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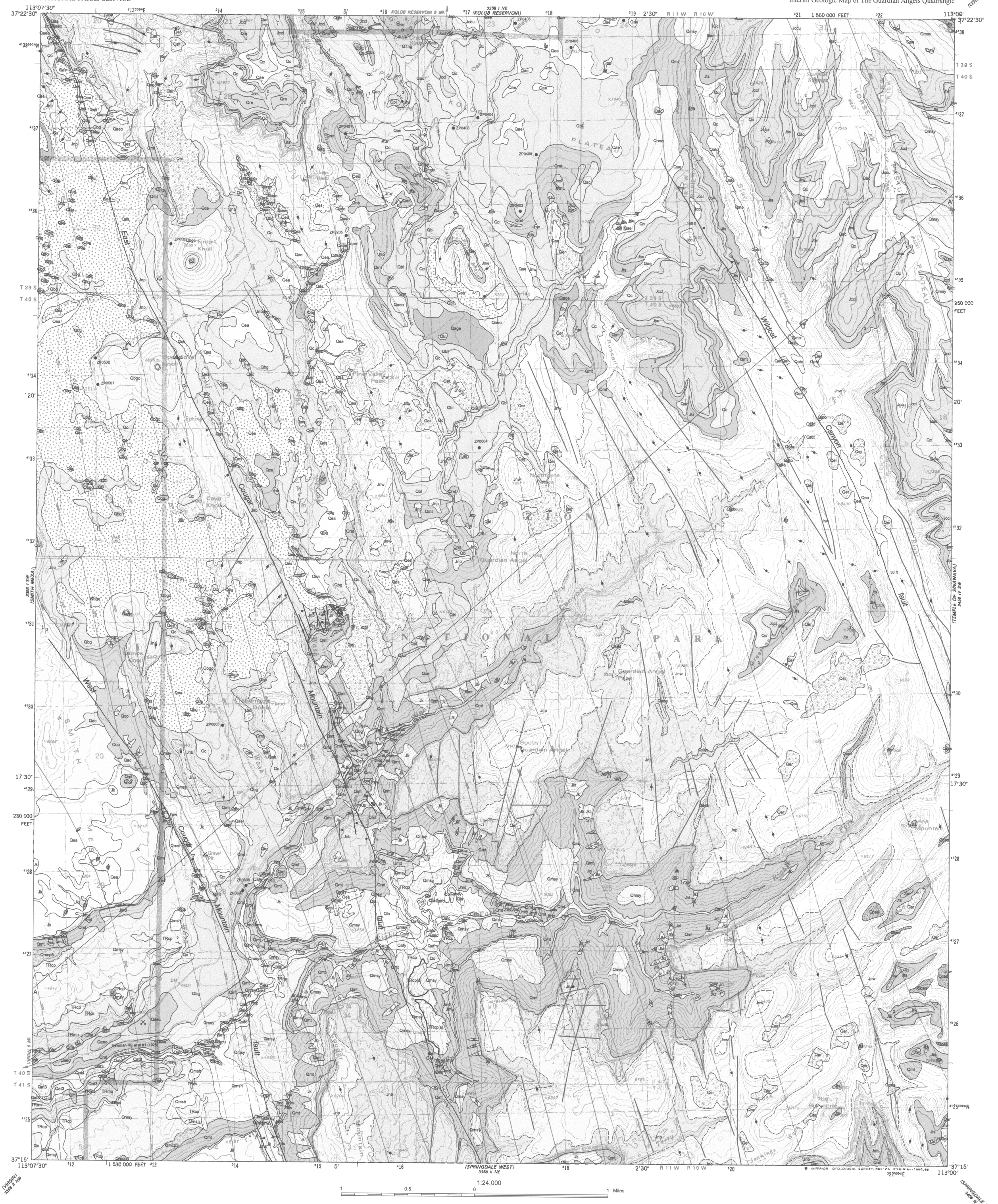

Interim Geologic Map of The Guardian Angels Quadrangle, Washington County, Utah

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OPEN-FILE REPORT 395 **July 2002**
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6/24/02

Description of Map Units

QUATERNARY

Fill Deposits

Qf **Fill (Historical) –** Fill, mostly sand, placed by humans in dams and dikes; most road fill not shown; includes some disturbed areas; 0 to 50 feet (0-15 m) thick.

Alluvial Deposits

Qa1 **Level 1 alluvial deposits (upper Holocene) –** Stratified, fine- to coarse-grained, pale-orange to yellowish-brown sand with varying amounts of poorly to moderately sorted, subangular to subrounded gravel, cobbles, and boulders of sandstone, limestone, basalt, and minor silt and clay; mapped along the lower part of North Creek; generally less than 20 feet (6 m) thick.

Qa2 **Level 2 alluvial deposits (upper Holocene) –** Similar to Qa1 deposits above, except deposits form incised surfaces generally 10 to 20 feet (3-6 m) above the modern channel; as much as 20 feet (6 m) thick.

Alluvial terrace deposits – Terrace remnants deposited by streams; locally preserved as much as 225 feet (68 m) above the modern stream channels; consist of poorly to moderately well-sorted cobble gravel with sand, silt, and clay in stringers and matrix; clasts are mostly exotic and consist of quartzite, basalt, sandstone, limestone, and chert; deposits are subdivided by elevation of terraces above the adjacent modern streams, which in turn reflects relative age of deposits; ages are estimated based on calculated incision rates of the Virgin River (outside of quadrangle), which is the major local control of base level; map units locally include a thin apron of colluvium draped downslope from the terrace deposits; 10 to 30 feet (3-9 m) thick.

Qat3 **Level 3 alluvial-terrace deposits (middle Holocene to upper Pleistocene) –** Deposits forming terraces 26 to 35 feet (8-12 m) above North Creek in the southwest corner of the quadrangle; estimated a few thousand to about 20,000 years old.

Qat4 **Level 4 alluvial-terrace deposits (upper Pleistocene) –** Deposits forming terraces 35 to 90 feet (12-30 m) above North Creek in the southwest corner of the quadrangle; estimated 20,000 to 100,000 years old.

Qato **Older alluvial-terrace deposits (Pleistocene) –** Mostly cobble to boulder gravel, with pebbles, sand, silt, and clay deposited in terrace remnants along minor drainages; generally less well sorted than Qat deposits; along upper Left Fork of North Creek, remnants are up to 225 feet (68 m) above the creek; correlation with deposits of similar elevations above other tributaries of the Virgin River is uncertain because creek bed is not to grade in this area.

Qafy **Younger alluvial-fan deposits (upper Holocene) –** Non-stratified, coarse- to fine-grained, reddish-brown, poorly sorted sand and pebble to cobble gravel with silt and scattered boulders; clasts are angular to subangular sandstone, limestone, and basalt; graded to modern stream channels and up to about 10 feet (3 m) above modern channels; deposited by debris flows issuing from small side canyons; 0 to 10 feet (3 m) thick.

Qafm **Middle-age alluvial-fan deposits (Holocene) –** Similar to Qafy deposits, except deposits are graded to older alluvial surfaces (Qalo), and are incised by modern stream channels; deposited by debris flows issuing from small side canyons; probably less than 20 feet (6 m) thick.

Qafo **Older alluvial-fan deposits (lower Holocene to upper Pleistocene) –** Similar to Qafy and Qafm deposits described above but preserved as remnants incised by stream channels and graded to alluvial surfaces older than most Qa2 deposits.

Qas **Alluvial sand deposits (Holocene to upper Pleistocene) –** Well-sorted, fine- to medium-grained sand weathered from the Navajo Sandstone and deposited in washes; locally includes minor silt, gravel, and colluvium; common in sediment-choked streams in areas draining Navajo Sandstone; 0 to 20 feet (0-6 m) thick.

Qaso **Older alluvial sand deposits (lower Holocene to upper Pleistocene) –** Similar to alluvial sand deposits (Qas) except incised up to 30 feet (9 m) by streams.

Qav **Alluvial gravel and sand consisting primarily of basaltic sediment (middle Pleistocene) –** Moderately well-sorted cobble gravel interbedded with basaltic sand and silt; well-stratified; cross-bedded; clasts are mostly basalt, but also include sandstone, quartzite, chert, and limestone; preserved in local areas on top of basalt flows up to about 450 feet (140 m) above modern channels; 0 to 60 feet (0-18 m) thick; deposited by streams that re-established on top of the Grapevine Wash basalt flows (dated at 0.22 to 0.31 Ma) shortly after the flows partially filled the stream valleys.

Colluvial Deposits

Qc **Colluvium (Holocene to upper Pleistocene) –** Unsorted, nonstratified sand and silt with subangular to angular sandstone blocks and gravel; color and clast composition vary with parent material; deposited primarily by creep and slope wash; generally less than 20 feet (6 m) thick.

Qces **Colluvial and eolian sand (Holocene to Pleistocene) –** Moderately well-sorted sand with varying amounts of angular blocks of sandstone (and basalt locally) deposited on moderate slopes and deep slot canyons; generally present in areas with weathered Navajo Sandstone; 0 to 20 feet (0-6 m) thick.

Qco **Older colluvium (Pleistocene) –** Similar to colluvium (Qc) described above, but preserved as isolated remnants dissected by washes and streams.

Mixed Alluvial and Colluvial Deposits

Qac **Mixed alluvium and colluvium (Holocene to upper Pleistocene) –** Poorly to moderately sorted, poorly stratified sand, silt, and clay with scattered subangular to angular boulders, cobbles, and pebbles; brown to gray; deposited in minor drainages and topographic depressions primarily by ephemeral streams, slope wash, and creep processes; includes mix of alluvial materials carried down drainages and colluvial materials derived from adjacent slopes; may be dissected up to about 20 feet (6 m) by modern ephemeral stream channels; thickness less than 30 feet (9 m).

Qaco **Older mixed alluvium and colluvium (lower Holocene to upper Pleistocene) –** Similar to mixed alluvium and colluvium (Qac) described above, but deeply dissected by ephemeral streams.

Mass-Movement and Related Deposits

Qmt **Talus (Holocene to upper Pleistocene) –** Primarily unsorted, coarse, angular blocks on steep slopes; fine-grained component varies from abundant to absent; composed of blocks derived from immediately upslope ledges and cliffs; locally contains small landslide and slump deposits, and boulders with diameters exceeding 30 feet (9 m); mantles steep slopes beneath cliffs and ledges; locally includes undifferentiated colluvium; commonly grades downslope into colluvial and other deposits; generally 15 feet thick (4.5 m) or less, locally up to 30 feet (9 m) thick.

Qmsh **Historical undifferentiated mass-movement slide and slump deposits (Historical) –** Masses of rock and unconsolidated material that have undergone translational and/or rotational downslope movement; include zones of highly disturbed material, especially at landslide toes where movement is characterized by earth flow; typically associated with low-strength smectitic mudstone and claystone in the Petrified Forest Member of the Chinle Formation; landslide features such as scarps and slide blocks are morphologically distinct; historical age documented by disturbed vegetation and open fractures; deposits may deflect stream flow; vary greatly in thickness, but most are estimated to be less than 50 feet (15 m) thick.

Qmsy **Younger undifferentiated mass-movement slide and slump deposits (Holocene to upper Pleistocene) –** Masses of rock and unconsolidated material that have undergone translational and/or rotational downslope movement; bedrock strata within the blocks are commonly tilted and shattered; individual blocks may be as much as several hundred feet long; slip surfaces commonly develop in the clays of the Petrified Forest Member of the Chinle Formation and in silt and clay units in the Kayenta Formation; similar in character and occurrence to Qmsh, but landslide features such as scarps and slide blocks are morphologically less distinct as the result of weathering and erosion; locally includes deposits with historical movement; probably formed mostly during wet climatic regimes in the Pleistocene, but continue to move near springs and other wet areas, and where undercut or oversteepened by stream erosion; vary greatly in thickness, but most are estimated to be less than 50 feet (15 m) thick.

Qmfy **Younger mass-movement flow deposits (Holocene) –** Unsorted, nonstratified, typically clast-supported debris-flow or debris-flood deposits of subangular to subrounded gravel, cobbles, and boulders with minor amounts of sand, silt, and clay; deposits form levees and elevated surfaces within and adjacent to washes; less than 10 feet (3 m) thick.

Qmcp3 **Older mass-movement, colluvial, and alluvial pediment-mantle deposits (upper to middle Pleistocene) –** Remnants of rock-fall, small slump block and landslide, colluvial, and generally minor alluvial-fan debris that mantle and armor gently sloping, pediment-like benches cut across bedrock; consist of poorly sorted, angular to subangular large boulders to fine-grained sand, and lesser amounts of silt derived from local cliffs and ledges; materials become coarser upslope; preserved as remnants that form inclined benches near steep bedrock slopes at high levels; these benches may be either remnants of much larger surfaces that were graded to an ancestral North Creek, which, at the time of deposition, would have been several hundred feet above its present position; or, they are remnants of sloping erosional surfaces armored and protected from erosion by the coarse deposits and were not graded to the creek; color is dependent on source formations; mapped deposits locally include aprons of colluvium derived from the pediment-mantle deposits; as much as 30 feet (9 m) thick; sloping surfaces project about 400 feet (120 m) above the stream; surfaces mapped in Springdale East and West quadrangles at lower levels (Qmcp1 and Qmcp2) not present in this quadrangle.

Lacustrine and Basin-Fill Deposits

Qla **Lacustrine and basin-fill deposits (Pleistocene) –** Well-sorted, pale-gray to pale-yellowish-brown, thin-bedded to laminated, planar-bedded clay, silt, sand, and marl; includes reworked bouldery colluvium near basin margins; locally slumped and with soft-sediment slump features; form remnants draped across older alluvial and mass-movement deposits; deposits are mapped only in Right Fork of North Creek drainage where deposited by ancient Trail Canyon Lake (Hamilton, 1995); the lake was created by a large landslide dam and/or basalt dam; if dammed by the basalt flow (unit Qbg), then the deposits are slightly less than about 260,000 years old; locally as much as 150 feet (45 m) thick.

Mixed Eolian, Colluvial, and Alluvial Deposits

Qce **Mixed colluvial and eolian deposits (Holocene to Pleistocene) –** Mostly poorly sorted colluvium mapped on moderate slopes that are partially mantled with well-sorted, windblown sand.

Qea **Mixed eolian and alluvial deposits (Holocene to Pleistocene) –** Well-sorted, pale-reddish-brown to pale-yellowish-brown, windblown sand with generally minor alluvial pebbles on broad, gently sloping surfaces; surfaces are relatively old and stable and are isolated from most erosion, allowing eolian deposits to gradually accumulate; generally less than 10 feet (3 m) thick.

Qaec **Mixed alluvial, eolian, and colluvial deposits (Holocene to Pleistocene) –** Poorly to moderately sorted sand, silt, clay, cobbles, and small boulders; most of unit deposited by streams that briefly flowed on top of basalt flows before becoming entrenched at the side of the flow; includes colluvium weathered from the basalt and adjacent formations, and eolian silt, calcareous dust, and sand; commonly has a thick pedogenic carbonate (caliche) soil; 0 to 10 feet (0-3 m) thick.

Qae **Mixed alluvial and eolian deposits (Holocene to upper Pleistocene) –** Locally derived, unsorted, fine-grained sand and silt with minor scattered, subangular to angular gravel; deposited in shallow topographic depressions and on broad gentle slopes at higher elevations by slope wash and wind; includes small fans and colluvium from adjacent slopes; less than 10 feet (3 m) thick.

Qaeo **Older mixed alluvial and colluvial deposits (Holocene to Pleistocene) –** Poorly sorted cobble to small boulder gravel, sand, silt, and clay preserved as remnants incised by modern streams; commonly have thick pedogenic carbonate (caliche) soil; partially mantled by windblown sand; 0 to 50 feet (0-15 m) thick.

Qaes **Mixed alluvial and eolian sand deposits (Holocene to upper Pleistocene) --** Primarily pale-yellowish- to pale-reddish-gray, well-sorted sand deposited or reworked by ephemeral streams, with minor intermixed alluvial sand and pebble gravel deposits, rock-fall debris, and colluvium; deposited in stream channels and deep slot canyons cut into Navajo Sandstone; deposits in slot canyons commonly include windblown and talus sand; 0 to 20 feet (0-6 m) thick.

Qage **Mixed alluvial gravel and eolian sand deposits (Holocene to middle Pleistocene) –** Similar to younger to older alluvial-fan deposits described above, but fan morphology is more poorly defined and partially mantled by eolian sand; deposited on basalt flows in Pocket Mesa area of the quadrangle where minor side streams were forced out of equilibrium by basalt flows that filled the larger canyons, causing a decrease in gradient; contain clasts of quartzite, chert, limestone, sandstone, and basalt with boulders to 2 feet (0.6 m) in diameter; less than 20 feet (6 m) thick.

Eolian and Residual Deposits

Qes **Eolian sand (Holocene to upper Pleistocene) –** Well-sorted, pale-yellowish-gray to pale-reddish-gray, mostly fine-grained, windblown sand deposited in sheets, mounds, and dunes; derived primarily from the Navajo Sandstone; locally includes minor residual weathered rock from underlying unit; 0 to 20 feet (0-6 m) thick.

Qer **Mixed eolian and residual deposits (Holocene to upper Pleistocene) –** Pale-reddish-orange, windblown, well-sorted, mostly fine-grained sand with scattered to common angular to subrounded residual sandstone blocks derived from the Navajo Sandstone; locally includes minor alluvial sand and sandstone fragments; deposited in shallow topographic depressions and on gently sloping surfaces mostly on Navajo Sandstone; 0 to 20 feet (0-6 m) thick.

Qre **Mixed fine-grained residual and eolian deposits (Holocene to upper Pleistocene) –** Reddish-brown to pale-yellowish-gray, residual silt and fine sand with scattered subangular gravel deposited on flat surfaces eroded on lower part of Co-op Creek Limestone Member of the Carmel Formation; partly reworked by eolian processes; deposited by wind and as residual accumulation on weathered

slopes; 0 to 10 feet (0-3 m) thick.

Qrlc **Residual deposits of Little Creek Peak flow (Holocene to Pleistocene) –** Residual lag of angular to subangular basalt blocks derived from the Little Creek Peak flow, which is preserved in place on high ridges near these deposits and to the north (Biek, 2002); although Little Creek Peak basalt is the virtually the only rock type seen in blocks, 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 tens of feet.

Volcanic rocks

Qbg **Grapevine Wash basalt flows (middle Pleistocene) –** Medium-gray (fresh surfaces), weathering to dark-brownish-gray to dark-brownish-black, phenocryst poor, olivine basalt, trachybasalt, and basaltic andesite; vesicular to dense; locally jointed; flow textures still evident on upper surface in places; rubbly base where exposed; typically 20 to 40 feet (6-12 m) thick, but locally up to 400 feet (120 m) thick where ponded in paleodrainages; forms inverted valley followed by highway in southern and western parts of quadrangle; $^{40}Ar/^{39}Ar$ plateau ages on five samples of 0.22 ± 0.03 0.26 ± 0.01, 0.26±0.03, 0.29±0.02, and 0.31±0.04 Ma.

Qbgc **Grapevine Wash basalt cinders (middle Pleistocene) –** Dark-brown, dark-reddish-brown, and dark-brownish-red, loosely compacted basaltic cinders; forms two large symmetrical cinder cones (Firepit Knoll and Spendlove Knoll) and several small poorly formed cinder cones and mounds.

Qblp **Lava Point basalt flows (lower Pleistocene) –** Medium-gray (fresh surfaces), weathering to dark-brownish-gray to dark-brownish-black, phenocryst poor, olivine basaltic trachyandesite to basaltic andesite; vesicular to dense; locally jointed; upper surface of flows generally strongly weathered; rubbly base where exposed; typically 20 to 40 feet (6-12 m) thick, but locally up to 200 feet (60 m) thick where ponded in paleodrainages; forms inverted valleys locally over 1,000 feet (300 m) above modern drainages; caps broad sloping bench in northern part of quadrangle; $^{40}Ar/^{39}Ar$ plateau ages of 1.02± 0.03, 1.08± 0.02, and 1.14± 0.16 Ma (unpublished UGS data) and 1.06± 0.01 (USGS data).

Qblc **Little Creek basalt flow (lower Pleistocene) –** Medium-gray (fresh surfaces), weathering to dark-brownish-gray to dark-brownish-black olivine basalt; has small dispersed plagioclase and olivine phenocrysts; dense; highly jointed; upper surface of flows generally strongly weathered; typically 20 to 60 feet (6-18 m) thick; forms erosional remnants that cap highest plateaus in quadrangle, forming inverted valleys; $^{40}Ar/^{39}Ar$ plateau age on one sample of 1.44± 0.04 Ma.

QUATERNARY-TERTIARY

QTng **Older boulder gravel deposits (lower? Pleistocene) –** Highly weathered, slope-forming, bouldery debris; poorly sorted with well-developed soil; surfaces are littered with rounded to subrounded quartzite boulders up to about 2 feet (0.6 m) in diameter, and rounded, highly weathered, crumbly quartz monzonite porphry boulders up to about 6 feet (2 m) in diameter that appear similar in composition to the Pine Valley Mountains laccolith exposed about 10 miles (16 km) to the west; may locally exceed 100 feet (30 m) in thickness; relationships in the Kolob Reservoir quadrangle to the north suggest that deposits may be early Quaternary in age, though late Tertiary age is possible (Biek, 2002).

JURASSIC

Carmel Formation

Co-op Creek Limestone Member – Interbedded light-bluish-gray to yellowish-gray, resistant, very thin- to medium-bedded, blocky weathering limestone and slope-forming calcareous shale; overall,

forms steep ledgy slopes or a bench on top of the Temple Cap Formation; limestone is mostly micritic, but some beds are oolitic and sandy; has minor thin-bedded dolomite and sandstone; has locally abundant fossils, including pelecypods, gastropods, and crinoid columnals; *Pentacrinus asteriscus,* a Middle Jurassic crinoid, is common in some of the limestone beds; deposited in a marine (shallow sea) environment; uppermost part not preserved in quadrangle; complete member is 250 to 280 feet (76-85 m) thick.

Jccu **Upper unit –** Thin- to medium-bedded, pale-yellowish-gray-weathering, micritic limestone; forms sparsely vegetated slopes and cliffs; about 100 to 110 feet (30-33 m) thick; upper part not preserved in the quadrangle.

Jccl **Lower unit –** Mostly thinly laminated to thin-bedded, pale-yellowish-gray weathering, calcareous shale and platy limestone; local rip-up clast conglomerate at the base; forms steep, vegetated to partially barren slopes; contact with upper unit gradational and corresponds to a subtle break in slope and vegetation patterns; 150 to 170 feet (46-52 m) thick.

J-2 unconformity

Temple Cap Formation

Jtw **White Throne Member –** Very light-gray to pale-orange, cliff-forming sandstone resembling the white Navajo Sandstone; consists of fine-grained, well-sorted, cross-bedded sandstone; has high-angle tabular-planar or wedge-planar cross-beds in sets as much as 20 feet (6 m) thick; deposited in an eolian environment; thickness varies due to unconformity at top but thins overall to west; upper contact is sharp and marked by a reddish zone at the base of the Co-op Creek Limestone Member of the Carmel Formation; 40 to 80 feet (12-24 m) thick; thins westward.

Jts **Sinawava Member –** Interbedded fine-grained sandstone, silty sandstone, and mudstone; generally forms prominent reddish-brown to dark-red vegetated bench or ledgy slope; locally forms recessed cliff between the White Throne Member and the white Navajo Sandstone; red color locally streaks the white Navajo cliffs below; interfingers with the White Throne Member at the top; deposited in coastal sabkha and tidal-flat environments; 100 to 140 feet (30-42 m) thick; thins eastward.

J-1 unconformity

Jn **Navajo Sandstone –** (undivided on cross section only) Massive, cliff-forming, cross-bedded, locally highly jointed sandstone; forms spectacular sheer cliffs, deep canyons, and impressive spires, promontories, and monoliths; consists mostly of well-sorted, fine- to medium-grained, quartzose sandstone; bedding consists of high-angle, large-scale cross-bedding in tabular-planar, wedge-planar, or trough-shaped sets 10 to 45 feet or more (3-14+ m) thick; ironstone bands and concretions common; deposited in a vast eolian coastal to inland erg (dune field) environment with prevailing winds principally from the north; lower 200 to 400 feet (60-120 m) consists of a transitional interval with planar bedding, evaporite mineral casts, crinkly or wavy bedding, load structures (typically a few inches in amplitude), and bioturbation indicative of a coastal sabkha environment; upper contact is an unconformity that makes a sharp break below the slope of the red Sinawava Member; surface of unconformity is imperceptibly broadly rolling, but across the quadrangle, beveling results in a thickness difference in the Navajo of a few hundred feet; divided into three generalized non-stratigraphic units based on color and weathering habit; 1,800 to 2,200 feet (550-670 m) thick.

Jnw **White Navajo –** Upper part of Navajo Sandstone; very light gray or white because of alteration, remobilization, and bleaching of limonitic and hematitic (iron-bearing) cement; generally forms massive cliff; forms upper 0 to 800 feet (0-240 m) of the formation in Zion National Park; dies out to northwest in quadrangle.

Jnp **Pink Navajo –** Middle part of Navajo Sandstone; generally less resistant than the white Navajo

above and brown Navajo below; forms benches, steep slopes, and cliffs; pale-reddish-brown color is more uniform than in units above and below due to more uniformly dispersed hematitic (iron-bearing) cement; locally contains dark green cement (possibly celadonite - an iron-bearing micaceous mineral), and ironstone bands, concretions, and cement; 400 to 1,000 feet (120-300 m) thick.

Jnb **Brown Navajo –** Lower part of the Navajo Sandstone; upper contact is at the top of a dark-brown, irregular and undulating band overlain by a broad light-colored band; generally forms massive cliff; roughly correlative with the lower transitional beds of the Navajo; 400 to 600 feet (120-180 m) thick.

Jk **Kayenta Formation (entire formation in areas where Lamb Point Tongue of Navajo Sandstone not mapped, and on cross section; lower part (main body) in areas where Lamb Point and Tenney Canyon Tongues mapped separately) –** Moderate to dark reddish-brown siltstone and sandstone similar to that described for the Tenney Canyon Tongue; contains 20 to 30 percent sandstone ledges in the Zion National Park area; forms steep ledgy slope grading up to ledgy cliffs at top; upper contact gradational over a few feet but placed at top of slope- or ledgy cliff-forming, thin- to medium-bedded sandstone with siltstone partings, and at base of laterally continuous, thick- to massive-bedded, cliff-forming sandstone; deposited in an area of little relief near a terrestrial-marine transition zone alternating between mudflats and fluvial environments; locally has thin to medium ledgy sandstone beds similar to Springdale Sandstone in lower part; entire formation is between 550 and 700 feet (170-210 m) thick; lower part below the Lamb Point Tongue is about 290 to 400 feet (88-120 m) thick.

Jkt **Tenney Canyon Tongue of Kayenta Formation –** Upper part of Kayenta Formation in areas where Lamp Point Tongue is present; lenticular beds of pale-reddish-brown to moderate reddish-orange siltstone and very fine-grained sandstone; minor claystone and limestone; forms a steep slope grading up to ledgy cliffs at top; 140 to 315 feet (43-96 m) thick where separated from the main body.

Jnl **Lamb Point Tongue of Navajo Sandstone –** Mostly reddish-brown, fine- to very fine-grained, well-sorted, quartzose sandstone; prominently jointed; forms a vertical ledge in the upper one-third of the Kayenta Formation; strongly cross-bedded; contains scattered thin lenses of flat-bedded, pale-reddish-brown siltstone and claystone similar to Kayenta Formation beds; upper contact placed at top of thick, laterally consistent ledge interval; locally contains a 1-foot-thick (30 cm) bed of limestone near the top; deposited in an eolian erg and sabkha environment; thins and pinches out to west in the quadrangle; 0 to 40 feet (0-12 m) thick.

Moenave Formation

Jms **Springdale Sandstone Member of Moenave Formation –** Mostly pale-reddish purple to pale-reddish-brown, moderately sorted, very fine- to medium-grained, medium- to thick-bedded, cross-bedded sandstone; locally contains intraformational conglomerate consisting of rounded chips of mudstone and siltstone in a sandstone matrix; has large lenticular and wedge-shaped, low-angle, medium- to large-scale cross-bedding; secondary color banding that varies from concordant to discordant with cross-bedding is common in the sandstone; generally forms a vertical to irregular ledgy cliff; upper contact with Kayenta Formation is generally sharp and even; deposited in a fluvial environment of constantly shifting stream channels; 90 to 150 feet (27-46 m) thick.

Jmw **Whitmore Point Member of Moenave Formation –** Grayish-red, pale-reddish-brown, and greenish-gray siltstone, fine-grained sandstone and claystone; sandstone beds are similar to sandstone in Springdale Sandstone; siltstone is commonly thin bedded to laminated in lenticular or wedge-shaped beds; claystone is generally flat-bedded; slope forming; the upper contact of the member is generally sharp but irregular where scoured by the overlying Springdale; locally contains fish scales and bone fragments; deposited in low-energy lacustrine and fluvial environments; about 60 to 85 feet (18-26 m) thick.

Jmd **Dinosaur Canyon Member of Moenave Formation** – Uniformly colored, moderate-reddish-orange to pale-reddish-brown, thin-bedded siltstone, very fine-grained sandstone, and claystone; contains a minor amount of conglomerate similar to beds in underlying Petrified Forest Member of the Chinle Formation; forms an irregular slope slightly steeper than that of the Whitmore Point; the upper part is marked by a series of more resistant sandstone beds that help define the contact with the Whitmore Point Member above; commonly ripple-marked or mud-cracked; deposited on a broad, low, stream-meander floodplain that was locally shallowly flooded by water (fluvial mudflat); about 150 to 270 feet (46-82 m) thick.

J-0 unconformity

TRIASSIC

Chinle Formation

TRcp; TRcp(s)
Petrified Forest Member of Chinle Formation – Brightly variegated, light-brownish-gray, pale-greenish-gray, to grayish-purple, smectitic shale, siltstone, claystone, sandstone, and pebble to small cobble conglomerate; prone to landsliding; weathers as badlands; contains locally abundant fossilized wood; mostly slope-forming; upper contact is an erosional surface with only slight relief; contains locally prominent, thick, resistant sandstone and conglomerate ledges in lower and middle parts of unit; deposited in lacustrine, floodplain, and braided-stream environment; about 400 to 500 feet (120-150 m) thick; (s) designates relatively coherent blocks that slumped downslope.

TRcs **Shinarump Conglomerate Member of Chinle Formation** – Interbedded, medium- to coarse-grained sandstone, pebbly sandstone, and pebble conglomerate; locally with silty sandstone, claystone, and smectitic claystone interbeds; locally contains abundant fossilized wood; forms resistant ledges to cliffs; clasts are mostly black, gray, tan, and white chert and quartzite; locally heavily stained by iron-manganese oxides, forming "picture stone"; upper contact varies from sharp to gradational; deposited in fluvial environment; about 60 to 135 feet (18-41 m) thick.

unconformity

TRm Moenkopi Formation, undivided – Shown on cross section only; about 1,700 feet (520 m) thick.

TRmu **Upper red member of Moenkopi Formation** – Moderate- to dark-reddish-brown, very fine- to fine-grained sandstone, siltstone, and mudstone; mostly thin bedded and evenly stratified with a few thick beds that form resistant ledges; common ripple marks and planar, low-angle, and climbing-ripple cross-stratification; common secondary gypsum in thin beds and as cross-cutting veinlets increasing downward; sharp, locally deeply incised erosional upper contact; deposited in tidal flat environment; 210 to 275 feet (64-84 m) thick.

TRms **Shnabkaib Member of Moenkopi Formation** – Banded, light-gray to pale-red "bacon-striped," gypsiferous siltstone, bedded gypsum, mudstone, and calcareous mudstone; with thin interbeds of pale-brownish-gray dolomite, and moderate-reddish-brown siltstone; mostly nonresistant with thin resistant layers that form ledges; gypsum common as secondary cavity filling and cross-cutting veins; parts weather to a thick punky gypsiferous soil; upper contact placed at change from grayish mudstone to uniform reddish-brown siltstone and mudstone; deposited in shallow-marine to tidal-flat environment; about 50 feet (15 m) exposed in southwest corner of quadrangle; total member is probably about 400 feet (120 m) thick.

unconformity

PERMIAN

Pk **Kaibab Formation –** Shown on cross section only; about 350 feet (105 m) thick.

Pt **Toroweap Formation –** Shown on cross section only; about 400 feet (120 m) thick.

Pq **Queantoweap Sandstone –** Shown on cross section only; 1,000+ feet (300+ m) thick.

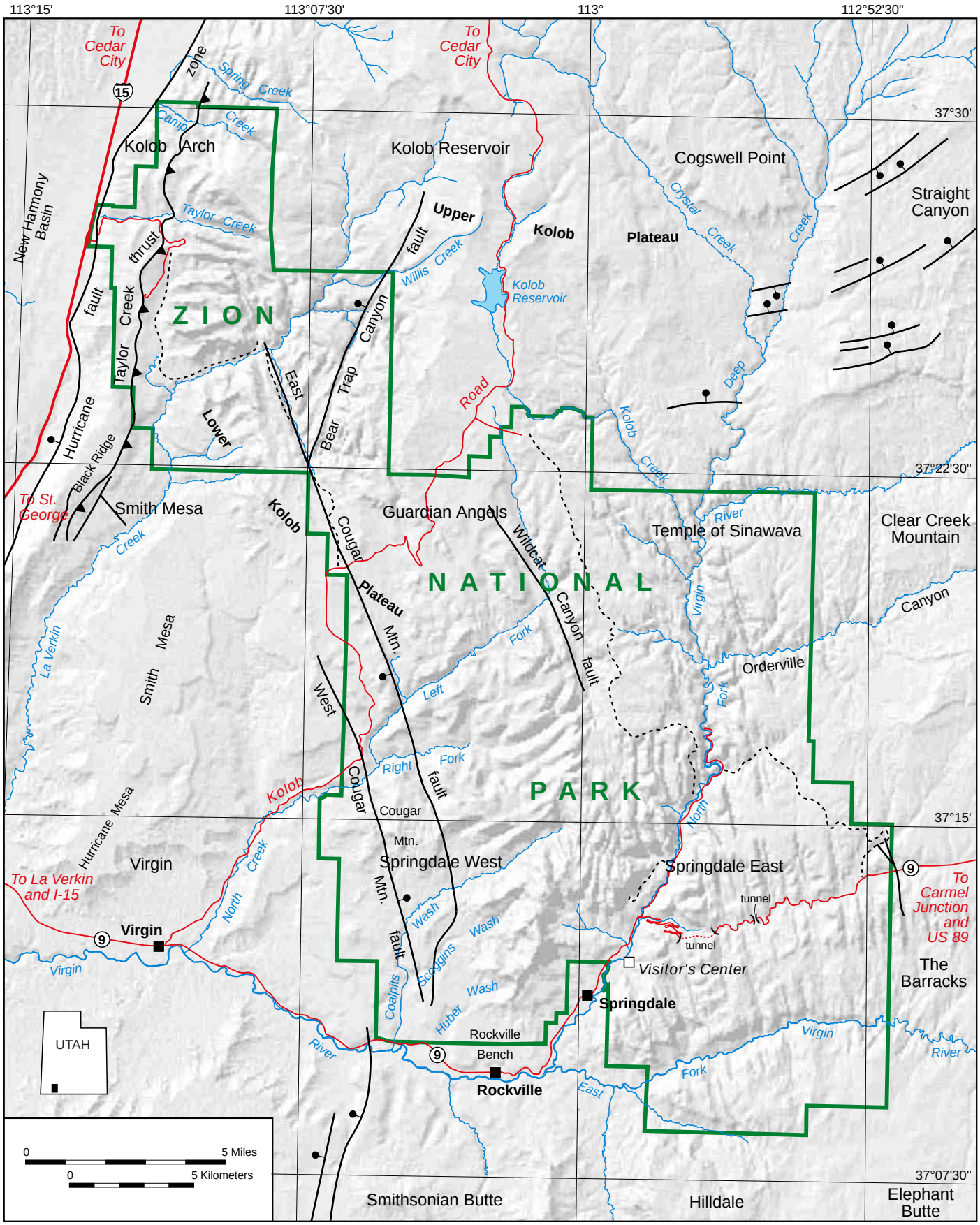
REFERENCES

Biek, R.F., 2002, Interim geologic map of the Kolob Reservoir quadrangle, Washington County, Utah: Utah Geological Survey Open-File Report 387, 1:24,000.

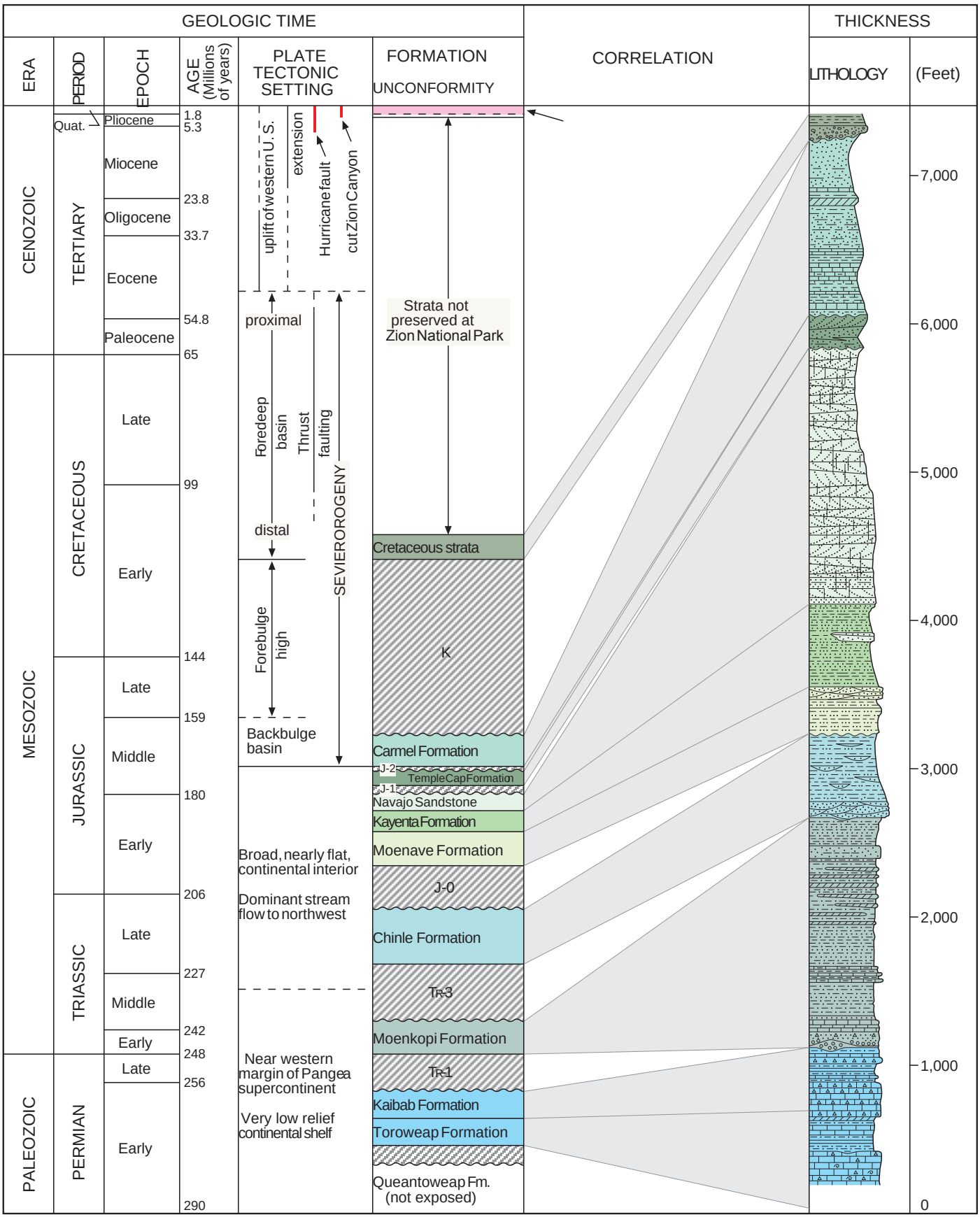
Hamilton, W.L., 1995, The Sculpturing of Zion: Zion Natural History Association, 132 p.

Caption for plate 2:

Zion National Park area. Available 1:24,000 scale, 7.5' quadrangle geologic maps are: Open-file report (black and white) geologic maps: Kolob Arch quadrangle - Biek, 2002, Utah Geological Survey Open-File Report 386; Kolob Reservoir quadrangle - Biek, 2002, Utah Geological Survey Open-File Report 387; Cogswell Point quadrangle, Biek and Hylland, 2002, Utah Geological Survey Open-File Report 388; The Guardian Angels quadrangle - Willis and Hylland, 2002, Utah Geological Survey Open-File Report 395; Temple of Sinawava quadrangle - Doelling, 2002, Utah Geological Survey Open-File Report 396; Clear Creek Mountain quadrangle, Hylland, 2001, Utah Geological Survey Open-File Report 371; Springdale West quadrangle - Willis and others, 2002, Utah Geological Survey Open-File Report 394; Springdale East quadrangle - Doelling and others, 2002, Utah Geological Survey Open-File Report 393. Published (color) geologic maps: The Barracks quadrangle - Sable and Doelling, 1993, Utah Geological Survey Map 147; Smithsonian Butte quadrangle - Moore and Sable, 2001, Utah Geological Survey Miscellaneous Publication 01-1; Hildale quadrangle - Sable, 1995, Utah Geological Survey Map 167.

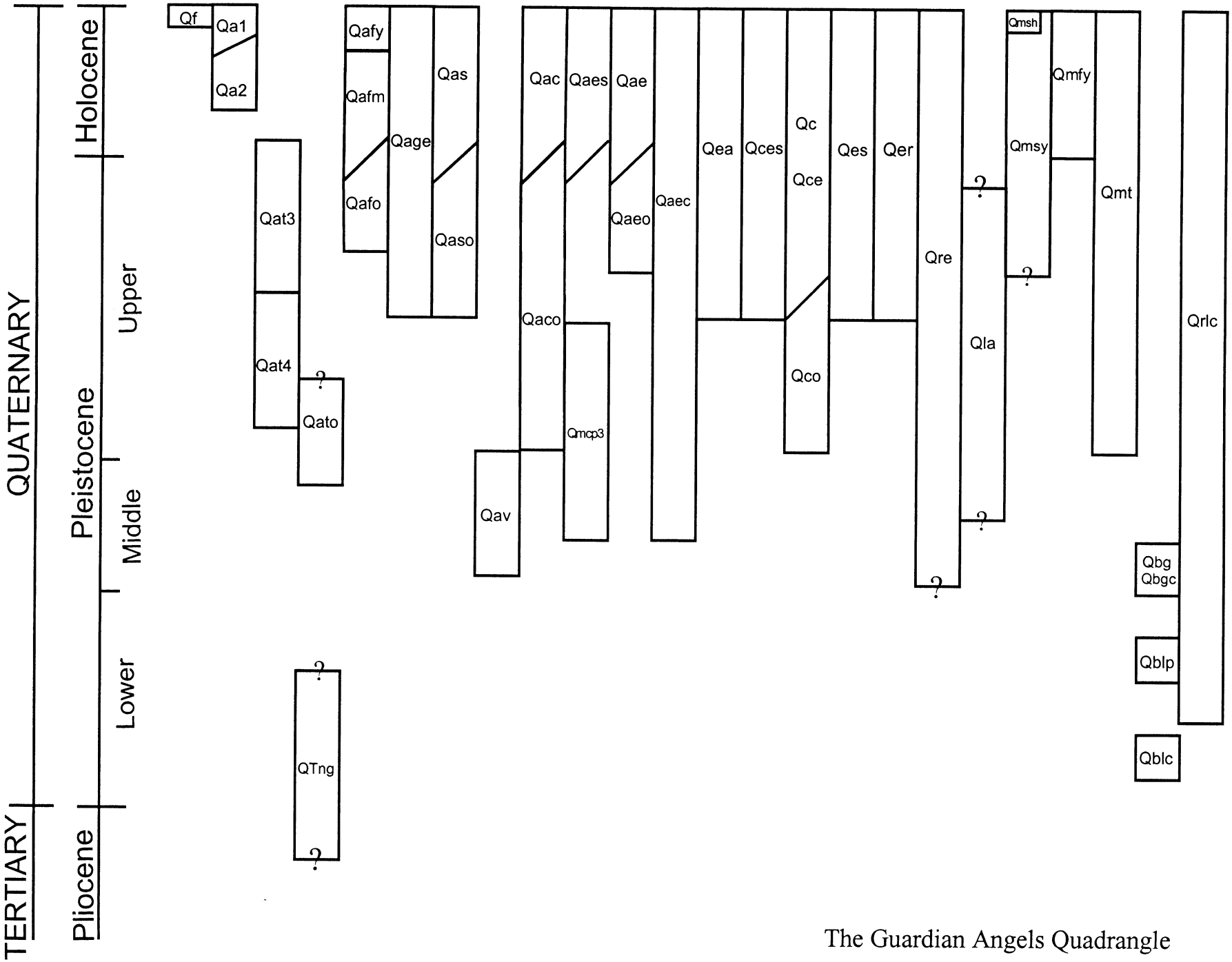


113°15'
113°07'30'
113°
112°52'30"
37°30'
37°22'30"
37°15'
37°07'30"
To Cedar City
To Cedar City
15
Spring Creek
Camp Creek
Kolob Arch
Kolob Reservoir
Cogswell Point
Straight Canyon
New Harmony Basin
Taylor Creek
Upper Kolob Plateau
Crystal Creek
Creek
Willis Creek
Kolob Reservoir
thrust
fault
Taylor Creek
ZION
Canyon
Trap
East
Bear
Road
Deep
Kolob Creek
Hurricane
Black Ridge
Lower
To St. George
Smith Mesa
Kolob
Cougar
Guardian Angels
Wildcat
Canyon
fault
Temple of Sinawava
River
Clear Creek Mountain
Creek
NATIONAL
Plateau
Mtn.
Virgin
Canyon
La Verkin
Smith Mesa
Fork
Orderville
West
Left
Fork
Right
Fork
Kolob
Cougar
fault
PARK
Cougar
Mtn.
North
Hurricane Mesa
Virgin
Springdale West
Springdale East
To La Verkin and I-15
North Creek
Mtn.
Wash
Wash
tunnel
tunnel
To Carmel Junction and US 89
9
Virgin
fault
Scoggins
Visitor's Center
The Barracks
Virgin
Coalpits
Wash
Huber
Springdale
UTAH
Rockville
Bench
Virgin
River
River
Fork
Rockville
East
0
5 Miles
0
5 Kilometers
Smithsonian Butte
Hilldale
Elephant Butte



Relationship between age and thickness of rocks exposed in Zion National Park.

Correlation of Surficial Map Units



The Guardian Angels Quadrangle

Explanation of Map Symbols

The Guardian Angels Quadrangle

Contact - dashed where approximately located

Normal fault - dashed where approximately located, dotted where concealed, bar and ball on down-thrown side

Surface trace of low-angle slip surface beneath gravity-slide block

4200

Structural contour – drawn on top of Navajo Sandstone in most of quadrangle; drawn top of Springdale Sandstone Member in southwest part of quadrangle; dashed where projected above ground surface; contour interval 100 feet (30 m); datum sea-level

Major joint – near vertical (only major joints mapped individually)

A A'

Cross section line

3

Strike and dip, measured in the field

3

Strike and dip, measured photogrammetrically

Joint, near vertical

Spring

Cinder (c) or road fill (no letter) pit

ZP0601

Sample location with sample number

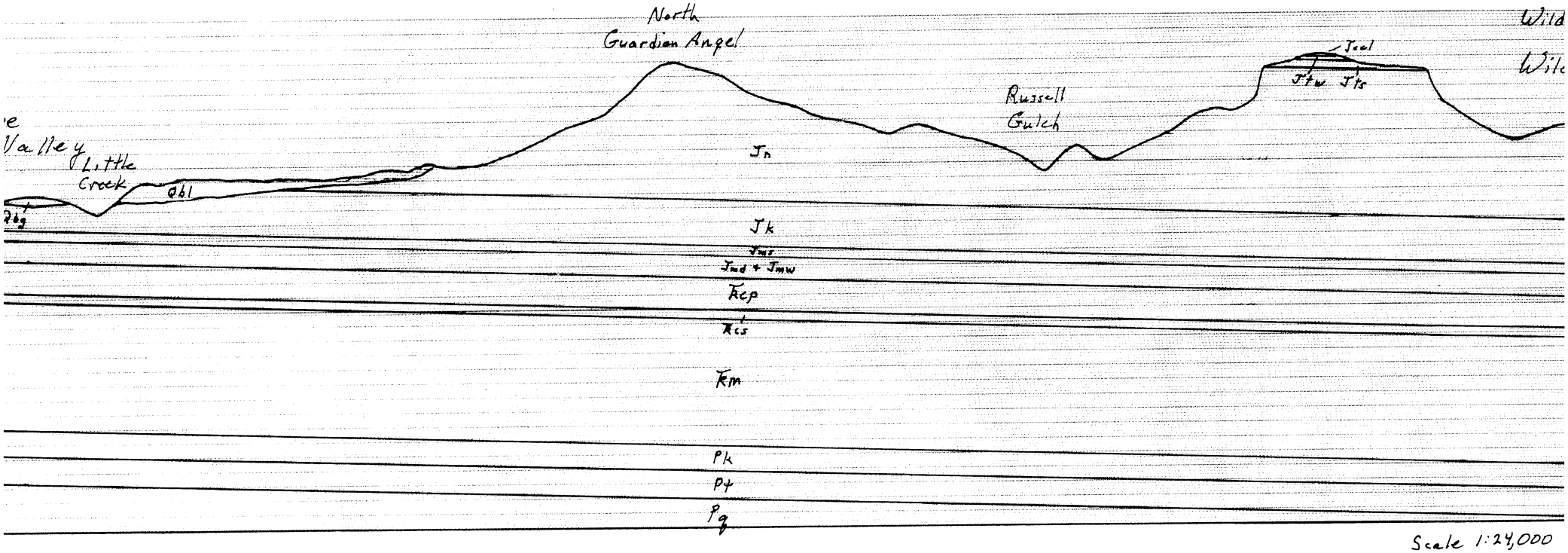
Petroleum exploration drill hole, dry and abandoned – with well name and year completed; reliability of location is uncertain

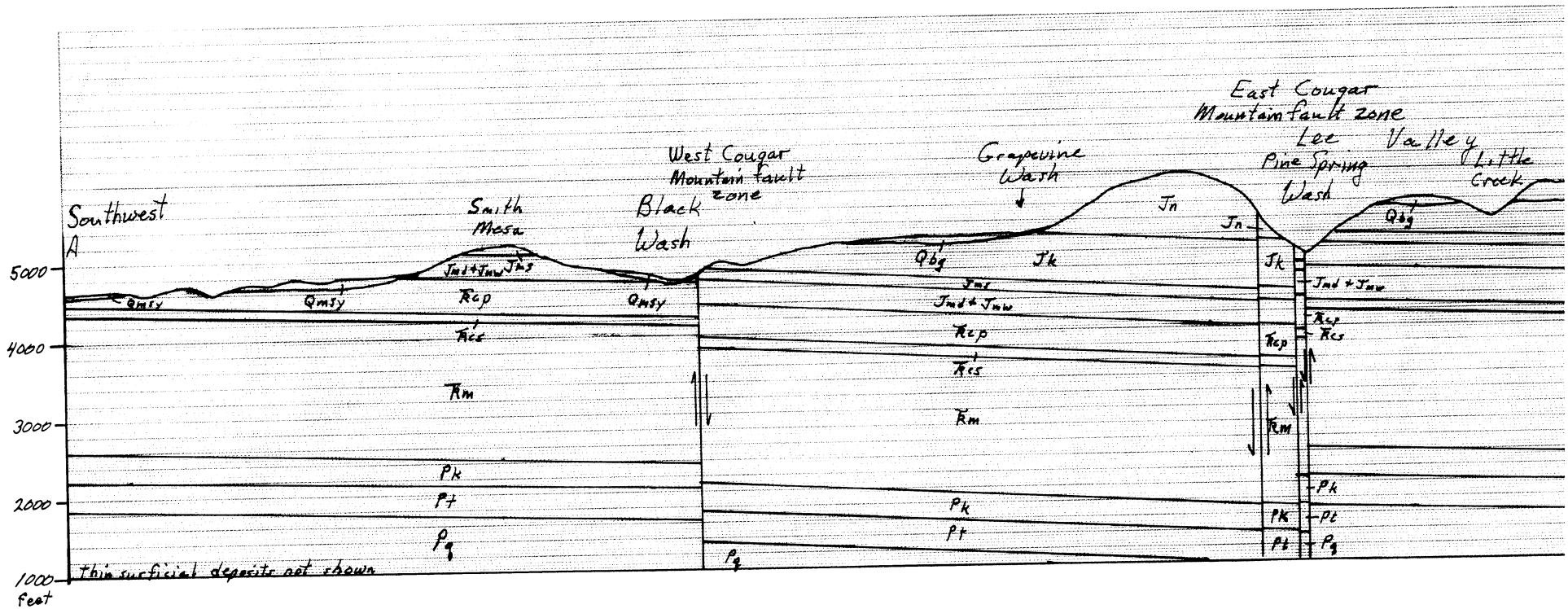
System	Series	Formation	Member	Symbol	Thickness feet (meters)	Lithology
QUATERNARY		surficial deposits		Q–	0-100+ (0-30+)	
		Grapevine Wash basalt flow + cinders		Qbg	0-400 (0-120)	0.22-0.31 Ma
		Lava Point basalt flows		Qblp	20-200 (6-60)	1.02-1.14 Ma
		Little Creek Peak basalt flow		Qblc	20-60 (6-18)	1.44 Ma
JURASSIC	Middle	Carmel Formation	Co-op Creek Limestone Member, upper	Jccu	100-110 (30-33)	resistant light-yellowish-gray fossiliferous
			Co-op Creek Limestone Member, lower	Jccl	150-170 (46-52)	limestone and shale
		Temple Cap Formation	White Throne Mbr	Jtw	40-80 (12-24)	unconformity ledge-forming
			Sinawava Member	Jts	100-140 (30-42)	red siltstone and shale
	Lower	Navajo Sandstone	white unit	Jnw	0-800 (0-240)	unconformity commonly streaked red from Sinawava Mbr weathering; white upper cliff and domes
			pink unit	Jnp	400-1,000 (120-300)	pink slopes and cliffs; local ironstone concretions
			brown unit	Jnb	400-600 (120-180)	dissolution fronts commonly mark color change; grades upward to massive crossbedding
					1,700-2,200 (550-670)	planer bedded sabkha environment red planer sandstone
		Kayenta Formation	Tenney Canyon Tongue	Jkt	140-315 (43-96)	
			Lamb Point T. of Navajo Ss	Jnl	0-40 (0-12)	pinches out to northwest discontinuous in Left Fork
			main body	Jk	290-400 (88-120)	locally forms landslides; local Springdale Ss-like ledge
					550-700 (170-210)	
		Moenave Formation	Springdale Sandstone Mbr	Jms	90-150 (27-46)	prominent cliff-former
			Whitmore Point Mbr	Jmw	60-85 (18-26)	fish scales
			Dinosaur Canyon Member	Jmd	150-270 (46-82)	uniform reddish-brown; unconformity
TRIASSIC	Upper	Chinle Formation	Petrified Forest Member	Rcp	500-650 (150-200)	variegated, brightly colored; forms many landslides; petrified wood
			Shinarump Congl. Mbr	Rcs	60-135 (18-41)	prominent cliff-former unconformity
	Lower-Mid?	Moenkopi Formation	upper red member	Rmu	210-275 (64-84)	brick red
			Shinabkaib Member	Rms	400-600 (120-180) 50+ (15+) exposed	impure thin white gypsum beds

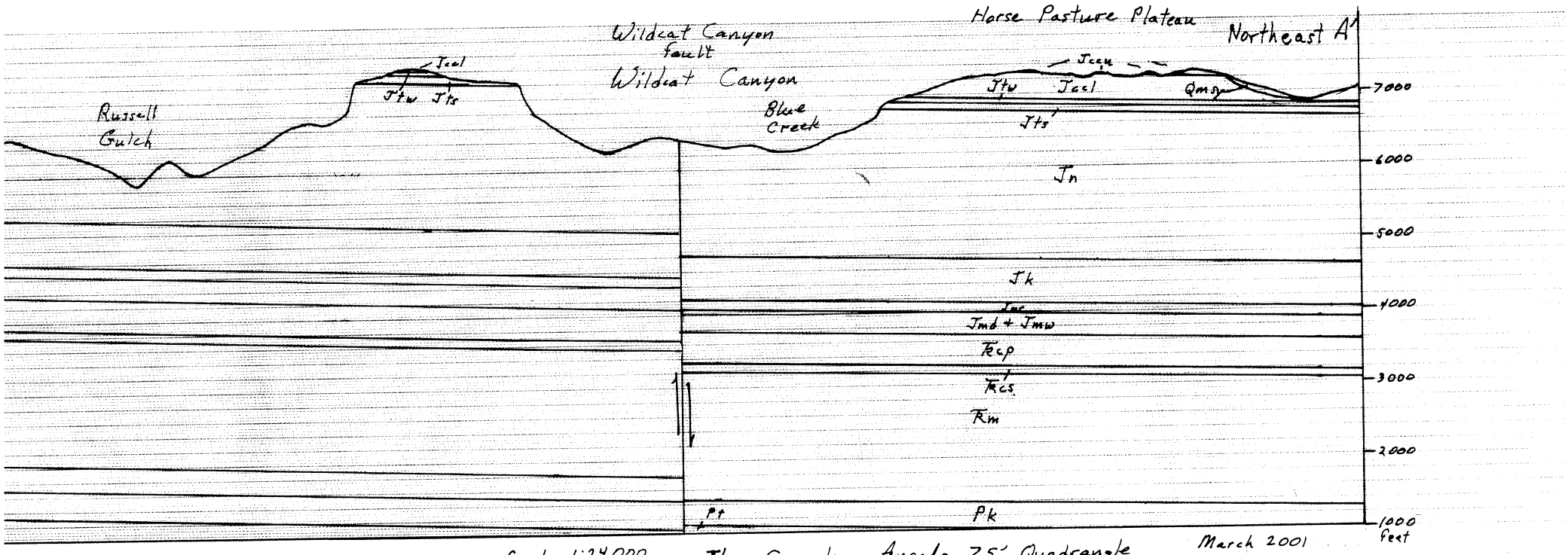
Sample No.	Latitude N.	Longitude W.	Flow	7.5' Quadrangle	Collected	Ar-Ar Age	Al2O3	CaO	Cr2O3	Fe2O3	K2O	MgO	MnO	Na2O	P2O5
KR-811004	37.389	113.040	Qblp	Kolob Reservoir	11-Aug-00		15.96	7.16	0.03	9.39	1.80	6.08	0.15	4.02	0.69
ZP-0901	37.387	113.031	Qblp	Kolob Reservoir	23-Jun-99		15.51	6.94	0.08	9.25	1.70	6.29	0.14	3.75	0.56
ZP-0601	37.388	113.041	Qblp	Kolob Reservoir	30-Sep-97	1.02±0.03	15.90	7.09	0.03	9.46	1.62	6.28	0.15	3.82	0.56
ZP-0602	37.386	113.040	Qblp	Kolob Reservoir	30-Sep-97	1.08±0.02	15.67	7.08	0.01	9.41	1.50	6.75	0.15	3.74	0.59
ZP-0902	37.359	113.072	Qblp	The Guardian Angels	23-Jun-99		15.60	7.07	0.04	9.47	1.70	6.31	0.14	3.75	0.59
ZP-0404	37.364	113.065	Qblp	The Guardian Angels	26-Aug-97		15.12	7.45	0.03	9.30	1.72	6.77	0.15	3.52	0.61
ZP-0406	37.372	113.052	Qblp	The Guardian Angels	27-Aug-97		16.30	7.12	0.02	9.67	1.69	5.86	0.16	4.06	0.76
ZP-0408	37.360	113.057	Qblp	The Guardian Angels	27-Aug-97		15.64	7.56	<0.01	9.91	1.67	7.35	0.15	4.25	0.77
ZP-0604	37.328	113.065	Qblp	The Guardian Angels	01-Oct-97		14.99	7.63	0.01	9.30	1.67	6.83	0.14	3.51	0.58
ZP-0407	37.375	113.044	Qblp	The Guardian Angels	27-Aug-97		15.70	7.56	0.01	9.39	1.48	6.89	0.15	3.54	0.59
ZP-0405	37.374	113.060	Qblp	The Guardian Angels	27-Aug-97	1.14±0.16	15.62	7.61	0.03	9.57	1.46	7.08	0.15	3.50	0.62
VR-4101	37.211	113.147	Qblp	Virgin	19-Mar-97		15.67	7.75	<0.01	10.00	2.10	7.41	0.15	4.19	0.77
KR-811004	37.356	113.073	Qblc	The Guardian Angels	21-Mar-97	1.44±0.04	15.33	9.01	<0.01	10.57	1.42	9.47	0.17	3.11	0.47
ZP-0401	37.362	113.083	Qblc	The Guardian Angels	20-Aug-97		15.40	7.48	0.01	9.20	1.68	7.04	0.14	3.56	0.63
VR-4105	37.257	113.132	Qbg	Smith Mesa	19-Mar-97		14.88	7.28	<0.01	9.25	3.05	6.16	0.14	3.65	0.71
ZP-0501	37.335	113.117	Qbg	The Guardian Angels	28-Aug-97		15.53	7.02	0.03	8.24	2.14	6.54	0.13	3.45	0.54
ZP-0502	37.338	113.117	Qbg	The Guardian Angels	28-Aug-97	0.22±0.03	14.95	7.58	0.03	8.75	2.15	6.88	0.13	3.62	0.58
ZP-0503	37.350	113.107	Qbg	The Guardian Angels	28-Aug-97	0.29±0.02	13.80	9.06	0.04	11.51	1.67	9.47	0.16	3.17	0.58
ZP-0605	37.298	113.099	Qbg	The Guardian Angels	03-Oct-97	0.31±0.04	14.77	9.15	0.01	10.85	1.14	7.11	0.15	3.26	0.38
ZP-0606	37.279	113.096	Qbg	The Guardian Angels	19-Nov-97	0.26±0.03	15.33	7.63	<0.01	9.28	2.30	6.27	0.14	3.64	0.78
ZP-0607	37.280	113.096	Qbg	The Guardian Angels	19-Nov-97	0.26±0.02	15.53	7.58	0.02	9.16	2.44	6.22	0.14	3.50	0.80
ZP-3205	37.351	113.083	Jnp	The Guardian Angels	31-Aug-99		4.18	4.21	0.02	0.93	2.65	1.48	0.06	<0.01	0.06

Sample No.	SiO2	TiO2	LOI	TOTAL	Ba	Ce	Cu	Ga	La	Pb	Nd	Ni	Nb	Rb	Sr	V	Y	Zn	Zr
KR-811004	51.54	1.60	0.28	98.70	1090	108.0	70	20	54.0	<5	46.5	135	29	19.0	865	155	27.5	95	258.0
ZP-0901	53.06	1.34	0.00	98.62	1105	102.5	50	20	51.0	<5	45.0	145	22	22.0	851	130	25.0	95	227.0
ZP-0601	53.25	1.36	-0.13	99.39	1070				52				22	18	864		26		236
ZP-0602	53.22	1.39	-0.30	99.21	994				49				21	24	830		26		231
ZP-0902	52.47	1.41	0.10	98.65	998	95.5	50	19	49.0	50	42.0	150	22	21.6	792	125	28	105	222.0
ZP-0404	52.33	1.41	0.02	98.43	1240				60				22	23	1040		26		224
ZP-0406	50.69	1.63	0.62	98.58	1080				61				27	17	910		31		267
ZP-0408	49.80	1.95	-0.25	98.80	850				53				25	19	1095		28		274
ZP-0604	51.96	1.33	0.41	98.36	1260				59				21	22	1035		26		219
ZP-0407	52.71	1.39	0.23	99.64	1285				62				22	20	1065		29		225
ZP-0405	52.53	1.39	-0.04	99.52	1255				59				23	18	1070		26		222
VR-4101	49.75	1.96	0.01	99.76	841				49				30	18	1025		27		258
VR-4301	47.40	1.68	0.01	98.64	660				33				31	17	696		29		166
ZP-0401	52.00	1.38	0.34	98.86	1285				60				22	22	1050		27		218
VR-4105	50.76	1.66	0.01	97.55	1700				67				30	25	1290		26		223
ZP-0501	53.33	1.34	0.29	98.58	1330				56				25	28	967		24		210
ZP-0502	52.06	1.52	0.20	98.45	1240				59				26	27	1065		25		204
ZP-0503	47.91	2.00	-0.13	99.24	856				50				40	25	741		23		191
ZP-0605	50.72	1.50	-0.38	98.66	744				35				20	18	601		23		145
ZP-0606	52.42	1.69	-0.09	99.39	1865				72				26	25	1385		26		246
ZP-0607	52.05	1.68	0.16	99.28	1925				73				27	27	1385		26		251
ZP-3205	79.97	0.26	5.26	99.08		(FeO - 0.11)													

Table 1. Geochemistry of samples collected from basaltic flows, cinder cones, and Navajo Sandstone in The Guardian Angels and adjacent quadrangles.


North
Guardian Angel
Wild
Wite
Jcol
Jtw Jts
Russell
Gulch
e
Valley
Little
Creek
Qbl
Qbg
Jn
Jk
Jmr
Jmd + Jmw
Kcp
Kcs
Km
Pk
Pt
Pq
Scale 1:24,000


Southwest
A
Smith Mesa
West Cougar Mountain fault zone
Black Wash
Grapevine Wash
East Cougar Mountain fault zone
Lee Valley
Pine Spring Wash
Little Creek
5000
4000
3000
2000
1000 feet
Thin surficial deposits not shown



Scale 1:24,000

The Guardian Angels 7.5' Quadrangle
Grant C. Willis + Michael O. Hylland

March 2001