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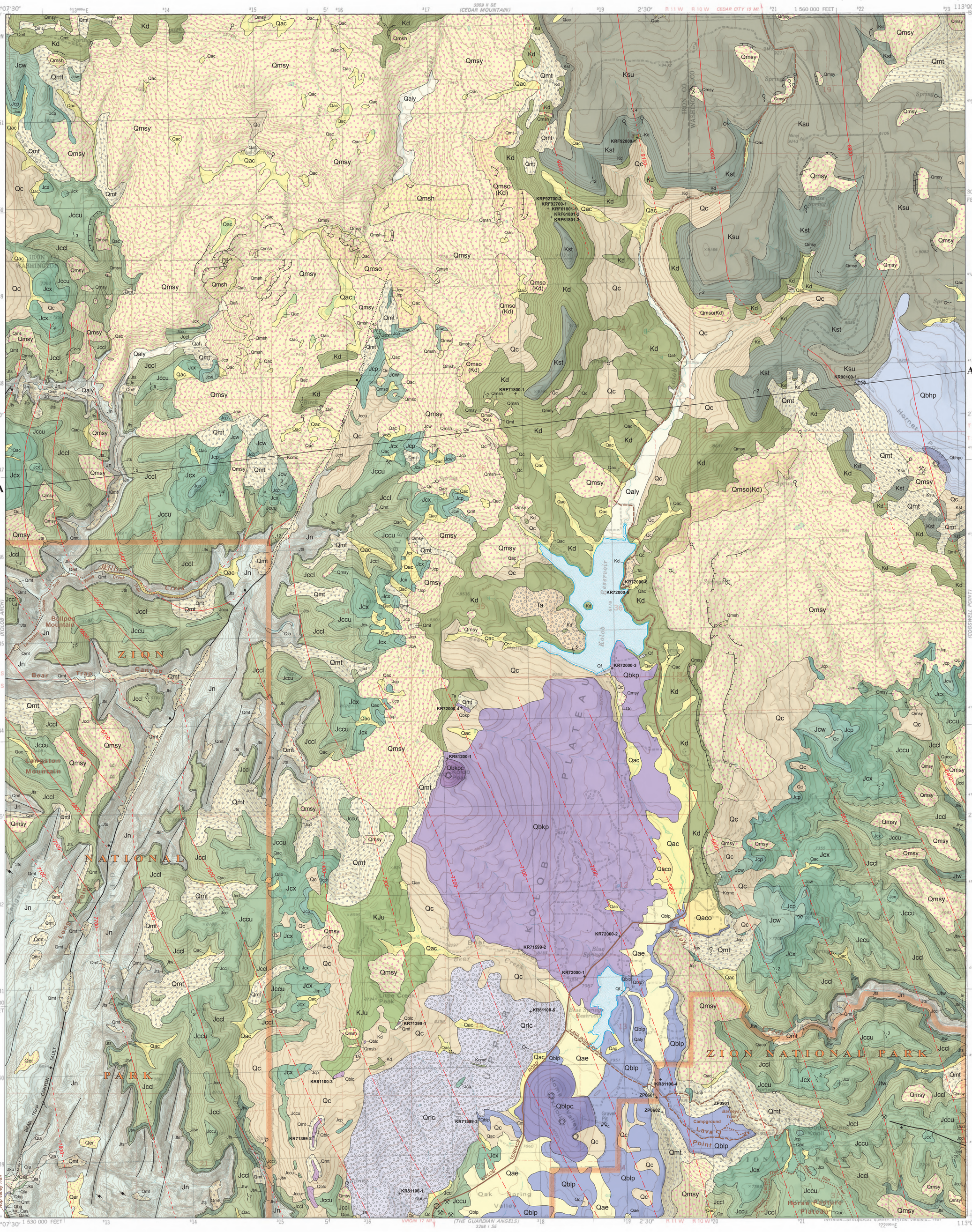

Base from U.S. Geological Survey,
Kolob Reservoir 7.5' quadrangle, 1980
Shaded topography generated from digital elevation data

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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
NATIONAL GEODETIC VERTICAL DATUM OF 1929

12°27'
TRUE NORTH
MAGNETIC NORTH
APPROXIMATE MEAN DECLINATION, 2007

GEOLOGIC MAP OF THE KOLOB RESERVOIR QUADRANGLE, WASHINGTON AND IRON COUNTIES, UTAH

by

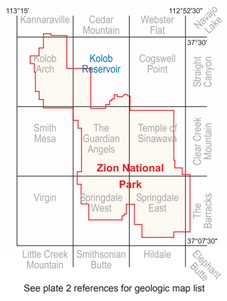
Robert F. Biek

2007

Key access roads, selected trails, and prominent features in and near Zion National Park shown in brown. Condition and status of roads and trails may change over time. Some not shown. From data provided by National Park Service.

UTAH
QUADRANGLE LOCATION

Fieldwork by author in 2000-01
Project Manager: Grant C. Willis
GIS Analyst: Kent D. Brown
Cartographer: James W. Parker
ISBN 1-55791-739-6



See plate 2 references for geologic map list

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DESCRIPTION OF MAP UNITS

QUATERNARY

Alluvial deposits

Qaly — **Younger stream deposits** (Holocene) – Stratified, moderately to well-sorted sand, silt, clay, and pebble to boulder gravel in river channels and flood plains; locally includes small alluvial-fan and colluvial deposits, and minor terraces as much as 20 feet (6 m) above current stream level; equivalent to stream deposits (Qal_1) and stream-terrace deposits (Qat_2) in the adjacent Kolob Arch quadrangle, but undivided here due to uncertain correlation between upper and lower reaches of drainages; generally 0 to 30 feet (0-9 m) thick.

Qas — **Alluvial sand deposits** (upper Holocene) – Well-sorted, fine- to medium-grained sand on the floor of Hop Valley, in the southwest corner of the quadrangle, where the Hop Valley stream has reworked the upper few feet of sandy basin-fill deposits.

Qaf_1 — **Alluvial-fan deposits** (Holocene) – Poorly to moderately sorted, non-stratified, boulder- to clay-size sediment deposited as small alluvial fans along major drainages; form active depositional surfaces, although locally the master stream is deeply entrenched; typically overlies alluvial channel deposits at the toe of the fans, and locally includes minor slope wash and talus along the upslope margins of the fans; many small fans, because they are too small to depict at this scale and because they are typically poorly developed, are lumped with mixed alluvial and colluvial deposits; generally 0 to 30 feet (0-9 m) thick.

Artificial-fill deposits

Qf — **Artificial-fill deposits** (historical) – Engineered fill used to create the Kolob Reservoir and Blue Springs Reservoir dams; unmapped fill is locally present in developed areas; as much as 60 feet (18 m) thick.

Colluvial deposits

Qc — **Colluvial deposits** (Holocene to upper Pleistocene) – Poorly sorted, angular, clay- to boulder-size, locally derived sediment deposited principally by slope wash and soil creep; gradational with talus deposits and mixed alluvial and colluvial deposits; locally includes large areas of talus where slope angles increase such that colluvium and talus form a thin mantle that grades from one deposit to another; may include undifferentiated landslide deposits; generally less than 20 feet (6 m) thick.

Lacustrine and basin-fill deposits

Qla — **Lacustrine and basin-fill deposits** (Holocene) – Well-stratified sand, silt, and minor peat deposited in the Hop Valley basin in the southwest corner of the quadrangle; grades into colluvial, alluvial, and alluvial-fan deposits at basin margins and in upper part of deposits; forms planar surfaces that slope downstream, which are incised about 40 feet (12 m) at the south end of Hop Valley; a radiocarbon age of 2640 ± 60 ^{14}C yr B.P. establishes a minimum age for the formation of Hop Valley Lake (Biek and others, 2003; Biek, 2007), and Eardley (1966) obtained a radiocarbon age of 670 ± 200 ^{14}C yr B.P. from the upper part of the deposits; deposits in Hop Valley are probably about 250 feet (75 m) thick (Biek, 2007), but are probably less than 60 feet (18 m) thick in this quadrangle; also mapped at Potamogeton (Chasm) Lake, a permanent pond about 2 miles (3 km) west of Kolob Reservoir that formed behind a rockfall of Navajo Sandstone; "Potamogeton" is Latin for pondweed, which sometimes covers the pond's surface. ^{14}C analytical data is available on the Utah Geological Survey Web site (http://geology.utah.gov/online/analytical_data.htm).

Mass-movement deposits

Qmsh, Qmsy, Qmso, Qmso (Kd) — **Landslide deposits** (historical to middle[?] Pleistocene) – Very poorly sorted, clay- to boulder-size, locally derived material deposited by rotational and translational movement; characterized by hummocky topography, numerous internal scarps, and chaotic bedding attitudes; basal slip surfaces most commonly form in the lower unit of the Co-op Creek Limestone Member of the Carmel Formation, the Dakota Formation, and the upper unit of the Straight Cliffs Formation, and the slides themselves incorporate these and overlying map units; the Dakota Formation especially forms very large, complex mass movements; Qmsh denotes slides with historical movement; younger landslides (Qmsy) may have historical movement, but typically are characterized by slightly more subdued landslide features indicative of early Holocene to late Pleistocene age; older landslides (Qmso) are deeply incised and their main scarps and hummocky topography have been extensively modified by erosion, suggestive of late to possibly middle(?) Pleistocene age, but they too may be locally active; Qmso(Kd) denotes large, relatively coherent bedrock blocks of the Dakota Formation as much as about 150 feet (45 m) thick that slumped downslope under the influence of gravity and which are late to possibly middle(?) Pleistocene in age.

Qmt — **Talus deposits** (Holocene to upper Pleistocene) – Very poorly sorted, angular boulders and finer-grained interstitial sediment deposited principally by rock fall on and at the base of steep slopes; typically grades downslope into colluvial deposits, and may include colluvial deposits where impractical to differentiate the two; generally less than 30 feet (9 m) thick.

Mixed-environment deposits

Qac, Qaco — **Alluvial and colluvial deposits** (Holocene to upper Pleistocene) – Poorly to moderately sorted, generally poorly stratified, clay- to boulder-size, locally derived sediments deposited principally in swales, small drainages, and along the upper reaches of larger streams by fluvial, slope-wash, and creep processes; gradational with both alluvial and colluvial deposits; Qac deposits form active depositional surfaces and are generally less than 20 feet (6 m) thick; Qaco deposits are deeply incised and of similar thickness.

Qae — **Alluvial and eolian deposits** (Holocene to upper Pleistocene) – Locally derived, fine- to coarse-grained sand and silt with subangular to angular gravel; deposited in topographic depressions by small streams, slope wash, and wind; includes small alluvial fans and colluvium along margins of deposits; 0 to 20 feet (0-6 m) thick.

Qer — **Eolian and residual deposits** (Holocene to upper Pleistocene) – Reddish-orange, fine- to medium-grained sand with residual Navajo Sandstone pebbles, cobbles, and boulders; forms irregular sheets on top of the Navajo Sandstone, from which it is derived, in the southwest corner of the quadrangle; generally less than 3 feet (1 m) thick.

Residual deposits

Qrlc — **Residual deposits** (Holocene to lower[?] Pleistocene) – Residual lag of angular to subangular basalt blocks derived from the Little Creek Peak lava flow, which is preserved in place on the ridge to the west; includes very rare blocks of Dakota Formation sandstone; although Little Creek Peak basalt is virtually the only rock type seen in this unit, nowhere is it clearly in place; probably represents a lag of basalt let down by erosion of underlying beds, but may represent a flow that cascaded southeastward from the adjacent ridge; thickness uncertain, but probably as much as several tens of feet thick.

Spring deposits

Qst — **Spring tufa** (Holocene) – Light-gray to light-brownish-gray, porous, calcareous tufa characterized by a sponge-like network of cavities; mapped at Birch Spring, about 2 miles (3 km) northwest of Kolob Reservoir; 0 to about 20 feet (0-6 m) thick.

Volcanic rocks

Major- and trace-element geochemistry and $^{40}Ar/^{39}Ar$ raw data is available on the Utah Geological Survey Web site (http://geology.utah.gov/online/analytical_data.htm); rock names are after LeBas and others (1986).

Qbg — **Grapevine Wash lava flows** (middle Pleistocene) – Medium-gray, weathering to dark-brownish-gray to dark-brownish-black, fine-grained olivine basaltic trachyandesite lava flows; erupted from a number of vents on the Lower Kolob Plateau, including the Firepit Knoll and Spendlove Knoll cinder cones; five $^{40}Ar/^{39}Ar$ plateau ages on these flows range from 0.22 ± 0.03 Ma to 0.31 ± 0.02 Ma (Willis and Hylland, 2002); only distal end of one flow is preserved at the south end of Hop Valley, in the southwest corner of the quadrangle, where it is about 20 feet (6 m) thick.

Qbhpc, Qbhp — **Hornet Point lava flow and cinder cone** (middle Pleistocene) – Medium- to dark-gray, medium- to coarse-grained olivine basalt to trachybasalt lava flow containing abundant pyroxene phenocrysts; locally deeply weathered to gruss-like soils; boulders typically have concentric weathering rinds; erupted from vent at deeply eroded cinder cone (Qbhpc) at Hornet Point; yielded $^{40}Ar/^{39}Ar$ isochron age of 0.74 ± 0.05 Ma from sample CP83100-3 in the Cogswell Point quadrangle (Biek and Hylland, 2007); lava flow is as much as 240 feet (73 m) thick in this quadrangle.

Qbkpc, Qbkp — **Kolob Peak lava flow and cinder cone** (lower Pleistocene) – Medium- to light-gray, fine-grained olivine basaltic trachyandesite lava flow; forms densely vegetated dip slope on the east side of Kolob Peak; erupted from vent at Kolob Peak, a cinder cone (Qbkpc) now eroded nearly in half; sample KR81200-1 yielded $^{40}Ar/^{39}Ar$ plateau age of 1.05 ± 0.05 Ma; thickness uncertain, but likely in excess of 100 feet (30 m) thick where it fills paleodrainages.

Qblpc, Qblp — **Lava Point lava flow and cinder cones** (lower Pleistocene) – Light- to medium-gray, fine- to medium-grained olivine basaltic trachyandesite to borderline basaltic andesite and trachybasalt lava flow; query indicates uncertain correlation near Blue Springs Reservoir; erupted from vents at Home Valley Knoll, a group of three overlapping cinder cones (Qblpc); yielded $^{40}Ar/^{39}Ar$ plateau ages of 1.02 ± 0.03 Ma (sample ZP-0601) and 1.08 ± 0.02 Ma (sample ZP-0602) for this flow at Lava Point, consistent with several published K-Ar and $^{40}Ar/^{39}Ar$ ages (Best and others, 1980; Hamblin and others, 1981; Willis and Hylland, 2002); as much as 120 feet (37 m) thick where it fills paleodrainages.

Qblc — **Little Creek Peak lava flow** (lower Pleistocene) – Medium-gray, fine- to medium-grained olivine basalt; locally caps ridge south of Little Creek Peak, and a basalt lag (Qrlc) derived from this flow covers the slope to the southeast of Little Creek Peak; yielded $^{40}Ar/^{39}Ar$ plateau age of 1.44 ± 0.04 Ma from sample VR43-01 in The Guardian Angels quadrangle (Willis and Hylland, 2002); source unknown; 0 to 30 feet (0-9 m) thick.

unconformity

TERTIARY

Ta — **Old boulder gravel deposits** (Miocene?) – Poorly sorted, clay- to very large boulder-size sediment characterized by very large quartz monzonite boulders; clasts also include large boulders of Cretaceous fossiliferous sandstone, cobbles and small boulders derived from the Carmel Formation, recycled, rounded pebbles and small cobbles of Precambrian and Cambrian quartzite, and uncommon cobbles and boulders of Claron limestone; most clasts are subangular to subrounded, but the quartzite clasts are well rounded; quartz monzonite boulders as much as 24 feet (7.3 m) long, 22 feet (6.7 m) wide, and at least 8 feet (2.4 m) high are present in the vicinity of Kolob Reservoir, and subspherical quartz monzonite boulders 10 to 15 feet (3-5 m) long are common; most quartz monzonite clasts, however, are 1.5 to 3 feet (0.5-1 m) in diameter; forms a deeply eroded surface that drapes over pre-existing topography; probably deposited by debris flows or possibly a gravity slide originating in the ancestral Pine Valley Mountains; this hypothesis, however, requires a complete eastward-to-westward reversal of drainage across the Hurricane fault; Averitt (1962, 1964) first described similar deposits farther north, east and southeast of Cedar City, and Anderson and Mehnert (1979) interpreted those exposures as debris-flow deposits shed off the ancestral Pine Valley Mountains; Hacker (1998) and Hacker and others (2002) provided evidence that the Pine Valley Mountains stood very high and shed gravity slides, volcanic rocks, and debris flows about 20.5 million years ago, long before initiation of the Hurricane fault; blocks of the Pine Valley laccolith caught in the Hurricane fault zone (Biek, 2007) show that the laccolith once likely reached east of the Hurricane fault, thus providing a somewhat closer source for the large Pine Valley boulders; thickness uncertain, but probably less than 30 feet (9 m) thick in this quadrangle; some deposits may contain just a lag of widely scattered larger clasts over poorly exposed bedrock, the matrix having been eroded away.

Two basalt boulders clearly incorporated into the deposits at Kolob Reservoir (samples KR72000-5 and KR72000-6) have a chemical signature similar to the Horse Ranch Mountain lava flow, and one boulder (KR72000-6) yielded a maximum $^{40}Ar/^{39}Ar$ age of 0.97 ± 0.18 Ma, analytically indistinguishable from the 1.03 ± 0.06 Ma Horse Ranch Mountain lava flow (Biek, 2007); how the basalt boulders came to be incorporated into these assumed Miocene-age deposits is not known.

unconformity

CRETACEOUS

Straight Cliffs Formation

Ksu — **Upper unit** (Upper Cretaceous, Santonian[?] to Turonian) – Slope-forming, grayish-orange to yellowish-brown, thin- to thick-bedded, fine-grained subarkosic sandstone and gray mudstone and shale; contains a few thin coal beds, common carbonaceous shale, and several thin coquina beds; forms broad, rounded hills typically mantled with unmapped colluvium; believed to be equivalent to the Smoky Hollow Member and possibly John Henry Member of the Straight Cliffs Formation of the Kaiparowits Plateau (see, for example, Eaton and others, 2001); deposited in fluvial, flood-plain, and lagoonal environments of a coastal plain (Eaton and others, 2001); incomplete thickness as much as 320 feet (100 m) in the quadrangle, but upper part not preserved.

Kst — **Tibbet Canyon Member** (Upper Cretaceous, Turonian) – Grayish-orange to yellowish-brown, generally medium- to thick-bedded, planar-bedded, fine- to medium-grained quartzose sandstone and lesser interbedded, grayish-orange to gray mudstone and siltstone; locally contains pelecypods, gastropods, and thin to thick beds of oyster coquina; typically forms cliffs, but in this quadrangle more commonly weathers to steep, vegetated slopes; upper contact corresponds to a break in slope and is placed at the top of a coquinoid oyster bed that caps the member; deposited in shoreface, lagoonal, estuarine, and flood-plain environments of a coastal plain (Laurin and Sageman, 2001; Tibert and others, 2003); thickens eastward across quadrangle from about 240 to 450 feet (75-135 m) thick.

KJu — **Dakota Formation, Cedar Mountain Formation, and Winsor Member of the Carmel Formation, undivided** (Upper Cretaceous to Middle Jurassic) – Mapped in the vicinity of Little Creek Peak, where access to private land was denied; the Dakota Formation is present over most of this area, Cedar Mountain strata may be present, and Winsor strata are likely present at the lowest elevations.

Kd — **Dakota Formation** (Upper Cretaceous, Cenomanian) – Interbedded, slope- and ledge-forming sandstone, siltstone, mudstone, claystone, carbonaceous shale, coal, and marl; sandstone is yellowish brown or locally white, thin to very thick bedded, fine to medium grained; includes two prominent cliff-forming sandstone beds, each several tens of feet thick, in the upper part of the formation; mudstone and claystone are gray to yellowish brown and commonly smectitic; oyster coquina beds, clams, and gastropods, including large *Craginia* sp., are common, especially in the upper part of the section; uppermost marl beds above the uppermost sandstone cliff contain distinctive gastropods with beaded edge *Admetopsis* n. sp. indicative of a latest Cenomanian brackish environment (Eaton and others, 2001) (samples KRF in sections 14 and 23, T. 38 S., R. 11 W.); Dakota strata are typically poorly exposed and involved in large landslides; includes the overlying Tropic Shale, which is restricted to the east part of the quadrangle where it is silty and sandy and no more than a few feet thick (see, for example, Eaton and others, 2001); upper contact placed at the top of a slope-forming, coaly and marly mudstone sequence and at the base of the typically cliff-forming sandstone of the Tibbet Canyon Member of the Straight Cliffs Formation; deposited in a variety of flood-plain, estuarine, lagoonal, and swamp environments (Gustason, 1989; Laurin and Sageman, 2001; Tibert and others, 2003); invertebrate and palynomorph fossil assemblages indicate shallow-marine, brackish, and fresh-water deposits of Cenomanian age (Nichols, 1995); probably about 850 feet (260 m) thick.

unconformity

Cedar Mountain Formation

Kcmc — **Conglomerate member** (Cretaceous, Cenomanian to Albian) – Thick- to very thick bedded, yellowish-brown, channel-form conglomerate, pebbly sandstone, and pebbly siltstone; clasts are subrounded to rounded, pebble- to small-cobble-size quartzite, chert, limestone, and rare, reworked petrified wood; locally stained reddish brown to dark yellowish brown; forms two small exposures southwest of Birch Spring and southeast of Little Creek Peak; deposited in river-channel environment on broad, coastal plain (Tschudy and others, 1984; Kirkland and others, 1997); Biek and Hylland (2007) reported a single-crystal $^{40}Ar/^{39}Ar$ age of 97.9 ± 0.5 Ma on sanidine from a volcanic ash in Cedar Mountain mudstone immediately above this conglomerate bed in the Straight Canyon quadrangle to the east; pollen analyses indicate an Albian or older age for these beds (Doelling and Davis, 1989; Hylland, 2000); upper contact not exposed, but regionally, east of the Hurricane fault, is unconformably overlain by the Dakota Formation (see, for example, Kirkland and others, 1997); previously mapped as the lower part of the Dakota Formation, but the lithology, age, and stratigraphic position of these beds suggest correlation to the Cedar Mountain Formation; 0 to 35 feet (0-11 m) thick.

unconformity (K)

JURASSIC

Carmel Formation

Jcw — **Winsor Member** (Middle Jurassic) – Light-reddish-brown, very fine to medium-grained sandstone and siltstone; poorly cemented and weathers to densely vegetated slopes; upper contact is the basal Cretaceous unconformity; near Birch Spring, Winsor strata are overlain by Cedar Mountain conglomerate, but in the northwest corner of the quadrangle, the conglomerate is missing and the Winsor Member is overlain by Dakota strata; deposited on a broad, sandy mudflat (Imlay, 1980; Blakey and others, 1983); thickens westward from about 240 to 320 feet (73-98 m) thick.

Jcp — **Paria River Member** (Middle Jurassic) – Laminated to very thin bedded, light-gray argillaceous limestone and micritic limestone that locally overlies a thick, white, alabaster gypsum bed common in the basal part of the Paria River Member; limestone weathers to small chips and plates and locally contains small pelecypod fossils; forms steep, ledgy slopes; upper contact is sharp and planar; deposited in shallow-marine and coastal-sabkha environments (Imlay, 1980; Blakey and others, 1983); about 50 to 160 feet (15-48 m) thick.

Jcx — **Crystal Creek Member** (Middle Jurassic) – Thin- to medium-bedded, reddish-brown gypsiferous siltstone, mudstone, and very fine to medium-grained sandstone; typically friable and weakly cemented with gypsum; forms vegetated, poorly exposed slopes; upper contact is sharp and broadly wavy and corresponds to the base of a thick Paria River gypsum bed or argillaceous limestone interval; deposited in coastal-sabkha and tidal-flat environments (Imlay, 1980; Blakey and others, 1983); about 150 to 250 feet (45-75 m) thick.

Co-op Creek Limestone Member (Middle Jurassic) – Thin- to medium-bedded, light-gray micritic limestone and calcareous shale; locally contains *Isocrinus* sp. columnals, pelecypods, and gastropods; deposited in a shallow-marine environment (Imlay, 1980; Blakey and others, 1983).

Jccu — **Upper unit** – Thin- to medium-bedded, light-gray micritic limestone; locally oolitic and sandy; forms sparsely vegetated, ledgy slopes and cliffs; upper contact is sharp and planar; about 100 to 140 feet (30-43 m) thick.

Jccl — **Lower unit** – Mostly thinly laminated to thin-bedded, light-gray calcareous shale and platy limestone; forms steep, vegetated slopes; contact with upper unit is gradational and corresponds to a subtle break in slope and vegetation patterns; about 240 to 380 feet (73-115 m) thick.

unconformity (J-2)

Temple Cap Formation

Jtw — **White Throne Member** (Middle Jurassic) – Very thick bedded, yellowish-gray to pale-orange, well-sorted, fine-grained quartz sandstone with large high-angle cross-beds similar to the Navajo Sandstone; upper contact is sharp and planar; deposited in coastal dune field (Blakey, 1994; Peterson, 1994); pinches out westward under the Upper Kolob Plateau due to truncation beneath the J-2 unconformity; 0 to 130 feet (0-40 m) thick.

Jts — **Sinawava Member** (Middle Jurassic) – Interbedded, slope-forming, moderate-reddish-brown mudstone, siltstone, and very fine grained silty sandstone; forms narrow, but prominent, deep-reddish-brown, vegetated slope at the top of the Navajo Sandstone; upper contact is gradational and interfingering with the White Throne Member, and, in western exposures, unconformable with light-gray calcareous shale and micritic limestone of the Co-op Creek Limestone Member; deposited in coastal-sabkha and tidal-flat environments (Blakey, 1994; Peterson, 1994); about 10 to 40 feet (3-12 m) thick.

unconformity (J-1)

Jn — **Navajo Sandstone** (Lower Jurassic) – Moderate-reddish-orange to moderate-orange-pink, massively cross-bedded, poorly to moderately well-cemented sandstone that consists of well-rounded, fine- to medium-grained, frosted quartz; contains few planar interdune deposits of sandstone and siltstone; forms spectacular, sheer cliffs and is locally prominently jointed; upper, unconformable contact is sharp and planar and corresponds to a prominent break in slope, with cliff-forming, cross-bedded sandstone below and reddish-brown mudstone above; corresponds to the "pink Navajo" and "brown Navajo" of Willis and Hylland (2002); deposited in a vast coastal and inland dune field with prevailing winds principally from the north (Blakey, 1994; Peterson, 1994); lower few hundred feet is characterized by planar sandstone beds and represents deposition in a sand-dominated sabkha environment (Tuesink, 1989; Sansom, 1992); about 2100 to 2200 feet (640-670 m) thick.

Kayenta Formation

Marzolf (1994) and Blakey (1994) presented evidence to restrict the Moenave Formation to the Dinosaur Canyon and Whitmore Point Members, with a major regional unconformity at the base of the Springdale Sandstone. Further work supports this evidence, indicating that the Springdale Sandstone is more closely related to the Kayenta Formation and should be made its basal member (see, for example, Lucas and Heckert, 2001; Molina-Garza and others, 2003; Steiner, 2005). We anticipate that this change will be formalized, and so here informally reassign the Springdale Sandstone as the basal member of the Kayenta Formation.

Jku — **Upper unit** (Lower Jurassic) – Interbedded, thin- to very thick bedded, moderate-reddish-brown siltstone, fine-grained sandstone, and mudstone with planar, low-angle, and ripple cross-stratification; contains several thin, light-olive-gray weathering, light-gray dolomite beds; upper contact is conformable and gradational and corresponds to the top of the highest thin siltstone and mudstone beds, above which lie the towering cliffs of Navajo Sandstone; deposited in fluvial, distal fluvial/playa, and minor lacustrine environments (Tuesink, 1989; Sansom, 1992; Blakey, 1994; Peterson, 1994); only upper few tens of feet of the formation is exposed in the quadrangle at Hop Valley, but the entire upper unit is about 700 to 1000 feet (210-300 m) thick.

Jks — **Springdale Sandstone Member (Lower Jurassic)** – Shown in cross section only; about 100 to 150 feet (30-45 m) thick (Willis and Hylland, 2002; Biek, 2007).

unconformity

JURASSIC AND TRIASSIC

JŦm — Moenave Formation, undivided (Lower Jurassic to Upper Triassic) – Shown in cross section only; age from Lucas and others (2005); about 200 to 350 feet (60-105 m) thick (Willis and Hylland, 2002; Biek, 2007).

J-0 unconformity

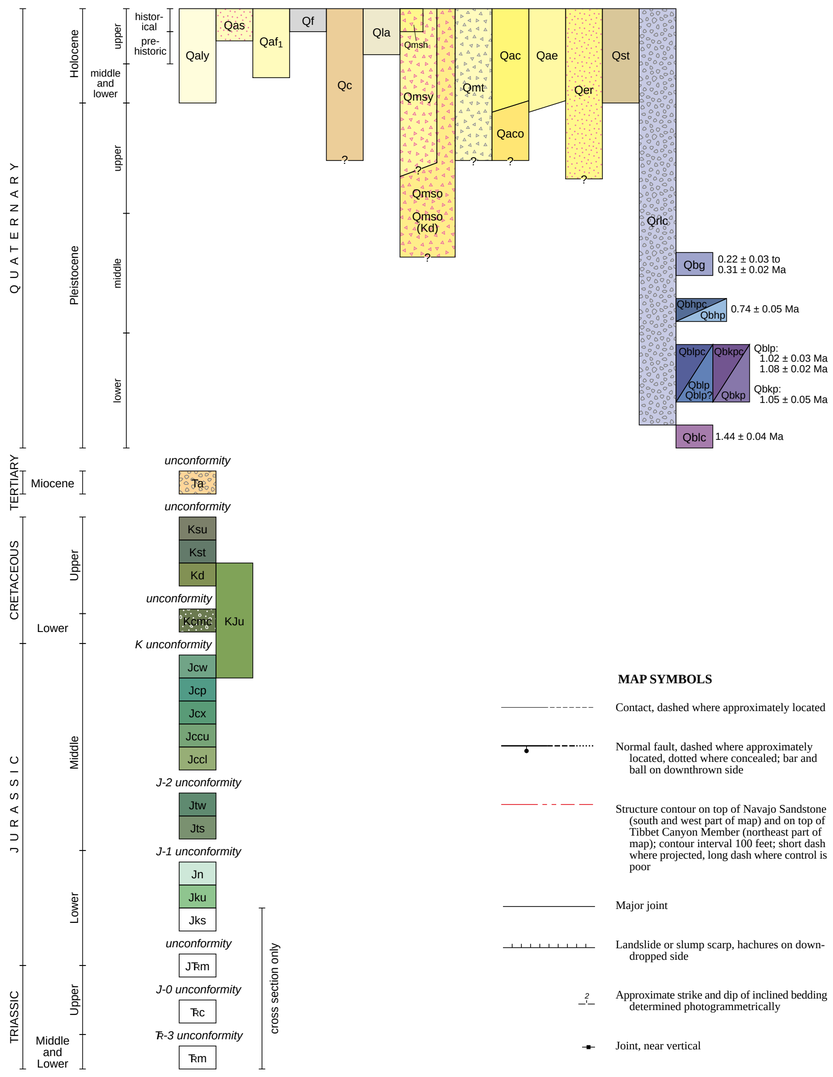
TRIASSIC

Ŧc — Chinle Formation, undivided (Upper Triassic) – Shown in cross section only; about 450 to 650 feet (135-200 m) thick (Willis and Hylland, 2002; Biek, 2007).

Ŧ-3 unconformity

Ŧm — Moenkopi Formation, undivided (Middle to Lower Triassic) – Shown in cross section only; about 1700 to 1800 feet (520-550 m) thick (Willis and Hylland, 2002; Biek, 2007).

CORRELATION OF MAP UNITS



MAP SYMBOLS

- Contact, dashed where approximately located
- Normal fault, dashed where approximately located, dotted where concealed; bar and ball on downthrown side
- Structure contour on top of Navajo Sandstone (south and west part of map) and on top of Tibbet Canyon Member (northeast part of map); contour interval 100 feet; short dash where projected, long dash where control is poor
- Major joint
- Landslide or slump scarp, hachures on down-dropped side
- Approximate strike and dip of inclined bedding determined photogrammetrically
- Joint, near vertical
- Pit - sand and gravel (no letter), cinders (c)
- Quarry
- Spring
- Volcanic vent
- Collapse feature (sinkhole)
- KR81100-1 Sample location and number

ACKNOWLEDGMENTS

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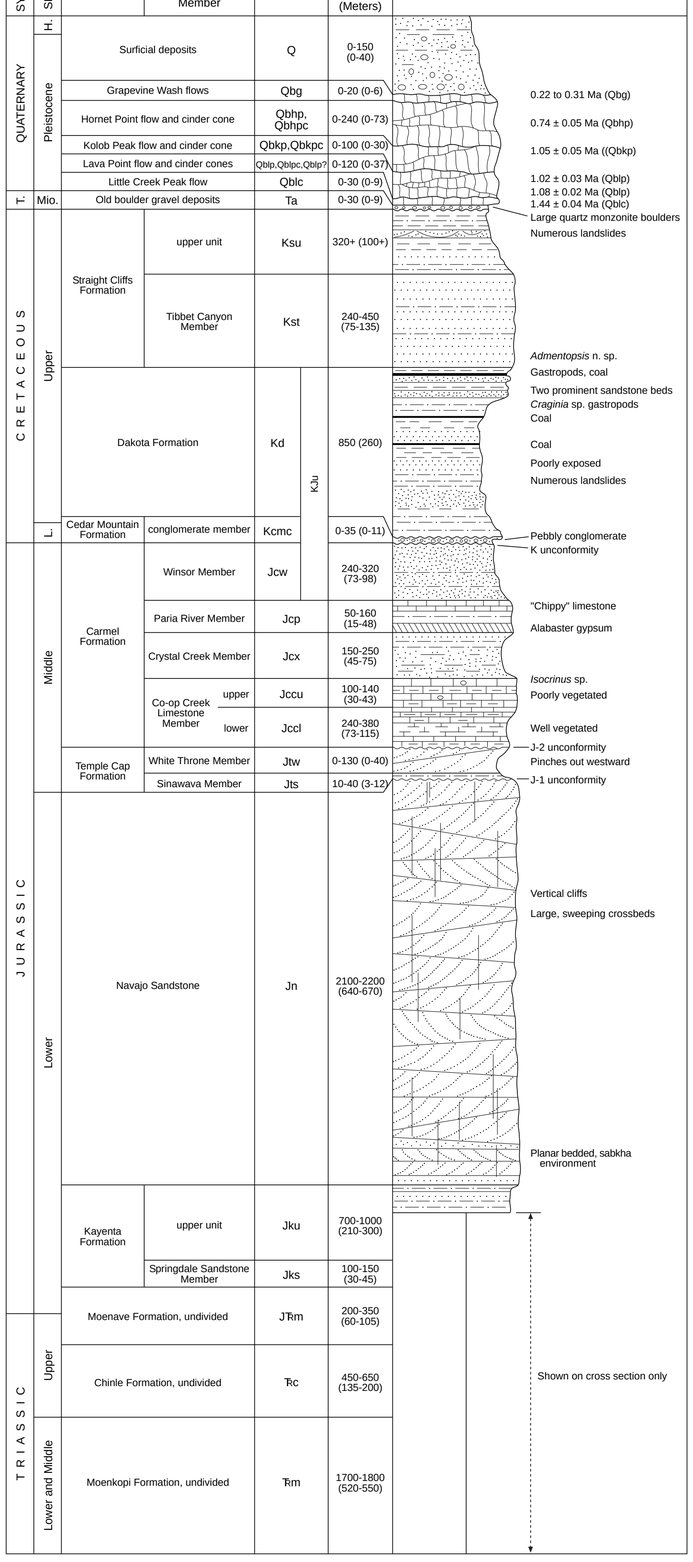
Selected geologic maps available for the Zion National Park area

In addition to the 1:24,000-scale geologic quadrangle maps listed below, Hamilton (1978) provided a 1:31,680-scale geologic map of Zion National Park. See index map on plate 1 for quadrangle locations.

Cedar Mountain	Averitt (1962)	Smithsonian Butte	Moore and Sable (2001)
Clear Creek Mountain	Hylland (2000)	Springdale East	Doelling and others (2002)
Cogswell Point	Biek and Hylland (2007)	Springdale West	Willis and others (2002)
Elephant Butte	Sable and Doelling (1990)	Straight Canyon	Cashion (1967), Sable and Hereford (2004)
Hildale	Sable (1995)	Temple of Sinawava	Doelling (2002)
Kanarraville	Averitt (1967)	The Barracks	Sable and Doelling (1993)
Little Creek Mountain	Hayden (2004)	The Guardian Angels	Willis and Hylland (2002)
Navajo Lake	Moore and others (2004)	Virgin	Hayden (in preparation)
Kolob Arch	Biek (2007)	Webster Flat	Doelling and Graham (1972)
Smith Mesa	Sable and others (in prep.)		

LITHOLOGIC COLUMN

SYSTEM	SERIES	FORMATION	Member	SYMBOL	THICKNESS Feet (Meters)
QUATERNARY	H.	Surficial deposits		Q	0-150 (0-40)
	Pleistocene	Grapevine Wash flows		Qbg	0-20 (0-6)
		Hornet Point flow and cinder cone		Qbhp, Qbhpc	0-240 (0-73)
		Kolob Peak flow and cinder cone		Qbkp,Qbkpc	0-100 (0-30)
		Lava Point flow and cinder cones		Qblp,Qblpc,Qblp?	0-120 (0-37)
		Little Creek Peak flow		Qblc	0-30 (0-9)
T.	Mio.	Old boulder gravel deposits		Ta	0-30 (0-9)
CRETACEOUS	Upper	Straight Cliffs Formation	upper unit	Ksu	320+ (100+)
			Tibbet Canyon Member	Kst	240-450 (75-135)
		Dakota Formation		Kd (KJu)	850 (260)
	L.	Cedar Mountain Formation	conglomerate member	Kcmc	0-35 (0-11)
JURASSIC	Middle	Carmel Formation	Winsor Member	Jcw	240-320 (73-98)
			Paria River Member	Jcp	50-160 (15-48)
			Crystal Creek Member	Jcx	150-250 (45-75)
			Co-op Creek Limestone Member: upper	Jccu	100-140 (30-43)
			Co-op Creek Limestone Member: lower	Jccl	240-380 (73-115)
		Temple Cap Formation	White Throne Member	Jtw	0-130 (0-40)
			Sinawava Member	Jts	10-40 (3-12)
	Lower	Navajo Sandstone		Jn	2100-2200 (640-670)
		Kayenta Formation	upper unit	Jku	700-1000 (210-300)
			Springdale Sandstone Member	Jks	100-150 (30-45)
		Moenave Formation, undivided		JŦm	200-350 (60-105)
TRIASSIC	Upper	Chinle Formation, undivided		Ŧc	450-650 (135-200)
	Lower and Middle	Moenkopi Formation, undivided		Ŧm	1700-1800 (520-550)



Above: View northwest to old boulder gravel deposits (Ta) along the east side of Kolob Reservoir. These deposits are characterized by very large boulders of quartz monzonite as much as 24 feet (7.3 m) long, 22 feet (6.7 m) wide, and at least 8 feet (2.4 m) high, and quartz monzonite boulders 10 to 15 feet (3-5 m) long are common as shown in the accompanying photo. These deposits also contain abundant smaller quartz monzonite boulders, and cobbles and small boulders derived from Cretaceous fossiliferous sandstone, the Carmel Formation, and Claron limestone, as well as recycled, rounded pebbles and small cobbles of Precambrian and Cambrian quartzite. These old boulder gravels likely represent Miocene-age debris-flow deposits shed off the ancestral Pine Valley Mountains, prior to development of the Hurricane fault. Boulders of the one-million-year-old Horse Ranch Mountain lava flow are locally incorporated into these deposits, but the mechanism by which they became incorporated into the deposits remains unclear.

Left: The hill in the distance is capped by the Tibbet Canyon Member of the Straight Cliffs Formation (Kst), which overlies the Dakota Formation (Kd).

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