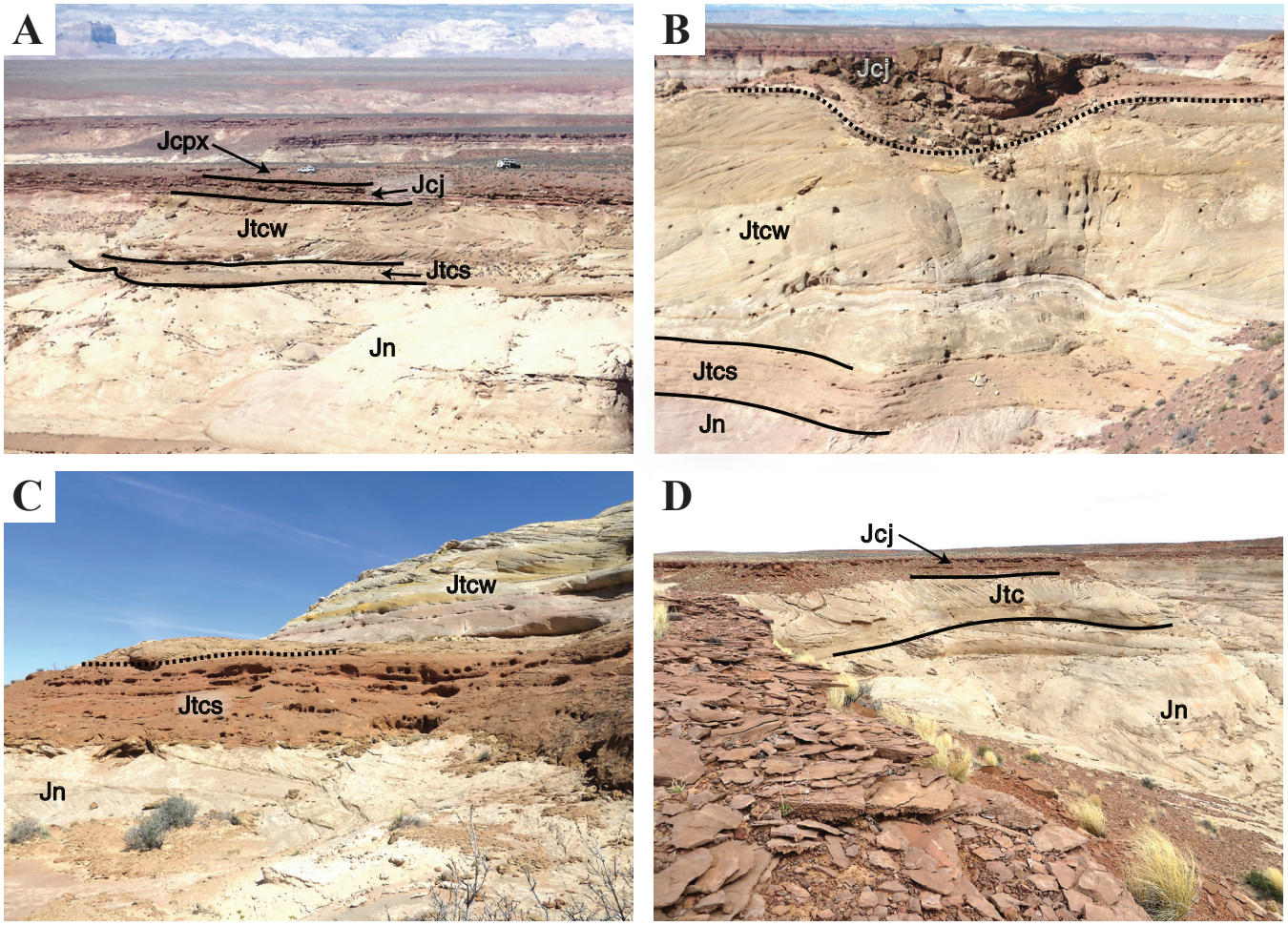
Annotated Photographs of Geologic Units Exposed in the Quadrangle

Lower Jurassic formations



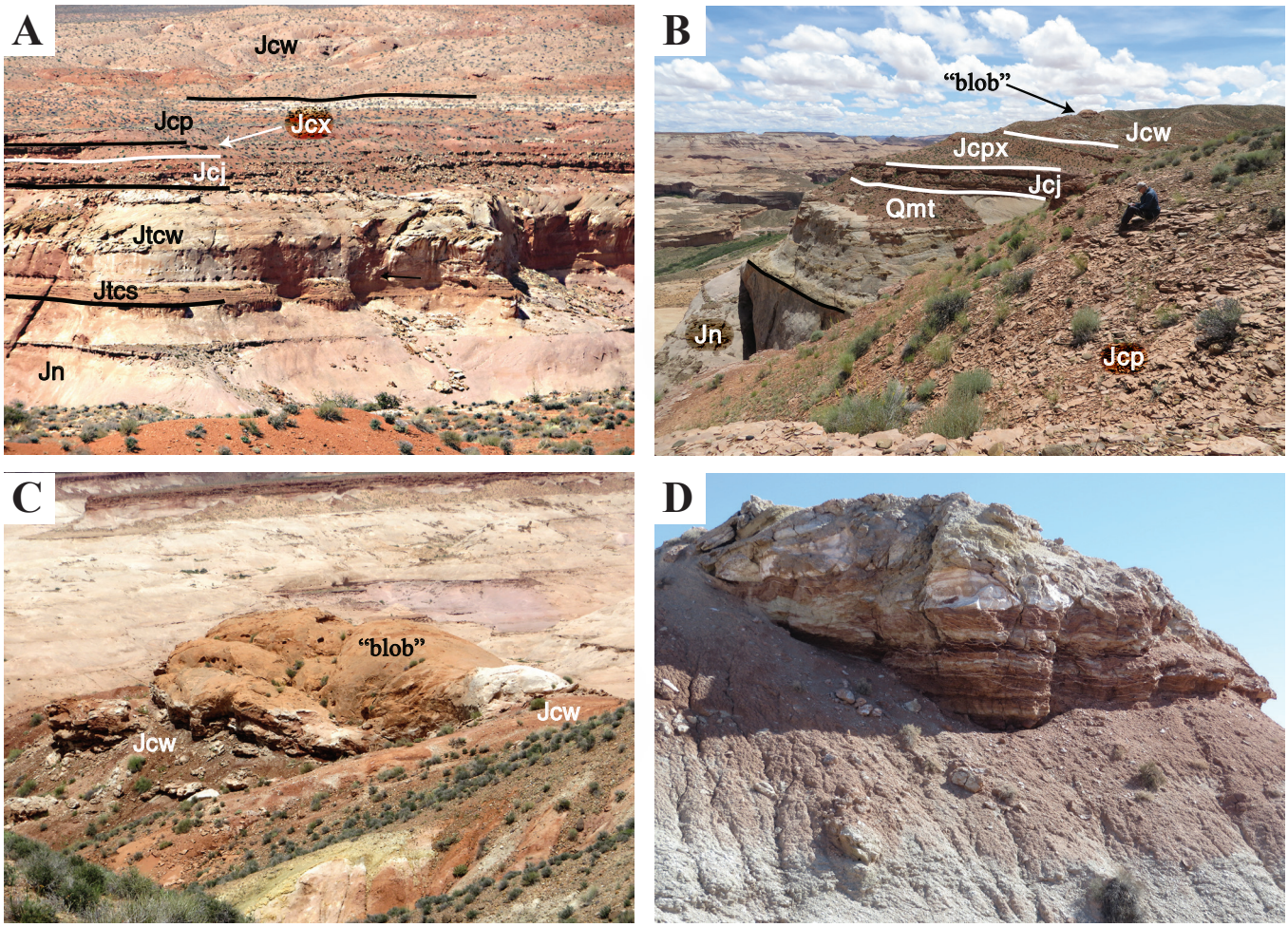
A. *Wingate Sandstone (JTRw)/Chinle Formation (TRc) contact in Poison Springs Canyon. This canyon is about 10 miles south of the Angel Cove quadrangle.* ***B.*** *Navajo Sandstone (Jn) resting on Kayenta Formation (Jk), resting on the Wingate Sandstone (JTRw), also in Poison Springs Canyon.* ***C.*** *Kayenta Formation (Jk) resting on Wingate Sandstone (JTRw) in the southeast part of the Angel Cove quadrangle.* ***D.*** *Navajo Sandstone (Jn) resting on Kayenta Formation (Jk) in the southeast part of the Angel Cove quadrangle.*

Middle and Lower Jurassic formations



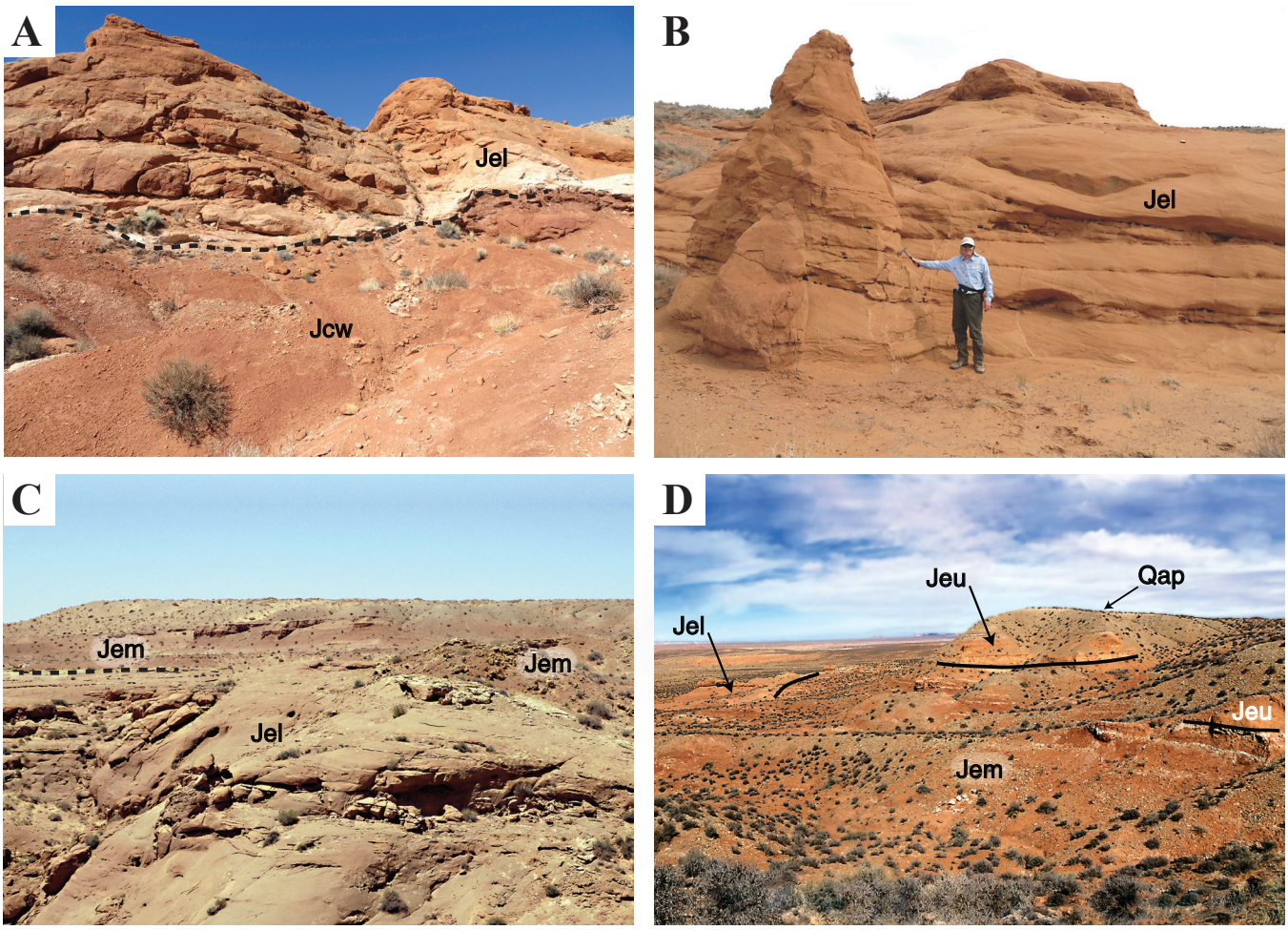
A. *Tributary canyon wall showing* Jn *(Navajo Sandstone),* Jtcs *and* Jtcw *(Sinawava and White Throne Members of the Temple Cap Formation);* Jcj *(Judd Hollow Member) and* Jcpx *(Crystal Creek and Paria River Members) of the Carmel Formation.* ***B.*** Jcj *(Judd Hollow Member) filling in a channel in* Jtcw *(Temple Cap Formation, White Throne Member).* Jtcs *is the Sinawava Member of the Temple Cap and* Jn *is the Navajo Sandstone.* ***C.*** *Contacts,* Jtcs/Jn *(Sinawava over Navajo) and* Jtcw/Jtcs *(White Throne over Sinawava).* ***D.*** *Judd Hollow (Jcj) resting on* Jtc *(Temple Cap) resting on* Jn *(Navajo). In foreground is the platy upper limestone ledge of the Judd Hollow Member.*

Temple Cap and Carmel Formation members



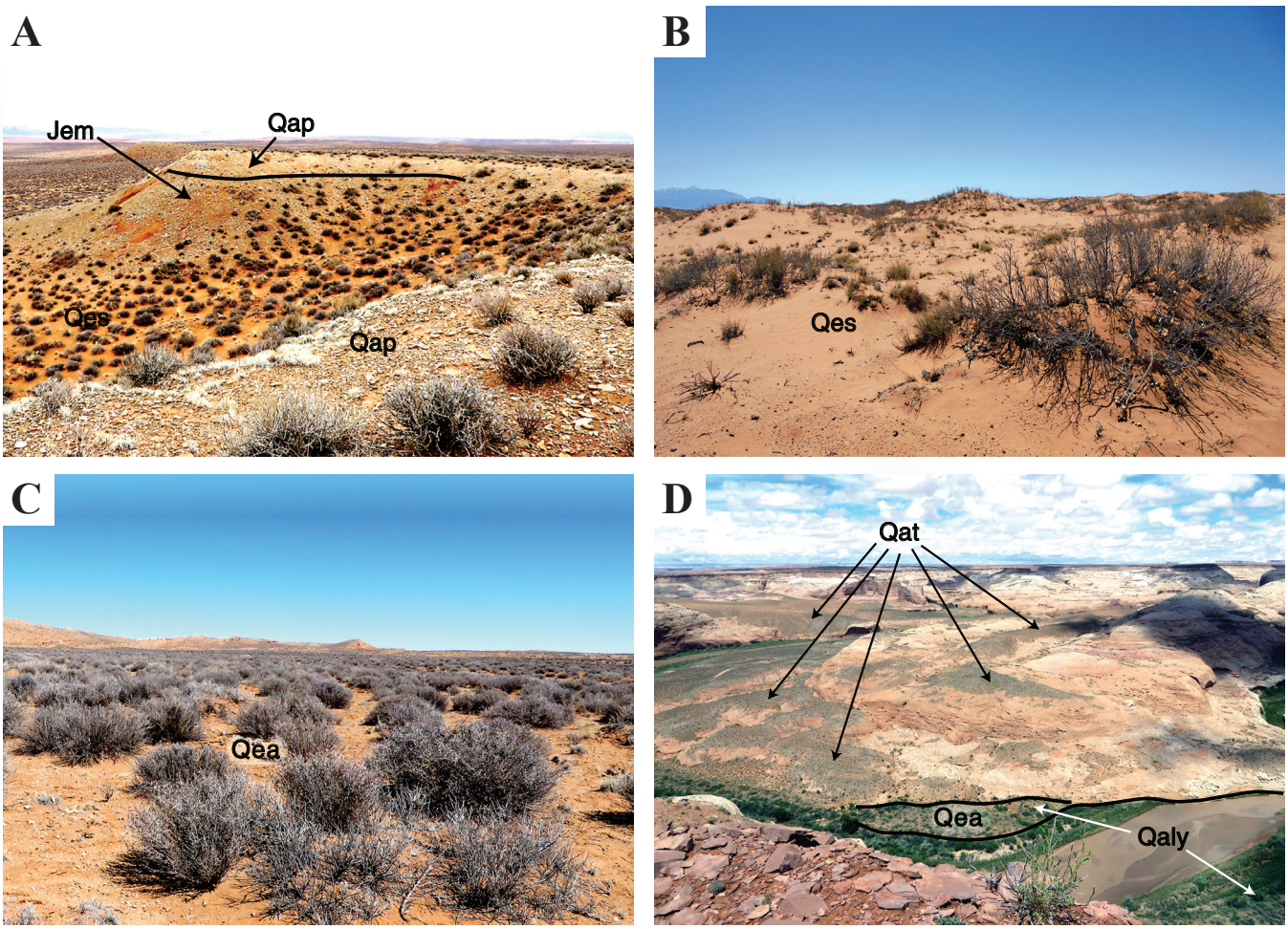
A. *Outcrops on the west side of the Dirty Devil River:* Jn *(Navajo Sandstone); Temple Cap Formation:* Jtcs *(Sinawava Member),* Jtcw *(White Throne Member); Carmel Formation:* Jcj *(Judd Hollow Member),* Jcx *(Crystal Creek Member),* Jcp *(Paria River Member),* Jcw *(Winsor Member). In most cases the upper part of the Winsor Member is overlain by pediment or other Q units.* ***B.*** *Same units of the Carmel Formation, including the Temple Cap and upper Navajo Sandstone. The "blob" shown in B. is the same as that in* ***C.*** ***D.*** *Shows bedded gypsum (alabaster) overlying crisscrossing satin spar in red-brown siltstone in the Winsor Member.*

Entrada Sandstone members



A. *Entrada/Carmel contact. Contact is normally somewhat contorted.* ***B.*** *Typical lower Entrada slickrim outcrops in the Angel Cove quadrangle. The Entrada is generally poorly exposed in the Angel Cove quadrangle; however, here along Beaver Ridge all three members are sequentially exposed.* ***C.*** *Middle Entrada (Jem) / lower Entrada (Jel) contact. Uppermost layer of Jel is commonly bleached.* ***D****. Upper Entrada Sandstone (Jeu) is generally lighter hued than the Jem beds below, but weathers smoothly with subtle horizontal banding. The Entrada is the youngest bedrock unit on the quadrangle. Some pediment mantle deposits (Qap) are present at this location, covering the Jeu unit.*

Typical Quaternary surficial units



A. *Alluvial pediment mantle (Qap) on middle member of Entrada Sandstone (Jem).* ***B.*** *Coppice dunes (low hills of windblown sand partially stabilized by vegetation) are common in eolian sand deposits (Qes).* ***C.*** *Typical bench with mixed eolian and alluvial deposits (Qea) and blackbrush.* ***D.*** *Alluvial terrace deposits (Qat) on Navajo Sandstone in the Dirty Devil River canyon. Young alluvial river channel (Qaly) and mixed eolian and alluvial deposits (Qea) are in the foreground.*